SIEMENS

SIMATIC

S7-200
Programmable Controller

System Manual

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Warning

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indicates that minor personal injury or property damage can result if proper precautions are not taken.

Note

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We have checked the contents of this manual for agreement with the hardware and software described. Since deviations cannot be precluded entirely, we cannot guarantee full agreement. However, the data in this manual are reviewed regularly and any necessary corrections included in subsequent editions. Suggestions for improvement are welcomed.

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Preface

Purpose

The S7-200 series is a line of micro-programmable logic controllers (Micro PLCs) that can control a variety of automation applications. Compact design, low cost, and a powerful instruction set make the S7-200 controllers a perfect solution for controlling small applications. The wide variety of CPU sizes and voltages and the Windows-based programming tool give you the flexibility you need to solve your automation problems.

The S7-200 product line has been redesigned to be smaller, faster, and to have increased functionality. The new S7-200 products are intended to replace the previous products.

This manual provides information about installing and programming the S7-200 Micro PLCs. The *S7-200 Programmable Controller System Manual* includes the following topics:

- Installing and wiring
- Understanding the CPU operations, data types and addressing modes, scan cycle, password protection, and network communication
- Specifications
- Descriptions and examples for the SIMATIC and IEC 11313 programming instructions
- Using the USS Protocol Instructions to communicate with drives
- Typical execution times for SIMATIC STL instructions

Audience

This manual is designed for engineers, programmers, installers, and electricians who have a general knowledge of programmable logic controllers.

Scope of the Manual

The information contained in this manual pertains in particular to the following products:

- S7-200 CPU models: CPU 221, CPU 222, and CPU 224 (firmware release 1.1), and CPU 226 (firmware release 1.0).
- STEP 7Micro/WIN 32, version 3.1, a 32-bit programming software package for Windows 95, Windows 98, and the Windows NT environment
- STEP 7Micro/WIN 32 Toolbox, a 32-bit programming software package for the Windows 95, Windows 98, and the Windows NT 4.0 environment.
  STEP 7Micro/WIN 32 Toolbox is designed for customers who use the S7-200 CPU with other microsystem components (such as the TP070 Touch Panel or a MicroMaster drive).

Agency Approvals

The SIMATIC S7-200 series meets the following regulations:

- European Community (CE) Low Voltage Directive 73/23/EEC
- European Community (CE) EMC Directive 89/336/EEC
- Underwriters Laboratories, Inc.: UL 508 Listed (Industrial Control Equipment)
- Canadian Standards Association: CSA C22.2 Number 142 Certified (Process Control Equipment)
- Factory Mutual Research: FM Class I, Division 2, Groups A, B, C, & D Hazardous Locations, T4A and Class I, Zone 2, IIC, T4.

Refer to Appendix A for compliance information.

Related Information

Refer to the following for more detailed information about selected topics:

- STEP 7Micro/WIN 32 CD/disk: provides online help, the *STEP 7Micro/WIN Getting Started* (a printable online manual), and Tips and Tricks projects.
- STEP 7Micro/WIN 32 Toolbox CD: provides the TP070 Touch Panel Configuration Software, USS Protocol Instructions, online help, the *STEP 7Micro/WIN Getting Started* (a printable online manual), and Tips and Tricks projects.
- Process Field Bus (PROFIBUS) standard (EN 50170): describes the standard protocol for the S7-200 DP communication capability.
- *TD 200 Operator Interface User Manual:* describes how to install and use the TD 200 with an S7-200 programmable logic controller.

How to Use This Manual

If you are a first-time (novice) user of S7-200 Micro PLCs, you should read the entire *S7-200 Programmable Controller System Manual*. If you are an experienced user, refer to the manual table of contents or index to find specific information.

The *S7-200 Programmable Controller System Manual* is organized according to the following topics:

- “Introducing the S7-200 Micro PLC” (Chapter 1) provides an overview of some of the features of the equipment.
- “Installing an S7-200 Micro PLC” (Chapter 2) provides procedures, dimensions, and basic guidelines for installing the S7-200 CPU modules and expansion I/O modules.
- “Getting Started with an S7-200 Programming System” (Chapter 3) describes how to set up an S7-200 programming system.
- “Basic Concepts for Programming an S7-200 CPU” (Chapter 4), “CPU Memory: Data Types and Addressing Modes” (Chapter 5), and “CPU and Input/Output Control” (Chapter 6) provide information about how the S7-200 CPU processes data and executes your program.
- “Setting Up Communications Hardware and Network Communications” (Chapter 7) provides information about how to install and remove communications hardware and how to connect the S7-200 CPU to different types of networks.
- “Conventions for S7-200 Instructions” (Chapter 8) provides an overview of the different programming language concepts and terminology.
- “SIMATIC Instructions” (Chapter 9) provides descriptions and examples of SIMATIC LAD, FBD, and STL programming instructions.
- “IEC 11313 Instructions” (Chapter 10) provides descriptions and examples of IEC 11313 LAD and FBD programming instructions.
- “Using USS Protocol Instructions to Communicate with Drives” (Chapter 11) provides descriptions and examples of USS Protocol Instructions and information about how to use these instructions to communicate with drives.

Additional information (such as the equipment specifications, error code descriptions, troubleshooting, and STL instruction execution times) are provided in the appendices.

Additional Assistance

For assistance in answering technical questions, for training on this product, or for ordering, contact your Siemens distributor or sales office.

For Internet information about Siemens products and services, technical support, or FAQs (frequently asked questions) and application tips, use the following Internet addresses:

http://www.ad.siemens.de	for general Siemens information
http://www.siemens.com/s7200	for S7-200 product information

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Introducing the S7-200 Micro PLC

1

The S7-200 series is a line of micro-programmable logic controllers (Micro PLCs) that can control a variety of automation applications. Figure 1-1 shows an S7-200 Micro PLC. The compact design, expandability, low cost, and powerful instruction set of the S7-200 Micro PLC make a perfect solution for controlling small applications. In addition, the wide variety of CPU sizes and voltages provides you with the flexibility you need to solve your automation problems.

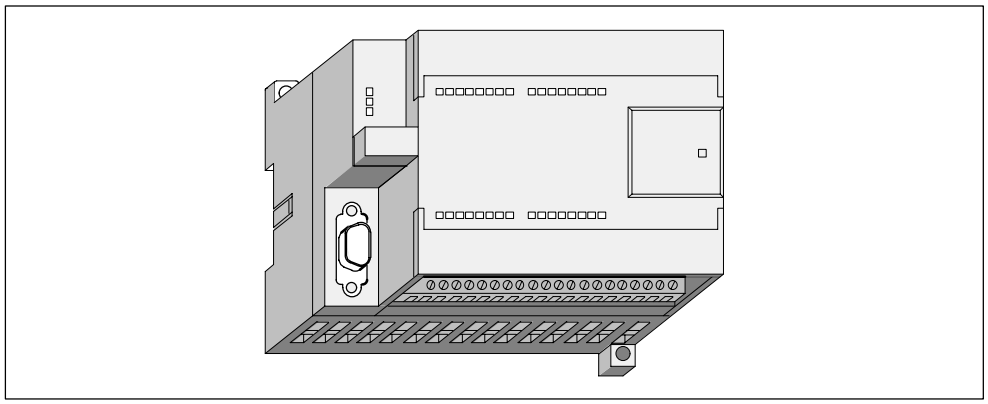

Figure 1-1 S7-200 Micro PLC

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1.2	Major Components of the S7-200 Micro PLC	1-5
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1.1 Comparing the Features of the S7-200 Micro PLCs

Equipment Requirements

Figure 1-2 shows the basic S7-200 Micro PLC system, which includes an S7-200 CPU, a personal computer, STEP 7-Micro/WIN 32, version 3.1 programming software, and a communications cable.

In order to use a personal computer (PC), you must have one of the following:

- A PC/PPI cable
- A communications processor (CP) and multipoint interface (MPI) cable
- A multipoint interface (MPI) card. A communications cable is provided with the MPI card.

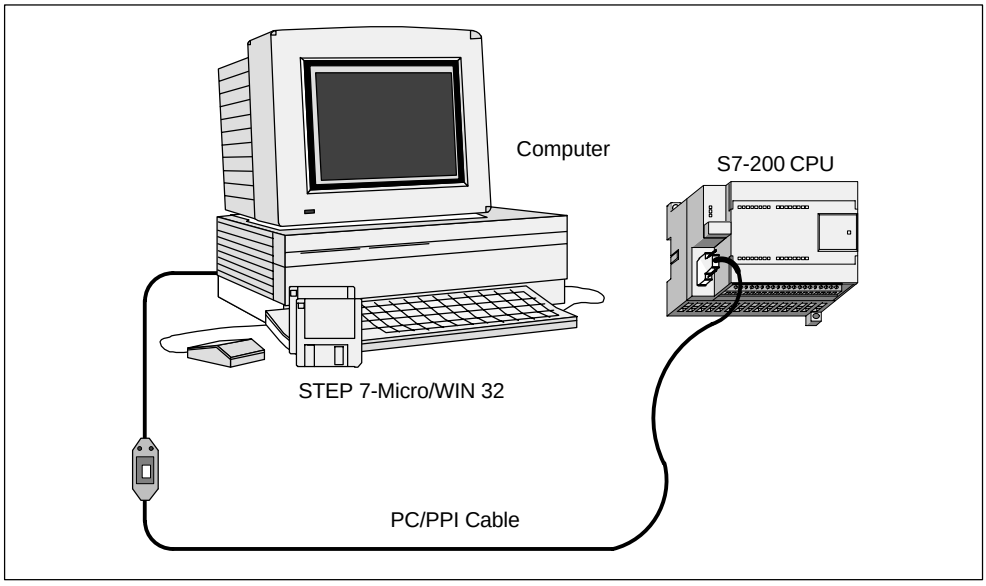

Figure 1-2 Components of an S7-200 Micro PLC System

Capabilities of the S7-200 CPUs

The S7-200 family includes a wide variety of CPUs. This variety provides a range of features to aid in designing a cost-effective automation solution. Table 1-1 provides a summary of the major features of the S7-200 CPUs, firmware release 1.1.

Table 1-1 Summary of the S7-200 CPU

Feature	CPU 221	CPU 222	CPU 224	CPU 226
Physical Size of Unit	90 mm x 80 mm x 62 mm	90 mm x 80 mm x 62 mm	120.5 mm x 80 mm x 62 mm	190 mm x 80 mm x 62 mm
Memory				
Program	2048 words	2048 words	4096 words	4096 words
User data	1024 words	1024 words	2560 words	2560 words
User program storage	EEPROM	EEPROM	EEPROM	EEPROM
Data backup (super capacitor)	50 hours typical	50 hours typical	190 hours typical	190 hours typical
Local I/O				
Local I/O	6 In/4 Out	8 In/6 Out	14 In/10 Out	24 In/16 Out
Number of expansion modules	none	2 modules	7 modules	7 modules
Total I/O				
Digital I/O image size	256 (128 In/128 Out)	256 (128 In/128 Out)	256 (128 In/128 Out)	256 (128 In/128 Out)
Analog I/O image size	none	16 In/16 Out	32 In/32 Out	32 In/32 Out
Actual I/O count that can be realized with each CPU may be limited by image register size, module count, 5V power, and the physical number of I/O points on each product. See Section 1.3.				
Instructions				
Boolean execution speed at 33 MHz	0.37µs/ instruction	0.37 µs/ instruction	0.37 µs/ instruction	0.37 µs/ instruction
I/O Image Register	128 I and 128 Q	128 I and 128 Q	128 I and 128 Q	128 I and 128 Q
Internal relays	256	256	256	256
Counters/Timers	256/256	256/256	256/256	256/256
Word In / Word Out	None	16/16	32/32	32/32
Sequential control relays	256	256	256	256
For/Next loops	Yes	Yes	Yes	Yes
Integer math (+ - * /)	Yes	Yes	Yes	Yes
Real math (+ - * /)	Yes	Yes	Yes	Yes
Enhanced Features				
Built-in high-speed counter	4 H/W (20 KHz)	4 H/W (20 KHz)	6 H/W (20 KHz)	6 H/W (20 KHz)
Analog adjustments	1	1	2	2
Pulse outputs	2 (20 KHz, DC only)	2 (20 KHz, DC only)	2 (20 KHz, DC only)	2 (20 KHz, DC only)
Communication interrupts	1 transmit/ 2 receive	1 transmit/ 2 receive	1 transmit/ 2 receive	2 transmit/ 4 receive
Timed interrupts	2 (1 ms to 255 ms)	2 (1 ms to 255 ms)	2 (1 ms to 255 ms)	2 (1 ms to 255 ms)
Hardware input interrupts	4, input filter	4, input filter	4, input filter	4, input filter
Real-time clock	Yes (cartridge)	Yes (cartridge)	Yes (built-in)	Yes (built-in)
Password protection	Yes	Yes	Yes	Yes

Table 1-1 Summary of the S7-200 CPU

Communications				
Number of comm ports:	1 (RS-485)	1 (RS-485)	1 (RS-485)	2 (RS-485)
Protocols supported				
Port 0:	PPI, DP/T, Freeport	PPI, DP/T, Freeport	PPI,DP/T, Freeport	PPI,DP/T, Freeport
Port 1:	N/A	N/A	N/A	PPI, DP/T, Freeport
PROFIBUS peer-to-peer	(NETR/NETW)	(NETR/NETW)	(NETR/NETW)	(NETR/NETW)

1.2 Major Components of the S7-200 Micro PLC

An S7-200 Micro PLC consists of an S7-200 CPU alone or with a variety of optional expansion modules.

S7-200 CPU

The S7-200 CPU combines a central processing unit (CPU), power supply, and discrete I/O points into a compact, stand-alone device.

- The CPU executes the program and stores the data for controlling the automation task or process.
- The digital inputs and outputs are the system control points: the inputs monitor the signals from the field devices (such as sensors and switches), and the outputs control pumps, motors, or other devices in your process.
- The power supply provides electrical power for the CPU and for any expansion module that is connected.
- The communications port(s) allow you to connect the CPU to a programming device or to other devices.
- Status lights provide visual information about the CPU mode (RUN or STOP), the current state of the local I/O, and whether a system fault has been detected.
- Additional I/O points can be added to the CPU with expansion modules. (The CPU 221 is not expandable.)
- Higher performance communications can be added with expansion modules.
- Some CPUs provide a real-time clock as a built-in feature, while other CPUs have an optional real-time clock cartridge.
- An optional plug-in serial EEPROM cartridge provides a means to store CPU programs and transfer programs from one CPU to another.
- An optional plug-in battery cartridge provides extended retention of data memory in RAM.

Figure 1-3 shows the S7-200 CPU.

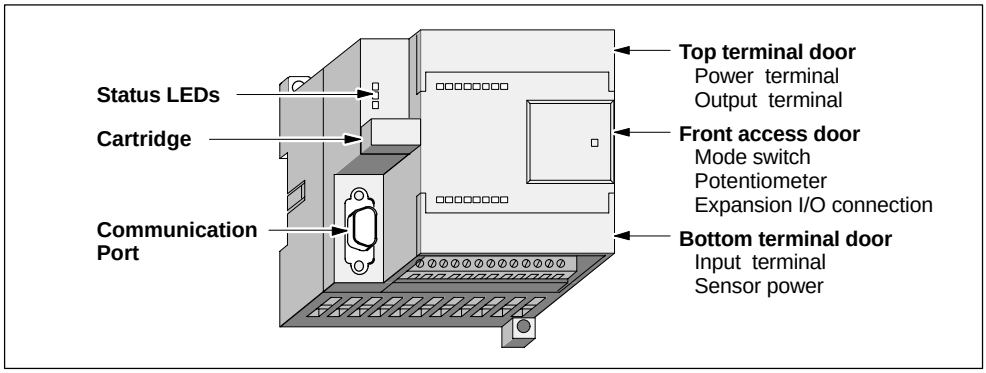

Figure 1-3 S7-200 CPU

Expansion Modules

The S7-200 CPU provides a certain number of local I/O. Adding an expansion module provides additional input or output points (see Figure 1-4).

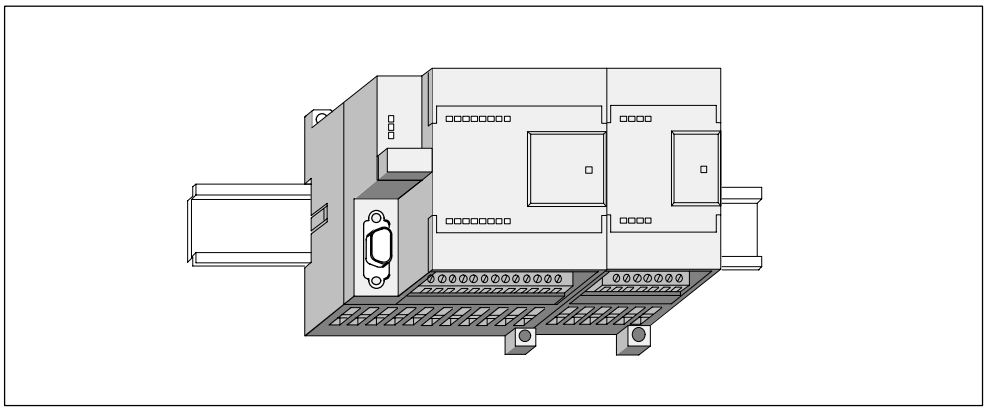

Figure 1-4 CPU with an Expansion Module

1.3 Maximum I/O Configurations

The maximum I/O configuration for each CPU system is subject to the following limits:

- Module count:

  CPU 221: no expansion available

  CPU 222: maximum of 2 expansion modules

  CPU 224 and CPU 226: maximum of 7 expansion modules

  No more than 2 of the 7 modules can be intelligent expansion modules (EM 277 PROFIBUS-DP modules)

- Digital Image Register size: The logical space that each CPU allows for digital I/O is 128 inputs and 128 outputs. Some physical points cannot be realized in this logical space because this space is allocated in blocks of 8 points. An 8-point block may not be completely realized by a specific module. For example, the CPU 224 with 10 actual outputs consumes 16 points of logical output space. A 4-input/4-output module consumes 8 inputs and 8 outputs of logical space. At the time of printing of this manual, there is no combination of current release CPU and I/O modules that causes this item to be a limit. It can be a limit in systems including prior release CPU 22x or future release products.
- Analog Image Register size: The logical space allowed for analog I/O is:

  CPU 222: 16 inputs and 16 outputs

  CPU 224 and CPU 226: 32 inputs and 32 outputs

- 5V power budget: The maximum 5V current supplied by each CPU is listed in Table 1-2. Total current of all expansion modules in the system cannot exceed this budget. See Section 2.5 for further information on power considerations.

Table 1-3 shows the maximum I/O configuration allowed for each S7-200 CPU.

Table 1-2 Current Supplied by S7-200 CPU

CPU 22x 5 VDC Current Supplied for Expansion I/O - ma		**Expansion Module 5 VDC Current Consumption - ma**	
CPU 222	340	EM 221 DI8 x DC24V	30
CPU 224	660	EM 222 DO8 x DC24V	50
CPU 226	1000	EM 222 DO8 x Rly	40
		EM 223 DI4/DO4 x DC24V	40
		EM 223 DI4/DO4 x DC24V/Rly	40
		EM 223 DI8/DO8 x DC24V	80
		EM 223 DI8/DO8 x DC24V/Rly	80
		EM 223 DI16/DO16 x DC24V	160
		EM 223 DI16/DO16 x DC24V/Rly	150
		EM 231 AI4 x 12 Bit	20
		EM 231 AI4 x Thermocouple	60
		EM 231 AI4 x RTD	60
		EM 232 AQ2 x 12 Bit	20
		EM 235 AI4I/AQ1 x 12 Bit	30
		EM 277 PROFIBUS-DP	150

Table 1-3 Maximum I/O Configurations for S7-200 CPUs

Module	5V ma	Digital Inputs	Digital Outputs	Analog Inputs	Analog Outputs
CPU 221	No expansion possible				
CPU 222					
Max Digital In/Out					
CPU	+340	8	6		
2 x EM 223 DI16/DO16 x DC24V	-320 or	32	32		
or	-300				
2 x EM 223 DI16/DO16 x DC24V/Rly	**>0**				
Total =		**40**	**38**		
Max Analog In					
CPU	+340	8	6		
2 x EM 235 AI4/AQ1	-60			8	2
Total =	**>0**	**8**	**6**	**8**	**2**
Max Analog Out					
CPU	+340	8	6		
2 x EM 232 AQ2	-40			0	4
Total =	**>0**	**8**	**6**	**0**	**4**
CPU 224					
Max Digital In/Rly Out					
CPU	+660	14	10		
4 x EM 223 DI16/DO16 x DC24V/Rly	-600	64	64		
2 x EM 221 DI8 x DC24V	-60	16			
Total =	**=0**	**94**	**74**		
Max Digital In/DC Out					
CPU	+660	14	10		
4 x EM 223 DI16/DO16 x DC24V	-640	64	64		
Total =	**>0**	**78**	**74**		
Digital In/Max Rly Out					
CPU	+660	14	10		
4 x EM 223 DI16/DO16 x DC24V/Rly	-600	64	64		
1 x EM 222 DO8 x Rly	-40		8		
Total =	**>0**	**78**	**82**		
CPU 226					
Max Digital In/Rly Out					
CPU	+1000	24	16		
6 x EM 223 DI16/DO16 x DC24V/Rly	-900	96	96		
1 x EM 223 DI8/DO8 x DC24V/Rly	-80	8	8		
Total =	**>0**	**128**	**120**		
Max Digital In/DC Out					
CPU	+1000	24	16		
6 x EM 223 DI16/DO16 x DC24V	-960	96	96		
1 x EM 221 DI8 x DC24V	-30	8			
Total =	**>0**	**128**	**112**		
CPU 224 or CPU 226					
Max Analog In					
CPU	>660	14 (24)	10 (16)		
7 x EM 235 AI4/AQ1	-210			28	7
Total =	**>0**	**14 (24)**	**10 (16)**	**28**	**7**
Max Analog Out					
CPU	>660	14 (24)	10 (16)		
7 x EM 232 AQ2	-140			0	14
Total =	**>0**	**14 (24)**	**10 (16)**	**0**	**14**

Installing an S7-200 PLC

2

The installation of the S7-200 equipment is designed to be easy. You can use the mounting holes to attach the modules to a panel, or you can use the built-in clips to mount the modules onto a standard (DIN) rail. The small size of the S7-200 allows you to make efficient use of space.

This chapter provides guidelines for installing and wiring your S7-200 system.

Chapter Overview

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2.1 Panel Layout Considerations

Installation Configuration

You can install an S7-200 either on a panel or on a standard rail. You can mount the S7-200 either horizontally or vertically. You can connect the S7-200 to expansion modules by one of these methods:

- A flexible ribbon cable with mating connector is built into the I/O module for easy connection to the PLC or another expansion module.
- An I/O expansion cable is also available to add flexibility to your mounting configuration.

Figure 2-1 shows a typical configuration for these types of installations.

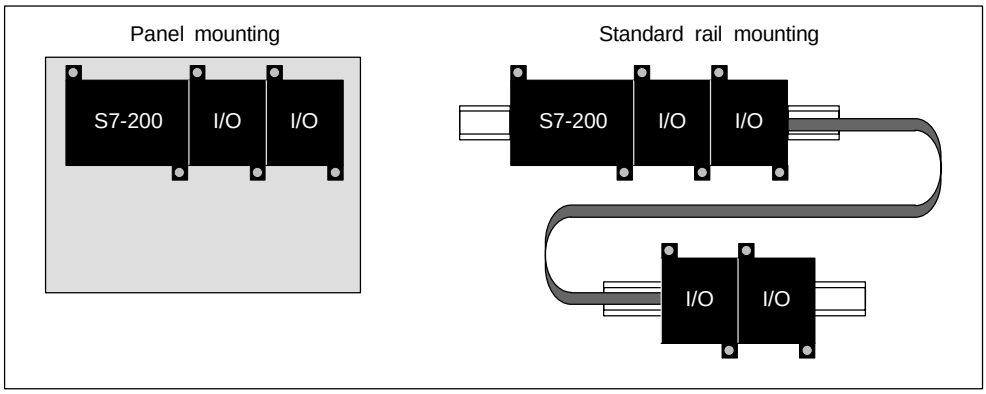

Figure 2-1 Mounting Configurations

Clearance Requirements for Installing an S7-200 PLC

Use the following guidelines as you plan your installation:

- The S7-200 CPU and expansion modules are designed for natural convection cooling. You must provide a clearance of at least 25 mm (1 in.), both above and below the units, for proper cooling. See Figure 2-2. Continuous operation of all electronic products at maximum ambient temperature and load reduces their life.
- For vertical mounting, the maximum ambient temperature is reduced by 10° C. The CPU should be mounted below any expansion modules. If you are mounting on a vertical DIN rail, you should use the DIN rail stop.
- Allow 75 mm (3 in.) for mounting depth. See Figure 2-2.
- Be sure to allow enough space in your mounting design to accommodate the I/O wiring and communication cable connections.

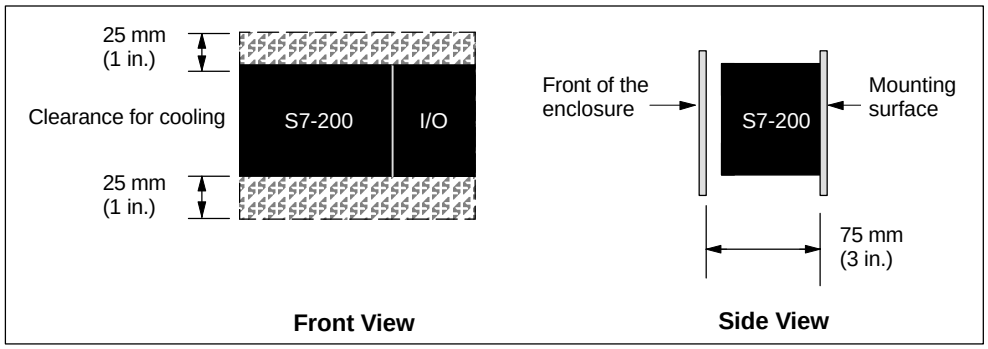

Figure 2-2 Horizontal and Vertical Clearance Requirements for Installing an S7-200 PLC

Standard Rail Requirements

The S7-200 CPU and expansion modules can be installed on a standard (DIN) rail (DIN EN 50 022). Figure 2-3 shows the dimensions for this rail.

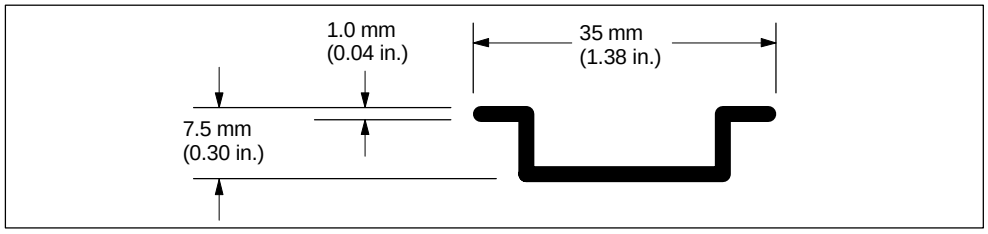

Figure 2-3 Standard Rail Dimensions

Panel-Mounting Dimensions

S7-200 CPUs and expansion modules include mounting holes to facilitate installation on panels. Figure 2-4 through Figure 2-7 provide the mounting dimensions for the different S7-200 CPUs and expansion modules.

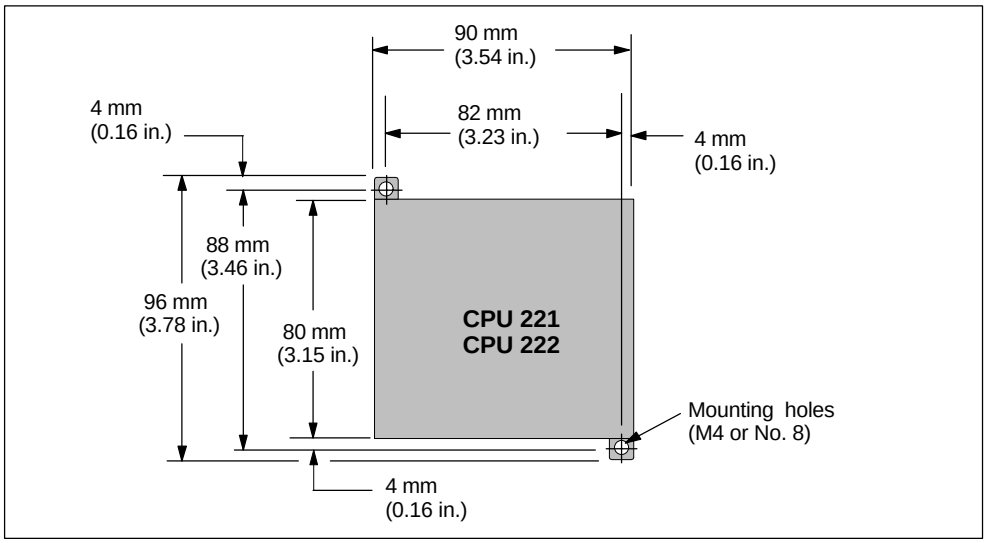

Figure 2-4 Mounting Dimensions for CPU 221 and CPU 222

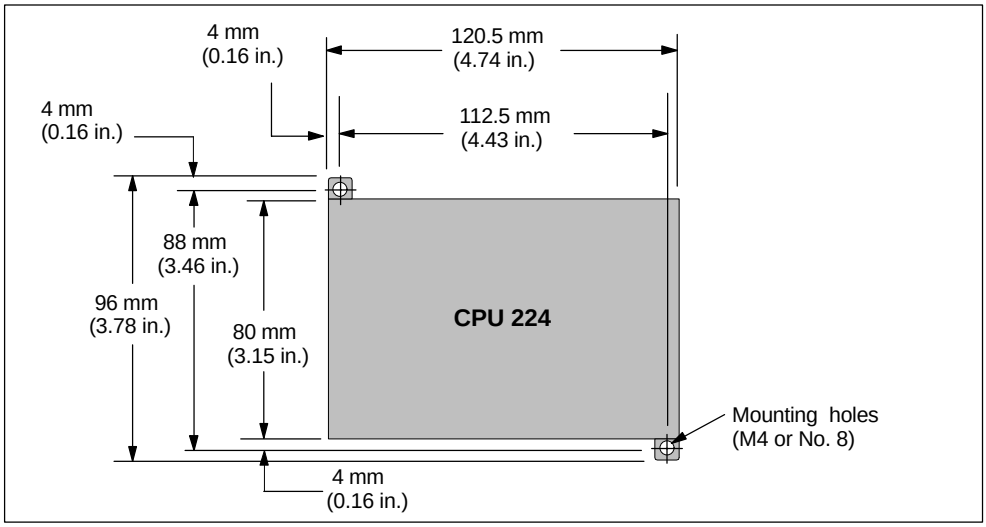

Figure 2-5 Mounting Dimensions for a CPU 224

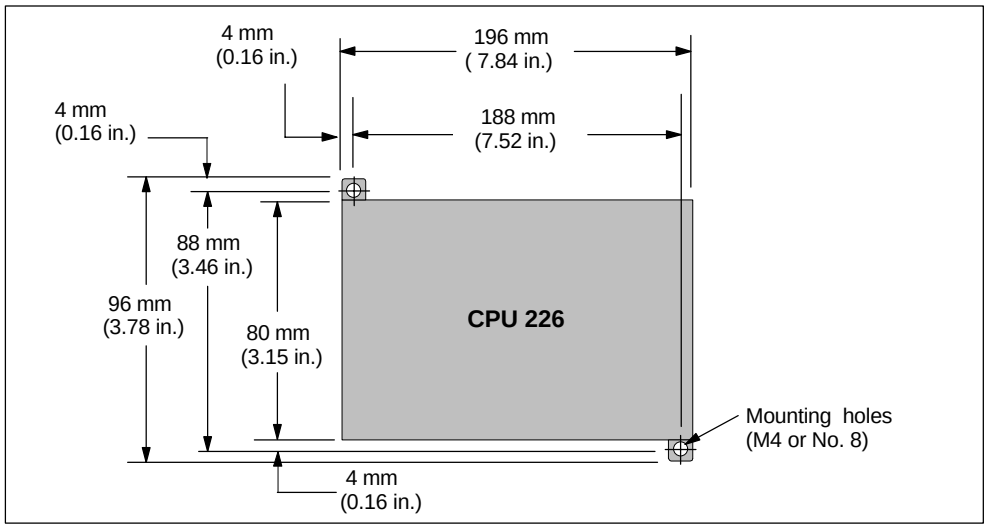

Figure 2-6 Mounting Dimensions for a CPU 226

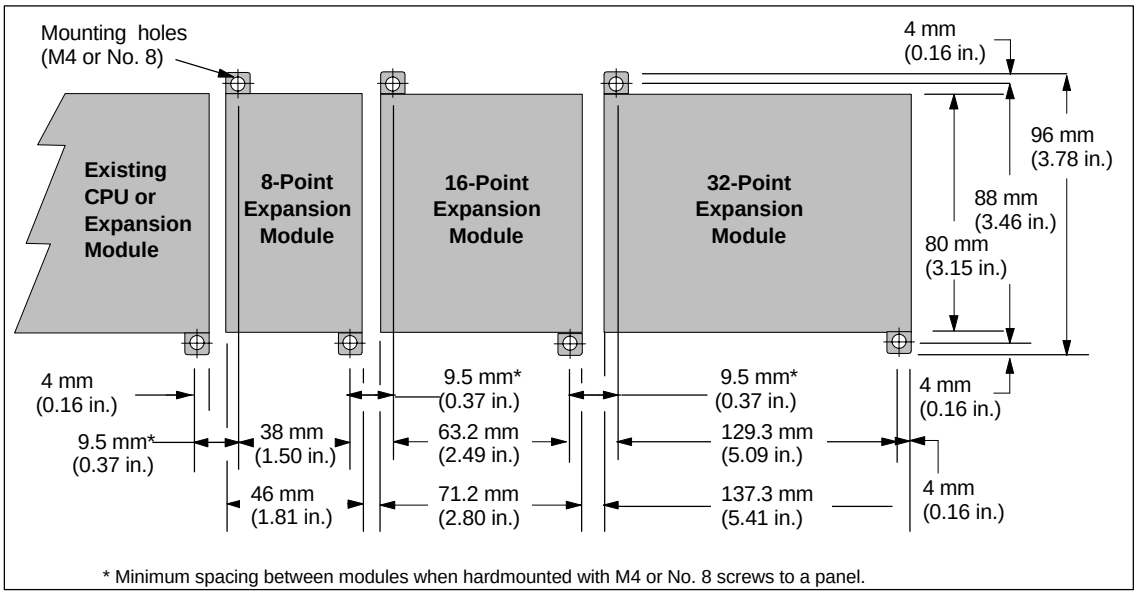

Figure 2-7 Mounting Dimensions for Expansion Modules

2.2 Installing and Removing an S7-200 Micro PLC or Expansion Module

Mounting an S7-200 Micro PLC or Expansion Module onto a Panel

Warning

Attempts to install or remove S7-200 CPUs or related equipment with power applied could cause electric shock or faulty operation of equipment.

Failure to disable all power to the S7-200 and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 is disabled before attempting to install or remove S7-200 CPUs or related equipment.

Use the following procedure for installing an S7-200 CPU onto a panel:

1. Locate, drill, and tap the mounting holes for DIN M4 or American Standard number 8 screws. Refer to Section 2.1 for mounting dimensions and other considerations.
2. Secure the S7-200 CPUs onto the panel, using DIN M4 or American Standard number 8 screws.

To install the expansion module onto a panel, follow these steps:

1. Locate, drill, and tap the mounting holes for DIN M4 or American Standard number 8 screws. Refer to Section 2.1 for mounting dimensions and other considerations.
2. Place the I/O module next to the PLC or expansion module and secure it.
3. Plug the expansion module ribbon cable into the CPU connector under the front access door. The cable is keyed for correct orientation.

Installation is complete.

Installing an S7-200 Micro PLC or Expansion Module onto a Standard Rail

Warning

Attempts to install or remove S7-200 CPUs or related equipment when they are powered up could cause electric shock or faulty operation of equipment.

Failure to disable all power to the S7-200 CPUs and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 is disabled before attempting to install or remove S7-200 CPUs or related equipment.

To install the S7-200 CPU onto a standard rail, follow these steps:

1. Secure the rail to the mounting panel every 75 mm (3.0 in.).
2. Snap open the clip (located on the bottom of the S7-200) and hook the back of the S7-200 onto the rail.
3. Snap the clip closed, carefully checking to ensure that the clip has fastened the S7-200 securely onto the rail.

To install the expansion module onto a standard rail, use the following steps:

1. Snap open the clip and hook the back of the expansion module onto the rail next to the CPU or expansion module.
2. Snap the clip closed to secure the expansion module to the rail. Carefully check to ensure that the clip has fastened the module securely onto the rail.
3. Plug the expansion module ribbon cable into the CPU connector under the front access door. The cable is keyed for correct orientation.
4. Installation is complete.

Note

Modules in an environment with high vibration potential or modules that have been installed in a vertical position may require DIN rail stops.

Removing the S7-200 Micro PLC or Expansion Module

Warning

Attempts to install or remove S7-200 CPUs or related equipment when they are powered up could cause electric shock or faulty operation of equipment.

Failure to disable all power to the S7-200 CPUs and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 modules is disabled before installation.

To remove the S7-200 CPU or expansion module, follow these steps:

1. Disconnect all the wiring and cabling that is attached to the module that you are removing. See Figure 2-8. Some CPUs and expansion modules have removeable connectors.
2. Open the front access door and disconnect the ribbon cable from the adjacent modules.
3. Unscrew the mounting screws or snap open the clip, and remove the module.

Warning

If you install an incorrect module, the program in the micro PLC could function unpredictably.

Failure to replace an expansion module and expansion cable with the same model or in the proper orientation may result in death or serious personal injury, and/or damage to equipment.

Replace an expansion module with the same model, and orient it correctly.

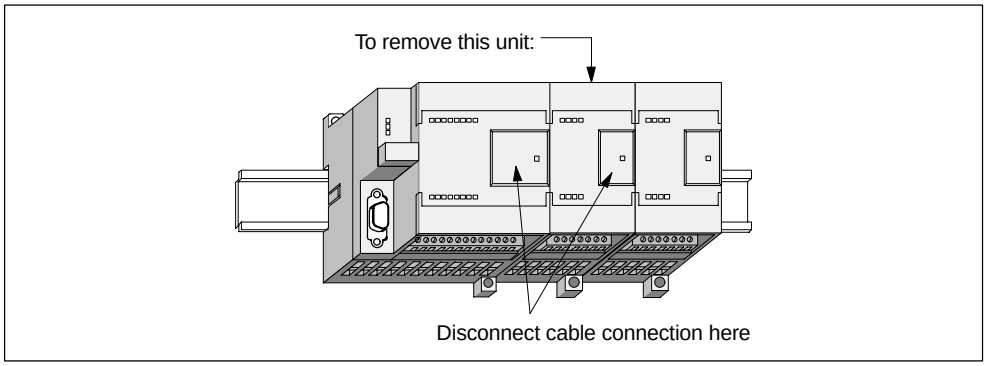

Figure 2-8 Removing the Expansion Module

2.3 Installing the Field Wiring

Warning

Attempts to install or remove S7-200 CPUs or related equipment when they are powered up could cause electric shock or faulty operation of equipment.

Failure to disable all power to the S7-200 CPUs and related equipment during installation or removal procedures may result in death or serious personal injury, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that power to the S7-200 is disabled before installing field wiring.

General Guidelines

The following items are general guidelines for designing the installation and wiring of your S7-200 Micro PLC:

- Ensure that you follow all applicable electrical codes when wiring the S7-200 Micro PLC. Install and operate all equipment according to all applicable national and local standards. Contact your local authorities to determine which codes and standards apply to your specific case.
- Always use the proper wire size to carry the required current. The S7-200 accepts wire sizes from 1.50 mm^2 to 0.50 mm^2 (14 AWG to 22 AWG).
- Ensure that you do not over-tighten the connector screws. The maximum torque is 0.56 N-m (5 inch-pounds).
- Always use the shortest wire possible (maximum 500 m shielded, 300 m unshielded). Wiring should be run in pairs, with a neutral or common wire paired with a hot or signal-carrying wire.
- Separate AC wiring and high-energy, rapidly switched DC wiring from low-energy signal wiring.
- Properly identify and route the wiring to the S7-200, using strain relief for the wiring as required. For more information about identifying the terminals, see the specifications in Appendix A.
- Install appropriate surge suppression devices for any wiring that is subject to lightning surges.
- External power should not be applied to an output load in parallel with a DC output point. This may cause reverse current through the output, unless a diode or other barrier is provided in the installation.

Warning

Control devices can fail in an unsafe condition, resulting in unexpected operation of controlled equipment.

Such unexpected operations could result in death or serious personal injury, and/or equipment damage.

Consider using an emergency stop function, electromechanical overrides, or other redundant safeguards that are independent of the programmable controller.

Grounding and Circuit Reference Point Guidelines for Using Isolated Circuits

The following items are grounding and circuit guidelines for using isolated circuits:

- You should identify the reference point (0 voltage reference) for each circuit in the installation, and the points at which circuits with possibly different references can connect together. Such connections can result in unwanted current flows that can cause logic errors or damage circuits. A common cause of different reference potentials is grounds that are physically separated by long distances. When devices with widely separated grounds are connected with a communication or sensor cable, unexpected currents can flow through the circuit created by the cable and the ground. Even over short distances, load currents of heavy machinery can cause differences in ground potential or can directly induce unwanted currents by electromagnetic induction. Power supplies that are improperly referenced with respect to each other can cause damaging currents to flow between their associated circuits.
- When you connect CPUs with different ground potentials to the same PPI network, you should use an isolated RS-485 repeater.
- S7-200 products include isolation boundaries at certain points to help prevent unwanted current flows in your installation. When you plan your installation, you should consider where these isolation boundaries are provided, and where they are not provided. You should also consider the isolation boundaries in associated power supplies and other equipment, and where all associated power supplies have their reference points.
- You should choose your ground reference points and use the isolation boundaries provided to interrupt unneeded circuit loops that could allow unwanted currents to flow. Remember to consider temporary connections that may introduce a new circuit reference, such as the connection of a programming device to the CPU.
- When locating grounds, you must also consider safety grounding requirements and the proper operation of protective interrupting devices.
- In most installations, you will have the best noise immunity if you connect the sensor supply M terminal to ground.

The following descriptions are an introduction to general isolation characteristics of the S7-200 family, but some features may be different on specific products. Consult your product specifications in Appendix A for information about which circuits include isolation boundaries and the ratings of the boundaries. Isolation boundaries rated less than 1,500 VAC are designed as functional isolation only, and should not be depended on as safety boundaries.

- Logic circuit reference is the same as DC sensor supply M.
- Logic circuit reference is the same as the input power supply M on a CPU with DC power supply.
- CPU communication ports have the same reference as logic circuit.
- Analog inputs and outputs are not isolated from logic circuit. Analog inputs are full differential to provide low voltage common mode rejection.
- Logic circuit is isolated from ground to 500 VAC.
- DC digital inputs and outputs are isolated from logic circuit to 500 VAC.
- DC digital I/O groups are isolated from each other by 500 VAC.
- Relay outputs are isolated from logic circuit to 1,500 VAC.
- Relay output groups are isolated from each other by 1,500 VAC.
- AC power supply line and neutral are isolated from ground, the logic circuit, and all I/O to 1,500 VAC.

Using the Optional Field Wiring Connector for Units Without a Removable Connector

The optional field wiring fan-out connector (Figure 2-9) allows for field wiring connections to remain fixed when you remove and re-install the S7-200 unit. Refer to Appendix E for the order number of the fan-out connector.

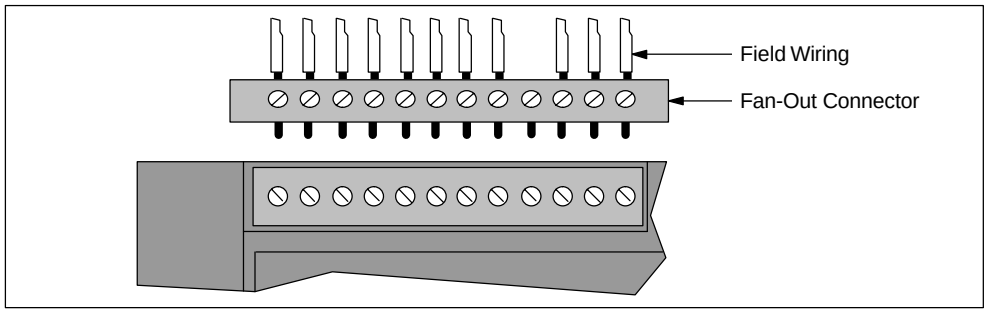

Figure 2-9 Optional Field Wiring Connector

Using the Removable Terminal Block Connector

The removable terminal block connector (Figure 2-10) allows field wiring connections to remain fixed when you remove and re-install the S7-200 CPU and I/O expansion modules.

To remove the terminal block connector from the CPU or expansion module, follow these steps:

1. Raise the top terminal door of the CPU or expansion module.
2. Insert a screwdriver in the notch in the middle of the terminal block as shown in Figure 2-10.
3. Press down firmly and pry out the terminal connector as shown below.

To reinstall a terminal block connector in a CPU or expansion module, follow these steps:

1. Raise the top terminal door of the CPU or expansion module.
2. Ensure that the new terminal block connector is properly aligned with the pins on the CPU or expansion module.
3. Press down the terminal block connector into the CPU or expansion module until the connector snaps into place.

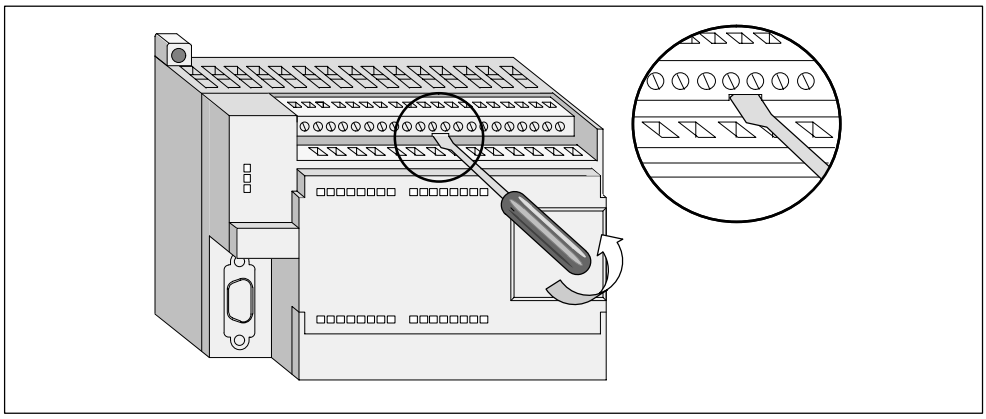

Figure 2-10 Removable Terminal Block Connector for the CPU 224 and I/O Expansion Modules.

Guidelines for AC Installation

The following items are general wiring guidelines for AC installations. Refer to Figure 2-11.

[a] Provide a single disconnect switch that removes power from the CPU, all input circuits, and all output (load) circuits.

[b] Provide overcurrent devices to protect the CPU power supply, the output points, and the input points. You can also fuse each output point individually for greater protection.

[c] External overcurrent protection for input points is not required when you use the 24 VDC sensor supply from the Micro PLC. This sensor supply is short-circuit protected.

[d] Connect all S7-200 ground terminals to the closest available earth ground to provide the highest level of noise immunity. It is recommended that all ground terminals be connected to a single electrical point. Use 14 AWG or 1.5 mm^2 wire for this connection.

[e] DC sensor supply from the CPU may be used for CPU inputs,

[f] expansion DC inputs, and [g] expansion relay coils. This sensor supply is short-circuit protected.

[h] In most installations, you will have the best noise immunity if you connect the sensor supply M terminal to ground.

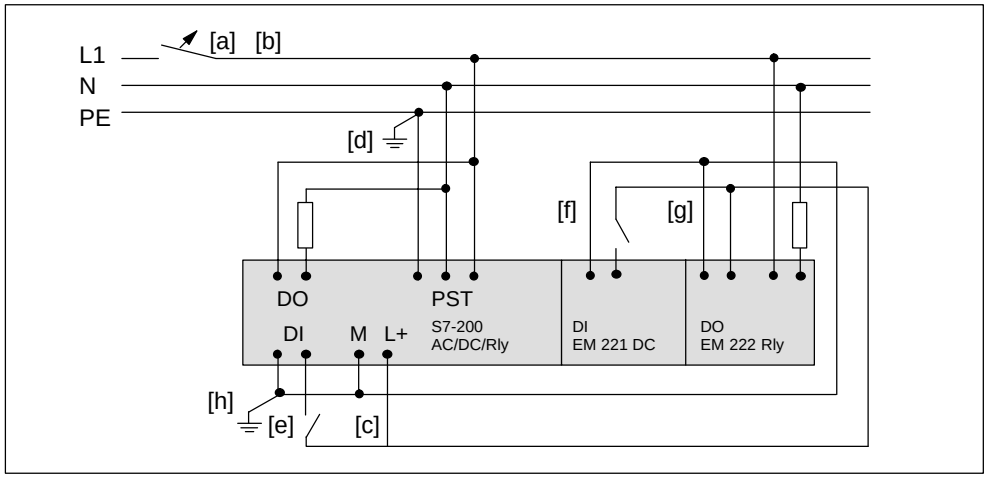

Figure 2-11 120 VAC/230 VAC Using a Single Overcurrent Switch to Protect the CPU and Load Wiring

Guidelines for DC Installation

The following items are general wiring guidelines for DC installations. Refer to Figure 2-12.

[a] Provide a single disconnect switch that removes power from the CPU, all input circuits, and all output (load) circuits.

[b] Provide overcurrent devices to protect the CPU power supply, [c] the output points, and [d] the input points. You can also fuse each output point individually for greater protection. External overcurrent protection for input points is not required when you use the 24 VDC sensor supply from the Micro PLC. This sensor supply is current limited internally.

[e] Ensure that the DC power supply has sufficient surge capacity to maintain voltage during sudden load changes. External capacitance may be required.

[f] In most installations, you will have best noise immunity by connecting all DC power supplies to ground. Equip ungrounded DC power supplies with a resistor and a capacitor in parallel [g] from the power source common to protective earth ground. The resistor provides a leakage path to prevent static charge accumulations, and the capacitor provides a drain for high frequency noise. Typical values are 1 MΩ and 4,700 pf.

[h] Connect all S7-200 ground terminals to the closest available earth ground to provide the highest level of noise immunity. It is recommended that all ground terminals be connected to a single electrical point. Use 14 AWG or 1.5 mm^2 wire for this connection.

Always supply 24 VDC circuits from a source that provides safe electrical separation from 120/230 VAC power and similar hazards.

The following documents provide standard definitions of safe separation:

- PELV (protected extra low voltage) according to EN60204-1
- Class 2 or Limited Voltage/Current Circuit according to UL 508

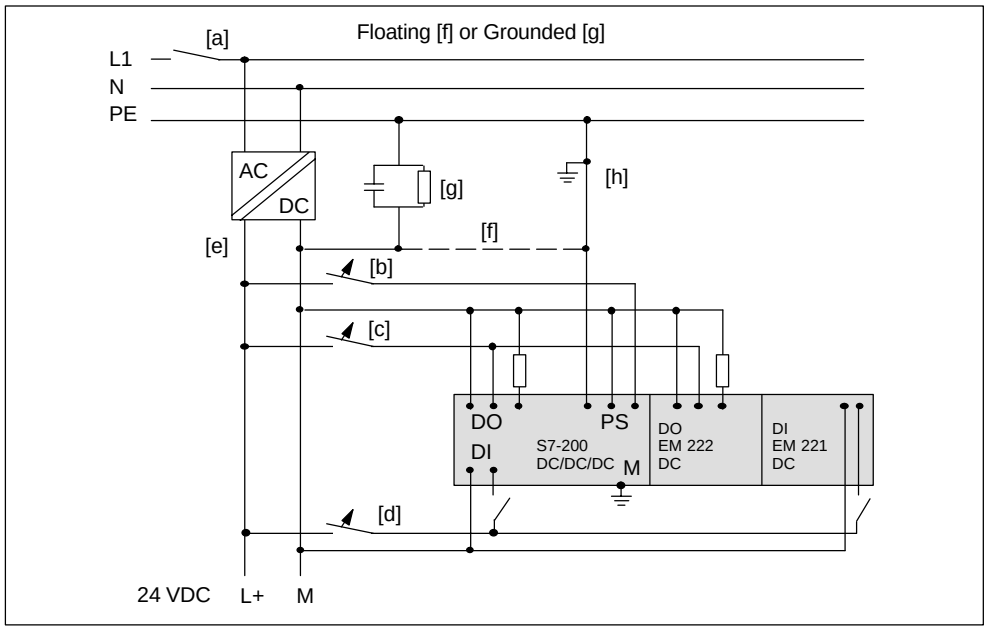

Figure 2-12 DC System Installation

2.4 Using Suppression Circuits

General Guidelines

Equip inductive loads with suppression circuits that limit voltage rise on loss of power. Use the following guidelines to design adequate suppression. The effectiveness of a given design depends on the application, and you must verify it for a particular use. Be sure all components are rated for use in the application.

Protecting DC Transistors

The S7-200 DC transistor outputs include zener-controlled clamping that is adequate for many installations. Use external suppression diodes for either large or frequently switched inductive loads to prevent overpowering the internal circuits. Figure 2-13 and Figure 2-14 show typical applications for DC transistor outputs.

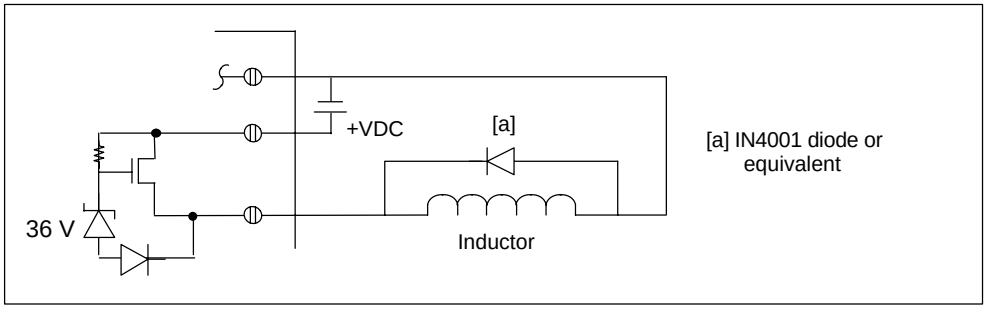

Figure 2-13 Diode Suppression for DC Transistor Outputs

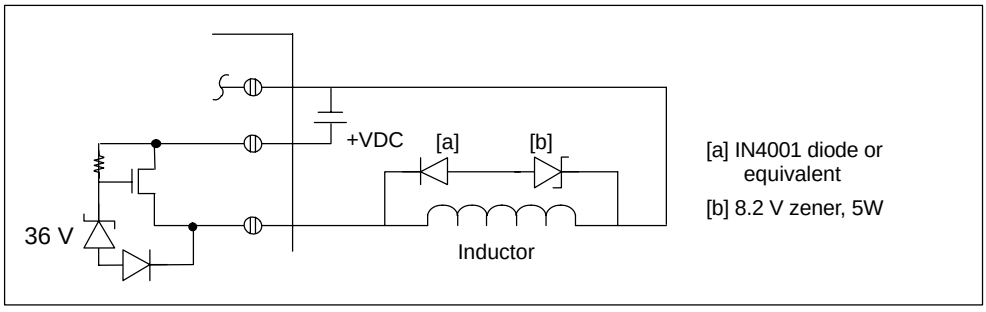

Figure 2-14 Zener Diode Suppression for DC Transistor Outputs

Protecting Relays That Control DC Power

Resistor/capacitor networks, as shown in Figure 2-15, can be used for low voltage (30 V) DC relay applications. Connect the network across the load.

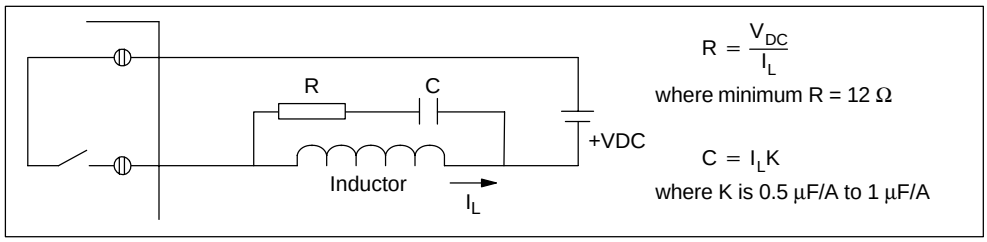

Figure 2-15 Resistor/Capacitor Network on Relay-Driven DC Load

You can also use diode suppression, as shown in Figure 2-13 and Figure 2-14, for DC relay applications. A threshold voltage of up to 36 V is allowed if you use a reverse zener diode.

Protecting Relays That Control AC Power

When you use a relay to switch 115 VAC/230 VAC inductive loads, you should place resistor/capacitor networks across the relay contacts as shown in Figure 2-16. You can also use a metal oxide varistor (MOV) to limit peak voltage. Ensure that the working voltage of the MOV is at least 20% greater than the nominal line voltage.

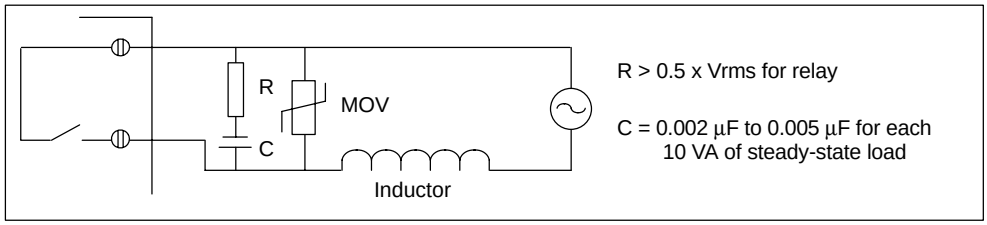

Figure 2-16 AC Load with Network across Relay

The capacitor allows leakage current to flow around the open switch. Be sure that the leakage current, I (leakage) = 2 x 3.14 x f x C x Vrms, is acceptable for the application.

For example: A NEMA size 2 contactor lists 183 VA coil inrush and 17 VA sealed coil load. At 115 VAC, the inrush current is 183 VA/115 V = 1.59 A, which is within the 2-A switching capability of the relay contacts.

The resistor = 0.5 x 115 = 57.5 Ω; choose 68 Ω as a standard value.
The capacitor = (17 VA/10) x 0.005 = 0.0085 μF; choose 0.01 μF as the value.
The leakage current = 2 x 3.14 x 60 x 0.01 x 10^{-6} x 115 = 0.43 mA rms.

2.5 Power Considerations

The S7-200 CPUs have an internal power supply that provides power for the CPU, the expansion modules, and other 24 VDC user power requirements. Use the following information as a guide for determining how much power (or current) the CPU can provide for your configuration.

Power Requirements

Each S7-200 CPU supplies both 5 VDC and 24 VDC power:

- Each CPU has a 24 VDC sensor supply that can supply 24 VDC for local input points or for relay coils on the expansion modules. If the power requirement for 24 VDC exceeds the power budget of the CPU, you can add an external 24 VDC power supply to provide 24 VDC to the expansion modules. You must manually connect the 24 VDC supply to the input points or relay coils.
- The CPU also provides 5 VDC power for the expansion modules when an expansion module is connected. If the 5 VDC power requirements for expansion modules exceeds the power budget of the CPU, you must remove expansion modules until the requirement is within the power budget.

The specifications in Appendix A provide information about the power budgets of the CPUs and the power requirements of the expansion modules.

Warning

Connecting an external 24 VDC power supply in parallel with the S7-200 DC Sensor Supply can result in a conflict between the two supplies as each seeks to establish its own preferred output voltage level.

The result of this conflict can be shortened lifetime or immediate failure of one or both power supplies, with consequent unpredictable operation of the PLC system. Unpredictable operation could result in death or serious injury to personnel, and/or damage to equipment and property.

The S7-200 DC Sensor Supply and any external power supply should provide power to different points. A single connection of the commons is allowed.

Calculating a Sample Power Requirement

Table 2-1 shows a sample calculation of the power requirements for an S7-200 Micro PLC that includes the following:

- CPU 224 AC/DC/Relay
- 3 each EM 223 8 DC In/8 Relay Out
- 1 each EM 221 8 DC In

This installation has a total of 46 inputs and 34 outputs.

The CPU in this example provides sufficient 5 VDC current for the expansion modules, but does not provide enough 24 VDC current from the sensor supply for all of the inputs and expansion relay coils. The I/O requires 400 mA and the CPU provides only 280 mA. This installation requires an additional source of at least 120 mA at 24 VDC power to operate all the included 24 VDC inputs and outputs.

Table 2-1 Power Budget Calculations for a Sample Configuration

CPU Power Budget	5 VDC	24 VDC
CPU 224 AC/DC/Relay	660 mA	280 mA

minus

System Requirements	5 VDC	24 VDC
CPU 224, 14 inputs		14 * 4 mA = 56 mA
3 EM 223, 5 V power required	3 * 80 mA = 240 mA	
1 EM 221, 5V power required	1 * 30 mA = 30 mA	
3 EM 223, 8 inputs each		3 * 8 * 4 mA = 96 mA
3 EM 223, 8 relay coils each		3 * 8 * 9 mA = 216 mA
1 EM 221, 8 inputs each		8 * 4 mA = 32 mA
Total Requirements	270 mA	400 mA

equals

Current Balance	5 VDC	24 VDC
Current Balance Total	390 mA	[120 mA]

Calculating Your Power Requirement

Use the table below to determine how much power (or current) the CPU can provide for your configuration. Refer to Appendix A for the power budgets of your CPU and the power requirements of your expansion modules.

Power Budget	5 VDC	24 VDC

minus

System Requirements	5 VDC	24 VDC
Total Requirements		

equals

Current Balance	5 VDC	24 VDC
Current Balance Total		

Getting Started with an S7-200 Programming System

3

This chapter describes how to set up an S7-200 programming system. The S7-200 programming system described in this chapter consists of:

- An S7-200 CPU
- A PC or programming device with STEP 7-Micro/WIN 32 installed
- An interconnecting cable

Chapter Overview

Section	Description	Page
3.1	Overview	3-2
3.2	Quick Start for STEP 7-Micro/WIN 32	3-3
3.3	How Do I Set Up Communications Using the PC/PPI Cable?	3-5
3.4	How Do I Complete the Communications Connection?	3-9
3.5	How Do I Change the Communications Parameters for My PLC?	3-10

3.1 Overview

General Information

You will need to base your installation on the following criteria:

- The operating system that you are using (Windows 95, Windows 98, or Windows NT 4.0)
- The type of hardware that you are using, for example:
  - PC with PC/PPI cable
  - PC or SIMATIC programming device with communications processor (CP) card
  - CPU 221, CPU 222, CPU 224, CPU 226
  - Modem
- The baud rate that you are using

Recommended Equipment

STEP 7-Micro/WIN 32, version 3.1, and STEP 7-Micro/WIN 32 Toolbox are Windows-based software applications that support the 32-bit Windows 95, Windows 98, and Windows NT environments. In order to use these software programs, the following equipment is recommended:

- TP070 Touch Panel for use with STEP 7-Micro/WIN 32 Toolbox
- A personal computer (PC) with an 80586 or greater processor and 16 Mbytes of RAM, or a Siemens programming device with STEP 7-Micro/WIN 32 installed (such as a PG 740). The minimum computer requirement is an 80486 processor with 8 Mbytes.
- One of the following sets of equipment:
  - A PC/PPI cable connected to your communications port
  - A communications processor (CP) card
- VGA monitor, or any monitor supported by Microsoft Windows with 1024 X 768 resolution
- At least 50 Mbytes of free hard disk space
- Windows 95, Windows 98, or Windows NT 4.0
- Optional but recommended: any mouse supported by Microsoft Windows

STEP 7-Micro/WIN 32 provides extensive online help and an online *Getting Started Manual*. Use the **Help** menu command or press F1 to obtain the most current information.

STEP 7-Micro/WIN 32 Toolbox also provides the TP070 Configuration Software for configuring the TP070 touch Panel, and the USS Protocol Instructions for use with MicroMaster Drives.

3.2 Quick Start for STEP 7-Micro/WIN 32

Pre-Installation Instructions

Before running the setup procedure, do the following:

- If a previous version of STEP 7-Micro/WIN 32 is installed, back up all STEP 7-Micro/WIN projects to diskette.
- Make sure all applications are closed, including the Microsoft Office toolbar.
- Be sure the cable between your personal computer and the CPU is connected. See Section 3.3 for instructions.

Installing STEP 7-Micro/WIN 32

Use the following procedure to install the STEP 7-Micro/WIN 32 software:

1. Start by inserting the CD or disk in the CD or disk drive of your computer.
2. Click once on the “Start” button to open the Windows menu.
3. Click on the **Run...** menu item.
4. If you are installing from a diskette: In the “Run” dialog box, type **`a:\setup`** and click on OK or press ENTER. This starts the setup procedure.

   If you are installing from a CD: In the “Run” dialog box, type **`e:\setup`** (where “e” is the drive letter of the CD) and click on OK or press ENTER. This starts the setup procedure.
5. Follow the online setup procedure to complete the installation.
6. The installation will automatically display the “Set the PG/PC Interface” dialog box. The PG/PC interface parameter is set up later in this chapter. Click on Cancel to continue.
7. The “Setup Complete” dialog box is now displayed with one of the following options:

   - Option 1: Yes, I want to restart my computer now. (default selected)
     No, I will restart my computer later

     If Option 1 is displayed, it is recommended that you accept the default settings, and select Finish to complete the installation and view the Read Me file for the the most recent information about STEP 7-Micro/WIN 32.
   - Option 2: Yes, I want to view the Read Me file now. (default selected)
     No, I want to launch STEP 7-Micro/WIN 32 now.

     If Option 2 is displayed, it is recommended that you accept the default settings and select Finish to complete the installation and view the Read Me file for the most recent information about STEP 7-Micro/WIN 32.

     For Option 2: both options can be selected. Selecting Finish with both options selected will complete the installation, display the Read Me file and launch STEP 7-Micro/WIN 32. See Figure 3-1.

Review the README*X*.TXT file included on your CD or diskettes for the most recent information about STEP 7-Micro/WIN 32. (In the *x* position, the letter A = German, B = English, C = French, D = Spanish, E = Italian.)

Note

Installing STEP 7-Micro/WIN in the same directory as an existing installation uninstalls the existing installation.

Common Problem List for Single Connection User

The following situations can cause the communication to fail:

- Wrong baud rate: Correct the baud rate
- Wrong station address: Correct the station address
- PC/PPI cable set incorrectly: Check DIP switch settings on PC/PPI cable
- Wrong communication port on personal computer: Check comm port
- CPU in freeport mode (comm port under control of user program): Put CPU in STOP mode
- Conflict with other masters: Disconnect the CPU from the network.

3.3 How Do I Set Up Communications Using the PC/PPI Cable?

This section explains how to set up communications between an S7-200 CPU and your personal computer using the PC/PPI cable. This is single master configuration with no other hardware (such as a modem or a programming device) installed.

How Do I Connect My Computer to the CPU?

Figure 3-1 shows a typical configuration for connecting your personal computer to your CPU with the PC/PPI cable. To establish proper communications between the components, follow these steps:

1. Set the DIP switches on the PC/PPI cable for the baud rate supported by your personal computer. You should also select 11-bit and DCE if these options are supported by your PC/PPI cable.
2. Connect the RS-232 end of the PC/PPI cable (labeled PC) to the communications port of your computer, either COM1 or COM2, and tighten the connecting screws.
3. Connect the RS-485 end of the PC/PPI cable (labeled PPI) to the communications port of the CPU, and tighten the connecting screws.

For the technical specifications of the PC/PPI cable, see Appendix A; for its order number, see Appendix E. For network applications with multiple connections see Chapter 7.

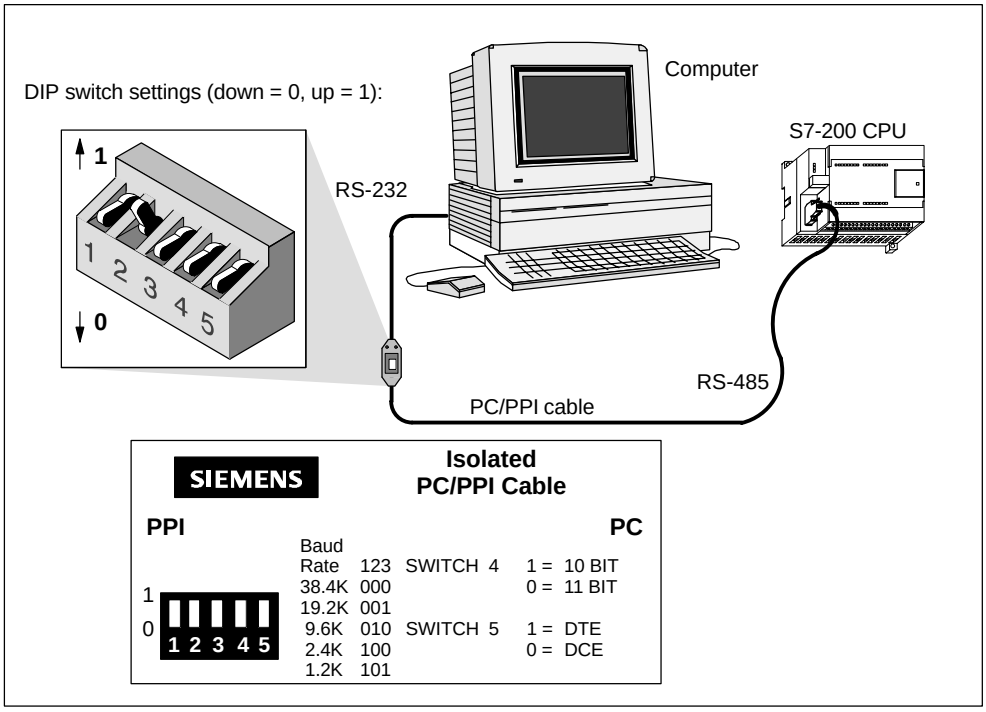

Figure 3-1 Communicating with a CPU in PPI Mode

How Do I Verify the Default Parameters for My Communications Interface?

You can verify the default parameters for your interface by following the steps below:

1. In the STEP 7-Micro/WIN 32 window, click the Communications icon, or select **View > Communications** from the menu. The Communications Links dialog box appears.
2. In the Communications Links dialog box, double-click on the icon for the PC/PPI cable. The Set the PG/PC Interface dialog box appears. See Figure 3-2.
3. Select the “Properties” button. The Properties dialog box for the interface appears (see Figure 3-3). Check the properties to ensure that they are correct. The default transmission rate is 9,600 baud (9.6 kbps).

For help in changing the default parameters, see Section 7.3 in Chapter 7.

Note
If the hardware that you are using does not appear on the list shown in “Set the PG/PC Interface” dialog box, then you must install the correct hardware. See Section 7.2.

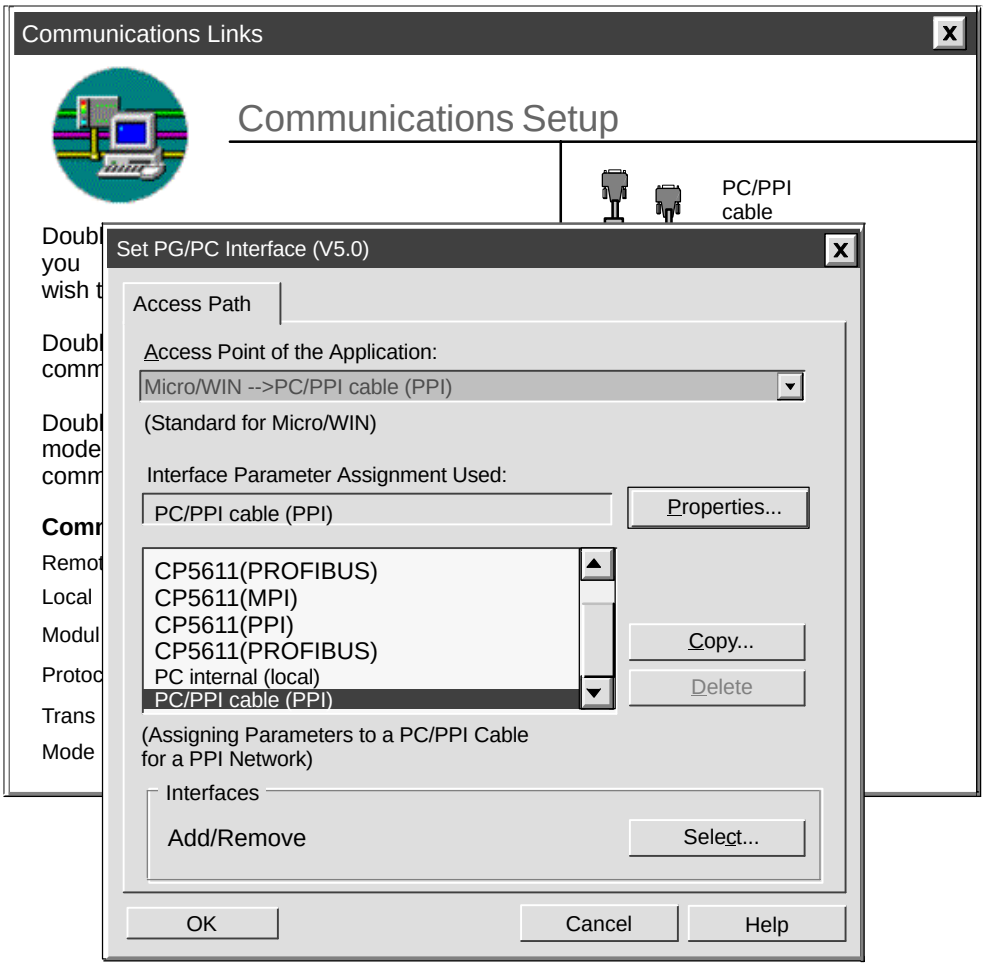

Figure 3-2 Set the PG/PC Interface Dialog Box

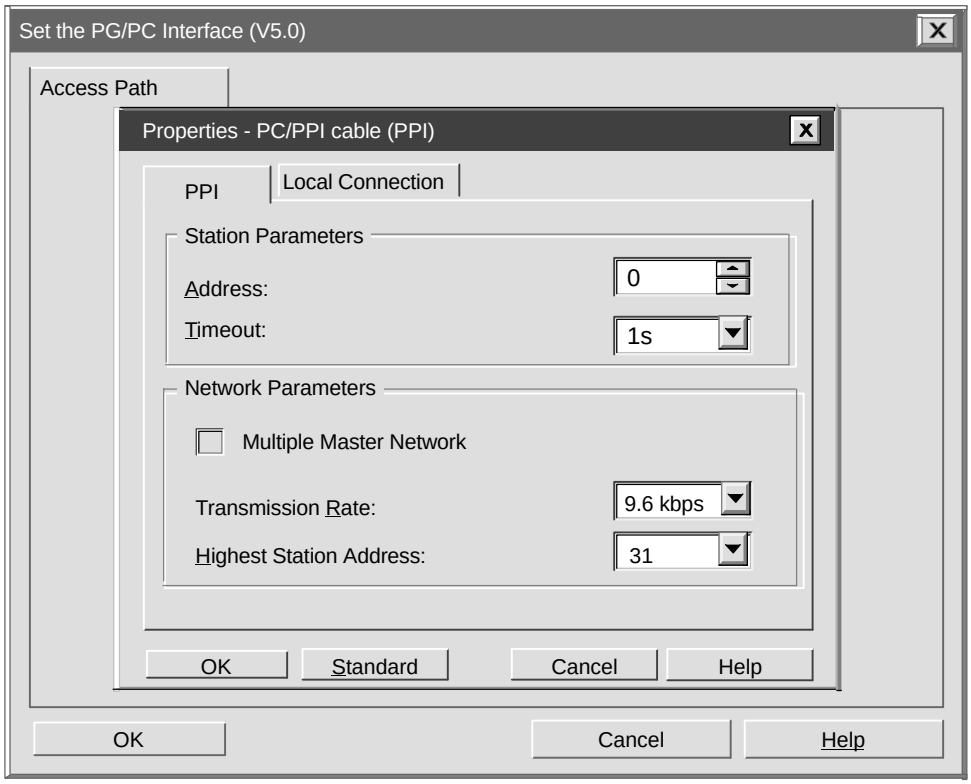

Figure 3-3 Properties Dialog Box for the PG/PC Interface

3.4 How Do I Complete the Communications Connection?

Once you have installed STEP 7-Micro/WIN 32 software on your PC and set up your PC for communications with the PC/PPI cable, you are ready to complete the logical connection to the S7-200 CPU. (If you are using a programming device (PG), STEP 7-Micro/WIN 32 is already installed.)

Follow the steps below to communicate with the S7-200 CPU:

1. In the STEP 7-Micro/WIN 32 screen, click the Communications icon, or select **View > Communications** from the menu. The Communications Links dialog box appears and shows that there are no CPUs connected.
2. Double click the refresh icon in the Communications Links dialog box. STEP 7-Micro/WIN 32 checks for any S7-200 CPUs (stations) that are connected, up to the highest station address in the specified communication parameters. A CPU icon appears on the Communications Links dialog box for each connected station. See Figure 3-4.
3. Double click the CPU station icon that you want to communicate with. You will notice that the communication parameters on the Setup Communications dialog box reflects the parameters for the selected station.
4. You are now communicating with the S7-200 CPU.

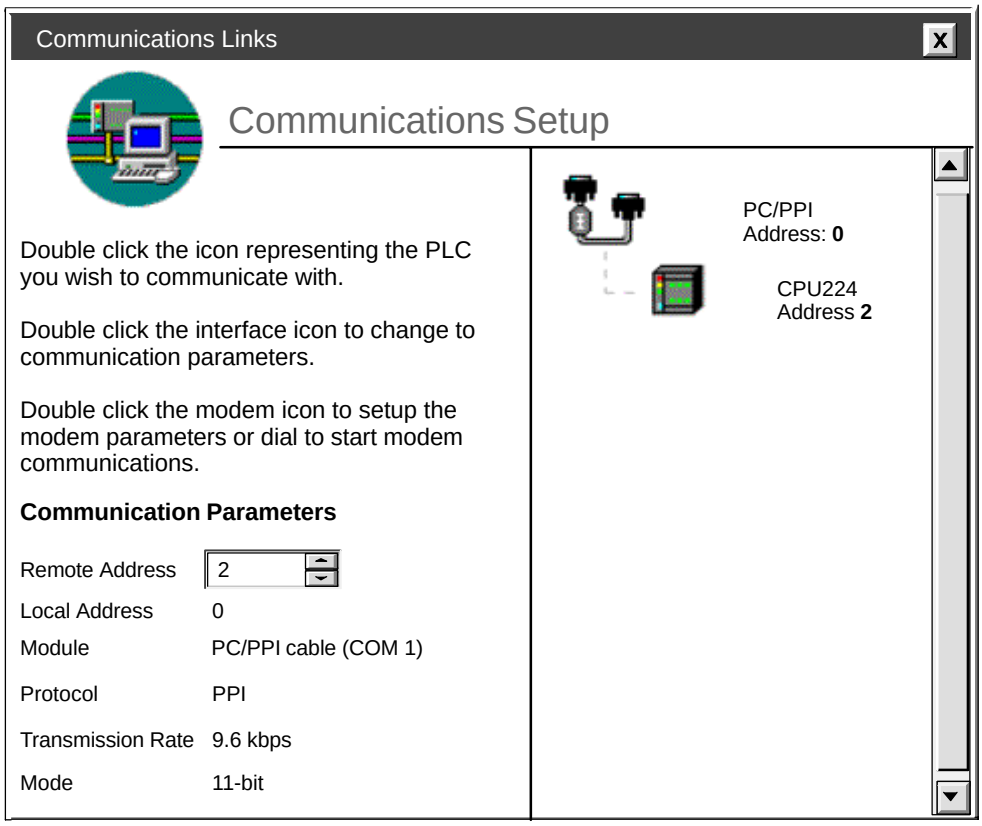

Figure 3-4 Communications Links Dialog Box

3.5 How Do I Change the Communications Parameters for My PLC?

Once you are communicating with the S7-200 CPU, you can verify or change the communications parameters for your CPU.

To change the communications parameters, follow the steps below:

1. Click the System Block icon on the navigation bar, or select **View > System Block** from the menu.
2. The System Block dialog box appears. Click on the Port(s) tab (see Figure 3-5). By default, the station address is 2, and the baud rate is 9.6 kbaud.
3. Select OK to keep these parameters. If you wish to change the parameters, make your changes, then click OK.
4. Click the Download icon on the toolbar to load the changes into the CPU.

Your communications parameters have been accepted.

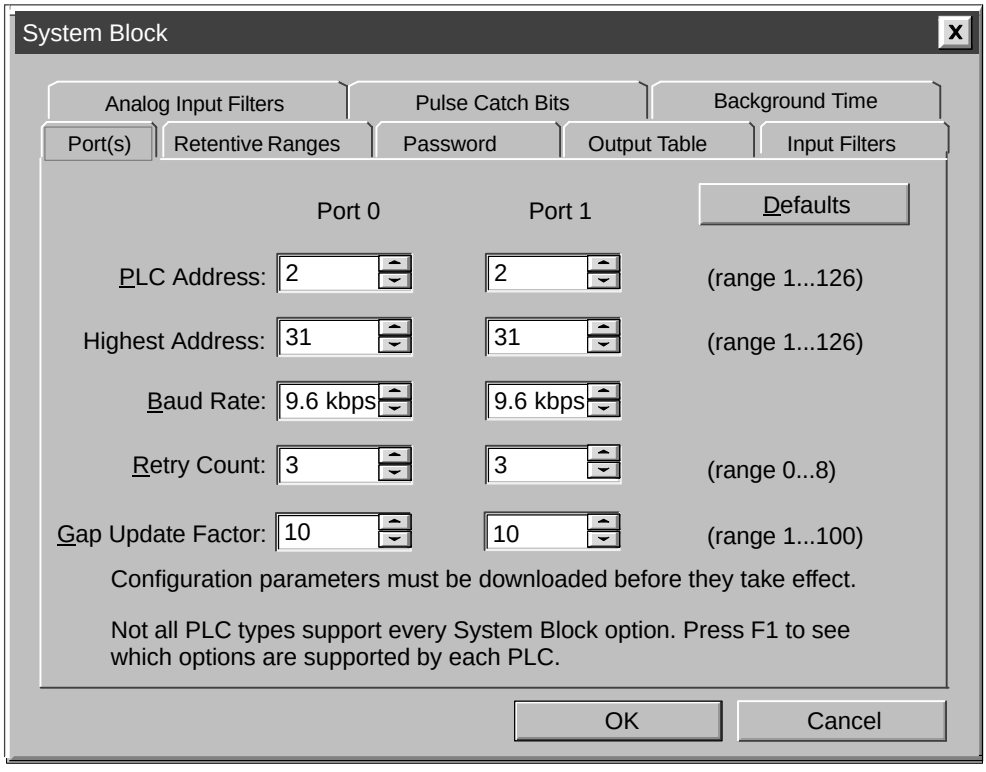

Figure 3-5 Changing the Communications Parameters

Basic Concepts for Programming an S7-200 CPU

4

Before you start to program your application using the S7-200 CPU, you should become familiar with some of the basic operational features of the CPU.

Chapter Overview

Section	Description	Page
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4.2	Concepts of an S7-200 Program	4-5
4.3	Concepts of the S7-200 Programming Languages and Editors	4-6
4.4	Understanding the Differences between SIMATIC and IEC 1131-3 Instructions	4-10
4.5	Basic Elements for Constructing a Program	4-18
4.6	Understanding the Scan Cycle of the CPU	4-22
4.7	Selecting the Mode of Operation for the CPU	4-25
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4.1 Guidelines for Designing a Micro PLC System

There are many methods for designing a Micro PLC system. This section provides some general guidelines that can apply to many design projects. Of course, you must follow the directives of your own company's procedures and of the accepted practices of your own training and location. Figure 4-1 shows some of the basic steps in the design process.

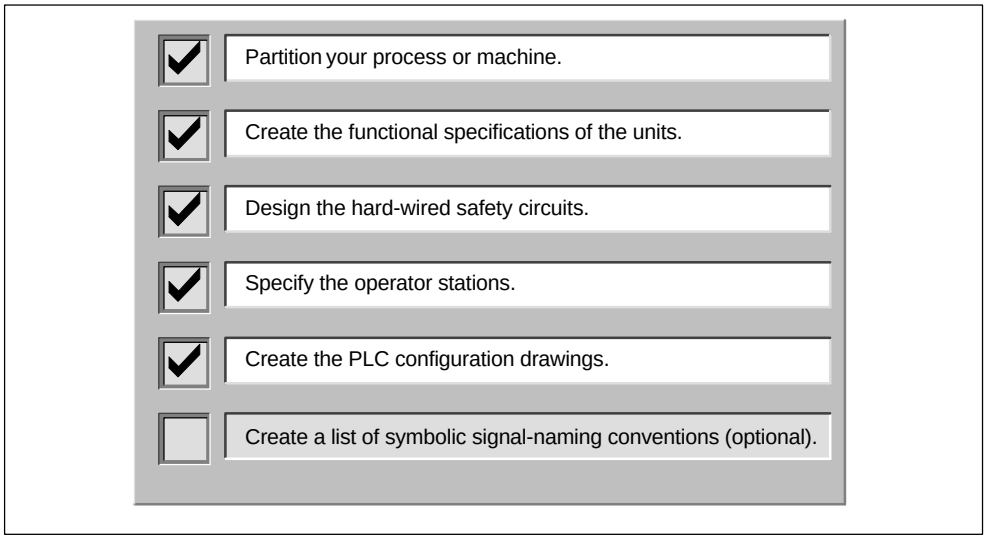


Figure 4-1 Basic Steps for Planning a PLC System

Partitioning Your Process or Machine

Divide your process or machine into sections that have a level of independence from each other. These partitions determine the boundaries between controllers and influence the functional description specifications and the assignment of resources.

Creating the Functional Specifications

Write the descriptions of operation for each section of the process or machine. Include the following topics:

- Input/output (I/O) points
- Functional description of the operation
- Permissive states (states that must be achieved before allowing action) for each actuator (solenoids, motors, drives, etc.)
- Description of the operator interface
- Interfaces with other sections of the process or machine

Designing the Safety Circuits

Identify equipment requiring hard-wired logic for safety. Control devices can fail in an unsafe manner, producing unexpected startup or change in the operation of machinery. Where unexpected or incorrect operation of the machinery could result in physical injury to people or significant property damage, consideration should be given to the use of electro-mechanical overrides which operate independently of the CPU to prevent unsafe operations.

The following tasks should be included in the design of safety circuits:

- Identify improper or unexpected operation of actuators that could be hazardous.
- Identify the conditions that would assure the operation is not hazardous, and determine how to detect these conditions independently of the CPU.
- Identify how the CPU and I/O affect the process when power is applied and removed, and when errors are detected. This information should only be used for designing for the normal and expected abnormal operation, and should not be relied on for safety purposes.
- Design manual or electro-mechanical safety overrides that block the hazardous operation independent of the CPU.
- Provide appropriate status information from the independent circuits to the CPU so that the program and any operator interfaces have necessary information.
- Identify any other safety-related requirements for safe operation of the process.

Specifying the Operator Stations

Based on the requirements of the functional specifications, create drawings of the operator stations. Include the following items:

- Overview showing the location of each operator station in relation to the process or machine
- Mechanical layout of the devices (display, switches, lights, etc.) for the operator station
- Electrical drawings with the associated I/O of the CPU or expansion module

Creating the Configuration Drawings

Based on the requirements of the functional specification, create configuration drawings of the control equipment. Include the following items:

- Overview showing the location of each CPU in relation to the process or machine
- Mechanical layout of the CPU and expansion I/O modules (including cabinets and other equipment)
- Electrical drawings for each CPU and expansion I/O module (including the device model numbers, communication addresses, and I/O addresses)

Creating a List of Symbolic Names

If you choose to use symbolic names for addressing, create a list of symbolic names for the absolute addresses. Include not only the physical I/O signals, but also the other elements to be used in your program.

4.2 Concepts of an S7-200 Program

Relating the Program to Inputs and Outputs

The basic operation of the S7-200 CPU is very simple:

- The CPU reads the status of the inputs.
- The program that is stored in the CPU uses these inputs to evaluate the control logic. As the program runs, the CPU updates the data.
- The CPU writes the data to the outputs.

Figure 4-2 shows a simple diagram of how an electrical relay diagram relates to the S7-200 CPU. In this example, the state of the operator panel switch for opening the drain is added to the states of other inputs. The calculations of these states then determine the state for the output that goes to the solenoid which closes the drain.

The CPU continuously cycles through the program, reading and writing data.

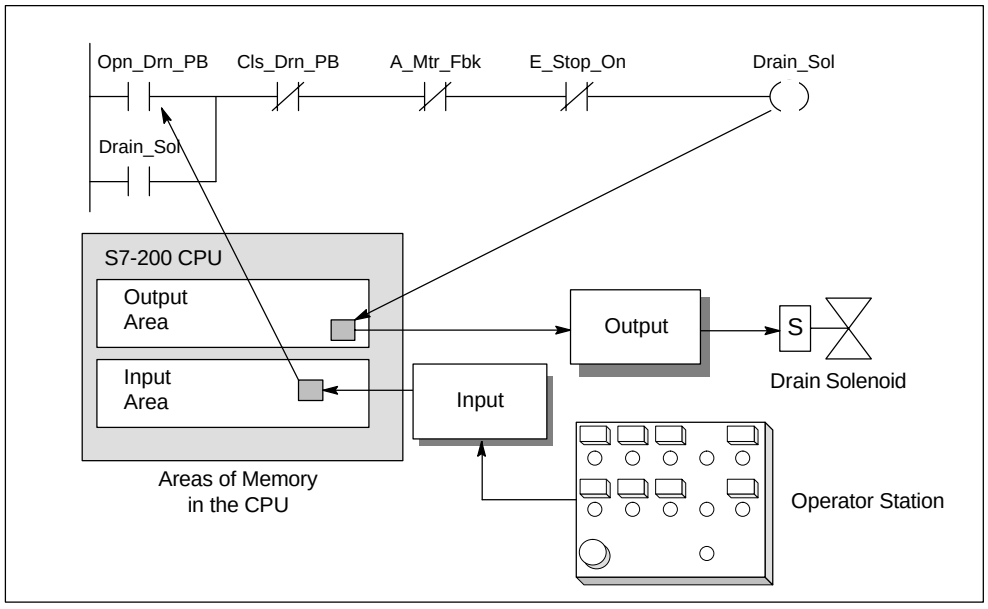


Figure 4-2 Relating the Program to Inputs and Outputs

4.3 Concepts of the S7-200 Programming Languages and Editors

The S7-200 CPUs offer many types of instructions that allow you to solve a wide variety of automation tasks. There are two basic instruction sets available in the S7-200 CPU: SIMATIC and IEC 1131-3. Also, our PC-based programming software, STEP 7-Micro/WIN 32, provides different editor choices that allow you to create control programs with these instructions. For example, you may prefer to create programs in a more graphical environment, while someone else in your company may prefer a text-based assembly-language style of editor.

You have two primary choices to consider whenever you create your programs:

- Type of instruction set to use (SIMATIC or IEC 1131-3)
- Type of editor to use (Statement List, Ladder Logic, or Function Block Diagram)

The S7-200 instruction set and editor combinations shown in Table 4-1 are possible.

Table 4-1 SIMATIC and IEC 1131-3 Instruction Set and Editors

SIMATIC Instruction Set	IEC 1131-3 Instruction Set
Statement List (STL) Editor	STL not available
Ladder Logic (LAD) Editor	Ladder Logic (LAD) Editor
Function Block Diagram (FBD) Editor	Function Block Diagram (FBD) Editor

Statement List Editor

The STEP 7-Micro/WIN 32 Statement List (STL) editor allows you to create control programs by entering the instruction mnemonics. In general, the STL editor is more suitable for experienced programmers who are familiar with PLCs and logic programming. The STL editor also allows you to create programs that you could not otherwise create with the Ladder Logic or Function Block Diagram editors. This is because you are programming in the native language of the CPU, rather than in a graphical editor where some restrictions must be applied in order to draw the diagrams correctly. Figure 4-3 shows an example of a statement list program.

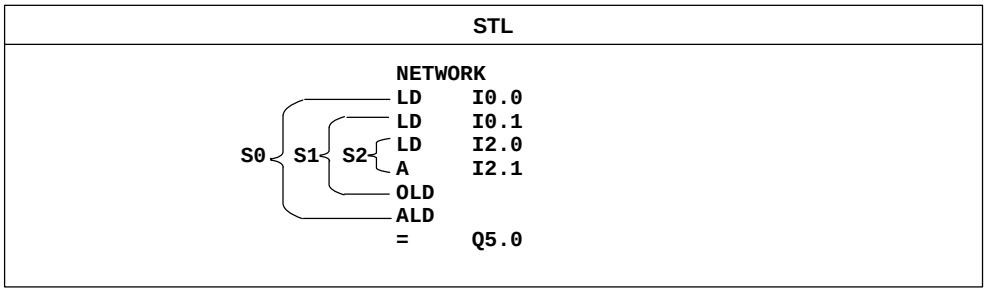


Figure 4-3 Example of an STL Program

As you can see from Figure 4-3, this text-based concept is very similar to assembly language programming. The CPU executes each instruction in the order dictated by the program, from top to bottom, and then restarts at the top. STL and assembly language are also similar in another sense. S7-200 CPUs use a logic stack to resolve the control logic (see Figure 4-4). The LAD and FBD editors automatically insert the instructions that are necessary to handle the stack operation. In STL, you have to insert these instructions to handle the stack.

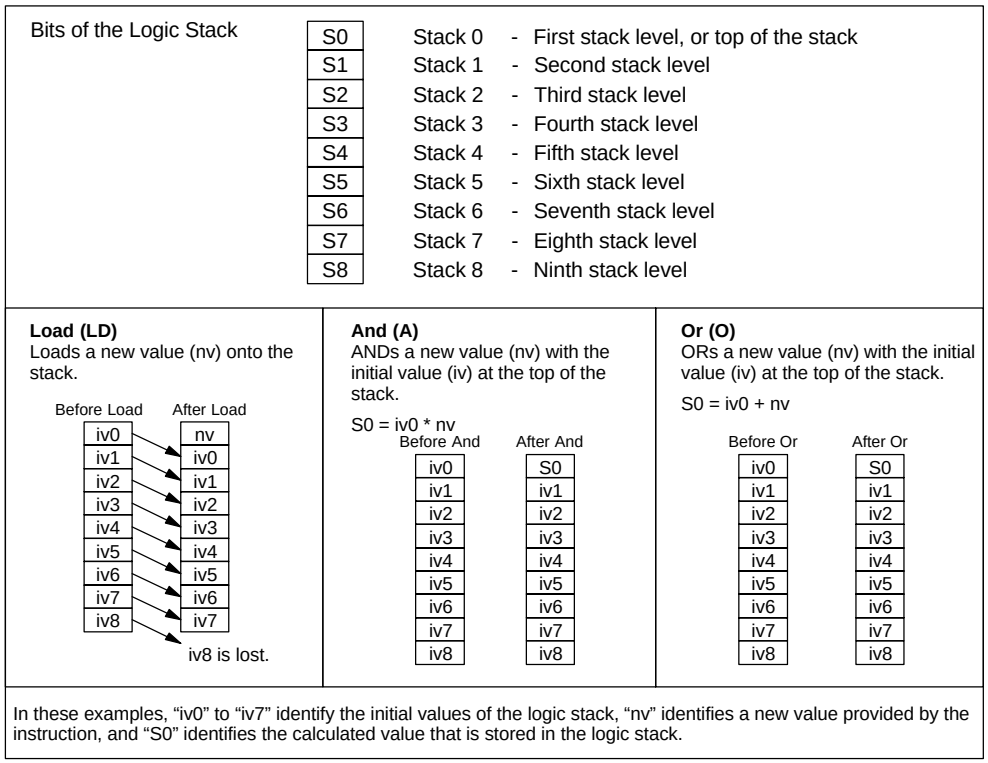


Figure 4-4 Logic Stack of the S7-200 CPU

The main points to consider when you select the STL editor are:

- STL is most appropriate for experienced programmers.
- STL sometimes allows you to solve problems that you cannot solve very easily with the LAD or FBD editor.
- You can only use the STL editor with the SIMATIC instruction set.
- While you can always use the STL editor to view or edit a program that was created with the SIMATIC LAD or FBD editors, the reverse is not always true. You cannot always use the SIMATIC LAD or FBD editors to display a program that was written with the STL editor.

Ladder Logic Editor

The STEP 7-Micro/WIN 32 Ladder Logic (LAD) editor allows you to build programs that resemble the equivalent of an electrical wiring diagram. Ladder programming is probably the method of choice for many PLC programmers and maintenance personnel. Basically, the ladder programs allow the CPU to emulate the flow of electric current from a power source, through a series of logical input conditions that in turn enable logical output conditions. The logic is usually separated into small, easy-to-understand pieces that are often called “rungs” or “networks.” The program is executed one network at a time, from left to right and then top to bottom as dictated by the program. Once the CPU has reached the end of the program, it starts over again at the top of the program.

Figure 4-5 shows an example of a ladder logic program.

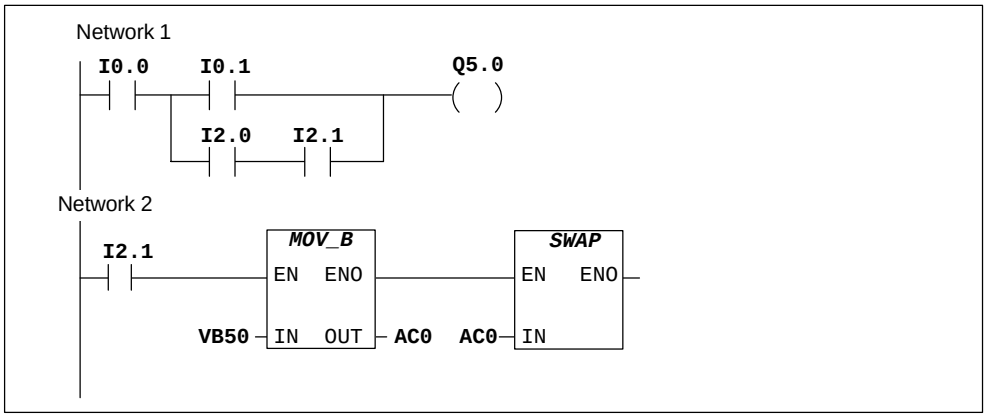


Figure 4-5 Example of LAD Program

The various instructions are represented by graphic symbols and include three basic forms. As shown in Figure 4-5, you can connect multiple box instructions in series.

- Contacts - represent logic “input” conditions analogous to switches, buttons, internal conditions and so on.
- Coils - usually represent logic “output” results analogous to lamps, motor starters, interposing relays, internal output conditions and so on.
- Boxes - represent additional instructions such as timers, counters, or math instructions.

The main points to consider when you select the LAD editor are:

- Ladder logic is easy for beginning programmers to use.
- Graphical representation is often easy to understand, and is popular around the world.
- The LAD editor can be used with both the SIMATIC and IEC 1131-3 instruction sets.
- You can always use the STL editor to display a program created with the SIMATIC LAD editor.

Function Block Diagram Editor

The STEP 7-Micro/WIN 32 Function Block Diagram (FBD) editor allows you to view the instructions as logic boxes that resemble common logic gate diagrams. There are no contacts and coils as found in the LAD editor, but there are equivalent instructions that appear as box instructions. The program logic is derived from the connections between these box instructions. That is, the output from one instruction (such as an AND box) can be used to enable another instruction (such as a timer) to create the necessary control logic. This connection concept allows you to solve a wide variety of logic problems.

Figure 4-6 shows an example of a program created with the Function Block Diagram editor.

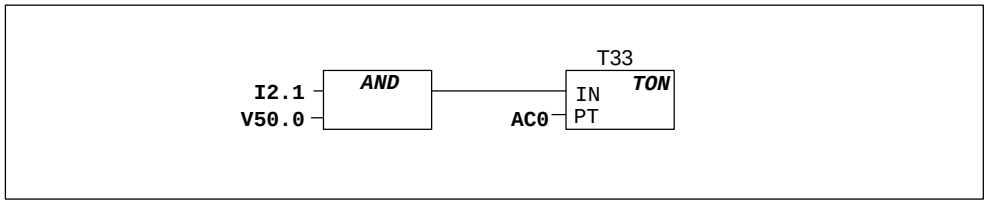


Figure 4-6 Example of FBD Program

The main points to consider when you select the FBD editor are:

- The graphical logic gate style of representation is good for following program flow.
- The FBD editor can be used with both the SIMATIC and IEC 1131-3 instruction sets.
- You can always use the STL editor to display a program created with the SIMATIC FBD editor.

4.4 Understanding the Differences between SIMATIC and IEC 1131-3 Instructions

SIMATIC Instruction Set

Most PLCs offer similar basic instructions, but there are usually small differences in their appearance, operation, etc., from vendor to vendor. The SIMATIC instruction set is designed for the S7-200 CPU. These instructions may look and operate slightly differently when compared to similar instructions in another brand of PLC. Consider these points when you select the SIMATIC instruction set:

- SIMATIC instructions usually have the shortest execution times.
- All three editors (LAD, STL, FBD) work with the SIMATIC instruction set.

IEC 1131-3 Instruction Set

The International Electrotechnical Commission is a worldwide organization that develops global standards for all fields of electrotechnology. Over the last several years, the commission has developed an emerging standard that specifically relates to many aspects of PLC programming. This standard encourages different PLC manufacturers to offer instructions that are the same in both appearance and operation. There are a few key differences between the SIMATIC instruction set and the IEC1131-3 instruction set.

- The IEC 1131-3 instruction set is restricted to those instructions that are standard among PLC vendors. Some instructions that are normally included in the SIMATIC set are not standard instructions in the IEC 1131-3 specification. (These are still available for use as non-standard instructions, but if you use them, the program is no longer strictly IEC 1131-3 compatible).
- Some box instructions accept multiple data formats. This practice is often referred to as overloading. For example, rather than have separate ADD_I (Add Integer) and ADD_R (Add Real), math boxes, the IEC 1131-3 ADD instruction examines the format of the data being added, and automatically chooses the correct instruction in the CPU. This can save valuable program design time.
- When you use the IEC 1131-3 instructions, the instruction parameters are automatically checked for the proper data format. The data format checking is not obvious to the user. For example, if you tried to enter an integer value for an instruction that expected a bit value (on/off), an error results. This feature helps to minimize programming syntax errors.

Consider these points when you select IEC 1131-3 instructions:

- It is usually easier to learn how to create programs for different brands of PLCs.
- Fewer instructions are available (as specified by the standard) but you can always use many of the SIMATIC instructions as well.
- Some instructions operate differently than their SIMATIC counterparts (timers, counters, multiply, divide, etc.)
- These instructions may have longer execution times.
- These instructions can only be used within the LAD and FBD editors.
- IEC 1131-3 specifies that variables must be declared with a type and supports system checking of data type.

SIMATIC and IEC 1131-3 Variable Data Types

Every SIMATIC and IEC 1131-3 instruction or parameterized subroutine is identified by a precise definition referred to as a signature. For all standard instructions, the allowable data types for each instruction operand is obtained from the signature. For parameterized subroutines, the signature of the subroutine is created by the user through the Local Variable Table.

STEP 7-Micro/WIN 32 implements simple data type checking for the SIMATIC mode, and strong data type checking for the IEC 1131-3 mode. When a data type is specified for either a local or global variable, STEP 7-Micro/WIN 32 ensures that the operand data type matches the instruction signature to the level specified. Table 4-2 defines elementary data types and Table 4-3 shows complex data types available in STEP 7-Micro/WIN 32.

Table 4-2 IEC 1131-3 Elementary Data Types

Elementary Data Types	Data Type Size	Description	Data Range
BOOL (1 bit)	1 bit	Boolean	0 to 1
BYTE (8 bits)	8 bits	Unsigned byte	0 to 255
WORD (16 bits)	16 bits	Unsigned integer	0 to 65,535
INT (16 bits)	16 bits	Signed integer	-32768 to +32767
DWORD (32 bits)	32 bits	Unsigned double integer	0 to 2^{32} - 1
DINT (32 bits)	32 bits	Signed double integer	-2^{31} to $+2^{31}$ - 1
REAL (32 bits)	32 bits	IEEE 32-bit floating point	-10^{38} to $+10^{38}$

Table 4-3 IEC 1131-3 Complex Data Types

Complex Data Types	Description	Address Range
TON	On-Delay Timer	1 ms T32, T96 10 ms T33 to T36, T97 to T100 100 ms T37 to T63, T101 to T255
TOF	Off-Delay Timer	1 ms T32, T96 10 ms T33 to T36, T97 to T100 100 ms T37 to T63, T101 to T255
TP	Pulse Timer	1 ms T32, T96 10 ms T33 to T36, T97 to T100 100 ms T37 to T63, T101 to T255
CTU	Up Counter	0 to 255
CTD	Down Counter	0 to 255
CTUD	Up/Down Counter	0 to 255
SR	Set Dominant Bistable	--
RS	Reset Dominant Bistable	--

Data Type Checking There are three levels of data type checking: strong data type checking, simple data type checking, and no data type checking.

Strong Data Type Checking In this mode, the parameter data type must match the symbol or variable data type. Each formal parameter has only one data type (except for overloaded instructions). For example, the IN parameter of an SRW (Shift Right Word) instruction has the data type WORD. Only variables that are assigned the WORD data type will compile successfully. Variables that are data typed as INT are not valid for WORD instruction parameters when strong data type checking is enforced.

Strong data type checking is performed only within IEC 1131-3 modes. See Table 4-4.

Table 4-4 Strong Data Type Checking User Selected and Equivalent Data Types

User Selected Data Type	Equivalent Data Type
BOOL	BOOL
BYTE	BYTE
WORD	WORD
INT	INT
DWORD	DWORD
DINT	DINT
REAL	REAL

Simple Data Type Checking In the simple data type checking mode, when a symbol or a variable is given a data type, it is also automatically assigned all data types that match the bit size of the selected data type. For example, if you select DINT as the data type, the local variable also automatically assigns the data type DWORD because both are 32-bit data types. The data type REAL is not automatically assigned, even though it is also a 32-bit data type. The data type REAL is defined as having no other data type equivalent; it is always unique. Simple data type checking is only performed within SIMATIC modes when you use local variables. See Table 4-5.

Table 4-5 Simple Data Type Checking: User Selected and Equivalent Data Types

User Selected Data Type	Equivalent Data Type
BOOL	BOOL
BYTE	BYTE
WORD	WORD, INT
INT	WORD, INT
DWORD	DWORD, DINT
DINT	DWORD, DINT
REAL	REAL

No Data Type Checking The no data type checking mode is available only for SIMATIC global variables where the data types are not selectable. In this mode, all data types of equivalent size are automatically assigned to the symbol. For example, a symbol that is assigned the address VD100 is assigned the data types shown in Table 4-6 automatically by STEP 7-Micro/WIN 32.

Table 4-6 Size Determined Data Type for SIMATIC Global Symbols

User Selected Address	Assigned Equivalent Data Type
V0.0	BOOL
VB0	BYTE
VW0	WORD, INT
VD0	DWORD, DINT, REAL

Advantages of Data Type Checking

Data type checking helps you to avoid common programming mistakes. If an instruction supports signed numbers, STEP 7-Micro/WIN 32 will flag the use of an unsigned number for an instruction operand. For example, the relation comparison < I is a signed instruction. -1 is less than 0 for signed data type operands. However, when the < I instruction is allowed to support an unsigned data type, the programmer must ensure that the following never occurs. During run-time program execution, an unsigned value of 40,000 is actually less than 0 for a < I instruction.

Warning

You should ensure that the use of the unsigned number for signed instructions does not cross the positive and negative boundary.

Failure to ensure that unsigned numbers for signed instructions do not cross the positive and negative boundary can create unpredictable results in your program or controller operation. Unpredictable controller operation can result in death or serious injury to personnel, and/or substantial property damage.

Always ensure that the unsigned number for a signed instruction does not cross the positive and negative boundary.

In summary, under the IEC 1131-3 editing mode, strong data type checking helps you to identify these errors during compilation by generating errors for data types that are illegal for the instruction. This capability is not available for the SIMATIC editors.

Selecting Between SIMATIC and IEC 1131-3 Programming Modes

Since IEC 1131-3 is strongly data typed, and SIMATIC is not strongly data typed, STEP 7-Micro/WIN 32 does not allow you to move programs between the two different editing modes. You must choose a preferred editing mode.

Overloaded Instructions

Overloaded instructions support a range of data types. Strong data type checking is still applied since all of the operand data types must match before the instruction compiles successfully. Table 4-7 shows an example of the IEC overloaded ADD instruction.

Table 4-7 Example of IEC Overloaded ADD Instruction

Instruction	Allowed Data Types (Strong Data Type Checking)	Allowed Data Types (Data Type Checking)	Compiled Instruction
ADD	INT	WORD, INT	ADD_I (Add Integer)
ADD	DINT	DWORD, DINT	ADD_D (Add Double Integer)
ADD	REAL	REAL	ADD_R (Add Real)

When all of the operands have the data type DINT, an Add Double Integer instruction will be generated by the compiler. A compilation error occurs if data types are mixed for the overloaded instruction. What is considered illegal depends on the level of data type checking. The following example will generate a compiler error under strong data type checking, but will pass compile for simple data type checking.

ADD IN1 = INT, IN2 = WORD, IN3 = INT

Strong data type checking: compile error
Data type checking: compiles to ADD_I (Add Integer)

The simple data type checking will not prevent common run-time programming errors from occurring. With simple data type checking, the compiler will not catch the following common programming errors: ADD 40000, 1 will be a negative number, not an unsigned 40,001.

Using Direct Addressing in IEC for Overloaded Instructions

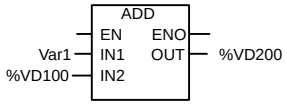
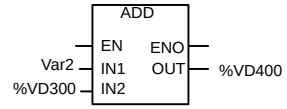
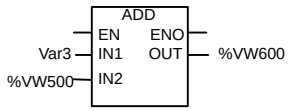
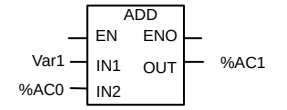
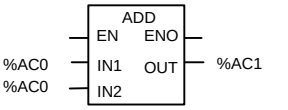
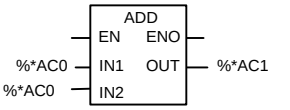
IEC 1131-3 programming modes permit you to use directly represented memory locations as a part of instruction parameter configuration. Both variables and memory locations can be used within parameters. Remember that directly represented memory locations do not contain explicit type information. Also, type information cannot be determined from any of the overloaded IEC instructions, because these instructions accept varying data types.

Data types for directly represented parameters are determined by examining other typed parameters included within the instruction. When an instruction parameter type is configured to use a variable that is of a specific type, all directly represented parameters will be assumed to be of that type. Table 4-8 and Table 4-9 show examples of data types for directly represented parameters. The percentage sign (%) is used to indicate a direct address.

Table 4-8 Example of Data Types for Direct Addressing

Name	Address	Data Type	Comment
Var1		REAL	This is a floating-point variable.
Var2		DINT	This is a double integer variable.
Var3		INT	This is an integer variable.

Table 4-9 Examples of Direct Addressing in Overloaded Instructions

Example	Description
	VD100 and VD200 will be assumed to be of type REAL since Var1 is of type REAL.
	VD300 and VD400 will be assumed to be of type DINT since Var2 is of type DINT.
	VW500 and VW600 will be assumed to be of type INT since Var3 is of type INT.
	AC0 and AC1 will be assumed to be of type REAL since Var1 is of type REAL.
	This configuration is illegal since the type cannot be determined. The type of data within the accumulators could be any type.
	This configuration is illegal since the type cannot be determined. The type of data within the accumulator pointers could be any type.
% indicates an indirect address.	

Using Conversion Instructions

Conversion instructions permit the movement from one data type to another. STEP 7-Micro/WIN 32 supports the conversion instructions shown in Table 4-10 for moving values between the simple data types.

Table 4-10 Conversion Instructions

Conversion Instruction	Strong Data Type Checking Allowed Operands	Data Type Checking Allowed Operands
BYTE to INT	IN: BYTE OUT: INT	IN: BYTE OUT: WORD, INT
INT to BYTE	IN: INT OUT: BYTE	IN: WORD, INT OUT: BYTE
INT to DINT	IN: DINT OUT DINT	IN: WORD, INT OUT: DWORD, DINT
DINT to INT	IN: DINT OUT: INT	IN: DWORD, DINT OUT: WORD, INT
DINT to REAL	IN: DINT OUT: REAL	IN: DWORD, DINT OUT: REAL
REAL to DINT (ROUND)	IN: REAL OUT: DINT	IN: REAL OUT: DWORD, DINT

Under the IEC 1131-3 editing mode you can use the overloaded MOVE instruction to convert between INT and WORD, and DINT and DWORD. The MOVE instruction allows data types of the same size to be moved without the compiler generating errors. See Table 4-11.

Table 4-11 Using Overloaded MOVE Instruction.

IEC 1131-3 Overloaded Move	IN	OUT
MOVE (INT to WORD)	INT	WORD
MOVE (WORD to INT)	WORD	INT
MOVE (DINT to DWORD)	DINT	DWORD
MOVE (DWORD to DINT)	DWORD	DINT

4.5 Basic Elements for Constructing a Program

The S7-200 CPU continuously executes your program to control a task or process. You create this program with STEP 7-Micro/WIN 32 and download it to the CPU. From the main program, you can call different subroutines or interrupt routines.

Organizing the Program

Programs for an S7-200 CPU are constructed from three basic elements: the main program, subroutines (optional), and interrupt routines (optional). An S7-200 program is structured into the following organizational elements:

- Main program: The main body of the program is where you place the instructions that control your application. The instructions in the main program are executed sequentially, once per scan of the CPU.
- Interrupt routines: These optional elements of your program are executed on each occurrence of the interrupt event.
- Subroutines: These optional elements of your program are executed only when they are called from the main program or an interrupt routine.

Example Program Using Subroutines and Interrupts

Following are sample programs for a timed interrupt that can be used for applications such as reading the value of an analog input. In this example, the sample rate of the analog input is set to 100 ms.

Figure 4-7 through Figure 4-11 show programs for using a subroutine and an interrupt routine for the various S7-200 programming languages.

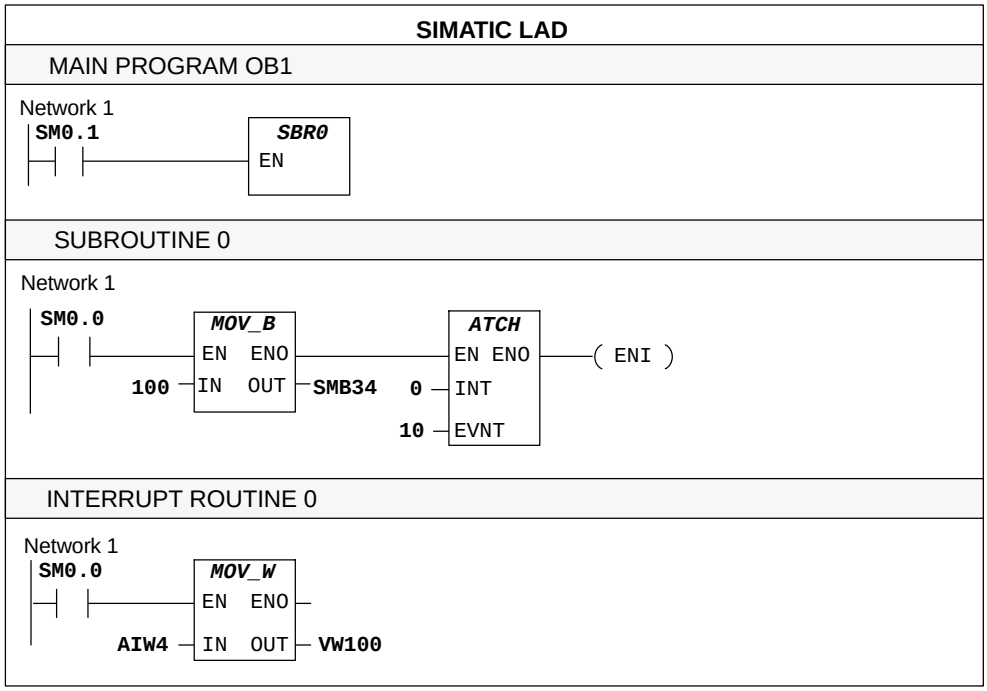


Figure 4-7 SIMATIC LAD Program for Using a Subroutine and an Interrupt Routine

Statement List

Main Program OB1

```
Network 1
LD     SM0.1      //When first scan cycle
                  //bit comes on
CALL   0          //Call subroutine 0.
```

Subroutine 0

```
Network 1
LD     SM0.0      //Always on memory bit.
MOVB   100, SMB34 //Set timed interrupt 0
                  //interval to 100 ms.
AENO              //If move is successful,
ATCH   0, 10      //attach timed interrupt 0
                  //to interrupt routine 0.
AENO              //If attach is successful,
ENI               //then enable Global Interrupt.
```

Interrupt Routine 0

```
                  //Begin interrupt routine 0.

Network 1
LD SM0.0          //Always on memory bit.
MOVW  AIW4,VW100  //Sample Analog Input 4.
```

Figure 4-8 SIMATIC STL Program for Using a Subroutine and an Interrupt Routine

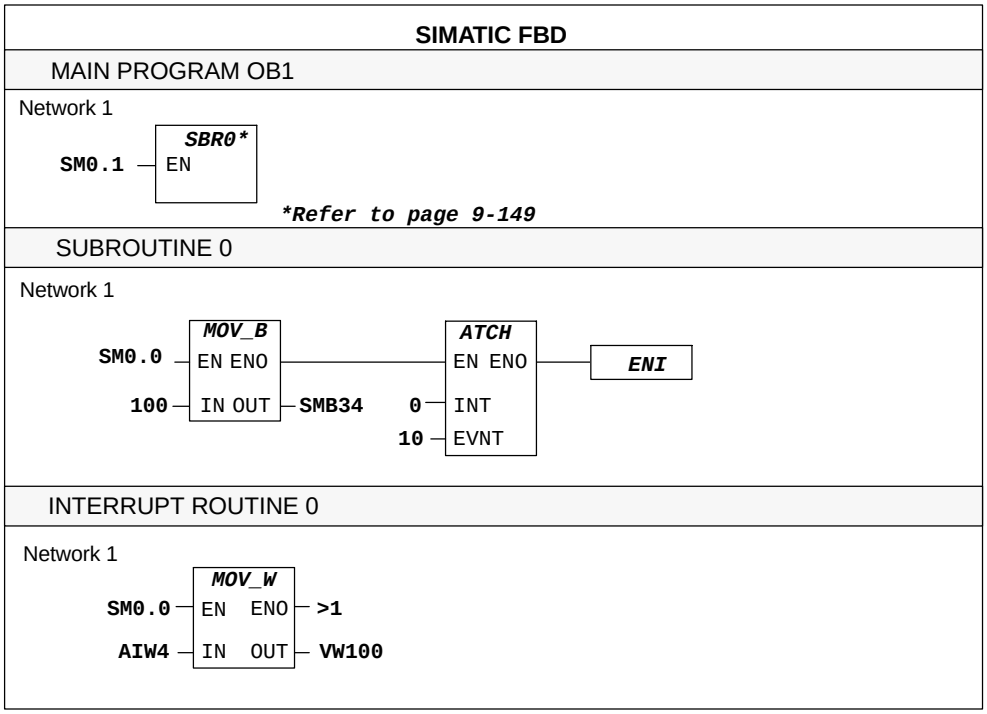


Figure 4-9 SIMATIC FBD Program for Using a Subroutine and an Interrupt Routine

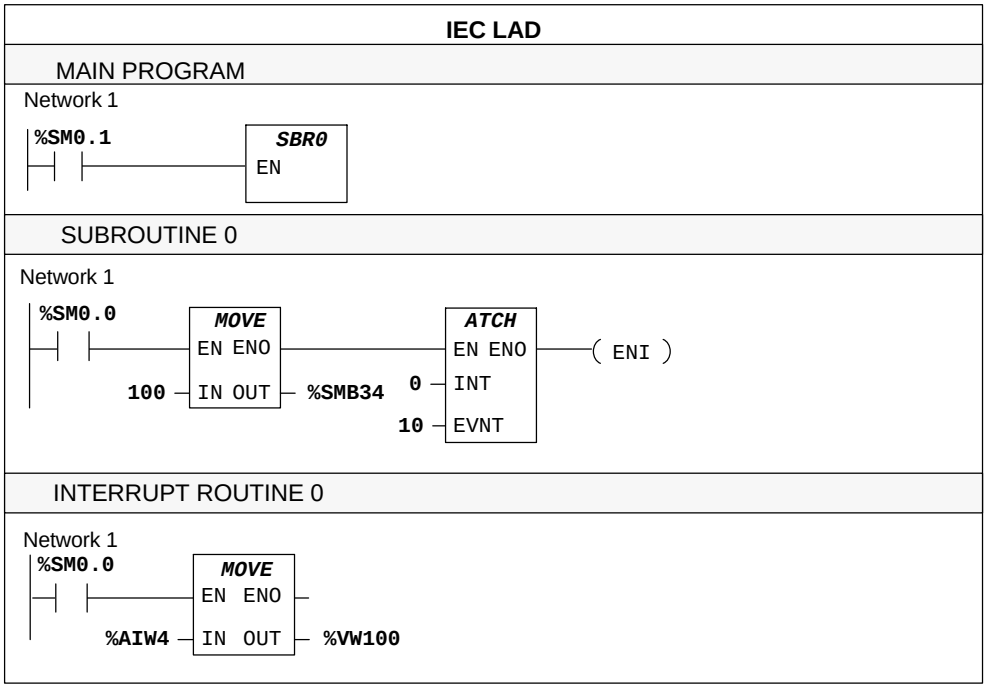


Figure 4-10 IEC LAD Program for Using a Subroutine and an Interrupt Routine

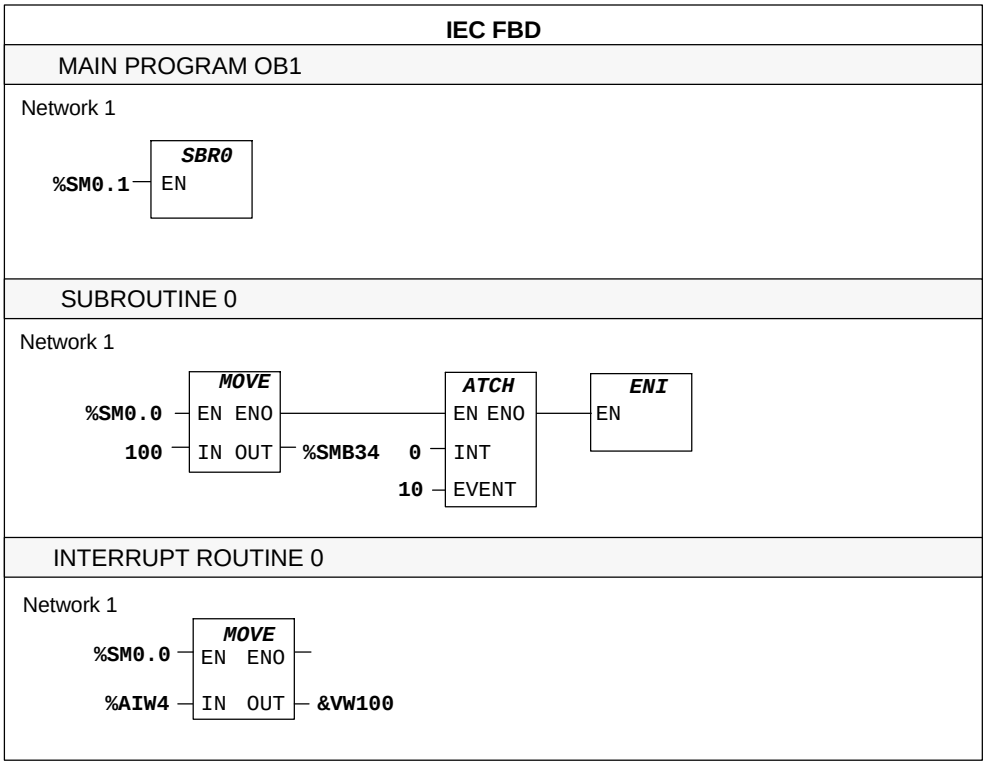


Figure 4-11 IEC FBD Program for Using a Subroutine and an Interrupt Routine

4.6 Understanding the Scan Cycle of the CPU

The S7-200 CPU is designed to execute a series of tasks, including your program, repetitively. This cyclical execution of tasks is called the scan cycle. During the scan cycle shown in Figure 4-12, the CPU performs most or all of the following tasks:

- Reading the inputs
- Executing the program
- Processing any communication requests
- Executing the CPU self-test diagnostics
- Writing to the outputs

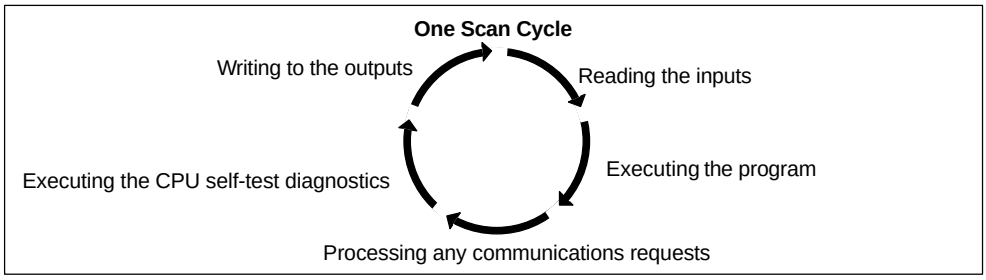


Figure 4-12 Scan Cycle of the S7-200 CPU

The series of tasks executed during the scan cycle is dependent upon the operating mode of the CPU. The S7-200 CPU has two modes of operation, STOP mode and RUN mode. With respect to the scan cycle, the main difference between STOP and RUN mode is that in RUN mode your program is executed, and in STOP mode your program is not executed.

Reading the Digital Inputs

Each scan cycle begins by reading the current value of the digital inputs and then writing these values to the process-image input register.

The CPU reserves the process-image input register in increments of eight bits (one byte). If the CPU or expansion module does not provide a physical input point for each bit of the reserved byte, you cannot reallocate these bits to subsequent modules in the I/O chain or use them in your program. The CPU resets these unused inputs to zero in the image register at the beginning of every scan. However, if your CPU can accommodate several expansion modules and you are not using this I/O capacity (have not installed the expansion modules), you can use the unused expansion input bits as additional memory bits.

The CPU does not update analog inputs as part of the normal scan cycle unless digital filtering of analog inputs is enabled. Digital filtering is provided as a user selectable option and can be individually enabled for each analog input point.

Digital filtering is intended for use with low-cost analog modules that do not provide filtering internal to the module. Digital filtering should be used in applications where the input signal varies slowly with time. If the signal is a high-speed signal, then digital filtering should not be enabled.

When analog input filtering is enabled for an analog input, the CPU updates that analog input once per scan cycle, performs the filtering function, and stores the filtered value internally. The filtered value is then supplied each time your program accesses the analog input.

When analog filtering is not enabled for an analog input, the CPU reads the value of the analog input from the physical module each time your program accesses the analog input.

Executing the Program

During the execution phase of the scan cycle, the CPU executes your program, starting with the first instruction and proceeding to the end instruction. The immediate I/O instructions give you immediate access to inputs and outputs during the execution of either the program or an interrupt routine.

If you use interrupts in your program, the interrupt routines that are associated with the interrupt events are stored as part of the program. (See Section 4.5.) The interrupt routines are not executed as part of the normal scan cycle, but are executed when the interrupt event occurs (which may be at any point in the scan cycle).

Processing the Communication Requests

During the message-processing phase of the scan cycle, the CPU processes any messages that were received from the communications port.

Executing the CPU Self-Diagnostic Test

During this phase of the scan cycle, the CPU checks its firmware and your program memory (RUN mode only). It also checks the status of any I/O modules.

Writing to the Digital Outputs

At the end of every scan cycle, the CPU writes the values stored in the process-image output register to the digital outputs.

The CPU reserves the process-image output register in increments of eight bits (one byte). If the CPU or expansion module does not provide a physical output point for each bit of the reserved byte, you cannot reallocate these bits to subsequent modules in the I/O chain.

When the CPU operating mode is changed from RUN to STOP, the digital outputs are set to the values defined in the Output Table, or are left in their current state (see Section 6.4).The default action is that the digital outputs are turned off. Analog outputs remain at the value last written.

Interrupting the Scan Cycle

If you use interrupts, the routines associated with each interrupt event are stored as part of the program. The interrupt routines are not executed as part of the normal scan cycle, but are executed when the interrupt event occurs (which may be at any point in the scan cycle). Interrupts are serviced by the CPU on a first-come-first-served basis within their respective priority assignments.

Process-Image Input and Output Registers

It is usually advantageous to use the process-image register rather than to directly access inputs or outputs during the execution of your program. There are three reasons for using the image registers:

- The sampling of all inputs at the top of the scan synchronizes and freezes the values of the inputs for the program execution phase of the scan cycle. The outputs are updated from the image register after the execution of the program is complete. This provides a stabilizing effect on the system.
- Your program can access the image register much quicker than it can access I/O points, allowing faster execution of the program.
- I/O points are bit entities and must be accessed as bits, but you can access the image register as bits, bytes, words, or double words. Thus, the image registers provide additional flexibility.

Immediate I/O

Immediate I/O instructions allow direct access to the actual input or output point, even though the image registers are normally used as either the source or the destination for I/O accesses. The corresponding process-image input register location is not modified when you use an immediate instruction to access an input point. The corresponding process-image output register location is updated simultaneously when you use an immediate instruction to access an output point.

The CPU treats analog I/O as immediate data unless digital filtering of analog input is enabled. See Section 6.5. When you write a value to an analog output, the output is updated immediately.

4.7 Selecting the Mode of Operation for the CPU

The S7-200 CPU has two modes of operation:

- STOP: The CPU is not executing the program. You can download a program or configure the CPU when the CPU is in STOP mode.
- RUN: The CPU is running the program.

The status LED on the front of the CPU indicates the current mode of operation.

You can change the mode of operation by:

- Manually changing the mode switch located on the CPU
- Using the STEP 7-Micro/WIN 32 programming software and setting the CPU mode switch to TERM or RUN
- Inserting a STOP instruction in your program

Changing the Operating Mode with the Mode Switch

You can use the mode switch (located under the front access door of the CPU) to manually select the operating mode for the CPU:

- Setting the mode switch to STOP mode stops the execution of the program.
- Setting the mode switch to RUN mode starts the execution of the program.
- Setting the mode switch to TERM (terminal) mode does not change the CPU operating mode.

If a power cycle occurs when the mode switch is set to either STOP or TERM, the CPU goes automatically to STOP mode when power is restored. If a power cycle occurs when the mode switch is set to RUN, the CPU goes to RUN mode when power is restored.

Changing the Operating Mode with STEP 7-Micro/WIN 32

As shown in Figure 4-13, you can use STEP 7-Micro/WIN 32 to change the operating mode of the CPU. To enable the software to change the operating mode, you must set the mode switch on the CPU to either TERM or RUN.

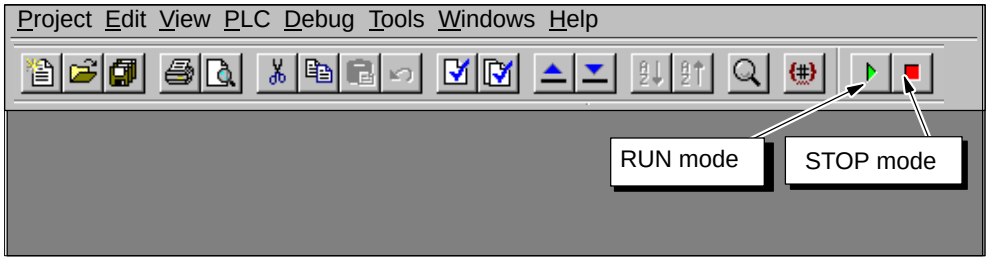


Figure 4-13 Using STEP 7-Micro/WIN 32 to Change the Operating Mode of the CPU

Changing the Operating Mode from the Program

You can insert the STOP instruction in your program to change the CPU to STOP mode. This allows you to halt the execution of your program based on the program logic. For more information about the STOP instruction, see Chapter 9 for SIMATIC instructions and Chapter 10 for IEC 1131-3 instructions.

4.8 Creating a Password for the CPU

All models of the S7-200 CPU provide password protection for restricting access to specific CPU functions. A password authorizes access to the CPU functions and memory: without a password, the CPU provides unrestricted access. When password protected, the CPU prohibits all restricted operations according to the configuration provided when the password was installed.

Restricting Access to the CPU

As shown in Table 4-12, S7-200 CPUs provide three levels of restricting access to CPU functions. Each level allows certain functions to be accessible without a password. For all three levels of access, entering the correct password provides access to all of the CPU functions. The default condition for the S7-200 CPU is level 1 (no restriction).

Entering the password over a network does not compromise the password protection for the CPU. Having one user authorized to access restricted CPU functions does not authorize other users to access those functions. Only one user is allowed unrestricted access to the CPU at a time.

Note

After you enter the password, the authorization level for that password remains effective for up to one minute after the programming device has been disconnected from the CPU. If another user immediately connects to the CPU within this time, he may have access to the programming device.

Table 4-12 Restricting Access to the S7-200 CPU

Task	Level 1	Level 2	Level 3
Read and write user data	Not restricted	Not restricted	Not restricted
Start, stop and restart the CPU			
Read and write the time-of-day clock			
Upload the user program, data, and the configuration			Password required
Download to the CPU		Password required	
STL Status			
Delete the user program, data, and the configuration			
Force data or single/multiple scan			
Copy to the memory cartridge			
Write outputs in STOP mode			

Configuring the CPU Password

You can use STEP 7-Micro/WIN 32 to create the password for the CPU. Select the menu command **View > System Block** and click the Password tab. See Figure 4-14. Enter the appropriate level of access for the CPU, then enter and verify the password for the CPU.

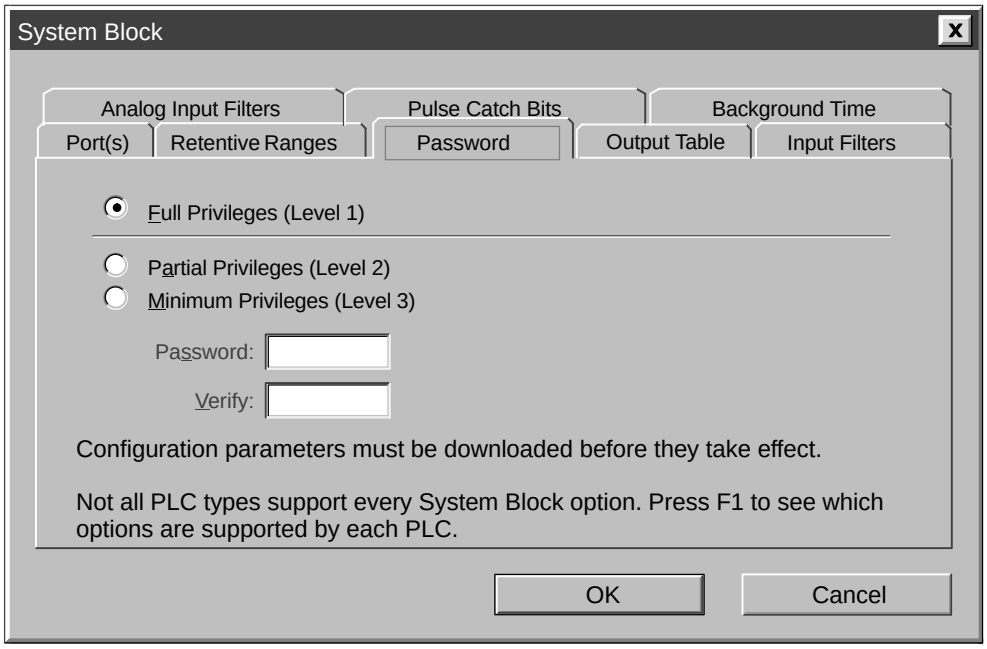


Figure 4-14 Configuring a Password for the CPU

What to Do If You Forget the CPU Password

If you forget the CPU password, you must clear the CPU memory and reload your program. Clearing the CPU memory puts the CPU in STOP mode and resets the CPU to the factory-set defaults, except for the CPU address, baud rate, and the time-of-day clock.

To clear your program in the CPU, select the **PLC > Clear...** menu command to display the Clear dialog box. Select all three blocks and confirm your action by clicking the OK button. If you have a password configured, a password-authorization dialog box is displayed. Entering the Clear password (clearplc) allows you to continue the Clear All operation.

The Clear All operation does not remove the program from a memory cartridge. Since the memory cartridge stores the password along with the program, you must also reprogram the memory cartridge to remove the lost password.

Warning

Clearing the CPU memory causes the outputs to turn off (or in the case of an analog output, to be frozen at a specific value).

If the S7-200 CPU is connected to equipment when you clear the CPU memory, changes in the state of the outputs can be transmitted to the equipment. If you had configured the “safe state” for the outputs to be different from the factory settings, changes in the outputs could cause unpredictable operation of your equipment, which could also cause death or serious injury to personnel, and/or damage to equipment.

Always follow appropriate safety precautions and ensure that your process is in a safe state before clearing the CPU memory.

4.9 Debugging and Monitoring Your Program

STEP 7-Micro/WIN 32 provides a variety of tools for debugging and monitoring your program.

Using First Scan/Multiple Scans to Monitor Your Program

You can specify that the CPU execute your program for a limited number of scans (from 1 scan to 65,535 scans). By selecting the number of scans for the CPU to run, you can monitor the program as it changes the process variables. Use the menu command **Debug >Multiple Scans** to specify the number of scans to be executed. Figure 4-15 shows the dialog box for entering the number of scans for the CPU to execute.

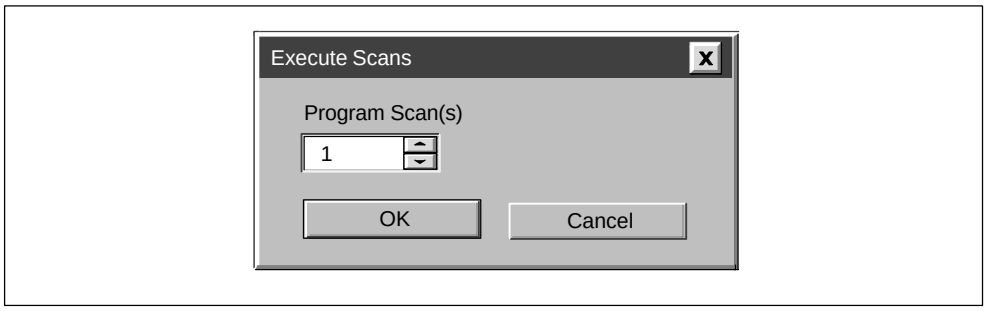


Figure 4-15 Executing Your Program for a Specific Number of Scans

Using a Status Chart to Monitor and Modify Your Program

As shown in Figure 4-16, you can use a Status Chart to read, write, force, and monitor variables while the program is running. Use the menu command **View > Status Chart**.

- The status chart toolbar icons are shown in the STEP 7-Micro/WIN 32 toolbar area. These toolbar icons (Sort Ascending, Sort Descending, Single Read, Write All, Force, Unforce, Unforce All, and Read All Forced) are enabled when you select the status chart.
- You can create multiple status charts.
- To select a format for a cell, select the cell, then press the right mouse button to enable the drop-down list (Figure 4-16).

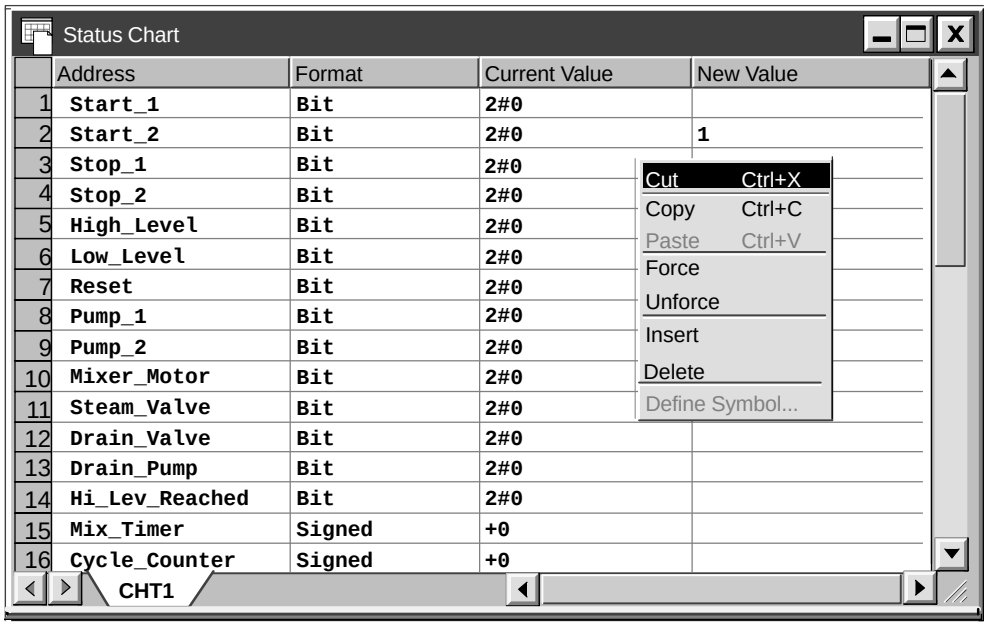


Figure 4-16 Monitoring and Modifying Variables with a Status Chart

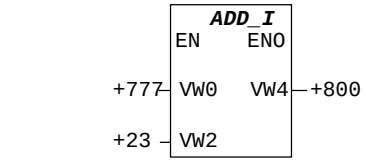
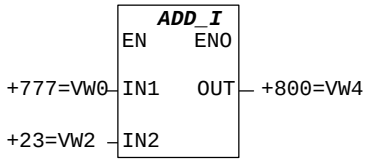
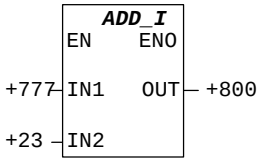
Displaying the Status of the Program in Ladder Logic

You can monitor the status of the ladder program by using STEP 7-Micro/WIN 32. STEP 7-Micro/WIN 32 must be displaying ladder logic. Ladder status displays the status of all instruction operand values. See Figure 4-17. All status is based upon the value of these elements that are read at the end of a CPU scan cycle. STEP 7-Micro/WIN 32 acquires the values for the status display across multiple PLC scan cycles and then updates the ladder status screen display. Consequently, the ladder status display does not reflect the actual status of each ladder element of the time of execution.

You can use the Options Tool to configure the status screen. Select **Tools > Options** and then select the LAD Status tab. Table 4-13 shows the LAD status display options.

To open the LAD status window, select the status icon from the toolbar (Figure 4-17).

Table 4-13 Selecting Display Options for LAD Status

Display Option	LAD Status Display
Show the address inside the instruction and the value outside the instruction.	
Show the address and value outside the instruction.	
Show only the status value.	

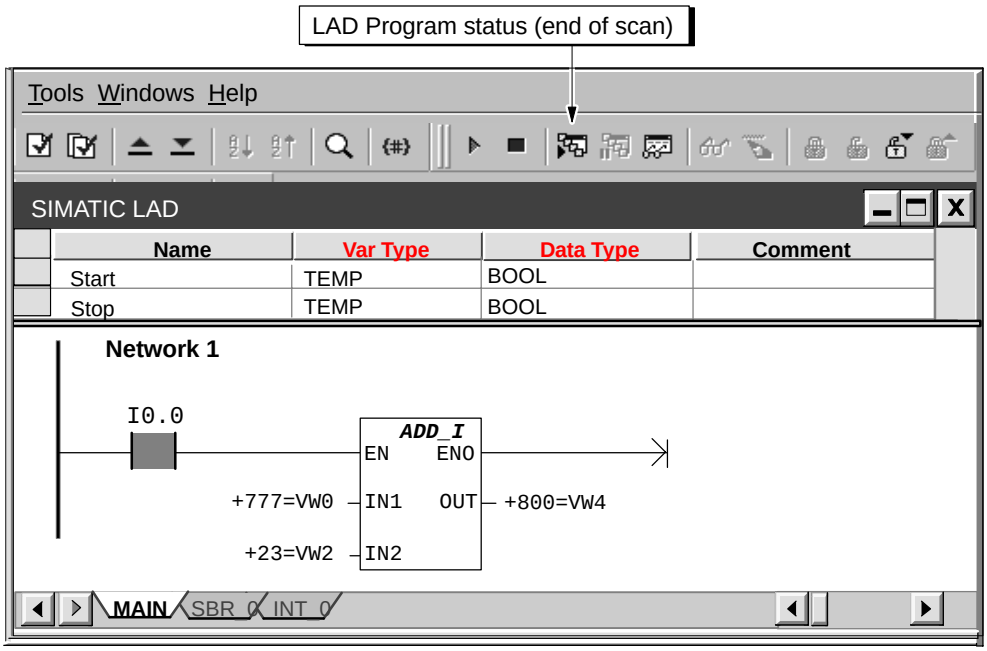


Figure 4-17 Displaying the Status of a Program in Ladder Logic

Displaying the Status of the Program in Function Block Diagram

You can monitor the status of the FBD program by using STEP 7-Micro/WIN 32. STEP 7-Micro/WIN 32 must be displaying FBD. FBD status displays the status of all instruction operand values. All status is based upon the values of operands that were read at the end of a PLC scan cycle. STEP 7-Micro/WIN 32 acquires the values for the status display across multiple PLC scan cycles and then updates the FBD status screen display. Consequently, the FBD status display does not reflect the actual status of each FBD element at the time of execution.

You can use the Options Tool to configure the status screen. Select **Tools > Options** and then select the FBD Status tab. Table 4-14 shows the FBD status display options.

To open the FBD status window, select the status icon from the toolbar (Figure 4-18).

Table 4-14 Selecting Display Options for FBD Status

Display Option	FBD Status Display
Show the address inside the instruction and the value outside the instruction.	ADD_I EN ENO +777 VW0 VW4 +800 +23 VW2
Show the address and value outside the instruction.	ADD_I EN ENO +777=VW0 IN1 OUT +800=VW4 +23=VW2 IN2
Show only the status value.	ADD_I EN ENO +777 IN1 OUT +800 +23 IN2

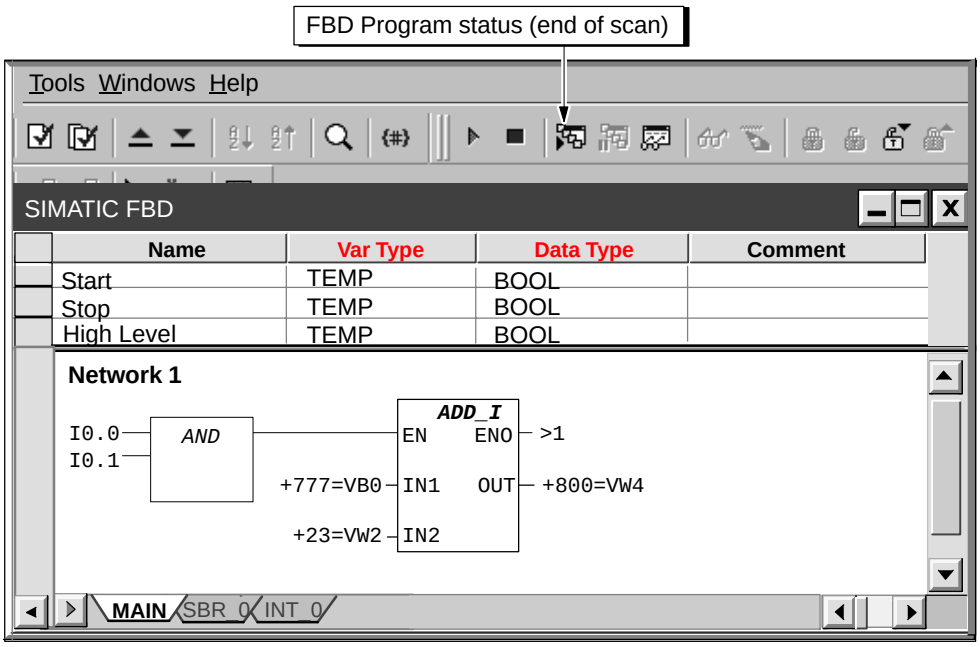


Figure 4-18 Displaying the Status of a Program in Function Block Diagram

Displaying the Status of the Program in Statement List

If you view your program using the STL editor, STEP 7-Micro/WIN 32 provides a method of monitoring the execution status of the program on an instruction-by-instruction basis. This status monitoring method is referred to as STL status. The portion of your program for which STL status is enabled is called the STL status window. This window is approximately the size of your STEP 7-Micro/WIN 32 screen. Information obtained from the CPU is limited to 200 bytes or 25 lines. STL lines that appear on the screen that exceed these limits are shown with "-" in the status window. Status information is gathered beginning from the first STL statement at the top of the editor window. As you scroll down the editor window, new information is gathered from the CPU. A typical STL Status window is shown in Figure 4-19.

To open the STL status window, select the program status button from the toolbar (Figure 4-19). Size the right margin of the STL program sheet to reveal the STL status sheet.

When you turn STL status on, STL code appears on the left side of the STL Status window; the status region containing operand values appears on the right. Indirect address operands display both the value at the pointer address and the pointer address. The pointer address is shown enclosed within parenthesis.

The STL Program Status button continuously updates values on the screen. If you want to halt screen updates on the next data update, select the Triggered Pause button (Figure 4-19). Current data will remain on the screen until you deselect the button.

Operand values are shown in columns in the order in which they appear in each instruction statement. These values are captured at the time each instruction is executed and therefore reflect the actual execution status of the instruction.

The color of the status values indicates the execution status of the instruction:

- Black indicates that the instruction executed correctly. Unconditional instructions that are not included within an SCR block are always executed regardless of the state of the logic stack. Conditional instructions use the logic stack to determine execution.
- Red indicates an error in execution. Refer to the page in Chapter 9 that discusses the particular instruction for "Error Conditions that set ENO."
- Gray indicates that the instruction did not execute because the top of stack value (s0) = 0, or because the instruction is present within an SCR block that is not enabled.
- Blank indicates that the instruction has not executed.

Conditions that cause instructions not to be executed include:

- Top of logic stack = 0.
- The instruction was bypassed because of jumps or other constructs in your program.
- The PLC is not in RUN mode.

To choose the categories of values that you want to appear in the STL status window, select **Tools > Options** and then select the STL Status tab. You can choose to monitor three categories of values in the STL status window:

- Operands (up to three operands per instruction)
- Logic Stack (up to four of the most recent values from the logic stack)
- Instruction Status Bits (up to twelve instruction status bits)

To obtain first scan information, place the PLC in STOP mode, enable STL status, then select **Debug > First Scan**.

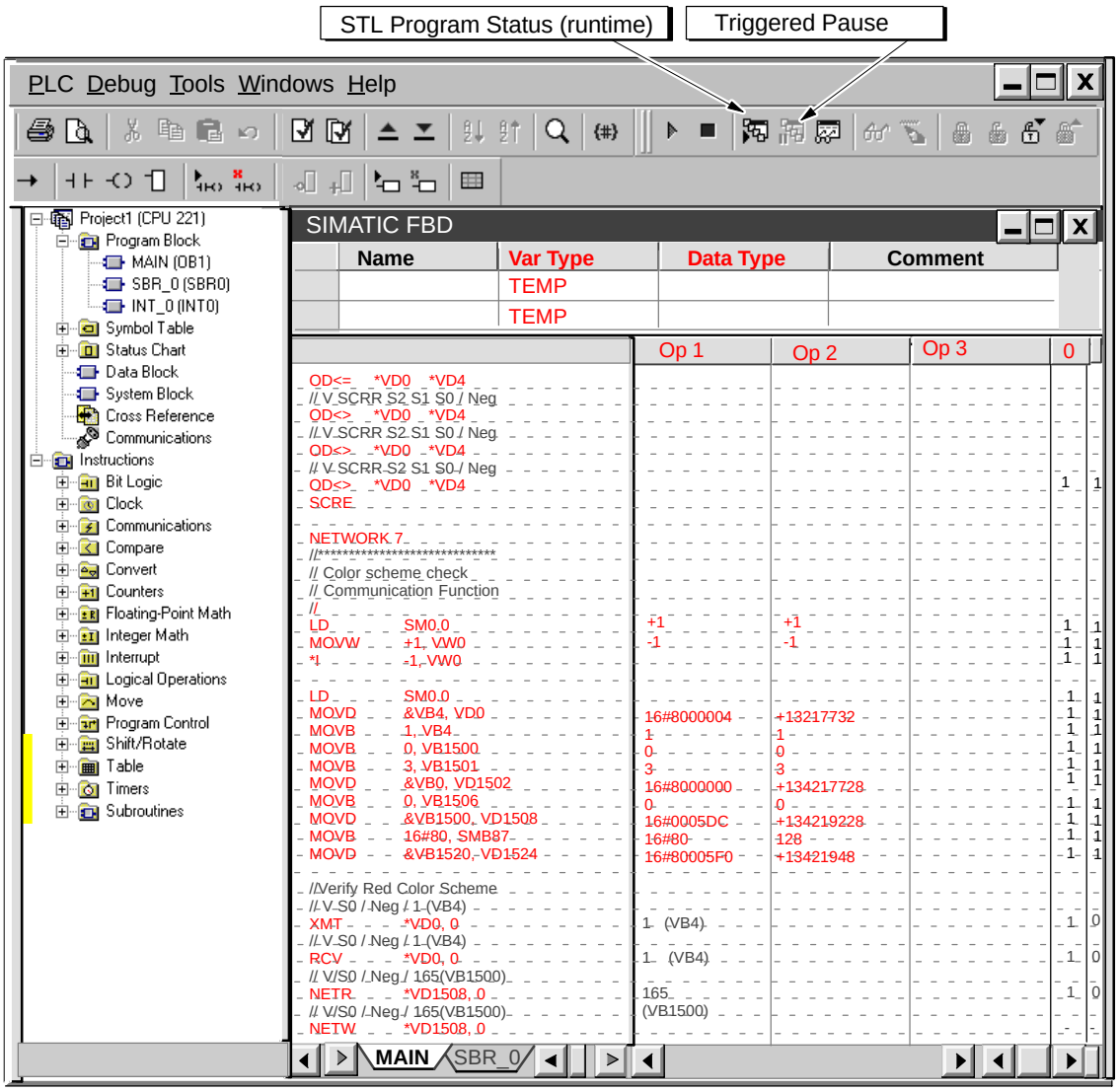


Figure 4-19 Displaying the Status of a Program in Statement List

Forcing Specific Values

The S7-200 CPU allows you to force any or all of the I/O points (I and Q bits). In addition, you can also force up to 16 internal memory values (V or M) or analog I/O values (AI or AQ). V memory or M memory values can be forced in bytes, words, or double words. Analog values are forced as words only, on even-numbered byte boundaries (such as AIW6 or AQW14). All forced values are stored in the permanent EEPROM memory of the CPU.

Because the forced data might be changed during the scan cycle (either by the program, by the I/O update cycle, or by the communications-processing cycle), the CPU reapplies the forced values at various times in the scan cycle. Figure 4-20 shows the scan cycle, highlighting when the CPU updates the forced variables.

The Force function overrides an immediate-read or immediate-write instruction. The Force function also overrides an output that was configured to go to a specified value on transition to STOP mode: if the CPU goes to STOP mode, the output reflects the forced value and not the configured value.

As shown in Figure 4-21, you can use the Status Chart to force values. To force a new value, enter the value in the New Value column of the Status Chart, then press the Force button on the toolbar. To force an existing value, highlight the value in the Current Value column, then press the Force button.

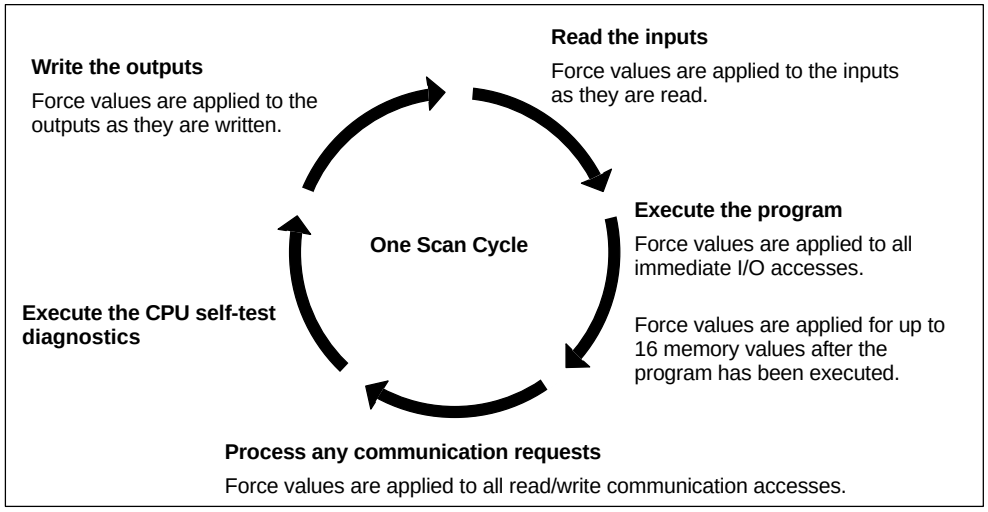


Figure 4-20 Scan Cycle of the S7-200 CPU

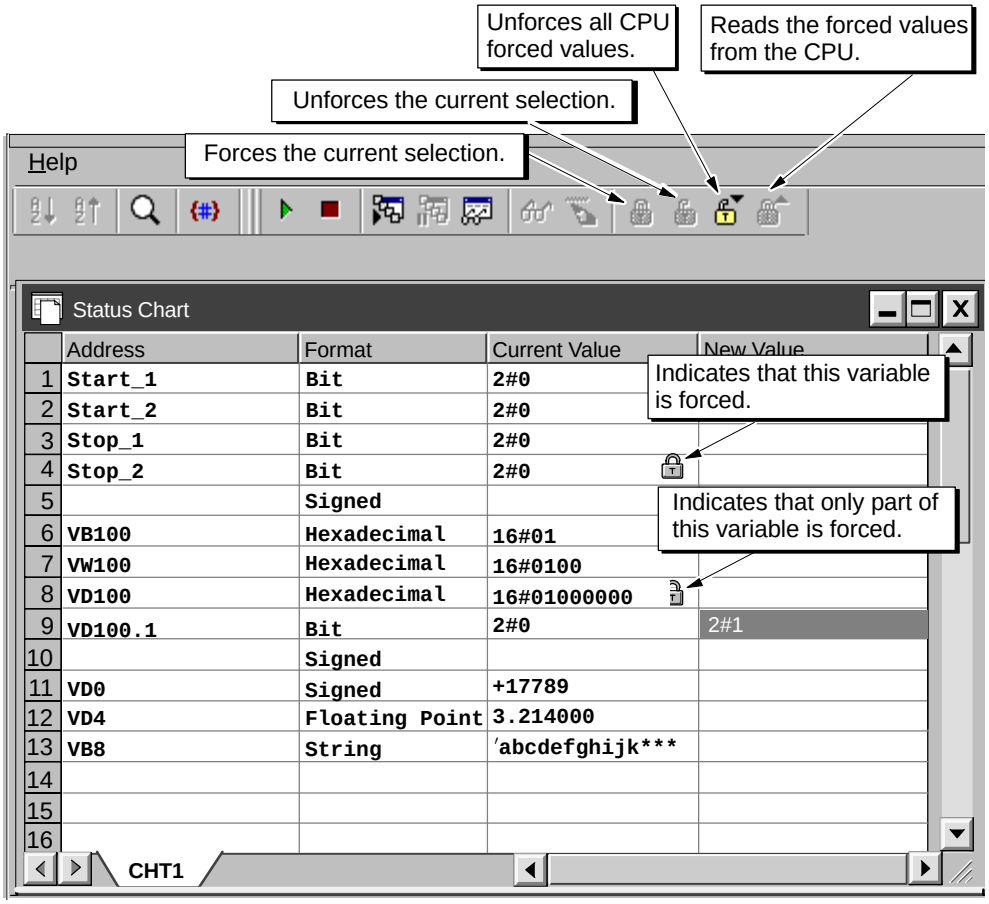


Figure 4-21 Forcing Variables with the Status Chart

4.10 Editing in RUN Mode

CPU 224 Rel. 1.10 (and higher) and CPU 226 Rel. 1.00 (and higher) models support RUN mode edits. The RUN mode edit capability is intended to allow you to make small changes to a user program with minimal disturbance to the process being controlled by the program. However, implementing this capability also allows massive program changes that may be disruptive or even dangerous.

Warning

When you download changes to a CPU in RUN mode, the changes immediately affect process operation. Changing the program in RUN mode can result in unexpected system operation, which can cause serious injury or death to personnel, and/or damage to equipment.

Only authorized personnel who understand the effects of RUN mode edits on system operation should perform a RUN mode edit.

To perform a program edit in RUN mode, the following conditions must be true:

- The online CPU must support RUN mode edits.
- The online CPU must be in RUN mode.

To perform a RUN mode edit, follow these steps:

1. Select **Debug > Program Edit in RUN**. (Figure 4-22 shows the Debug menu on the right side of the screen.)
2. If the project is different than the program in the CPU, you are prompted to save it. The RUN mode edit can be performed only on the program in the CPU.

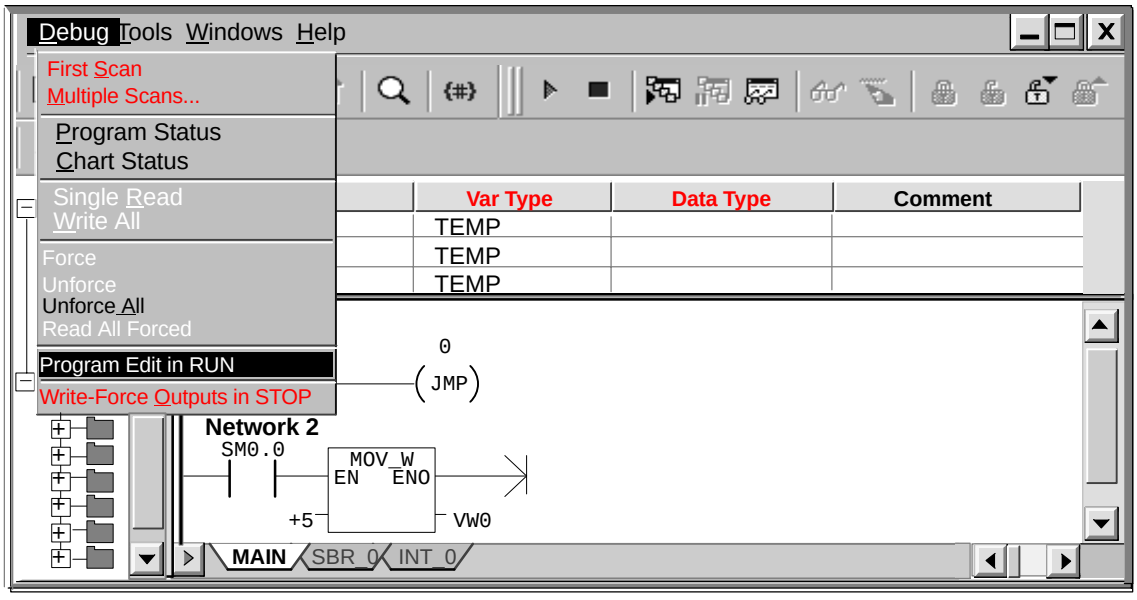


Figure 4-22 Displaying the Status of a Program in Function Block Diagram

3. The warning in Figure 4-23 appears. When you select the “Continue” button, the program from the connected CPU is uploaded and the application is in RUN mode edit. No restrictions on edits are enforced.

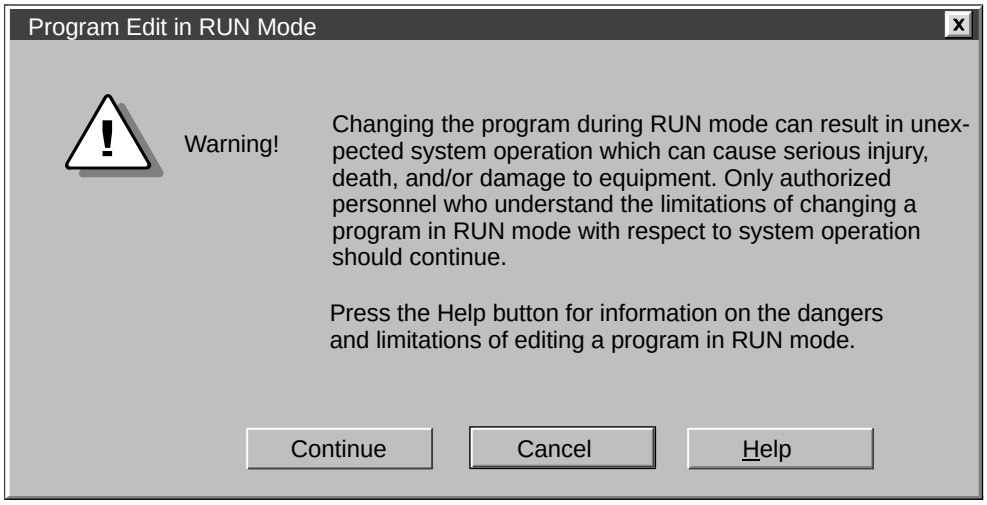


Figure 4-23 RUN mode Edit Dialog Box

Note

Positive (EU) and Negative (ED) transition instructions are shown with an operand. To see information about the previous state of edge instructions, select the Cross Reference icon in the View portion of your screen. The Edge Usage tab lists numbers for the edge instructions in your program. Be careful not to assign duplicate edge numbers as you edit your program.

Before You Download in RUN Mode

RUN mode editing allows you to download your program edits while the CPU is in RUN mode. To decide whether to download your program to the CPU in RUN mode or in STOP mode, consider the following facts:

- If the control logic for an output is deleted in a RUN mode edit, the output maintains its last state until the next power cycle or transition to STOP mode.
- If HSC or PTO/PWM functions which were running are deleted in a RUN mode edit, then these functions continue to run until the next power cycle or transition to STOP mode.
- If ATCH instructions are deleted in a RUN mode edit but the interrupt routine itself is not deleted, the interrupt continues to execute until the power cycle or transition to STOP mode. Likewise, if DTCH instructions are deleted, the interrupts are not shut down until the next power cycle or transition to STOP mode.
- If ATCH instructions are added in a RUN mode edit and are conditional on the first scan flag, these events are not activated until the next power cycle or STOP to RUN mode transition.
- If an ENI instruction is deleted in a RUN mode edit, the interrupts continue to operate until the next power cycle or transition from RUN to STOP mode.
- If the table address of a receive box is modified in a RUN mode edit and the receive box is active at the time of the switch over from old program to new program is made, the data received is written to the old table address. NETR and NETW instructions will function similarly.
- Logic conditional on the first scan flag is not executed until RUN mode is entered as a result of a power cycle or a transition from STOP to RUN mode, because the first scan flag is not affected by a RUN mode edit.

Downloading in RUN Mode

To download a program in RUN mode, select the download button on the toolbar or select **File > Download** from the menu bar. If the program compiles successfully, it is downloaded to the CPU. The CPU processing is indicated on a progress bar. Note that you can only download the program block to the CPU. For the download to be enabled, the following conditions must be met:

- The CPU must support RUN mode edits.
- The compile operation must have completed with no errors.
- Communication between the computer running STEP 7 Micro/WIN 32 and the CPU must be error-free.

Exiting RUN Mode Edit

To exit RUN Mode editing, select **Debug > Program Edit in RUN** and click on the checkmark to remove it. If you have changes that have not been saved, you can choose whether to continue editing, download changes and exit RUN mode editing, or exit without downloading.

4.11 Background Time

You can configure the percentage of the scan cycle that will be dedicated to processing communications requests that are associated with a RUN mode edit compilation or STL status gathering. As you increase the percentage of time that is dedicated to processing communication requests, you increase scan time, which makes your control process run more slowly.

Select the Background Time tab to set the scan cycle time-slice that is allowed for background communications (Figure 4-24). Edit the properties for the communications background time and then download the modifications to the CPU.

The default percentage of the scan dedicated to processing communications requests is set to 10%. This setting was chosen to provide a reasonable compromise for processing compilation/status operations while minimizing the impact to your control process. You can adjust this value by 5% increments up to a maximum of 50%.

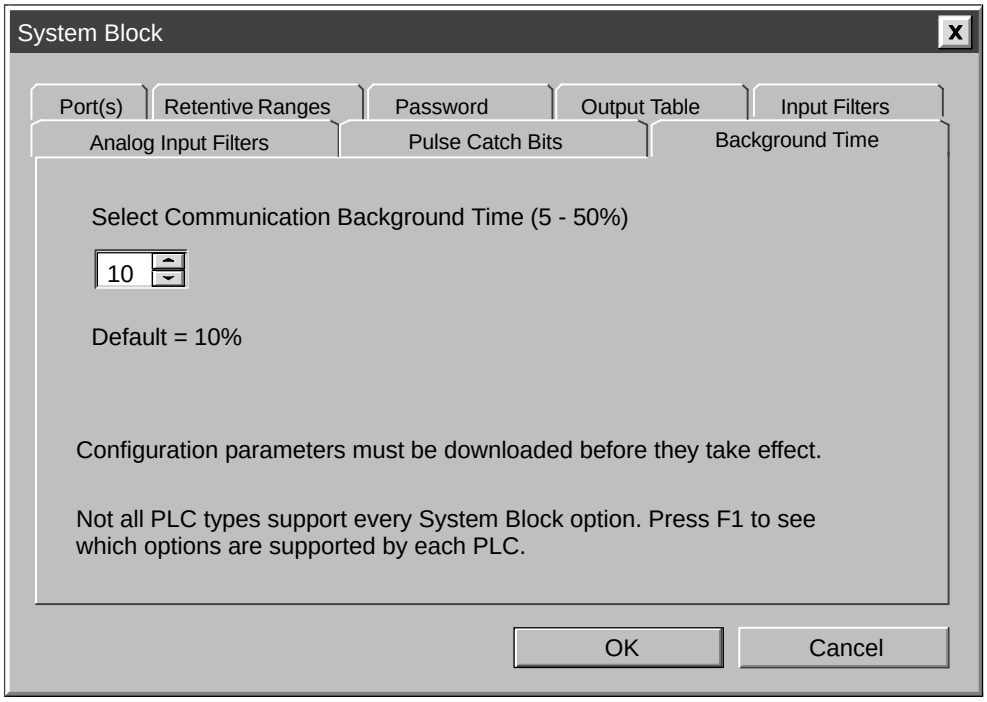


Figure 4-24 Background Time Configuration Screen

4.12 Error Handling for the S7-200 CPU

The S7-200 CPU classifies errors as either fatal errors or non-fatal errors. You can use STEP 7-Micro/WIN 32 to view the error codes that were generated by an error. Select **PLC > Information** from the menu bar to view these errors. Figure 4-25 shows the dialog box that displays the error code and the description of the error. Refer to Appendix B for a complete listing of the error codes.

In Figure 4-25, the Last Fatal field shows the previous fatal error code generated by the CPU. This value is retained over power cycles if the RAM is retained. This location is cleared whenever all memory of the CPU is cleared, or if the RAM is not retained after a prolonged power outage.

The Total Fatal field is the count of fatal errors generated by the CPU since the last time the CPU had all memory areas cleared. This value is retained over power cycles if the RAM is retained. This location is cleared whenever all memory of the CPU is cleared, or when the RAM is not retained after a prolonged power outage.

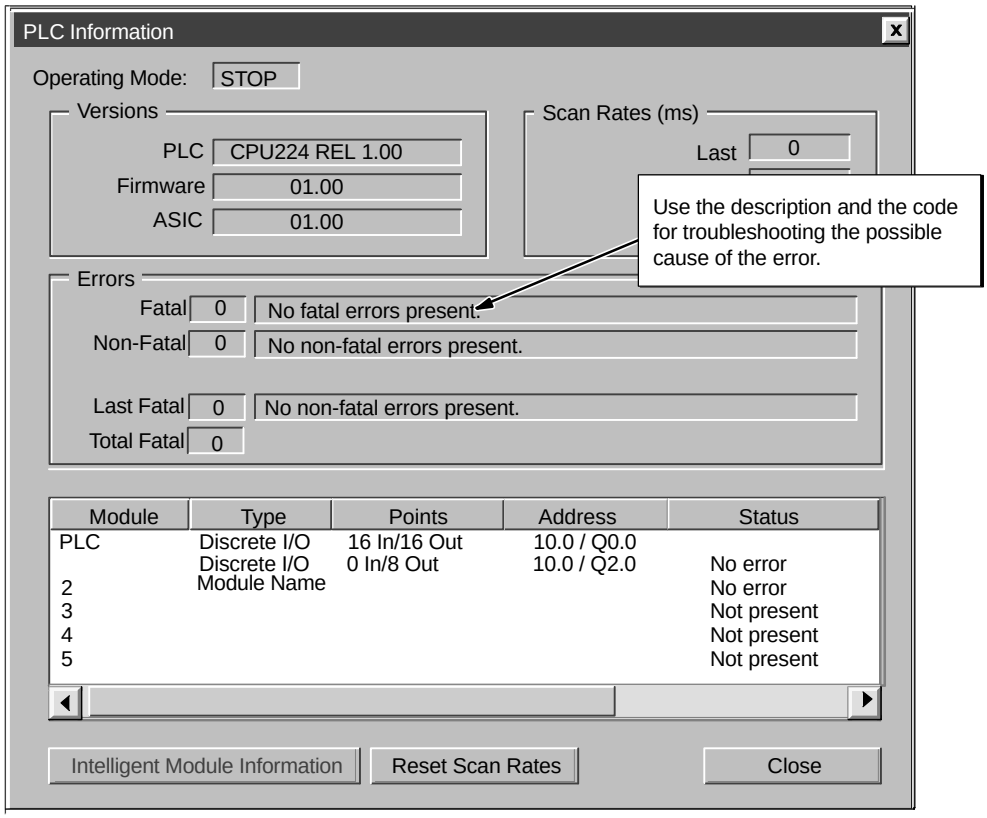


Figure 4-25 CPU Information Dialog: Error Status Tab

Responding to Fatal Errors

Fatal errors cause the CPU to stop the execution of your program. Depending upon the severity of the fatal error, it can render the CPU incapable of performing any or all functions. The objective for handling fatal errors is to bring the CPU to a safe state from which the CPU can respond to interrogations about the existing error conditions. When a fatal error is detected by the CPU, the CPU changes to the STOP mode, turns on the System Fault LED and the STOP LED, and turns off the outputs. The CPU remains in this condition until the fatal error condition is corrected.

Once you have made the changes to correct the fatal error condition, you must restart the CPU. You can restart the CPU by using one of these methods:

- Turning the power off and then on
- Changing the mode switch from RUN or TERM to STOP
- Use STEP 7-Micro/WIN to restart the CPU. STEP 7-Micro/WIN 32 implements the **PLC > Power-Up Reset** from the main menu bar. This forces the PLC to restart and clear any fatal errors.

Restarting the CPU clears the fatal error condition and performs power-up diagnostic testing to verify that the fatal error has been corrected. If another fatal error condition is found, the CPU again sets the fault LED indicating that an error still exists. Otherwise, the CPU begins normal operation.

There are several possible error conditions that can render the CPU incapable of communication. In these cases, you cannot view the error code from the CPU. These types of errors indicate hardware failures that require the CPU to be repaired; they cannot be fixed by changes to the program or clearing the CPU memory.

Responding to Non-Fatal Errors

Non-fatal errors can degrade some aspect of the CPU performance, but they do not render the CPU incapable of executing your program or updating the I/O. As shown in Figure 4-25, you can use STEP 7-Micro/WIN 32 to view the error codes that were generated by the non-fatal error. There are three basic categories of non-fatal errors:

- Run-time errors. All non-fatal errors detected in RUN mode are reflected in special memory (SM) bits. Your program can monitor and evaluate these bits. Refer to Appendix C for more information about the SM bits used for reporting non-fatal run-time errors.

  At startup, the CPU reads the I/O configuration and stores this information in the system data memory and in the SM memory. During normal operation, the I/O status is periodically updated and stored in the SM memory. If the CPU detects a difference in the I/O configuration, the CPU sets the configuration-changed bit in the module-error byte; the I/O module is not updated until this bit is reset. For the CPU to reset this bit, the module I/O must again match the I/O configuration stored in the system data memory.

- Program-compile errors. The CPU compiles the program as it downloads. If the CPU detects that the program violates a compilation rule, the download is aborted and an error code is generated. (A program that was already downloaded to the CPU would still exist in the EEPROM and would not be lost.) After you correct your program, you can download it again.

- Program execution errors. Your program can create error conditions while the program is being executed. For example, an indirect-address pointer that was valid when the program compiled may be modified during the execution of the program to point to an out-of-range address. This is considered a run-time programming error. Use the dialog box shown in Figure 4-25 on page 4-43 to determine what type of error occurred.

The CPU does not change to STOP mode when it detects a non-fatal error. It only logs the event in SM memory and continues with the execution of your program. However, you can design your program to force the CPU to STOP mode when a non-fatal error is detected. Figure 4-26 shows a network of a program that is monitoring an SM bit. This instruction changes the CPU to STOP mode whenever an I/O error is detected.

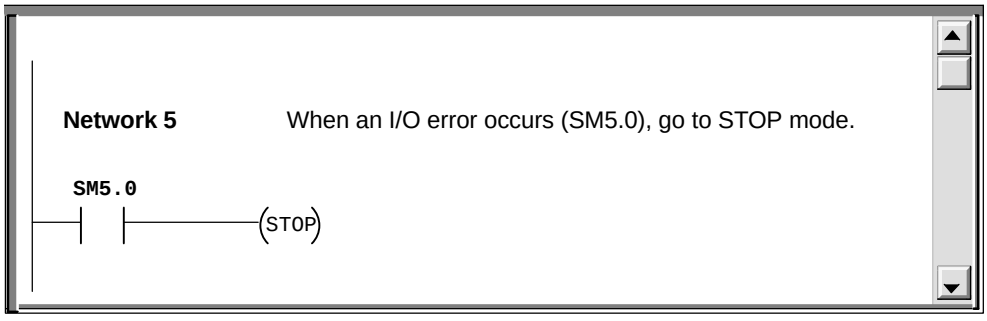


Figure 4-26 Designing Your Program to Detect Non-Fatal Error Conditions

CPU Memory: Data Types and Addressing Modes

5

The S7-200 CPU provides specialized areas of memory to make the processing of the control data faster and more efficient.

Chapter Overview

Section	Description	Page
5.1	Direct Addressing of the CPU Memory Areas	5-2
5.2	SIMATIC Indirect Addressing of the CPU Memory Areas	5-13
5.3	Memory Retention for the S7-200 CPU	5-15
5.4	Using Your Program to Store Data Permanently	5-20
5.5	Using a Memory Cartridge to Store Your Program	5-22

5.1 Direct Addressing of the CPU Memory Areas

The S7-200 CPU stores information in different memory locations that have unique addresses. You can explicitly identify the memory address that you want to access. This allows your program to have direct access to the information.

Using the Memory Address to Access Data

To access a bit in a memory area, you specify the address, which includes the memory area identifier, the byte address, and the bit number. Figure 5-1 shows an example of accessing a bit (which is also called “byte.bit” addressing). In this example, the memory area and byte address (I = input, and 3 = byte 3) are followed by a period (“.”) to separate the bit address (bit 4).

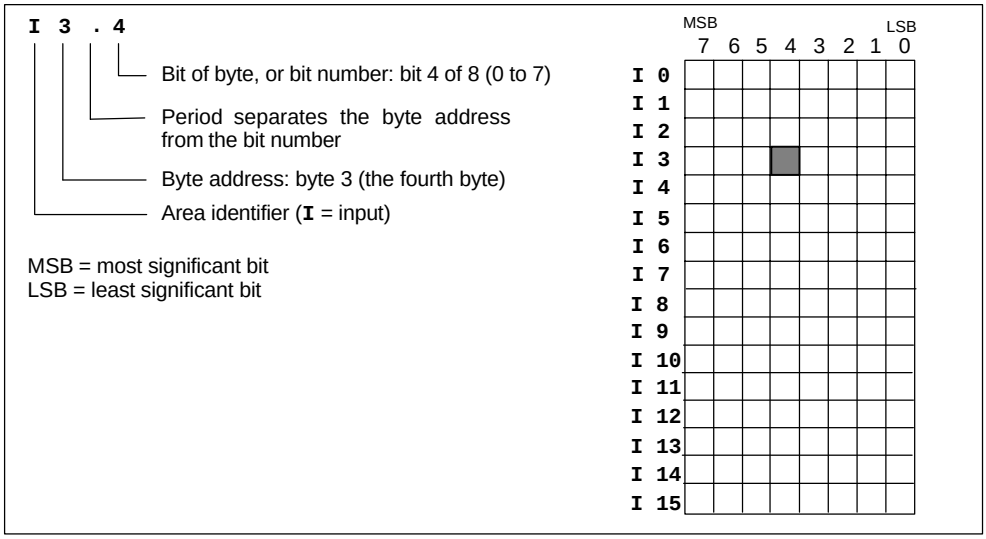


Figure 5-1 Accessing a Bit of Data in the CPU Memory (Byte.bit Addressing)

You can access data in many CPU memory areas (V, I, Q, M, S, L, and SM) as bytes, words, or double words by using the byte-address format. To access a byte, word, or double word of data in the CPU memory, you must specify the address in a way similar to specifying the address for a bit. This includes an area identifier, data size designation, and the starting byte address of the byte, word, or double-word value, as shown in Figure 5-2. Data in other CPU memory areas (such as T, C, HC, and the accumulators) are accessed by using an address format that includes an area identifier and a device number.

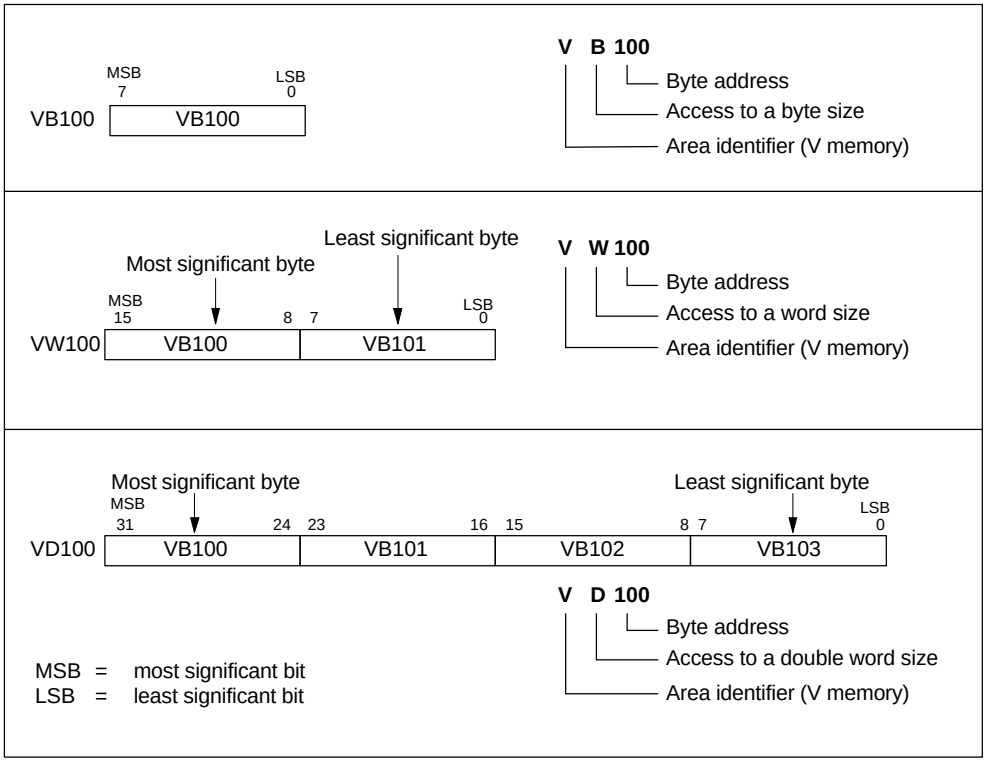


Figure 5-2 Comparing Byte, Word, and Double-Word Access to the Same Address

Representation of Numbers

Table 5-1 shows the range of integer values that can be represented by the different sizes of data.

Real (or floating-point) numbers are represented as 32-bit, single-precision numbers whose format is: +1.175495E-38 to +3.402823E+38 (positive), and -1.175495E-38 to -3.402823E+38 (negative). Real number values are accessed in double-word lengths. Refer to ANSI/IEEE 754-1985 standard for more information about real or floating-point numbers.

Table 5-1 Data Size Designations and Associated Integer Ranges

Data Size	Unsigned Integer Range		Signed Integer Range	
	Decimal	Hexadecimal	Decimal	Hexadecimal
B (Byte): 8-bit value	0 to 255	0 to FF	-128 to 127	80 to 7F
W (Word): 16-bit value	0 to 65,535	0 to FFFF	-32,768 to 32,767	8000 to 7FFF
D (Double word, Dword): 32-bit value	0 to 4,294,967,295	0 to FFFF FFFF	-2,147,483,648 to 2,147,483,647	8000 0000 to 7FFF FFFF

Addressing the Process-Image Input Register (I)

As described in Section 4.6, the CPU samples the physical input points at the beginning of each scan cycle and writes these values to the process-image input register. You can access the process-image input register in bits, bytes, words, or double words.

Format:

Bit	**I*[byte address].[bit address]***	**I0.1**
Byte, Word, Double Word	**I*[size][starting byte address]***	**IB4**

Addressing the Process-Image Output Register (Q)

At the end of the scan cycle, the CPU copies the values stored in the process-image output register to the physical output points. You can access the process-image output register in bits, bytes, words, or double words.

Format:

Bit	**Q*[byte address].[bit address]***	**Q1.1**
Byte, Word, Double Word	**Q*[size][starting byte address]***	**QB5**

Addressing the Variable (V) Memory Area

You can use V memory to store intermediate results of operations being performed by the control logic in your program. You can also use V memory to store other data pertaining to your process or task. You can access the V memory area in bits, bytes, words, or double words.

Format:

Bit	**V*[byte address].[bit address]***	**V10.2**
Byte, Word, Double Word	**V*[size][starting byte address]***	**VW100**

Addressing the Bit Memory (M) Area

You can use the bit memory area (M memory) as control relays to store the intermediate status of an operation or other control information. While the name “bit memory area” implies that this information is stored in bit-length units, you can access the bit memory area not only in bits, but also in bytes, words, or double words.

Format:

Bit	**M*[byte address].[bit address]***	**M26.7**
Byte, Word, Double Word	**M*[size][starting byte address]***	**MD20**

Addressing the Sequence Control Relay (S) Memory Area

Sequence Control Relay bits (S) are used to organize machine operations or steps into equivalent program segments. SCRs allow logical segmentation of the control program. You can access the S bits as bits, bytes, words, or double words.

Format:

Bit	**S*[byte address].[bit address]***	**S3.1**
Byte, Word, Double Word	**S*[size][starting byte address]***	**SB4**

Addressing the Special Memory (SM) Bits

The SM bits provide a means for communicating information between the CPU and your program. You can use these bits to select and control some of the special functions of the S7-200 CPU, such as:

- A bit that turns on for the first scan cycle
- Bits that toggle at fixed rates
- Bits that show the status of math or operational instructions

For more information about the SM bits, see Appendix C. While the SM area is based on bits, you can access the data in this area as bits, bytes, words, or double words.

Format:

Bit	**SM*[byte address].[bit address]***	**SM0.1**
Byte, Word, Double Word	**SM*[size][starting byte address]***	**SMB86**

Addressing the Local (L) Memory Area

The S7-200 PLCs provide 64 bytes of local (L) memory of which 60 can be used as scratchpad memory or for passing formal parameters to subroutines. If you are programming in either LAD or FBD, STEP 7-Micro/WIN 32 reserves the last four bytes of local memory for its own use. If you program in STL, all 64 bytes of L memory are accessible, but it is recommended that you do not use the last four bytes of L memory.

Local memory is similar to V memory with one major exception. V memory has a global scope while L memory has a local scope. The term global scope means that the same memory location can be accessed from any program entity (main program, subroutines, or interrupt routines). The term local scope means that the memory allocation is associated with a particular program entity. The S7-200 PLCs allocate 64 bytes of L for the main, 64 bytes for each subroutine nesting level, and 64 bytes for interrupt routines.

The allocation of L memory for the main cannot be accessed from subroutines or from interrupt routines. A subroutine cannot access the L memory allocation of the main, an interrupt routine, or another subroutine. Likewise, an interrupt routine cannot access the L memory allocation of the main or of a subroutine.

The allocation of L memory is made by the S7-200 PLC on an as-needed basis. This means that while the main portion of the program is being executed, the L memory allocations for subroutines and interrupt routines do not exist. At the time that an interrupt occurs or a subroutine is called, local memory is allocated as required. The new allocation of L memory may reuse the same L memory locations of a different subroutine or interrupt routine.

The L memory is not initialized by the PLC at the time of allocation and may contain any value. When you pass formal parameters in a subroutine call, the values of the parameters being passed are placed by the CPU in the appropriate L memory locations of the called subroutine. L memory locations, which do not receive a value as a result of the formal parameter passing step, will not be initialized and may contain any value at the time of allocation.

You can access L memory as bits, bytes, words or double words. You can use L memory as a pointer for indirect addressing but you cannot indirectly address L memory.

Format:

Bit	***L [byte address].[bit address]***	**L0.0**
Byte, Word, Double Word	***L [size] [starting byte address]***	**LB33**

Addressing the Timer (T) Memory Area

In the S7-200 CPU, timers are devices that count increments of time. The S7-200 timers have resolutions (time-base increments) of 1 ms, 10 ms, or 100 ms. There are two variables that are associated with a timer:

- Current value: this 16-bit signed integer stores the amount of time counted by the timer.
- Timer bit: this bit is set or cleared as a result of comparing the current and the preset value. The preset value is entered as part of the timer instruction.

You access both of these variables by using the timer address (T + timer number). Access to either the timer bit or the current value is dependent on the instruction used: instructions with bit operands access the timer bit, while instructions with word operands access the current value. As shown in Figure 5-3, the Normally Open Contact instruction accesses the timer bit, while the Move Word (MOV_W) instruction accesses the current value of the timer. For more information about the S7-200 instructions, see Chapter 9 for SIMATIC instructions and Chapter 10 for IEC 1131-3 instructions.

Format: **T*[timer number]*** **T24**

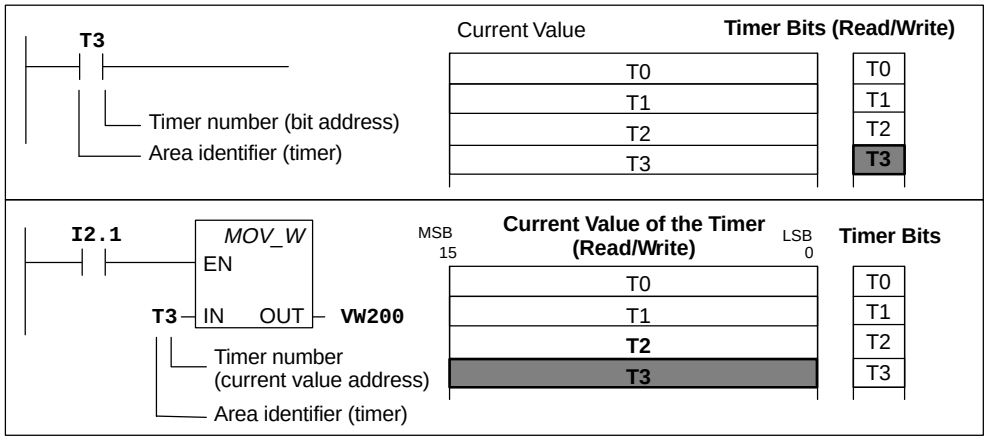


Figure 5-3 Accessing the SIMATIC Timer Data

Addressing the Counter (C) Memory Area

In the S7-200 CPU, counters are devices that count each low-to-high transition event on the counter input(s). The CPU provides three types of counters: one type counts up only, one type counts down, and one type counts both up and down. There are two variables that are associated with a counter:

- Current value: this 16-bit signed integer stores the accumulated count.
- Counter bit: this bit is set or cleared as a result of comparing the current and the preset value. The preset value is entered as part of the counter instruction.

You access both of these variables by using the counter address (C + counter number). Access to either the counter bit or the current value is dependent on the instruction used: instructions with bit operands access the counter bit, while instructions with word operands access the current value. As shown in Figure 5-4, the Normally Open Contact instruction accesses the counter bit, while the Move Word (MOV_W) instruction accesses the current value of the counter. For more information about the S7-200 instruction set, see Chapter 9 for SIMATIC instructions and Chapter 10 for IEC 1131-3 instructions.

Format: **C*[counter number]*** **C20**

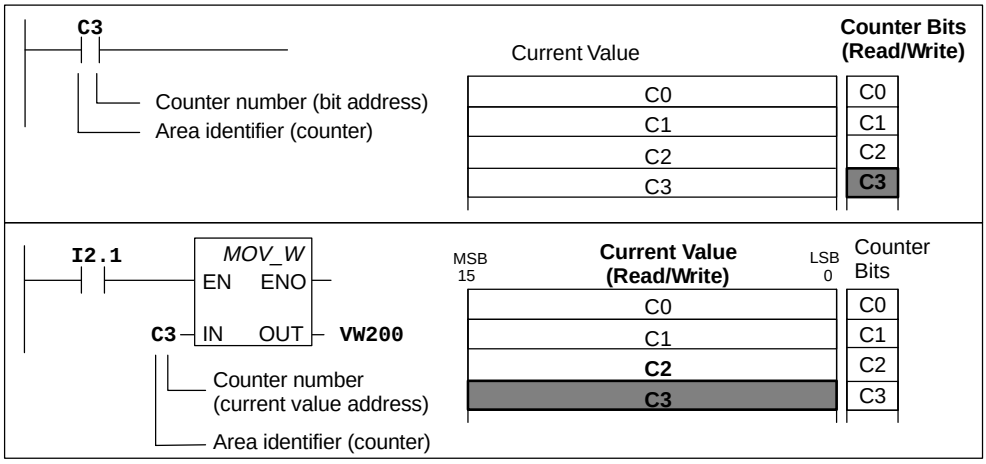


Figure 5-4 Accessing the SIMATIC Counter Data

Addressing the Analog Inputs (AI)

The S7-200 converts a real-world, analog value (such as temperature or voltage) into a word-length (16-bit) digital value. You access these values by the area identifier (AI), size of the data (W), and the starting byte address. Since analog inputs are words and always start on even-number bytes (such as 0, 2, or 4), you access them with even-number byte addresses (such as AIW0, AIW2, or AIW4), as shown in Figure 5-5. Analog input values are read-only values.

Format: **AIW*[starting byte address]*** **AIW4**

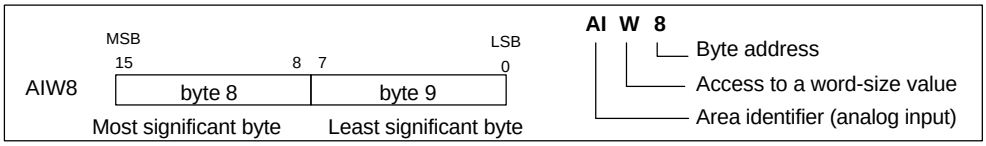


Figure 5-5 Accessing an Analog Input

Addressing the Analog Outputs (AQ)

The S7-200 converts a word-length (16-bit) digital value into a current or voltage, proportional to the digital value (such as for a current or voltage). You write these values by the area identifier (AQ), size of the data (W), and the starting byte address. Since analog outputs are words and always start on even-number bytes (such as 0, 2, or 4), you write them with even-number byte addresses (such as AQW0, AQW2, or AQW4), as shown in Figure 5-6. Analog output values are write-only values.

Format: **AQW*[starting byte address]*** **AQW4**

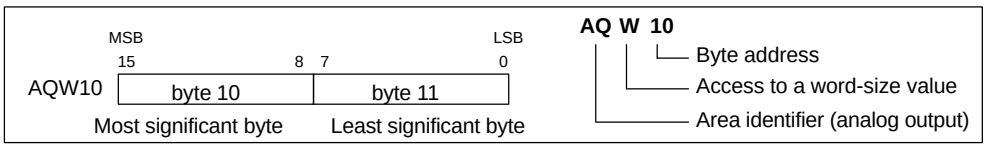


Figure 5-6 Accessing an Analog Output

Addressing the Accumulators (AC)

Accumulators are read/write devices that can be used like memory. For example, you can use accumulators to pass parameters to and from subroutines and to store intermediate values used in a calculation. The CPU provides four 32-bit accumulators (AC0, AC1, AC2, and AC3). You can access the data in the accumulators as bytes, words, or double words. As shown in Figure 5-7, to access the accumulator as bytes or words, you use the least significant 8 or 16 bits of the value that is stored in the accumulator. To access the accumulator as a double word, you use all 32 bits. The size of the data being accessed is determined by the instruction that is used to access the accumulator.

Format: **AC*[accumulator number]*** **AC0**

Note

See Section 9.15, SIMATIC Communications Instructions, in Chapter 9 for information about using the accumulators with interrupt routines.

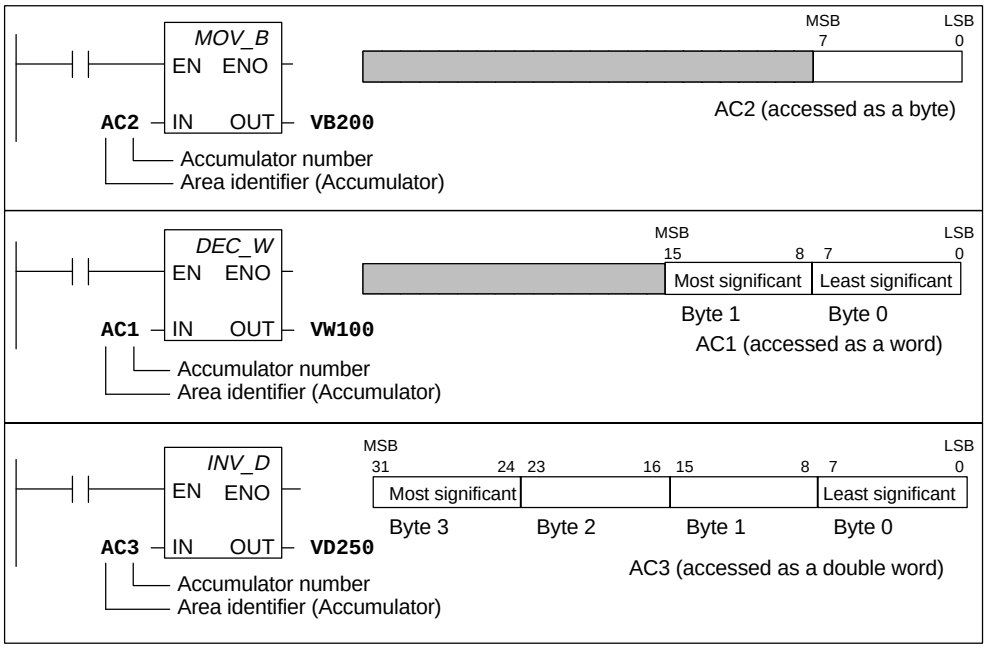


Figure 5-7 Addressing the Accumulators

Addressing the High-Speed Counters (HC)

High-speed counters are designed to count very high-speed events independent of the CPU scan. High-speed counters have a signed, 32-bit integer counting value (or current value). To access the count value for the high-speed counter, you specify the address of the high-speed counter, using the memory type (HC) and the counter number (such as HC0). The current value of the high-speed counter is a read-only value and, as shown in Figure 5-8, can be addressed only as a double word (32 bits).

Format: **HC*[high-speed counter number]* HC1**

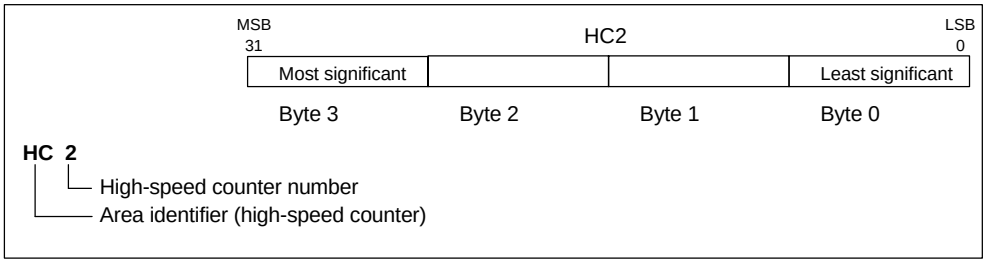


Figure 5-8 Accessing the High-Speed Counter Current Values

Using Constant Values

You can use a constant value in many of the S7-200 instructions. Constants can be bytes, words, or double words. The CPU stores all constants as binary numbers, which can then be represented in decimal, hexadecimal, ASCII or floating point formats.

Decimal Format:	**[decimal value]**
Hexadecimal Format:	**16#[hexadecimal value]**
ASCII Format:	**'[ASCII text]'**
Real or Floating-Point Format:	**ANSI/IEEE 754-1985**

The binary format is in the form of: **2#1010_0101_1010_0101**

The S7-200 CPU does not support "data typing" or data checking (such as specifying that the constant is stored as an integer, a signed integer, or a double integer). For example, an Add instruction can use the value in VW100 as a signed integer value, while an Exclusive Or instruction can use the same value in VW100 as an unsigned binary value.

The following examples show constants for decimal, hexadecimal, ASCII, and floating point format:

- Decimal constant: **20047**
- Hexadecimal constant: **16#4E4F**
- ASCII constant: **'Text goes between single quotes.'**
- Real or floating-point format: **+1.175495E-38 (positive)**
-1.175495E-38 (negative)
- Binary format **2#1010_0101_1010_0101**

5.2 SIMATIC Indirect Addressing of the CPU Memory Areas

Indirect addressing uses a pointer to access the data in memory. The S7-200 CPU allows you to use pointers to address the following memory areas indirectly: I, Q, V, M, S, T (current value only), and C (current value only). You cannot address individual bit or analog values indirectly.

Creating a Pointer

To address a location in memory indirectly, you must first create a pointer to that location. Pointers are double word memory locations that contain the address of another memory location. You can only use V memory locations, L memory locations, or accumulator registers (AC1, AC2, AC3) as pointers. To create a pointer, you must use the Move Double Word (MOVD) instruction to move the address of the indirectly addressed memory location to the pointer location. The input operand of the instruction must be preceded with an ampersand (&) to signify that the address of a memory location, instead of its contents, is to be moved into the location identified in the output operand of the instruction (the pointer).

```
Example:    MOVD      &VB100, VD204
            MOVD      &MB4, AC2
            MOVD      &C4, LD6
```

Using a Pointer to Access Data

Entering an asterisk (*) in front of an operand for an instruction specifies that the operand is a pointer. Using the example shown in Figure 5-9, *AC1 specifies that AC1 is a pointer to the word-length value being referenced by the Move Word (MOVW) instruction. In this example, the values stored in both V200 and V201 are moved to accumulator AC0.

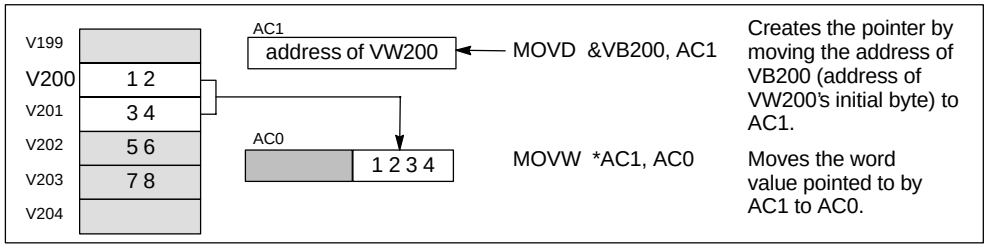


Figure 5-9 Using a Pointer for Indirect Addressing

Modifying Pointers

You can change the value of a pointer. Since pointers are 32-bit values, use double-word instructions to modify pointer values. Simple mathematical operations, such as adding or incrementing, can be used to modify pointer values. Remember to adjust for the size of the data that you are accessing:

- When accessing bytes, increment the pointer value by one.
- When accessing a word or a current value for a timer or counter, add or increment the pointer value by two.
- When accessing a double word, add or increment the pointer value by four.

Figure 5-10 shows an example of how you can create an indirect address pointer, how data is accessed indirectly, and how you can increment the pointer.

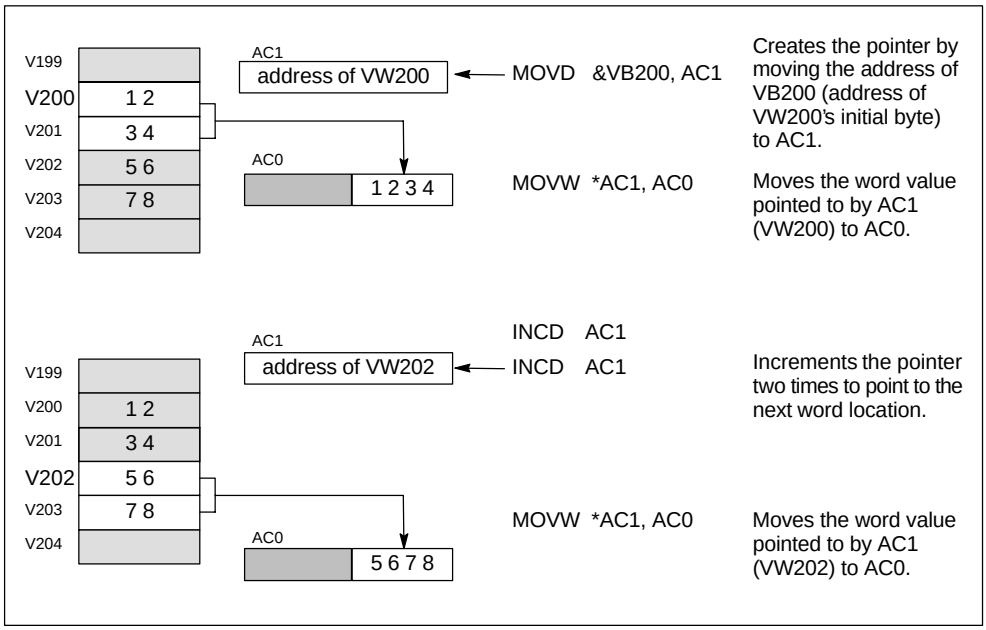


Figure 5-10 Modifying a Pointer When Accessing a Word Value

5.3 Memory Retention for the S7-200 CPU

The S7-200 CPU provides several methods to ensure that your program, the program data, and the configuration data for your CPU are properly retained. See Figure 5-11.

- The CPU provides an EEPROM to store permanently all of your program, user-selected data areas, and the configuration data for your CPU.
- The CPU provides a super capacitor that maintains the integrity of the RAM after power has been removed from the CPU. Depending on the CPU, the super capacitor can maintain the RAM for several days.
- The CPU supports an optional battery cartridge that extends the amount of time that the RAM can be maintained after power has been removed from the CPU. The battery cartridge provides power only after the super capacitor has been drained.

This section discusses the permanent storage and retention of the data in RAM under a variety of circumstances.

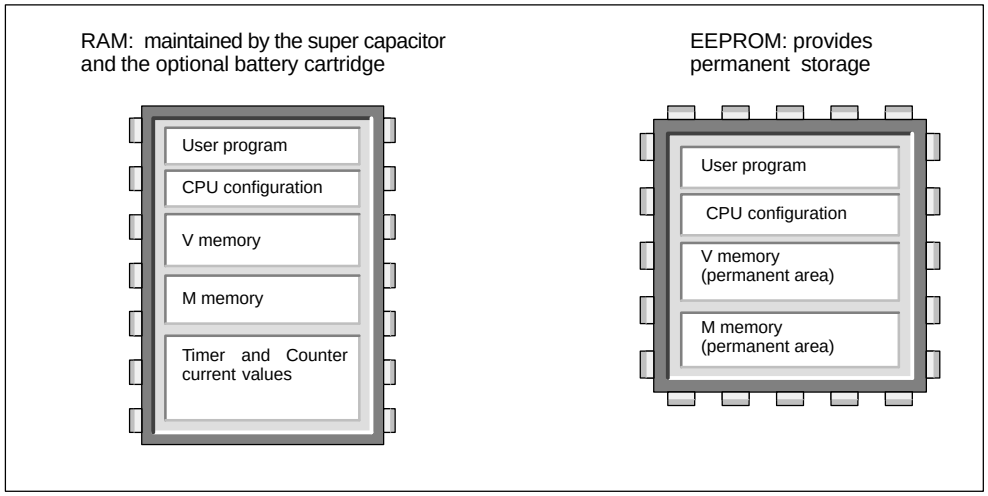


Figure 5-11 Storage Areas of an S7-200 CPU

Downloading and Uploading Your Project

Your project consists of three elements: the user program, the data block (optional), and the CPU configuration (optional). As shown in Figure 5-12, downloading the project stores these elements in the RAM area of the CPU memory. The CPU also automatically copies the user program, data block (DB1), and the CPU configuration to the EEPROM for permanent storage.

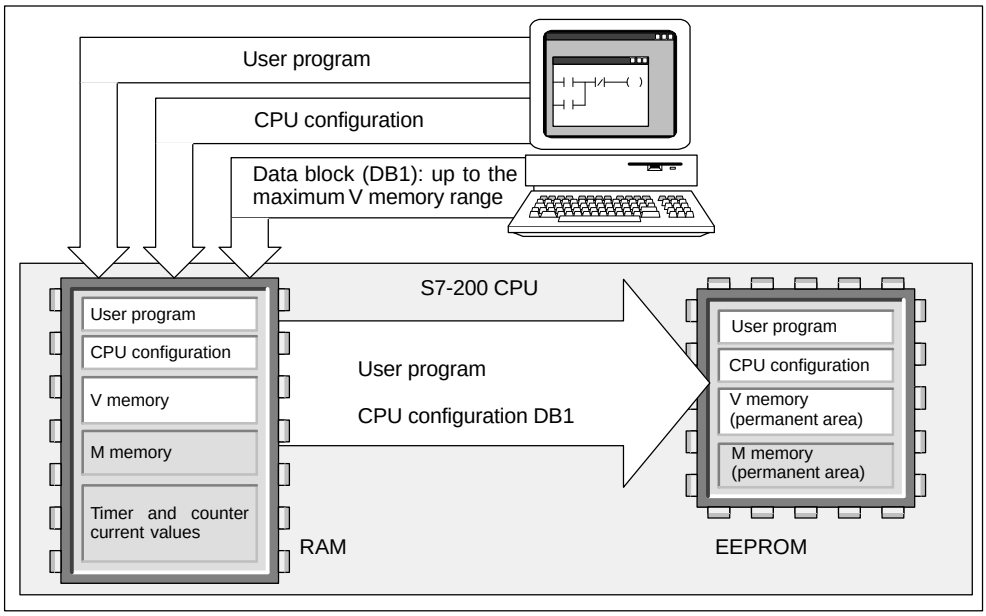


Figure 5-12 Downloading the Elements of the Project

When you upload a project from the CPU, as shown in Figure 5-13, the CPU configuration is uploaded from the RAM to your computer. The user program and the permanent V memory area are uploaded from the EEPROM to your computer.

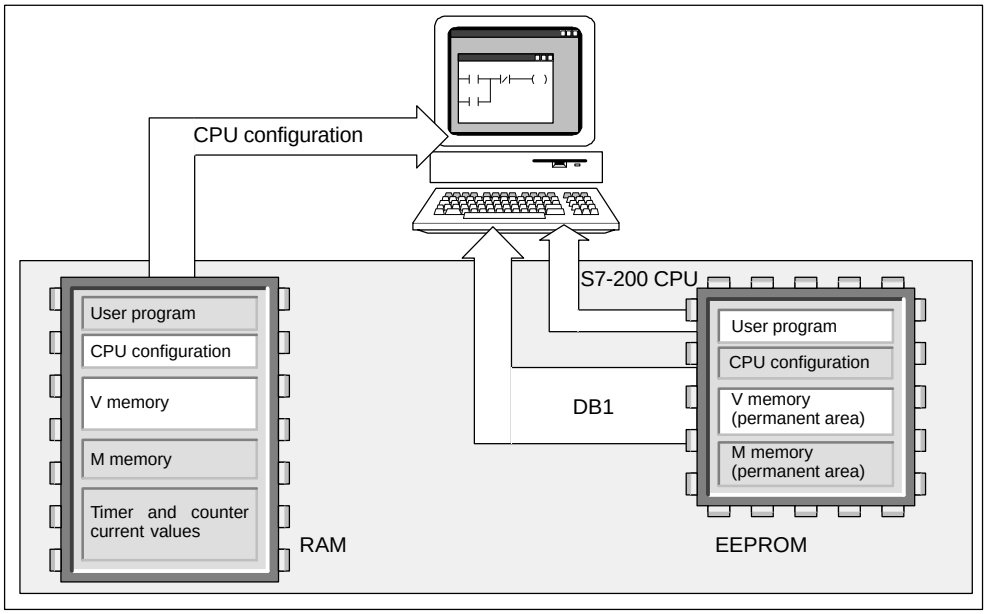


Figure 5-13 Uploading the Elements of the Project

Automatically Saving the Data from the Bit Memory (M) Area When the CPU Loses Power

If the first 14 bytes of M memory (MB0 to MB13) are configured to be retentive, they are permanently saved to the EEPROM when the CPU loses power. As shown in Figure 5-14, the CPU moves these retentive areas of M memory to the EEPROM. In STEP 7-Micro/WIN 32, the default setting is set to off.

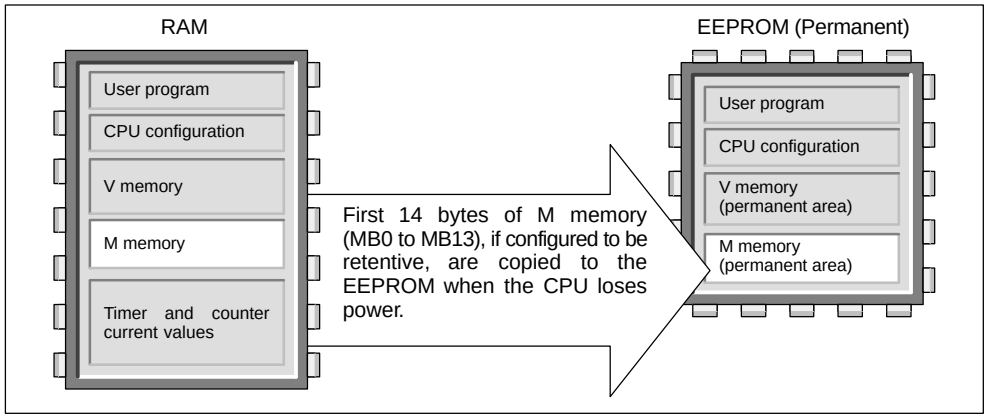


Figure 5-14 Saving Parts of Bit Memory (M) to EEPROM on Power Off

Retaining Memory on Power On

At power on, the CPU restores the user program and the CPU configuration from the EEPROM memory. See Figure 5-15.

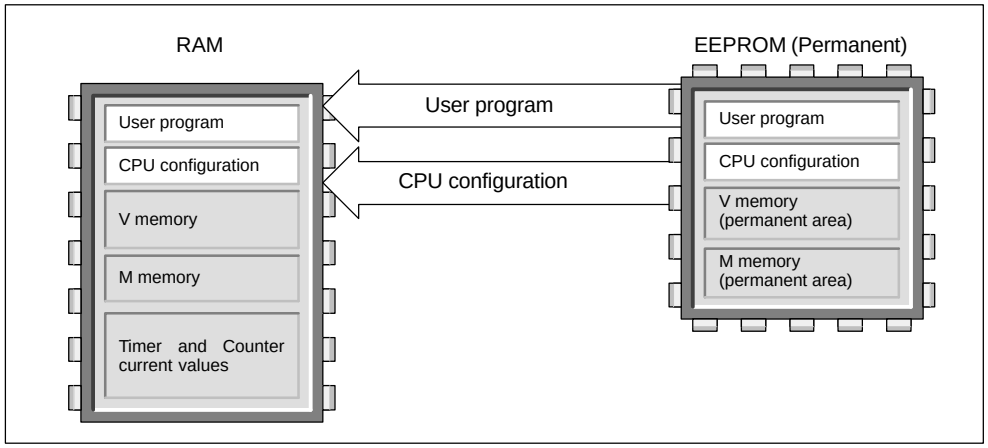


Figure 5-15 Restoring the User Program and CPU Configuration on Power On

At power on, the CPU checks the RAM to verify that the super capacitor successfully maintained the data stored in RAM memory. If the RAM was successfully maintained, the retentive areas of RAM are left unchanged. As shown in Figure 5-16, the non-retentive areas of V memory are restored from the corresponding permanent area of V memory in the EEPROM.

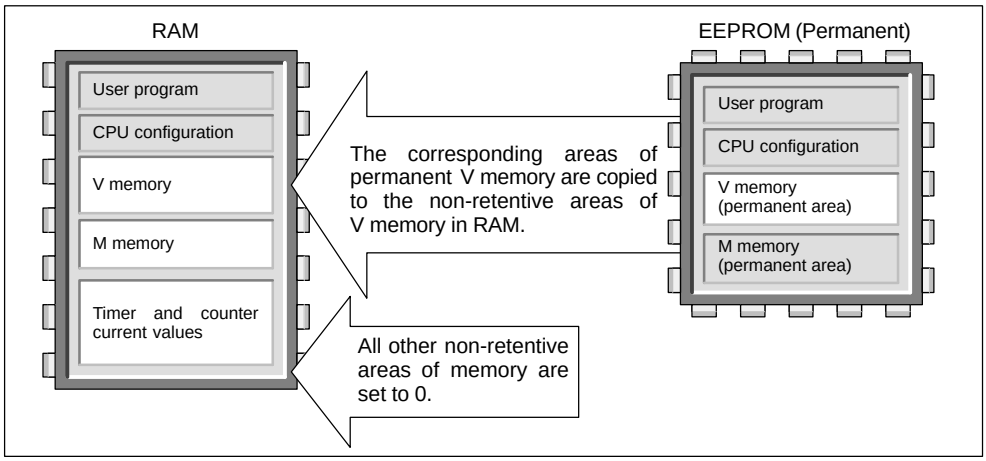


Figure 5-16 Restoring Program Data on Power On (Data Was Successfully Maintained in RAM)

If the contents of the RAM were not maintained (such as after an extended power failure), the CPU clears the RAM (including both the retentive and non-retentive ranges) and sets the Retentive Data Lost memory bit (SM0.2) for the first scan cycle following power on. As shown in Figure 5-17, the data stored in the permanent EEPROM are then copied to the RAM.

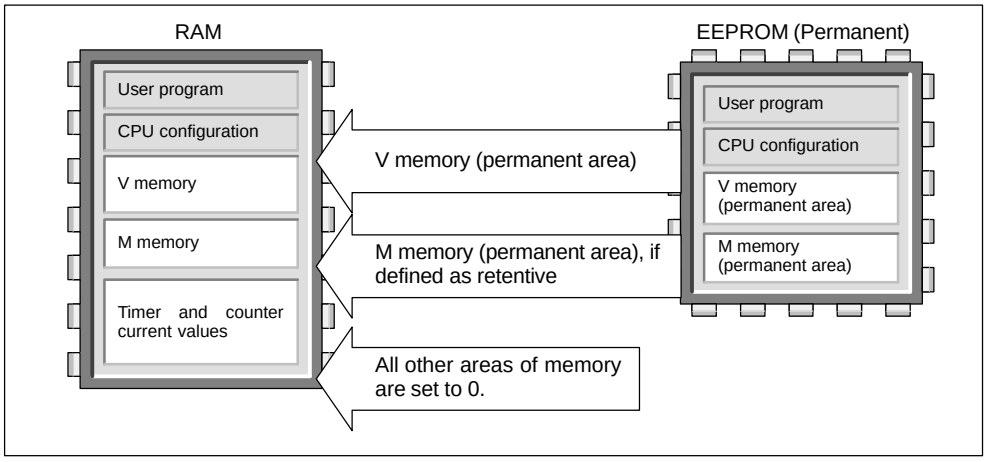


Figure 5-17 Restoring Program Data on Power On (Data Not Maintained in RAM)

Defining Retentive Ranges of Memory

You can define up to six retentive ranges to select the areas of memory you want to retain through power cycles (see Figure 5-18). You can define ranges of addresses in the following memory areas to be retentive: V, M, C, and T. For timers, only the retentive timers (TONR) can be retained. In STEP 7-Micro/WIN 32, the default is that the first 14 bytes of M memory is defined as non-retentive. The default disables the save that normally occurs when you power down (turn off) the CPU.

Note

Only the current values for timers and counters can be retained: the timer and counter bits are not retentive.

To define the retentive ranges for the memory areas, select the **View > System Block** menu command and click the Retentive Ranges tab. The dialog box for defining specific ranges to be retentive is shown in Figure 5-18. To obtain the default retentive ranges for your CPU, press the **Defaults** button.

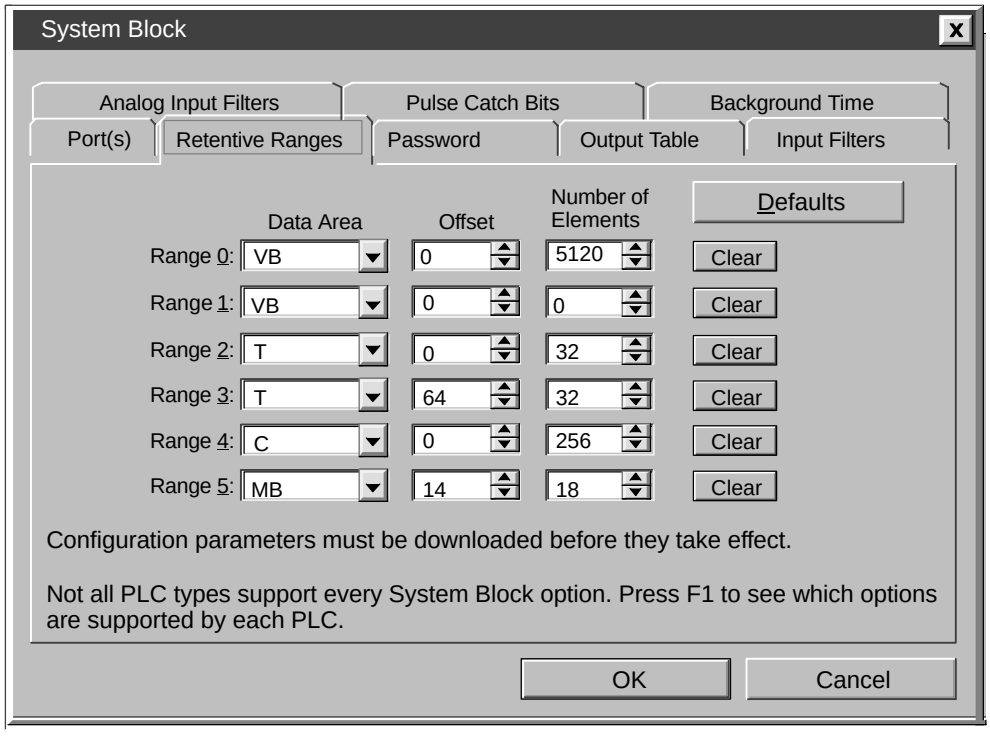


Figure 5-18 Configuring the Retentive Ranges for the CPU Memory

5.4 Using Your Program to Store Data Permanently

You can save a value (byte, word, or double word) stored in V memory to EEPROM. This feature can be used to store a value in any location of the permanent V memory area.

A save-to-EEPROM operation typically affects the scan time by up to 5 ms. The value written by the save operation overwrites any previous value stored in the permanent V memory area of the EEPROM.

Note

The save-to-EEPROM operation does not update the data in the memory cartridge.

Copying V Memory to the EEPROM

Special Memory Byte 31 (SMB31) and Special Memory Word 32 (SMW32) command the CPU to copy a value in V memory to the permanent V memory area of the EEPROM. Figure 5-19 shows the format of SMB31 and SMW32. Use the following steps to program the CPU to save or write a specific value in V memory:

1. Load the V memory address of the value to be saved in SMW32.
2. Load the size of the data in SM31.0 and SM31.1. (See Figure 5-19.)
3. Set SM31.7 to 1.

At the end of every scan cycle, the CPU checks SM31.7; if SM31.7 equals 1, the specified value is saved to the EEPROM. The operation is complete when the CPU resets SM31.7 to 0. Do not change the value in V memory until the save operation is complete.

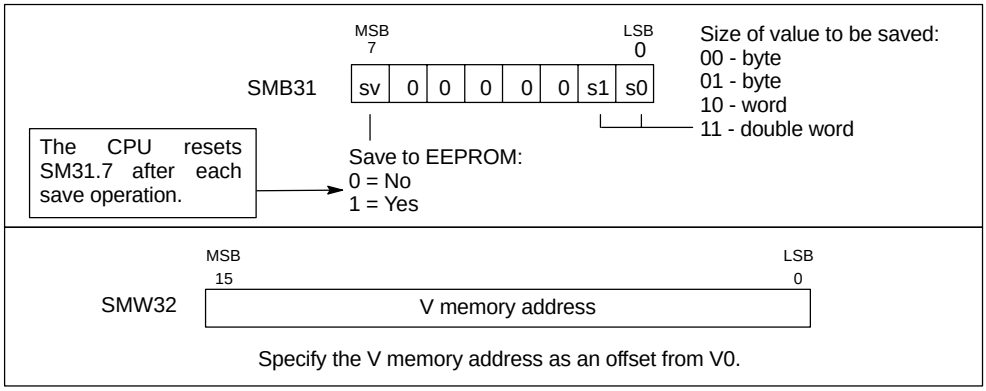


Figure 5-19 Format of SMB31 and SMW32

Limiting the Number of Programmed Saves to EEPROM

Since the number of save operations to the EEPROM is limited (100,000 minimum, and 1,000,000 typical), you should ensure that only necessary values are saved. Otherwise, the EEPROM can be worn out and the CPU can fail. Typically, you perform save operations at the occurrence of specific events that occur rather infrequently.

For example, if the scan time of the S7-200 is 50 ms and a value was saved once per scan, the EEPROM would last a minimum of 5,000 seconds, which is less than an hour and a half. On the other hand, if a value were saved once an hour, the EEPROM would last a minimum of 11 years.

5.5 Using a Memory Cartridge to Store Your Program

The CPUs support an optional memory cartridge that provides a portable EEPROM storage for your program. The CPU stores the following elements on the memory cartridge:

- User program
- Data stored in the permanent V memory area of the EEPROM
- CPU configuration (system block)

For more information about the memory cartridge, see Appendix A.

Copying to the Memory Cartridge

You can copy your program to the memory cartridge from the RAM only when the CPU is powered on, the CPU is in STOP mode, and the memory cartridge is installed.

Caution

Electrostatic discharge can damage the memory cartridge or the receptacle on the CPU.

Make contact with a grounded conductive pad and/or wear a grounded wrist strap when you handle the cartridge. Store the cartridge in a conductive container.

You can install or remove the memory cartridge while the CPU is powered on. To install the memory cartridge, remove the plastic cover from the PLC, and insert the memory cartridge on the PLC. (The memory cartridge is keyed for proper installation.) After the memory cartridge is installed, use the following procedure to copy the program.

1. Put the CPU in STOP mode.
2. If the program has not already been downloaded to the CPU, download the program.
3. Use the menu command **PLC > Program Memory Cartridge** to copy the program to the memory cartridge. Figure 5-20 shows the elements of the CPU memory that are stored on the memory cartridge.
4. Remove the memory cartridge (optional).

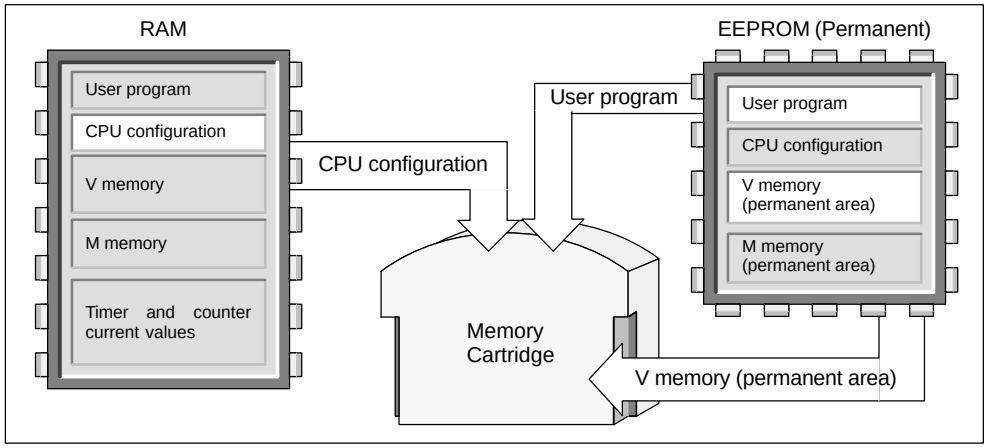


Figure 5-20 Copying the CPU Memory to the Memory Cartridge

Restoring the Program and Memory with a Memory Cartridge

To transfer the program from a memory cartridge to the CPU, you must cycle the power to the CPU with the memory cartridge installed. As shown in Figure 5-21, the CPU performs the following tasks after a power cycle (when a memory cartridge is installed):

- The RAM is cleared.
- The contents of the memory cartridge are copied to the RAM.
- The user program, the CPU configuration, and the V memory area are copied to the permanent EEPROM.

Note

Powering on a CPU with a blank memory cartridge, or a memory cartridge that was programmed in a different model number CPU may cause an error. Memory cartridges that were programmed by a lower model number CPU can be read by a higher model number CPU. However, the opposite is not true. For example, memory cartridges that were programmed by a CPU 221 or CPU 222 can be read by a CPU 224, but memory cartridges that were programmed by a CPU 224 will be rejected by a CPU 221 or CPU 222.

Remove the memory cartridge and power on again. The memory cartridge can then be inserted and reprogrammed, if desired.

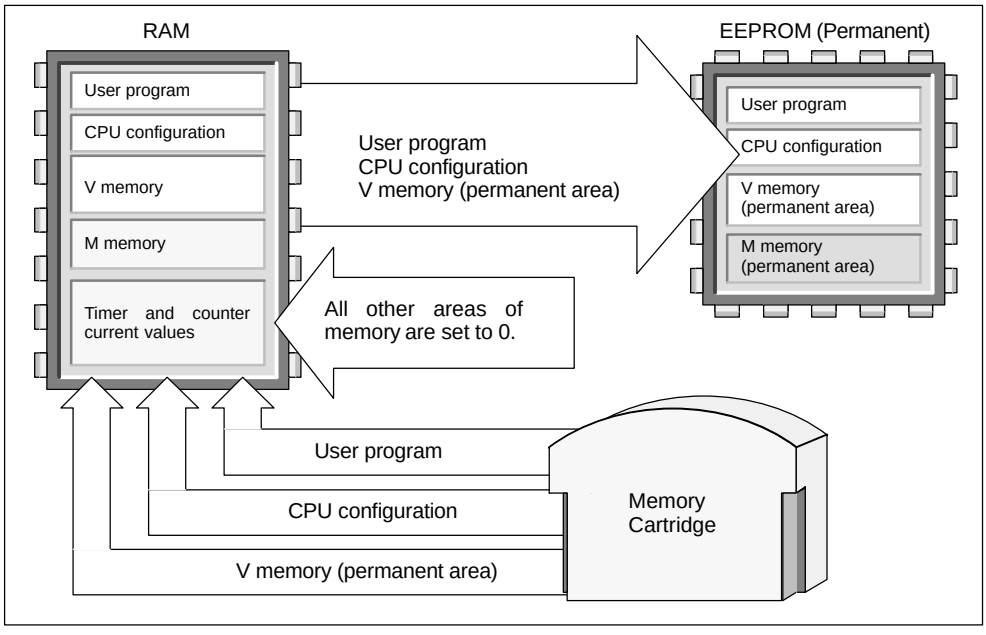


Figure 5-21 Restoring Memory on Power On (with Memory Cartridge Installed)

CPU and Input/Output Configuration 6

The inputs and outputs are the system control points: the inputs monitor the signals from the field devices (such as sensors and switches), and the outputs control pumps, motors, or other devices in your process. You can have local I/O (provided by the CPU) or expansion I/O (provided by an expansion I/O module). The S7-200 CPUs also provide high-speed I/O.

Chapter Overview

Section	Description	Page
6.1	Local I/O and Expansion I/O	6-2
6.2	Using the Selectable Input Filter to Provide Noise Rejection	6-4
6.3	Pulse Catch	6-5
6.4	Using the Output Table to Configure the States of the Outputs	6-8
6.5	Analog Input Filter	6-9
6.6	High-Speed I/O	6-10
6.7	Analog Adjustments	6-13

6.1 Local I/O and Expansion I/O

The inputs and outputs are the system control points: the inputs monitor the signals from the field devices (such as sensors and switches), and the outputs control pumps, motors, or other devices in your process. You can have local I/O (provided by the CPU) or expansion I/O (provided by an expansion I/O module):

- The S7-200 CPU provides a certain number of digital local I/O points. For more information about the amount of local I/O provided by your CPU, refer to the specifications in Appendix A.
- The S7-200 CPU 222, CPU 224, and CPU 226 support the addition of both digital and analog expansion I/O. For more information about the capabilities of the different expansion I/O modules, refer to the specifications in Appendix A.

Addressing the Local and Expansion I/O

The local I/O provided by the CPU provides a fixed set of I/O addresses. You can add I/O points to the CPU by connecting expansion I/O modules to the right side of the CPU, forming an I/O chain. The addresses of the points of the module are determined by the type of I/O and the position of the module in the chain, with respect to the preceding input or output module of the same type. For example, an output module does not affect the addresses of the points on an input module, and vice versa. Likewise, analog modules do not affect the addressing of digital modules, and vice versa.

Discrete or digital expansion modules always reserve process-image register space in increments of eight bits (one byte). If a module does not provide a physical point for each bit of each reserved byte, these unused bits cannot be assigned to subsequent modules in the I/O chain. For input modules, the unused bits in reserved bytes are set to zero with each input update cycle.

Analog expansion modules are always allocated in increments of two points. If a module does not provide physical I/O for each of these points, these I/O points are lost and are not available for assignment to subsequent modules in the I/O chain.

Examples of Local and Expansion I/O

Figure 6-1 and Figure 6-2 provide examples that show how different hardware configurations affect the I/O numbering. Notice that some of the configurations contain gaps in the addressing that cannot be used by your program.

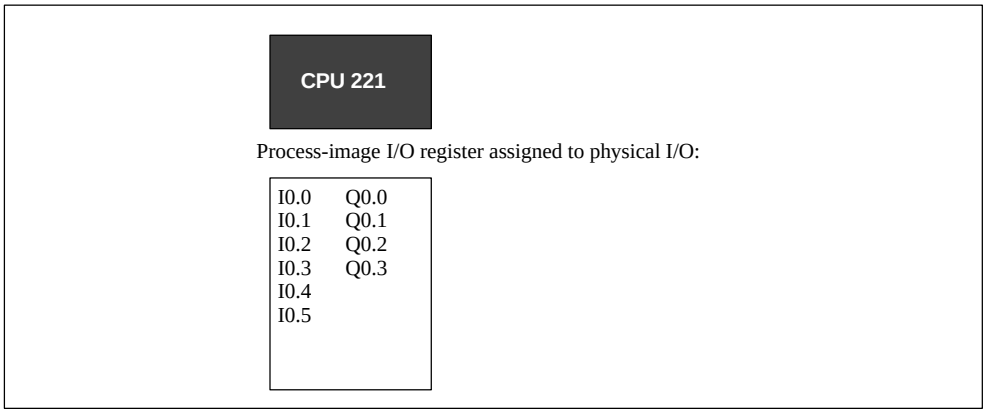


Figure 6-1 I/O Numbering Examples for a CPU 221

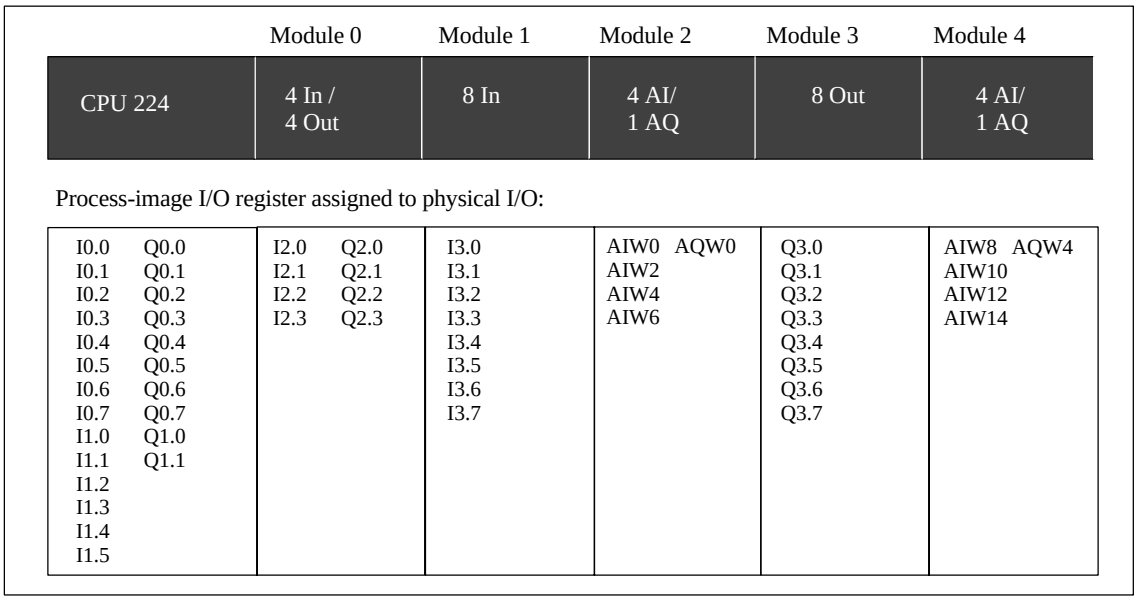


Figure 6-2 I/O Numbering Examples for a CPU 224

6.2 Using the Selectable Input Filter to Provide Noise Rejection

The S7-200 CPUs allow you to select input filter that defines a delay time (selectable from 0.2 ms to 12.8 ms) for some or all of the local digital input points. (See Appendix A for information about your particular CPU.) As shown in Figure 6-3, each delay specification applies to groups of four input points. This delay helps to filter noise on the input wiring that could cause inadvertent changes to the states of the inputs.

The input filter is part of the CPU configuration data that is downloaded and stored in the CPU memory. To configure the delay times for the input filter, use the menu command **View > System Block** and click on the Input Filters tab.

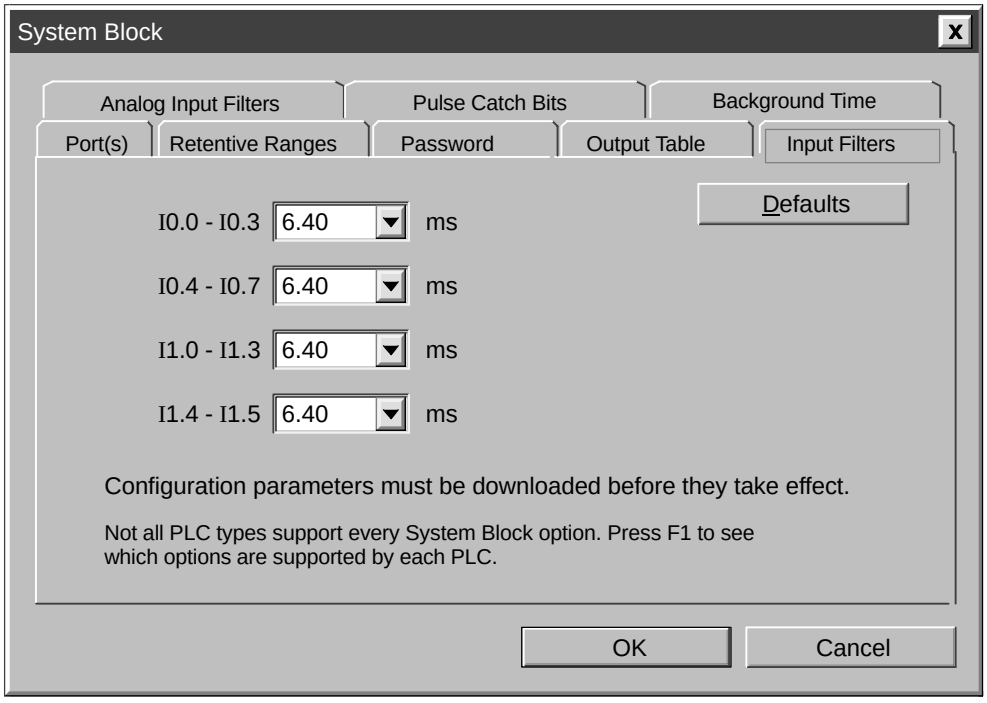


Figure 6-3 Configuring the Input Filters for Rejecting Noise

6.3 Pulse Catch

The S7-200 CPUs provide a pulse catch feature for some or all of the local digital input points. See Appendix A for more information about your particular CPU. The pulse catch feature allows you to capture high-going pulses or low-going pulses that are of such a short duration that they would not always be seen when the CPU reads the digital inputs at the beginning of the scan cycle.

Pulse catch operation can be individually enabled on each of the local digital inputs. When pulse catch is enabled for an input, a change in state of the input is latched and held until the next input cycle update. In this way a pulse that lasts for a short period of time is caught and held until the CPU reads the inputs, assuring you that the pulse will not be missed. The basic operation of the PLC with and without pulse catch enabled is shown in Figure 6-4.

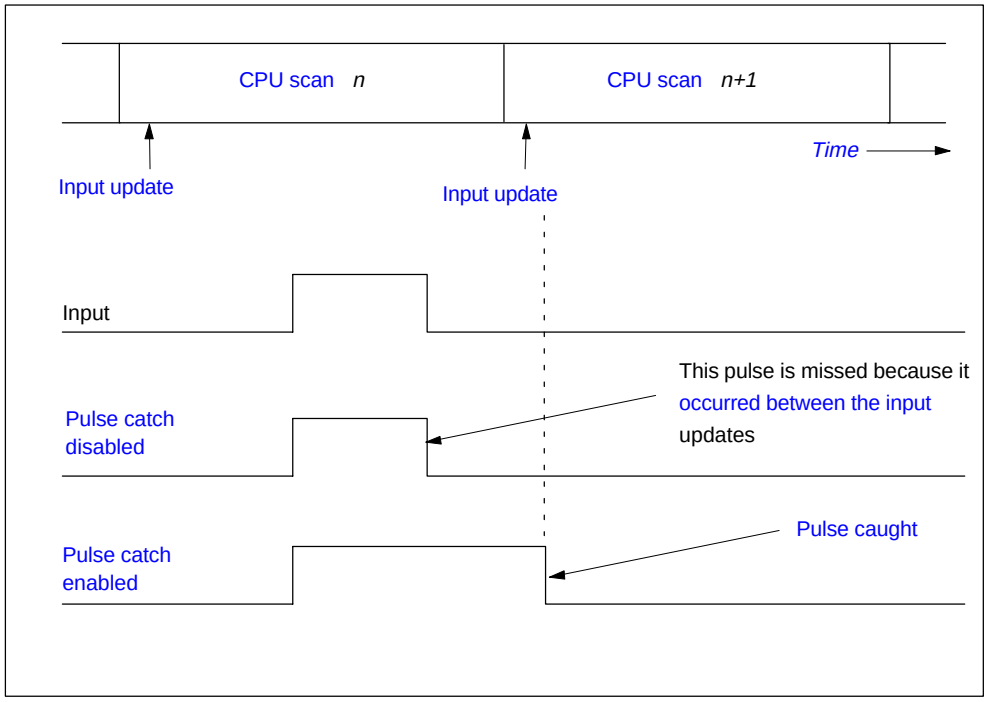


Figure 6-4 PLC Operation With and Without Pulse Catch

When using the pulse catch function, you must be sure to adjust the input filter time so that the pulse is not removed by the filter. (The pulse catch function operates on the input after it passes through the input filter.)

A block diagram of the digital input circuit is shown in Figure 6-5.

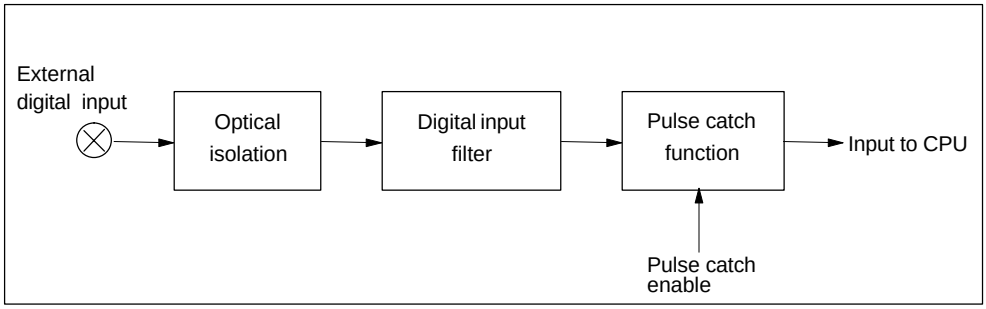


Figure 6-5 Digital Input Circuit

The response of an enabled pulse catch function to various input conditions is shown in Figure 6-6. If you have more than one pulse in a given scan, only the first pulse is read. If you have multiple pulses in a given scan, you should use the I/O interrupt described in Section 9.15.

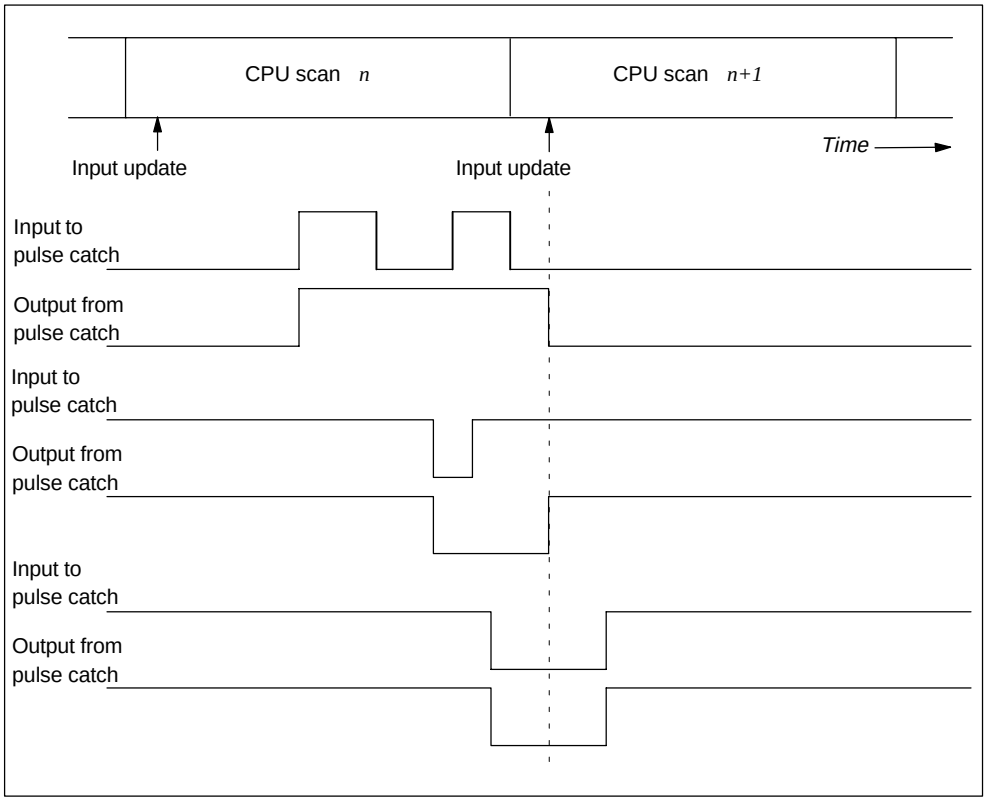


Figure 6-6 Pulse Catch Example

To access the pulse catch configuration screen, select the menu command **View > System Block** from the main menu bar and click on the Pulse Catch Bits tab. Figure 6-7 shows the Pulse Catch configuration screen. To enable the pulse catch function on a particular input, click the corresponding checkbox.

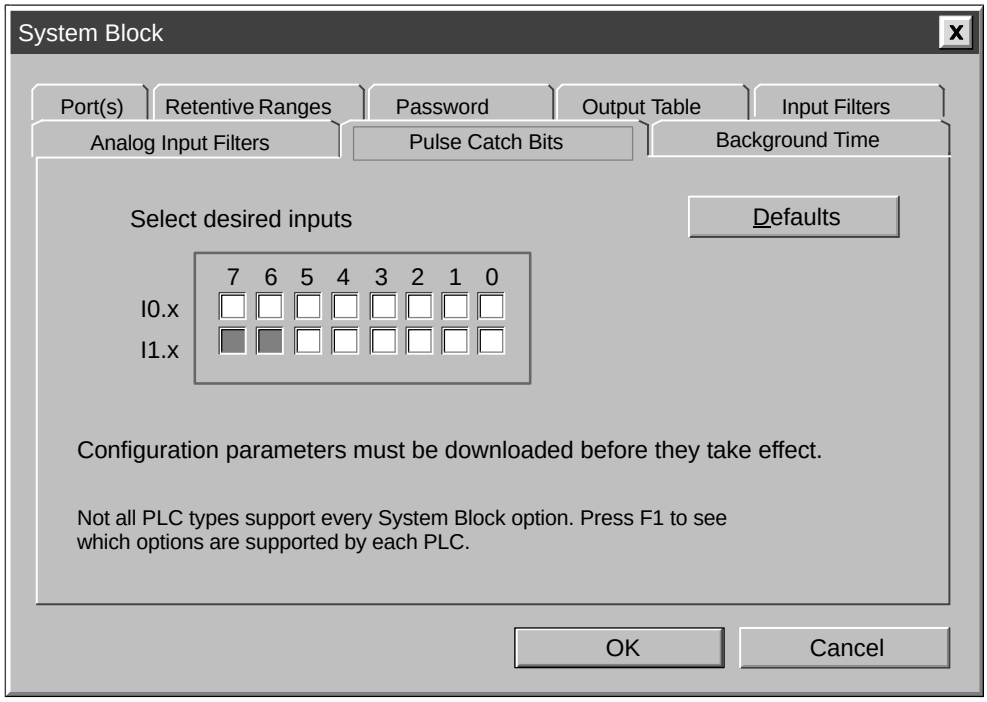


Figure 6-7 Pulse Catch Configuration Screen

6.4 Using the Output Table to Configure the States of the Outputs

The S7-200 CPU provides the capability either to set the state of the digital output points to known values upon a transition to the STOP mode, or to leave the outputs in the state they were in before the transition to the STOP mode.

The output table is part of the CPU configuration data that is downloaded and stored in the CPU memory.

The configuration of output values applies only to the digital outputs. Analog output values are effectively frozen upon a transition to the STOP mode. The CPU does not update the analog inputs or outputs as a system function. No internal memory image is maintained for these points by the CPU.

To access the output table configuration dialog box, select the menu command **View > System Block** and click on the Output Table tab. See Figure 6-8. You have two options for configuring the outputs:

- If you want to freeze the outputs in their last state, choose the Freeze Outputs box and click on “OK.”
- If you want to copy the table values to the outputs, then enter the output table values. Click the checkbox for each output bit you want to set to On (1) after a run-to-stop transition, and click on “OK” to save your selections.

The default values of the table are all zeroes.

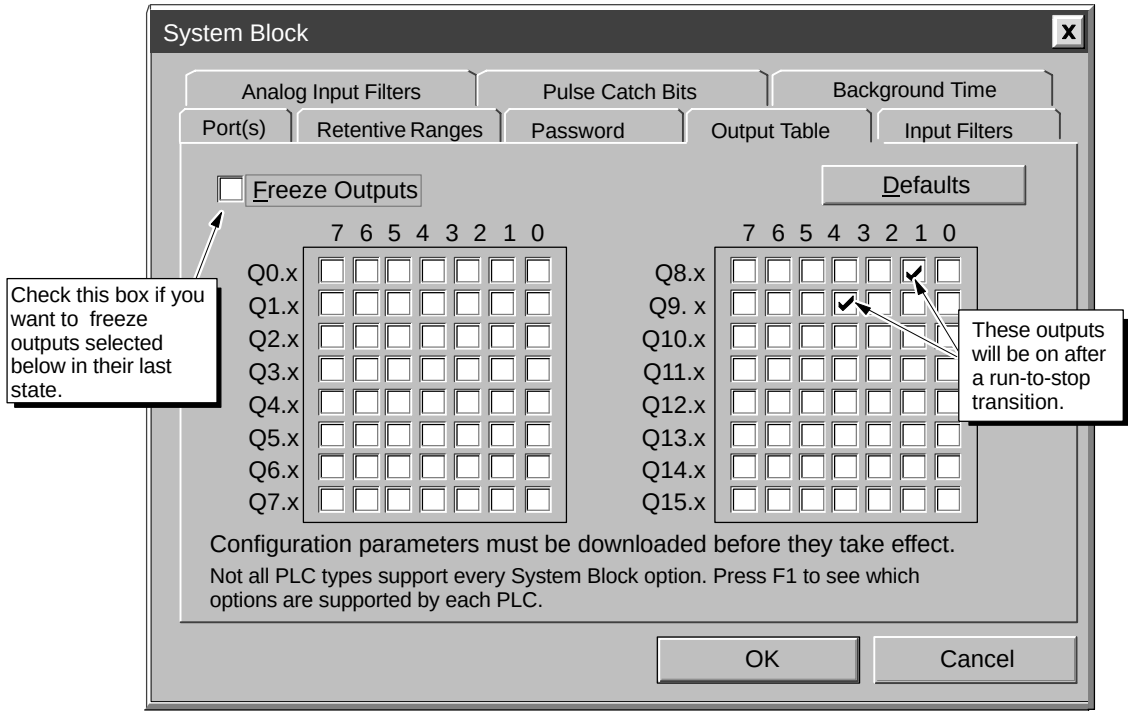


Figure 6-8 Configuring the State of the Outputs

6.5 Analog Input Filter

With the CPU 222, CPU 224, and CPU 226 you can select software filtering on individual analog inputs. The filtered value is the average value of the sum of a preselected number of samples of the analog input. The filter specification (number of samples and deadband) is the same for all analog inputs for which filtering is enabled.

The filter has a fast response feature to allow large changes to be quickly reflected in the filter value. The filter makes a step function change to the latest analog input value when the input exceeds a specified change from the average value. This change is called the dead band, and is specified in counts of the digital value of the analog input.

Note

Analog filtering should not be used with modules that pass digital information or alarm indications in the analog words. Use the screen shown in Figure 6-9 to disable analog filtering for RTD, Thermocouple, and AS-Interface Master modules.

To access the analog input filter, select the menu command **View > System Block** and click on the Analog Input Filters tab. Select the analog inputs that you want to filter and click OK. See Figure 6-9. Default STEP 7-Micro/WIN 32 analog input filter configuration is enabled for all inputs.

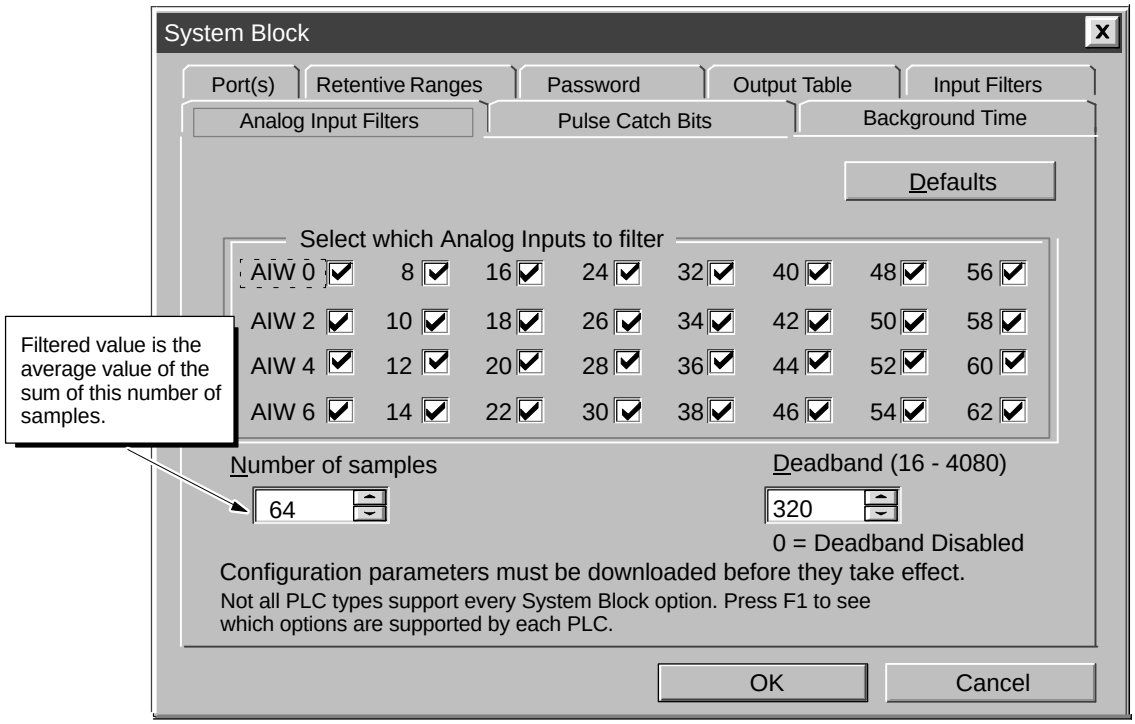


Figure 6-9 Analog Input Filter

6.6 High-Speed I/O

Your S7-200 CPU provides high-speed I/O for controlling high-speed events. For more information about the high-speed I/O provided by each CPU, refer to the specifications in Appendix A.

High-Speed Counters

The S7-200 CPUs provide integrated high-speed counter functions that count external events at rates up to 20 kHz without degrading the performance of the CPU. Each of the high-speed counters is described below:

- HSC0 and HSC4 are versatile counters that can be configured for one of eight different counting modes of operation, including single-phase and two-phase clock inputs.
- HSC1 and HSC2 are versatile counters that can be configured for one of twelve different counting modes of operation, including single-phase and two-phase clock inputs.
- HSC3 and HSC5 are simple counters that have one mode of operation (single-phase clock inputs only).

Table 6-1 defines the modes of operations supported by high-speed counters HSC0, HSC3, HSC4, and HSC5. All S7-200 CPUs support these high-speed counters.

Table 6-1 High-Speed Counters HSC0, HSC3, HSC4, HSC5

Mode	HSC0			HSC3	HSC4			HSC5
	I0.0	I0.1	I0.2	I0.1	I0.3	I0.4	I0.5	I0.4
0	Clk			Clk	Clk			Clk
1	Clk		Reset		Clk		Reset	
2								
3	Clk	Direction			Clk	Direction		
4	Clk	Direction	Reset		Clk	Direction	Reset	
5								
6	Clk Up	Clk Down			Clk Up	Clk Down		
7	Clk Up	Clk Down	Reset		Clk Up	Clk Down	Reset	
8								
9	Phase A	Phase B			Phase A	Phase B		
10	Phase A	Phase B	Reset		Phase A	Phase B	Reset	
11								

From this table you can see that if you are using HSC0 in modes 3 through 10 (Clock and Direction or any of the two-phase clocking modes), you cannot use HSC3 because HSC0 and HSC3 both use I0.1. The same is true for HSC4 and HSC5, which both use I0.4.

You can use I0.0 through I0.3 for high-speed counter inputs, or you can configure these inputs to provide edge interrupt events. You cannot use these inputs as edge interrupts and as high-speed counter inputs at the same time.

The same input cannot be used for two different functions; however, any input not being used by the present mode of its high-speed counter can be used for another purpose. For example, if HSC0 is being used in mode 2 which uses I0.0 and I0.2, I0.1 can be used for edge interrupts or for HSC3.

Table 6-2 defines the modes of operations supported by high-speed counters HSC1 and HSC2. Only the CPU 224 and CPU 226 support these high-speed counters.

Table 6-2 High-Speed Counters HSC1 and HSC2

Mode	HSC1				HSC2			
	I0.6	**I0.7**	**I1.0**	**I1.1**	**I1.2**	**I1.3**	**I1.4**	**I1.5**
0	Clk				Clk			
1	Clk		Reset		Clk		Reset	
2	Clk		Reset	Start	Clk		Reset	Start
3	Clk	Direction			Clk	Direction		
4	Clk	Direction	Reset		Clk	Direction	Reset	
5	Clk	Direction	Reset	Start	Clk	Direction	Reset	Start
6	Clk Up	Clk Down			Clk Up	Clk Down		
7	Clk Up	Clk Down	Reset		Clk Up	Clk Down	Reset	
8	Clk Up	Clk Down	Reset	Start	Clk Up	Clk Down	Reset	Start
9	Phase A	Phase B			Phase A	Phase B		
10	Phase A	Phase B	Reset		Phase A	Phase B	Reset	
11	Phase A	Phase B	Reset	Start	Phase A	Phase B	Reset	Start

Each counter has dedicated inputs for clocks, direction control, reset, and start, where these functions are supported. In quadrature modes, an option is provided to select one or four times the maximum counting rates. HSC1 and HSC2 are completely independent of each other and do not affect other high-speed functions. Both counters run at maximum rates without interfering with one another.

For more information about using the high-speed counters, see Section 9.4, SIMATIC High-Speed Counter Instructions in Chapter 9.

High-Speed Pulse Output

The S7-200 CPUs support high-speed pulse outputs. Q0.0 and Q0.1 can either generate high-speed pulse train outputs (PTO) or perform pulse width modulation (PWM) control.

- The pulse train function provides a square wave (50% duty cycle) output for a specified number of pulses and a specified cycle time. The number of pulses can be specified from 1 to 4,294,967,295 pulses. The cycle time can be specified in either microsecond or millisecond increments either from 50 μs to 65,535 μs or from 2 ms to 65,535 ms. Specifying any odd number of microseconds or milliseconds (such as 75 ms) causes some duty cycle distortion. The Pulse Train Output (PTO) function can be programmed to produce one train of pulses or it can be programmed to produce a pulse profile consisting of multiple trains of pulses. In the pulse profile mode of operation, the PTO function can be programmed to control a stepper motor through a simple ramp up, run, and ramp down sequence or more complicated sequences. The pulse profile can consist of up to 255 segments with a segment corresponding to the ramp up or run or ramp down operation.
- The pulse width modulation function provides a fixed cycle time with a variable duty cycle output. The cycle time and the pulse width can be specified in either microsecond or millisecond increments. The cycle time has a range either from 50 μs to 65,535 μs or from 2 ms to 65,535 ms. The pulse width time has a range either from 0 μs to 65,535 μs or from 0 ms to 65,535 ms. When the pulse width is equal to the cycle time, the duty cycle is 100 percent and the output is turned on continuously. When the pulse width is zero, the duty cycle is 0 percent and the output is turned off.

For more information about the high-speed outputs, see see Section 9.4, SIMATIC High-Speed Counter Instructions in Chapter 9.

6.7 Analog Adjustments

The analog adjustment potentiometers are located under the front access cover of the module. You can adjust these potentiometers to increase or decrease values that are stored in bytes of Special Memory (SMB28 and SMB29). These read-only values can be used by the program for a variety of functions, such as updating the current value for a timer or a counter, entering or changing the preset values, or setting limits.

SMB28 holds the digital value that represents the position of analog adjustment 0. SMB29 holds the digital value that represents the position of analog adjustment 1. The analog adjustment has a nominal range of 0 to 255 and a repeatability of ± 2 counts.

You use a small screwdriver to make the adjustments: turn the potentiometer clockwise (to the right) to increase the value, and counterclockwise (to the left) to decrease the value. Figure 6-10 shows an example program using the analog adjustment.

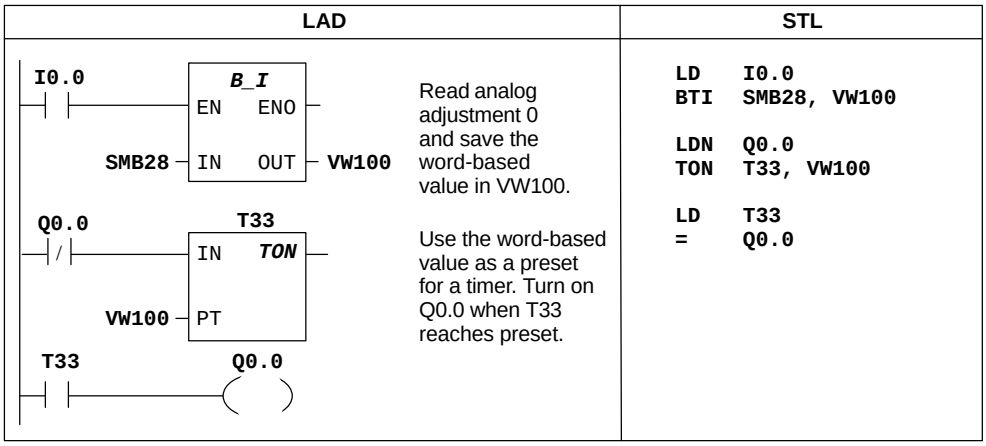


Figure 6-10 Example of Analog Adjustment

Setting Up Communications Hardware and Network Communications

7

This chapter describes communications using STEP 7-Micro/WIN 32, version 3.0. Previous versions of the software may operate differently. It also tells you how to set up your communications hardware and how to set up an S7-200 communications network.

Chapter Overview

Section	Description	Page
7.1	What Are My Communication Choices?	7-2
7.2	Installing and Removing Communication Interfaces	7-7
7.3	Selecting and Changing Parameters	7-9
7.4	Communicating With Modems	7-16
7.5	Network Overview	7-27
7.6	Network Components	7-32
7.7	Using the PC/PPI Cable with Other Devices and Freeport	7-36
7.8	Network Performance	7-42

7.1 What Are My Communication Choices?

You can arrange the S7-200 CPUs in a variety of configurations to support network communications. You can install the STEP 7-Micro/WIN 32 software on a personal computer (PC) that has a Windows 95, Windows 98, or Windows NT operating system, or you can install it on a SIMATIC programming device (such as a PG 740). You can use the PC or the programming device as a master device in any of the following communications configurations:

- Single Master: A single master device is connected to one or more slave devices. See Figure 7-1.
- Multiple Master: A single master device is connected to one or more slave devices and one or more master devices. See Figure 7-2.
- For 11-bit modem users: A single master device is connected to one or more slave devices. This master device is connected by means of 11-bit modems either to one S7-200 CPU functioning as a slave device or to a network of S7-200 CPUs functioning as slave devices.
- For 10-bit modem users: A single master device is connected to only one S7-200 CPU functioning as a slave device by means of a10-bit modem.

Figure 7-1 and Figure 7-2 show a configuration with a personal computer connected to several S7-200 CPUs. STEP 7-Micro/WIN 32 is designed to communicate with one S7-200 CPU at a time; however, you can access any CPU on the network. The CPUs could be either slave or master devices. The TD 200 is a master device. For detailed information on network communications, see Section 7.5.

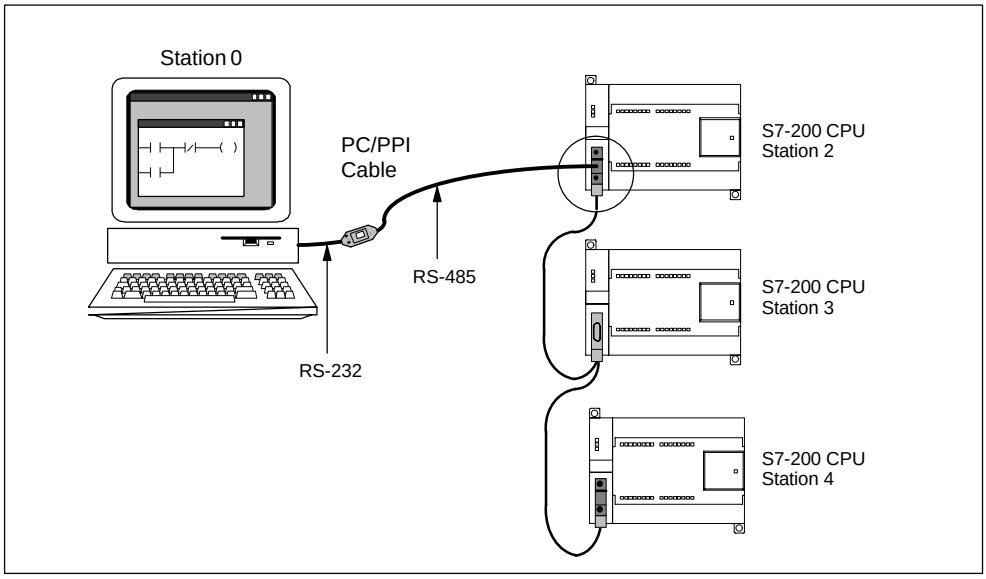


Figure 7-1 Using a PC/PPI Cable for Communicating with Several S7-200 CPUs

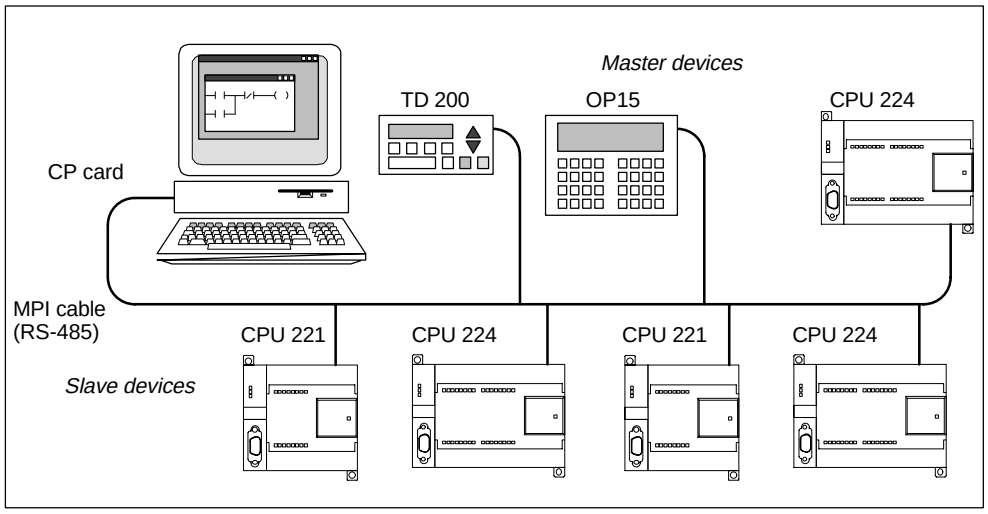


Figure 7-2 Example of a CP Card with Master and Slave Devices

How Do I Choose My Communication Configuration?

Table 7-1 shows the possible hardware configurations and baud rates that STEP 7-Micro/WIN 32 supports. Table 7-2 shows the capabilities of the S7-200 CPU and the EM 277 PROFIBUS-DP module.

Table 7-1 Hardware Configurations Supported by STEP 7-Micro/WIN 32

Hardware Supported	Type	Baud Rate Supported	Protocols Supported
PC/PPI cable	Cable connector to PC comm port	9.6 kbaud 19.2 kbaud	PPI protocol
CP 5511	Type II, PCMCIA-card	9.6 kbaud 19.2 kbaud 187.5 kbaud	PPI, MPI, and PROFIBUS protocols for notebook PCs
CP 5611	PCI-card (version 3 or greater)		PPI, MPI, and PROFIBUS protocols for PCs
MPI	Integrated in PG PC ISA-card		

Table 7-2 Capabilities of S7-200 and EM 277 Module

Connection Port	Baud Rate Supported	Number of Logical Connections	Protocols Supported
S7-200 CPU			
Port 0	9.6 kbaud	4 on each port	PPI, MPI, and PROFIBUS
Port 1	19.2 kbaud 187.5 kbaud 187.5 kbaud		
EM 277 PROFIBUS-DP Module			
Up to 2 per CPU	9.6 kbaud to 12 Mbaud	6 on each module	MPI and PROFIBUS

Data Communications Using the CP or MPI Card

Siemens offers several network interface cards that you can put into a personal computer or SIMATIC programming device. These cards allow the PC or SIMATIC programming device to act as a network master. These cards contain dedicated hardware to assist the PC or programming device in managing a multiple-master network, and can support different protocols at several baud rates. See Table 7-1.

The specific card and protocol are set up using the PG/PC Interface from within STEP 7-Micro/WIN 32. See Section 7.3. When using Windows 95, Windows 98, or Windows NT, you can select any protocol (PPI, MPI, or PROFIBUS) to be used with any of the network cards.

Each card provides a single RS-485 port for connection to the PROFIBUS network. The CP 5511 PCMCIA card has an adapter that provides the 9-pin D port. You connect one end of an MPI cable to the RS-485 port of the card and connect the other end to a programming port connector on your network. See Figure 7-2. For more information on the communications processor cards, see the *SIMATIC Components for Totally Integrated Automation Catalog ST 70*.

From What Point Do I Set Up Communications?

You can set up communications from the following points in Windows 95, Windows 98, or Windows NT 4.0:

- During the final step of the installation of your STEP 7-Micro/WIN 32 software
- Within STEP 7-Micro/WIN 32

How Do I Set Up Communications within STEP 7-Micro/WIN 32?

Within STEP 7-Micro/WIN 32, there is a Setup Communications dialog box that you can use to configure your communications setup. You can use one of the following ways to find this dialog box:

- Select the menu command **View > Communications**.
- Click the Communications icon on the STEP 7-Micro/WIN 32 screen (see Figure 7-3).

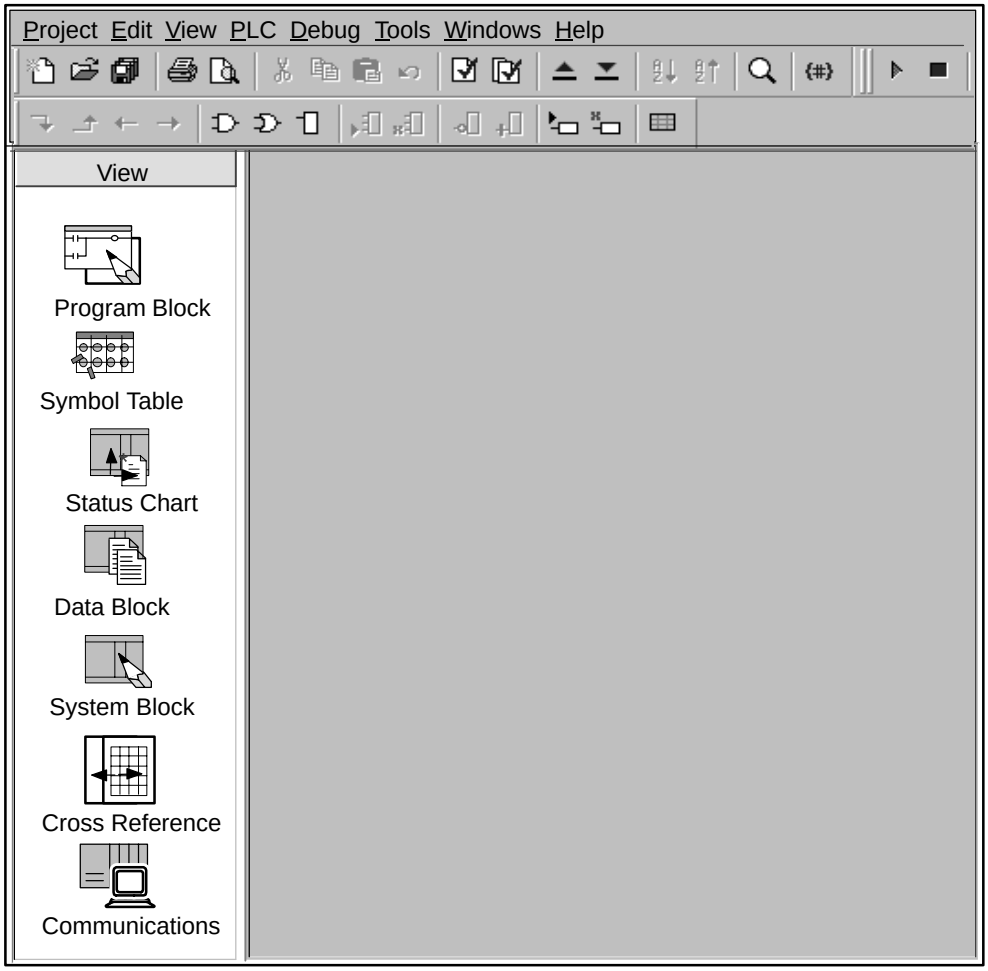


Figure 7-3 View Menu of STEP 7-Micro/WIN 32

In the Communications Setup dialog box, double-click the top icon on the right-hand side. The Set the PG/PC Interface dialog box appears. See Figure 7-4.

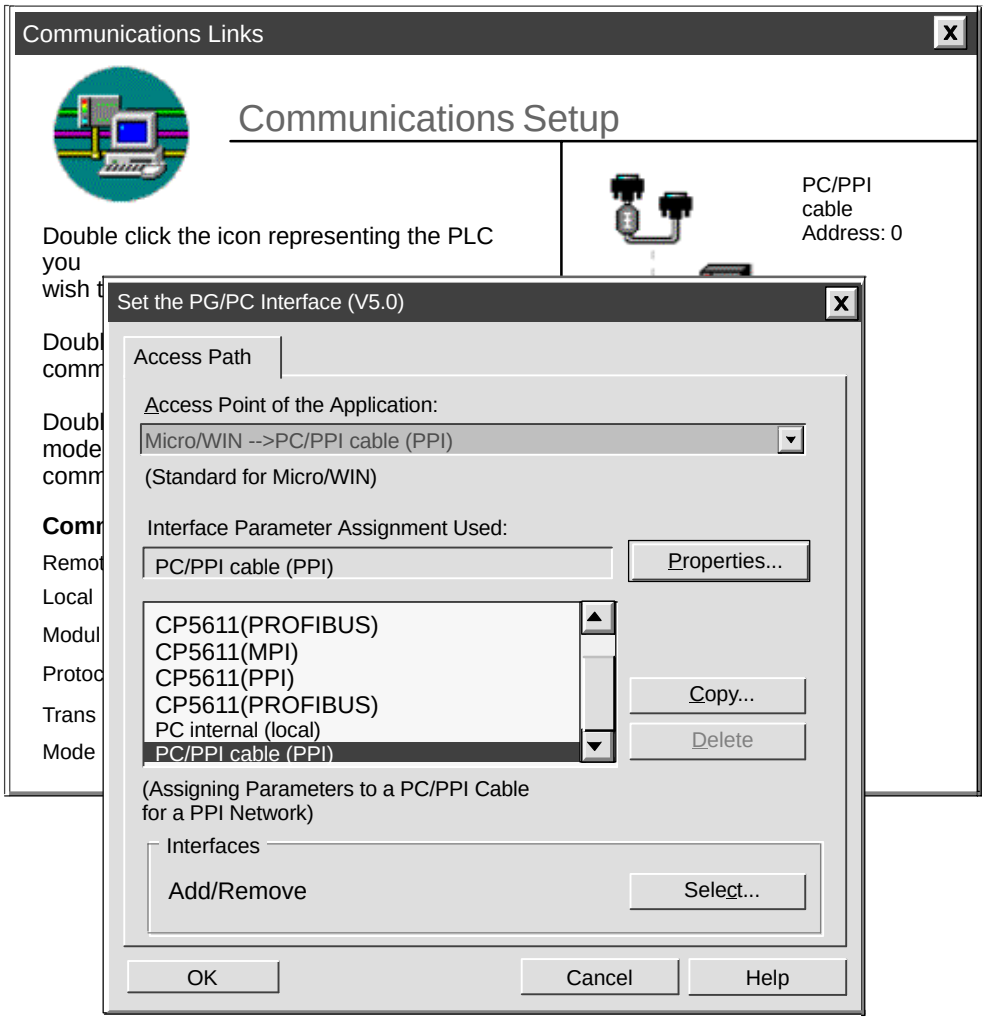


Figure 7-4 Set the PG/PC Interface Dialog Box

7.2 Installing and Removing Communication Interfaces

You can install or remove communications hardware by using the Install/Remove Interfaces dialog box shown in Figure 7-5. On the left side of this dialog box is a list of hardware types that you have not installed yet. On the right side is a list of currently installed hardware types. If you are using the Windows NT 4.0 operating system, there is a “Resources” button under the Installed list box.

Installing the Hardware:

To install the hardware, follow these steps:

1. In the Set the PG/PC Interface dialog box (shown in Figure 7-4), press the “Select...” button to access the Installing/Uninstalling Interfaces dialog box, shown in Figure 7-5.
2. From the Selection list box, select the hardware type that you have. A description of your selection is shown in the lower window.
3. Click the “Install -->” button.
4. When you are finished installing hardware, click the “Close” button. The Set the PG/PC Interface dialog box appears, and your selections are shown in the Interface Parameter Assignment Used list box (see Figure 7-4).

Removing the Hardware:

To remove hardware, follow these steps:

1. Select the hardware from the Installed list box on the right.
2. Click the “<-- Uninstall” button.
3. When you are finished removing hardware, click the “Close” button. The Set the PG/PC Interface dialog box appears, and your selections are shown in the Interface Parameter Assignment Used list box (see Figure 7-4).

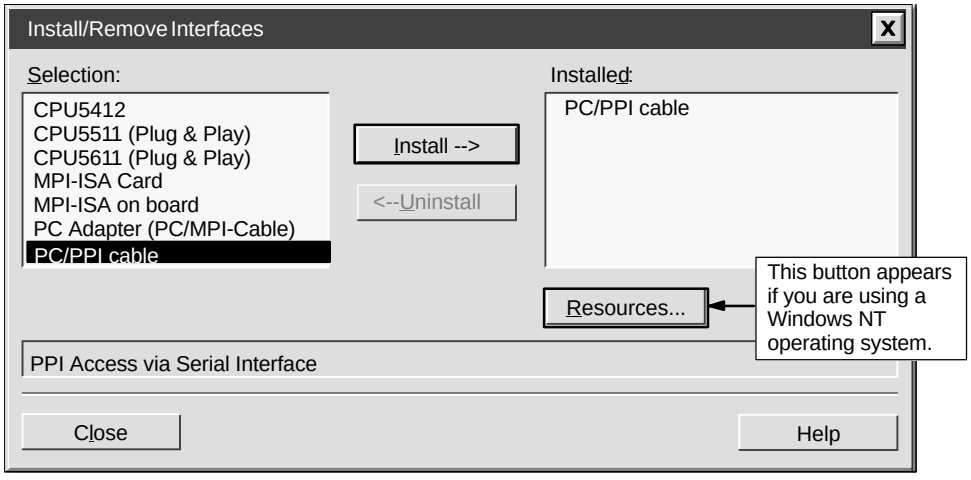


Figure 7-5 Install/Remove Interfaces Dialog Box

Special Hardware Installation Information for Windows NT Users

Installing hardware modules under the Windows NT operating system is slightly different from installing hardware modules under Windows 95. Although the hardware modules are the same for either operating system, installation under Windows NT requires more knowledge of the hardware that you want to install. Windows 95 tries automatically to set up system resources for you; however, Windows NT does not. Windows NT provides you with default values only. These values may or may not match the hardware configuration. However, these parameters can be modified easily to match the required system settings.

When you have installed a piece of hardware, select it from the Installed list box and click the “Resources” button (Figure 7-5). The Resources dialog box appears (Figure 7-6). The Resources dialog box allows you to modify the system settings for the actual piece of hardware that you installed. If this button is unavailable (gray), you do not need to do anything more.

At this point you may need to refer to your hardware manual to determine the setting for each of the parameters listed in the dialog box, depending on your hardware settings. You may need to try several different interrupts in order to establish communication correctly.

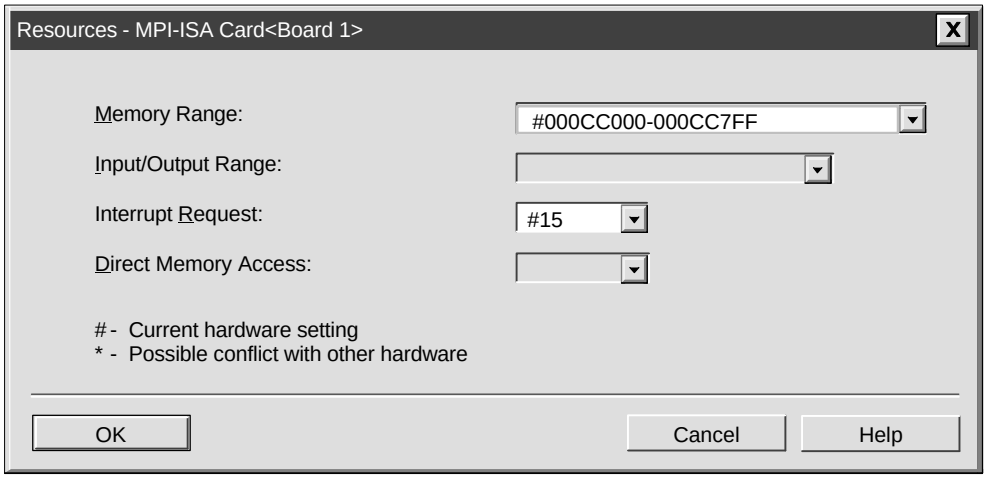


Figure 7-6 Resources Dialog Box for Windows NT

Note
If you are using Windows NT and a PC/PPI cable, no other master can be present on the network.

7.3 Selecting and Changing Parameters

Selecting the Correct Interface Parameter Set and Setting It Up

When you have reached the Set the PG/PC Interface dialog box, be sure that “Micro/WIN” appears in the Access Point of Application list box (see Figure 7-4). The Set the PG/PC Interface box is common to several different applications, such as STEP 7 and WinCC, so you may need to tell the program the application for which you are setting parameters.

When you have selected “Micro/WIN” and have installed your hardware, you need to set the actual properties for communicating with your hardware. The first step is to determine the protocol that you want to use on your network. You should use PPI protocol for all of your CPUs.

When you have decided what protocol you want to use, you can choose the correct setup from the Interface Parameter Assignment Used list box in the Set the PG/PC Interface dialog box. This box lists each hardware type that you have installed, along with the protocol type in parentheses. For example, a simple setup might require you to use the PC/PPI cable to communicate with a CPU 222. In this case, you select “PC/PPI cable(PPI).”

After you have selected the correct interface parameter set, you must set up the individual parameters for the current configuration. Click the “Properties...” button in the Set the PG/PC Interface dialog box. This action takes you to one of several possible dialog boxes, depending on the parameter set that you selected (see Figure 7-7). The sections that follow describe each of these dialog boxes in detail.

In summary, to select an interface parameter set, follow these steps:

1. In the Set the PG/PC Interface dialog box (see Figure 7-4), select “Micro/WIN” in the Access Point of Application list box in the Access Path tab.
2. Ensure that your hardware is installed. See Section 7.2.
3. Determine the protocol that you want to use. You should use PPI protocol for all of your CPUs.
4. Select the correct setup from the Interface Parameter Assignment Used list box in the Set the PG/PC Interface dialog box.
5. Click the “Properties...” button in the Set the PG/PC Interface dialog box.

From this point, you make selections according to the parameter set that you chose.

Setting Up the PC/PPI Cable (PPI) Parameters

This section explains how to set up the PPI parameters for the Windows 95, Windows 98, or Windows NT 4.0 operating systems, and for the PC/PPI cable.

From the Set the PG/PC Interface dialog box, if you are using the PC/PPI cable and you click the “Properties...” button, the properties sheet appears for PC/PPI cable (PPI). See Figure 7-7.

STEP 7-Micro/WIN 32 defaults to multiple-master PPI protocol when communicating to S7-200 CPUs. This protocol allows STEP 7-Micro/WIN 32 to co-exist with other master devices (TD 200s and operator panels) on a network. This mode is enabled by checking the “Multiple Master Network” check box on the PC/PPI Cable Properties dialog in the PG/PC Interface. Windows NT 4.0 does not support the multiple-master option.

STEP 7-Micro/WIN 32 also supports a single-master PPI protocol. When using the single-master protocol, STEP 7-Micro/WIN 32 assumes that it is the only master on the network and does not cooperate to share the network with other masters. Single-master protocol should be used when transmitting over modems or over very noisy networks. The single-master mode is selected by clearing the “Multiple Master Network” check box on the PC/PPI Cable Properties dialog box in the PG/PC Interface.

Follow these steps to set up the PPI parameters:

1. In the PPI tab, in the Station Parameters area, select a number in the Address box. This number indicates where you want STEP 7-Micro/WIN 32 to reside on the programmable controller network. The default station address for the personal computer on which you are running STEP 7-Micro/WIN 32 is station address 0. The default station address for the first PLC on your network is station address 2. Each device (PC, PLC, etc.) on your network must have a unique station address; do not assign the same address to multiple devices.
2. Select a value in the Timeout box. This value represents the length of time that you want the communications drivers to spend to attempt to establish connections. The default value should be sufficient.
3. Determine whether you want STEP 7-Micro/WIN 32 to participate on a network that has multiple masters. You can leave the check mark in the Multiple Master Network box, unless you are using a modem or Windows NT 4.0. In that case, the box cannot be checked because STEP 7-Micro/WIN 32 does not support that functionality.
4. Set the transmission rate at which you want STEP 7-Micro/WIN 32 to communicate over the network. The PPI cable supports 9.6 kbaud and 19.2 kbaud.
5. Select the highest station address. This is the address where STEP 7-Micro/WIN 32 stops looking for other stations on a PPI network.

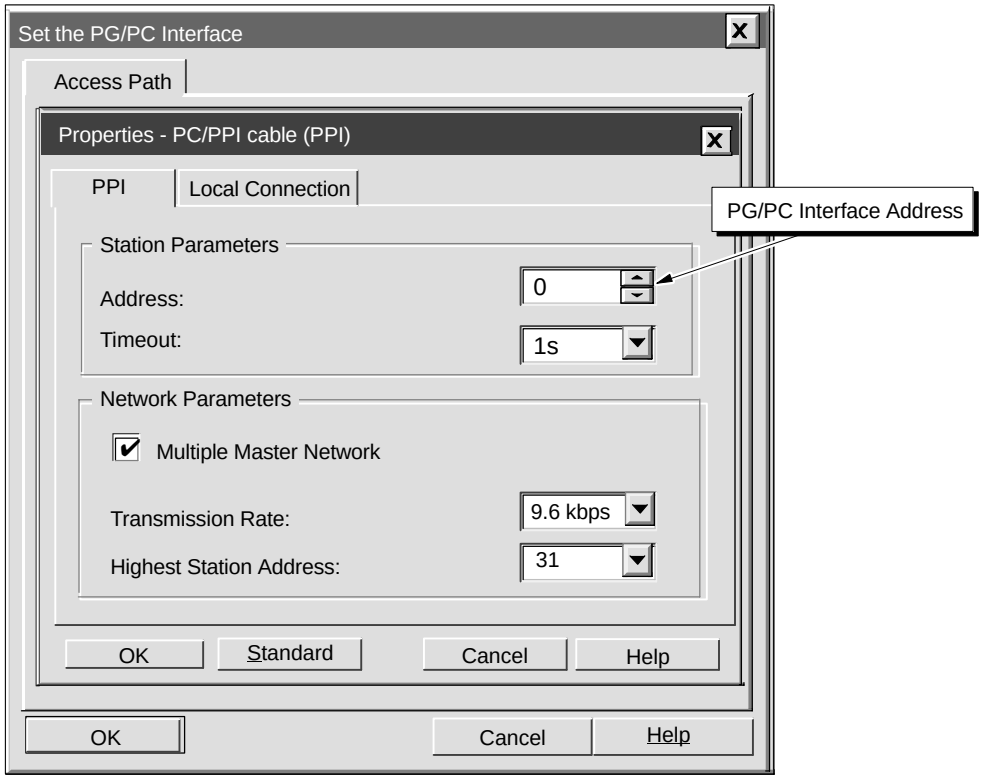


Figure 7-7 Properties - PC/PPI Cable (PPI) Dialog, PPI Tab

6. Click the Local Connection tab. See Figure 7-8.
7. In the Local Connection tab, select the COM port to which your PC/PPI cable is connected. If you are using a modem, select the COM port to which the modem is connected and select the Use Modem check box.
8. Click the “OK” button to exit the Set the PG/PC Interface dialog.

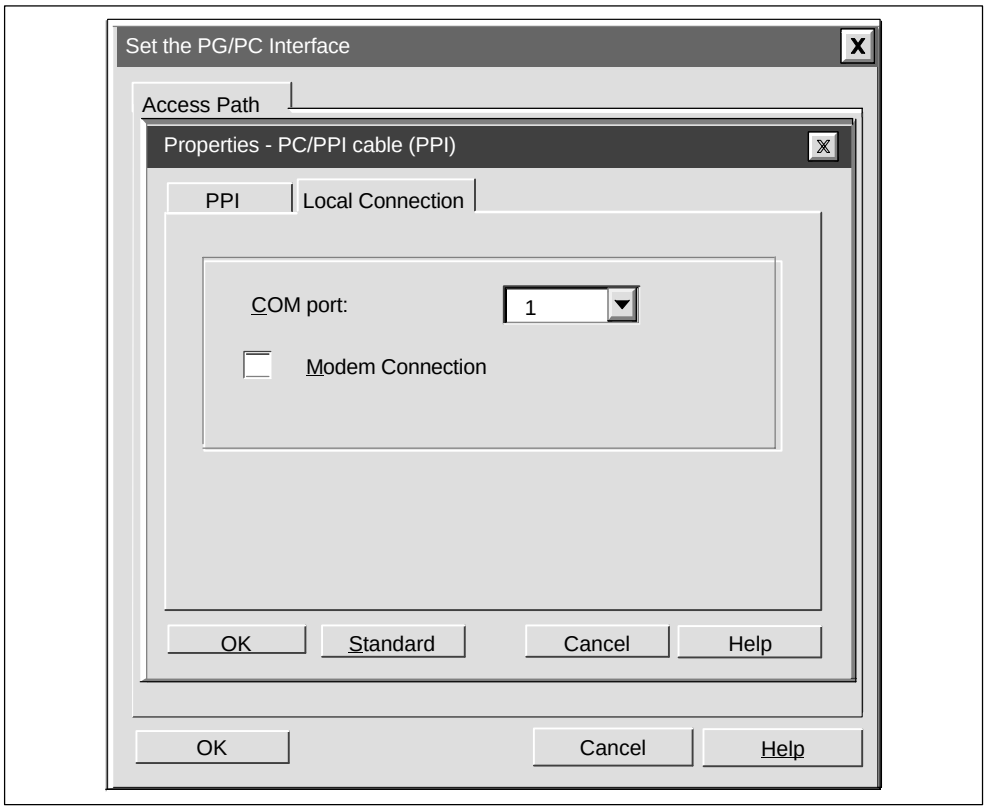


Figure 7-8 Properties - PC/PPI Cable (PPI) Dialog, Local Connection Tab

Configurations Using a PC with an MPI or CP Card: Multiple-Master Network

Many configurations are possible when you use a multipoint interface card or communications processor card. Either card provides a single RS-485 port for connection to the network using an MPI cable. You can have a station running the STEP 7-Micro/WIN 32 programming software (PC with MPI or CP card, or a SIMATIC programming device) connected to a network that includes several master devices. (This is also true of the PC/PPI cable if you have enabled multiple masters.) These master devices include operator panels and text displays (TD 200 units). Figure 7-9 shows a configuration with two TD 200 units added to the network.

Note
If you are using the PPI parameter set, STEP 7-Micro/WIN 32 does not support two different applications running on the same MPI or CP card at the same time. Close the other application before connecting STEP 7-Micro/WIN 32 to the network through the MPI or CP card.

In this configuration, the communication possibilities are listed below:

- STEP 7-Micro/WIN 32 (on station 0) can be monitoring the status on programming station 2, while the TD 200 units (stations 5 and 1) communicate with the CPU 224 modules (stations 3 and 4, respectively).
- Both CPU 224 modules can be enabled to send messages by using network instructions (NETR and NETW).
- Station 3 can read data from and write data to station 2 (CPU 222) and station 4 (CPU 224).
- Station 4 can read data from and write data to station 2 (CPU 222) and station 3 (CPU 224).

It is possible to connect many master and slave stations to the same network. However, the performance of the network can be adversely affected as more stations are added.

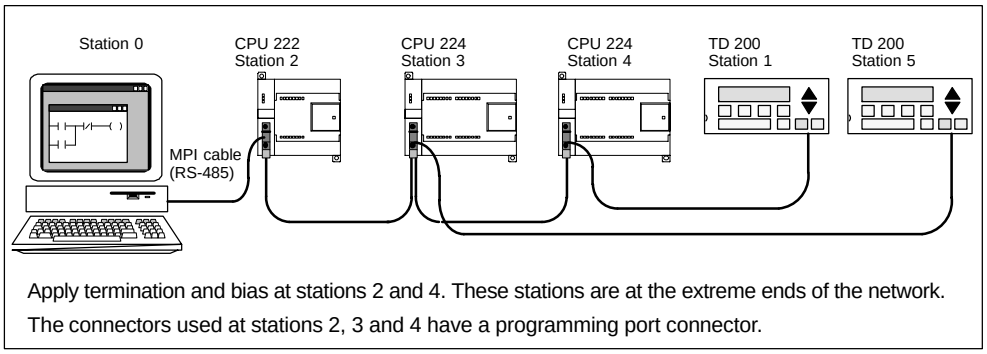


Figure 7-9 Using an MPI or CP Card to Communicate with S7-200 CPUs

Setting Up the CP or MPI Card (PPI) Parameters

This section explains how to set up the PPI parameters for the Windows 95, Windows 98 or Windows NT 4.0 operating systems and the following hardware:

- CP 5511
- CP 5611
- MPI

From the Set the PG/PC Interface dialog box, if you are using any of the MPI or CP cards listed above along with the PPI protocol, and you click the “Properties...” button, the properties sheet appears for XXX Card (PPI), where “XXX” stands for the type of card you installed, for example, MPI-ISA. See Figure 7-10.

Note

Use the MPI protocol when you are communicating to an S7-200 CPU 215, port 1. For more information about the CPU 215 and the MPI protocol, see the previous *S7-200 Programmable Controller System Manual* (order number 6ES7-298-8FA01-8BH0).

Follow these steps to set up PPI parameters:

1. In the PPI tab, select a number in the Address box. This number indicates where you want STEP 7-Micro/WIN 32 to reside on the programmable controller network.
2. Select a value in the Timeout box. This value represents the length of time that you want the communications drivers to spend to attempt to establish connections. The default value should be sufficient.
3. Set the transmission rate at which you want STEP 7-Micro/WIN 32 to communicate over the network.
4. Select the highest station address. This is the address where STEP 7-Micro/WIN 32 stops looking for other masters on the network.
5. Click the “OK” button to exit the Set the PG/PC Interface dialog box.

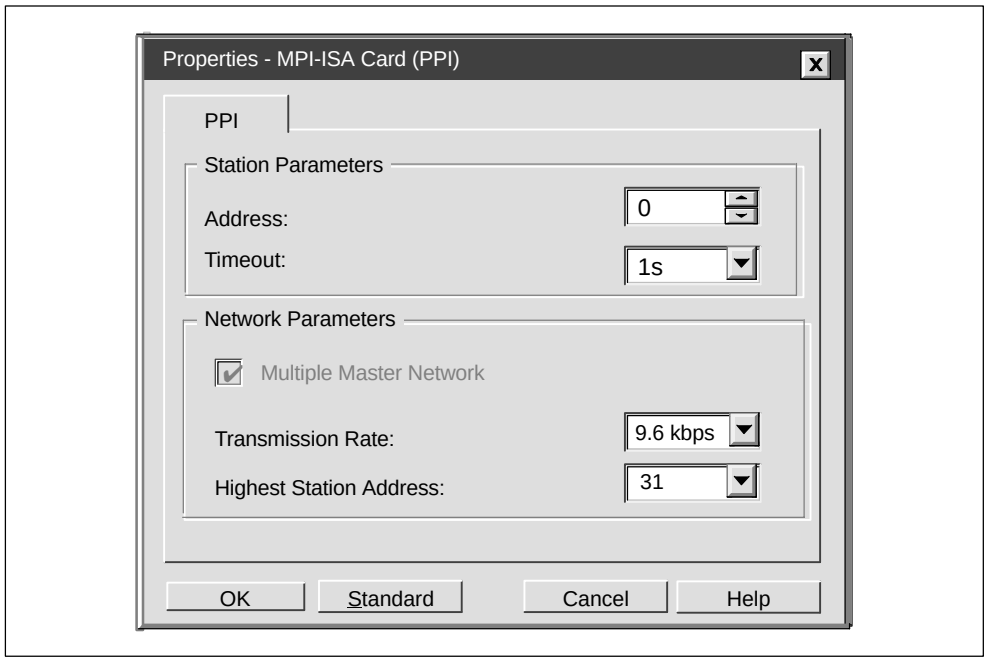


Figure 7-10 MPI-ISA Card (PPI) Properties Sheet

7.4 Communicating With Modems

Setting Up the Communications Parameters When Using Modems

To set up communications parameters between your programming device or PC and the CPU when using modems, you must use the module parameter set for the PC/PPI cable. Otherwise, the Configure Modems function is not available. Ensure that the Configure Modems function is enabled, and then set up the configuration parameters by following these steps:

Note

STEP 7-Micro/WIN 32 displays predefined modems in the Modem Setup dialog box. These modem types have been tested and verified to work with STEP 7-Micro/WIN 32 at the settings displayed.

Setting Up The Local Modem:

1. Select the menu command **View > Communications** (or click on the Communications icon).

   In the Communications Setup dialog box, double click on the PC/PPI cable icon, and the Set the PG/PC Interface dialog box appears. Go on to step 3.

   If the Communications Setup dialog box does not show the PC/PPI cable icon, double-click the PC card icon or the top icon in the right-hand area.

2. In the Set the PG/PC Interface dialog box, select PC/PPI cable (PPI). If this selection is not in the list box, you must install it. See Section 7.2.
3. Click the “Properties” button. The PC/PPI cable(PPI) properties sheet for your CPU and modem appears. See Figure 7-8.
4. In the Properties - PC/PPI cable (PPI) sheet, click the Local Connection tab.
5. In the COM Port area, ensure that the Use Modem box contains a check mark. If the box is empty, select it to insert a check mark. See Figure 7-8.
6. Click the “OK” button. The Set the PG/PC Interface dialog box appears.
7. Click the “OK” button. The Communications Setup dialog box appears. There are now two modem icons and a Connect Modem icon (see Figure 7-11).

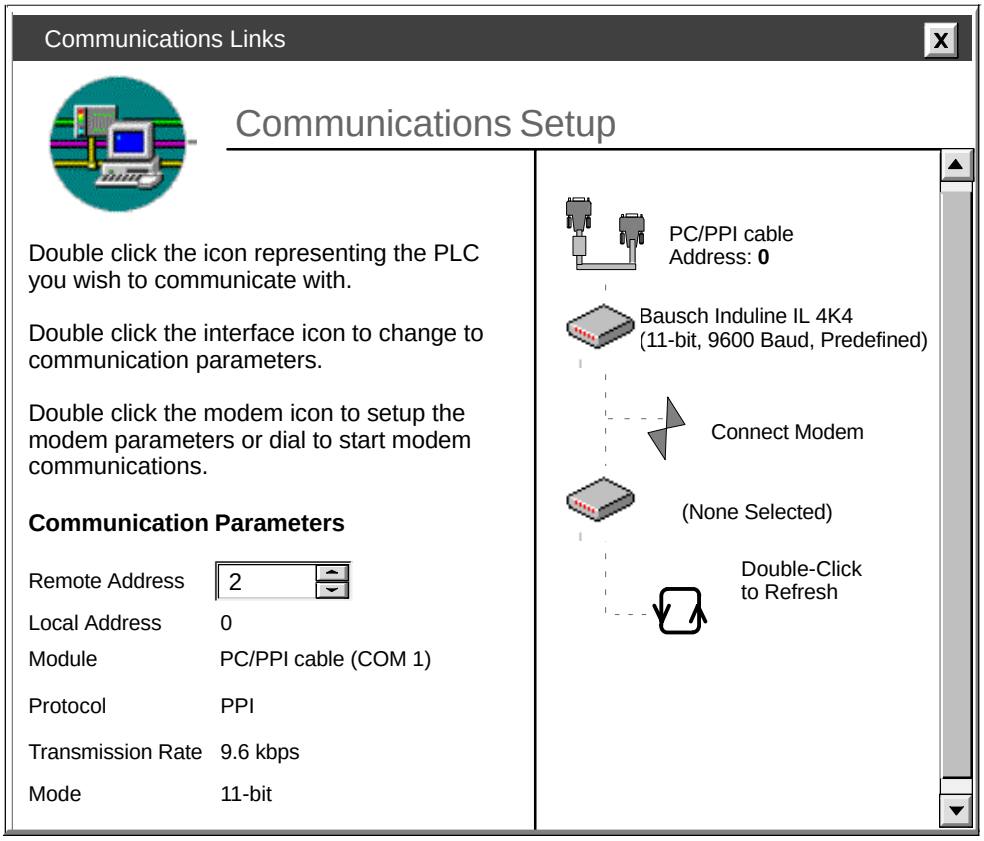


Figure 7-11 Communications Setup Dialog Box

8. In the Communications Setup dialog box, double-click on the first modem icon. The Modem Setup dialog box for the local modem appears (Figure 7-12).
9. In the Local Modem area, select your modem type. If your modem is not listed, select the “Add” button to configure your modem. To do this, you must know the AT commands for your modem. Refer to the documentation for your modem.
10. In the Communications Mode area, select the communications mode (either 10-bit or 11-bit). The communications mode that you select depends upon your modem capabilities. (The 10-bit and 11-bit communications modes are described later in this section.) Both the local and the remote modem must have the same communications mode. Click the “Configure” button.

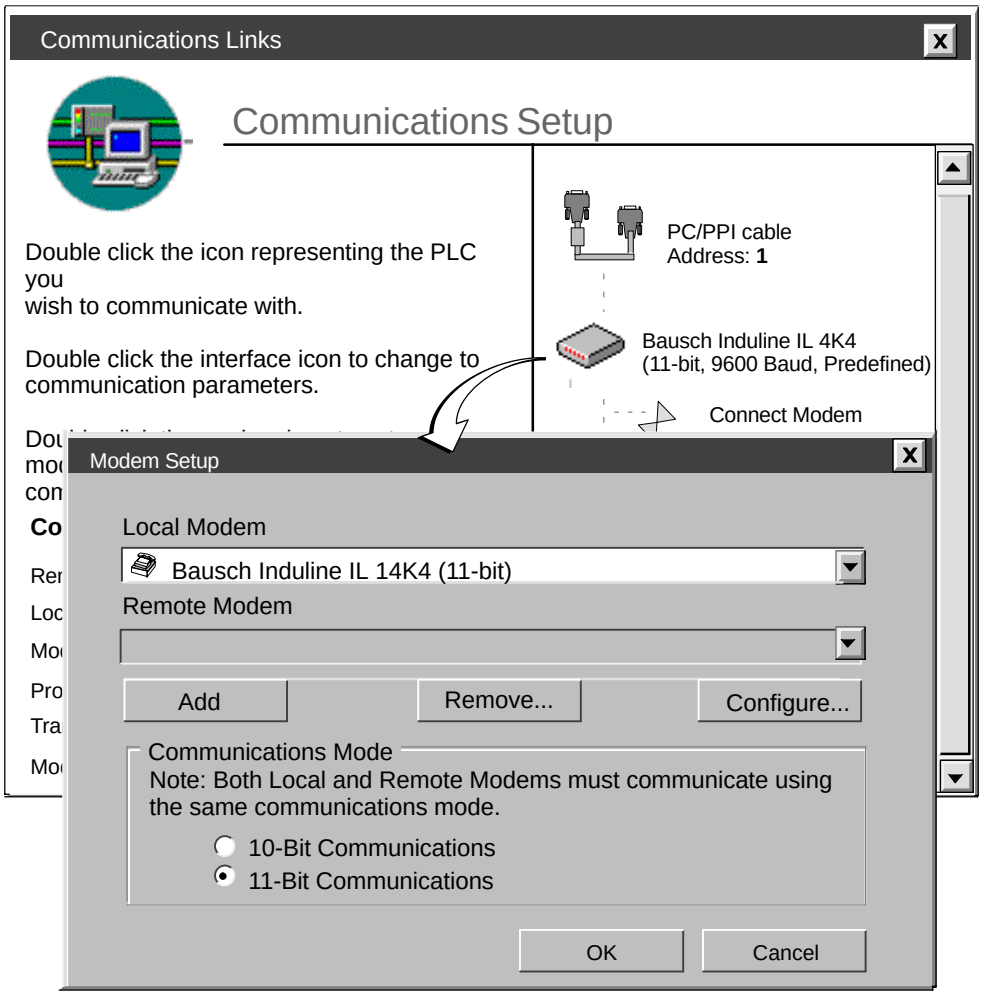


Figure 7-12 Modem Setup Dialog Box for the Local Modem

11. The Configure dialog box appears (Figure 7-13). If you are using a predefined modem, the only field that you can edit in this dialog box is the Timeout area. The timeout is the length of time that the local modem attempts to set up a connection to the remote modem. If the time indicated in seconds in the Timeout field elapses before the connection is set up, the attempt to connect fails. If you are not using a predefined modem, you must enter the AT command string for your modem. Refer to the documentation for your modem.
12. If you want to test the configuration of your local modem, click the “Program/Test” button while the modem is connected to your local machine (programming device or PC). This configures the modem to the current protocol and settings, and verifies that the modem accepts the configuration settings. Click ‘‘OK’’ to return to the Communications Setup dialog box.
13. Disconnect your local modem and connect your remote modem to your local machine (programming device or PC).

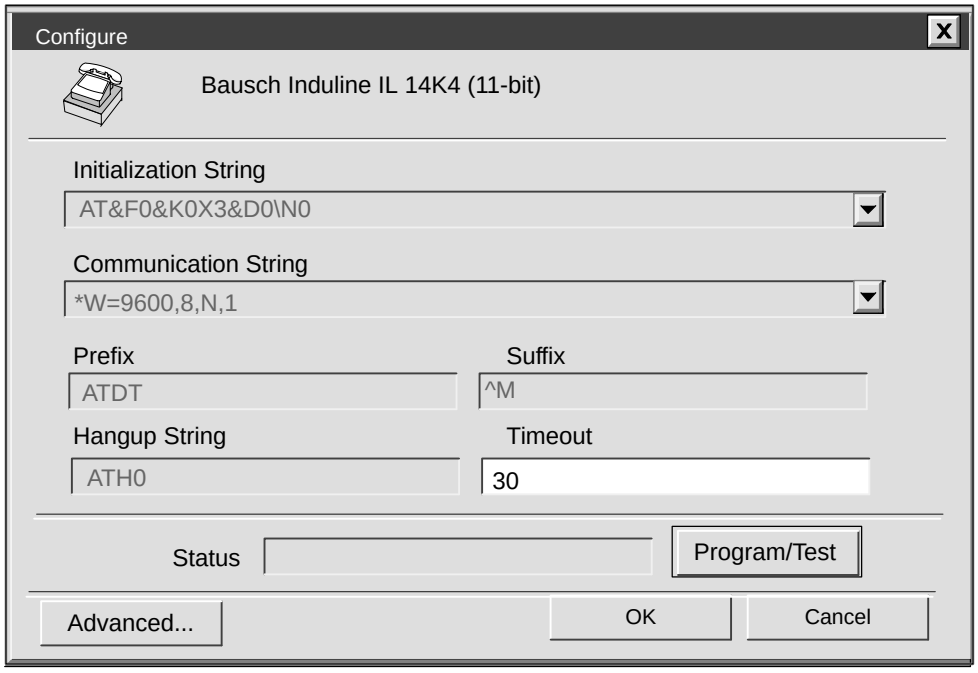


Figure 7-13 Local Modem Configuration

Setting Up The Remote Modem:

1. In the Communications Setup dialog box, double-click on the second modem icon (Figure 7-11). The Modem Setup dialog box for the remote modem appears (Figure 7-14).
2. In the Remote Modem area, select your modem type. If your modem is not listed, select the “Add” button to configure your modem. To do this, you must know the AT commands for your modem. Refer to the documentation for your modem.
3. In the Communications Mode area, select the communications mode (either 10-bit or 11-bit). The communications mode that you select depends upon your modem capabilities. (The 10-bit and 11-bit communications modes are described later in this section.) Both the local and the remote modem must have the same communications mode. Click the “Configure” button.
4. The Configure dialog box appears (Figure 7-15). If you are using a predefined modem, there are no fields that you can edit. If you are not using a predefined modem, you must enter the AT command string for your modem. Refer to the documentation for your modem.
5. To test the configuration of your remote modem, click the “Program/Test” button while the modem is connected to your local machine (programming device or PC). This action transfers the parameters into a memory chip in the remote modem.
6. Click the “OK” button. The Communications Setup dialog box appears.

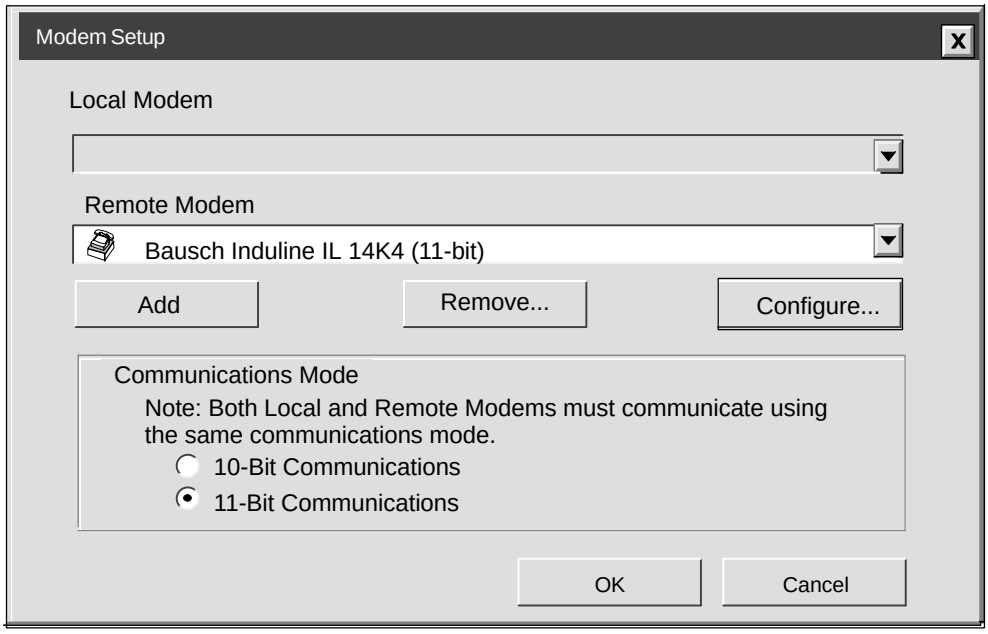


Figure 7-14 Modem Setup Dialog Box for Remote Modem

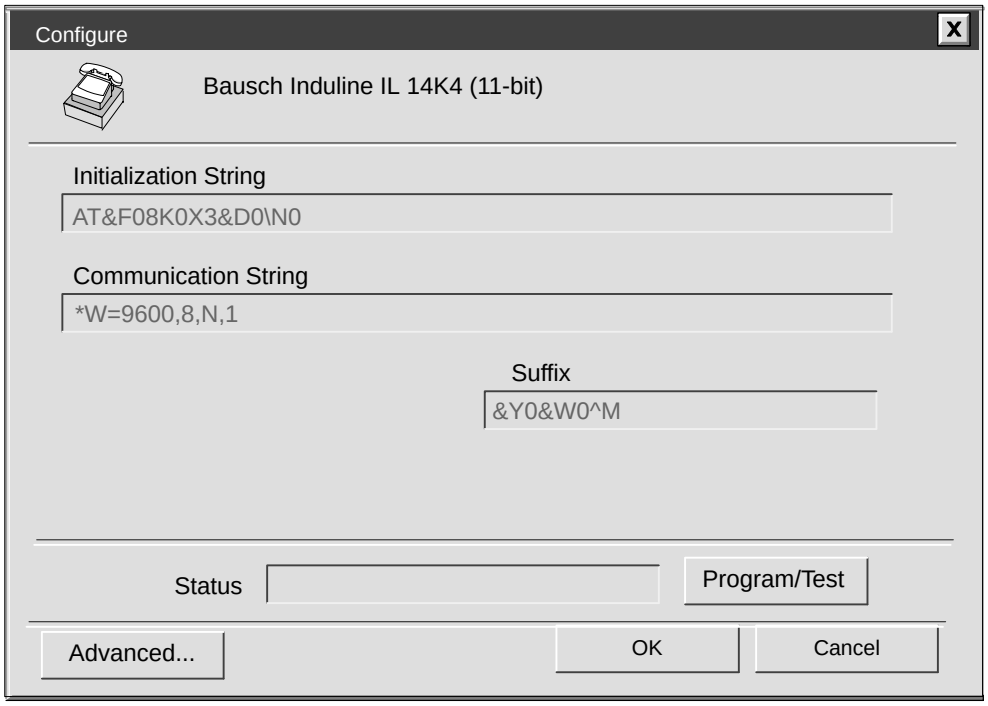


Figure 7-15 Remote Modem Configuration

7. Disconnect your remote modem from your local machine (your programming device or PC).
8. Connect the remote modem to your S7-200 programmable controller.
9. Connect your local modem to your programming device or PC.

Connecting the Modems:

1. To connect your modem, double-click on the Connect Modem icon in the Communications Setup dialog box. The Dial dialog box appears. See Figure 7-16.
2. Enter the phone number in the Phone Number field of the Dial dialog box.
3. To connect the local modem to the remote modem, click the “Connect” button.

Your modem setup is complete.

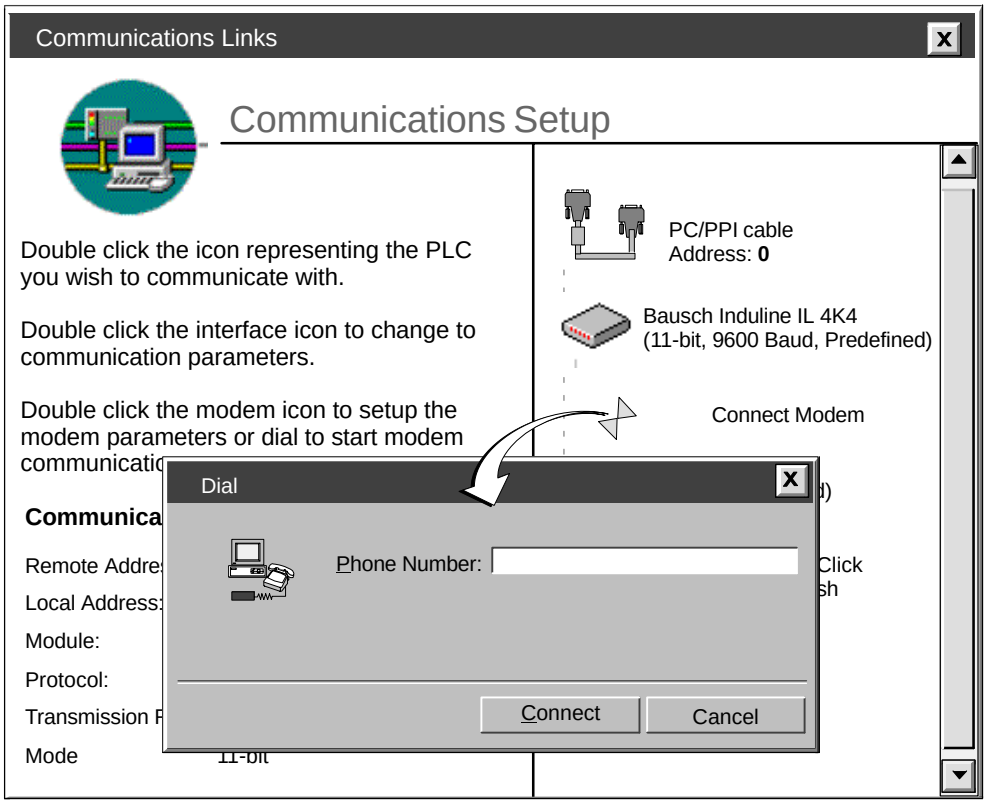


Figure 7-16 Connecting the Modems

Using a 10-Bit Modem to Connect an S7-200 CPU to a STEP 7-Micro/WIN 32 Master

Using STEP 7-Micro/WIN 32 on a PC with a Windows 95, Windows 98, or Windows NT operating system, or using a SIMATIC programming device (such as a PG 740) as a single-master device, you can connect to only one S7-200 CPU. You can use a Hayes-compatible 10-bit modem to communicate to a single remote S7-200 CPU. Figure 7-17 shows S7-200 data communications using a 10-bit modem with a 5-switch PC/PPI cable.

You will need the following equipment:

- A single S7-200 CPU as a slave device. The CPU 221, CPU 222, CPU 224, and CPU 226 support the 10-bit format. Previous S7-200 CPUs do not support the 10-bit format.
- An RS-232 cable to connect the PC or SIMATIC programming device to a full-duplex,10-bit local modem
- A 5-switch PC/PPI cable (set to the proper baud rate, 10-bit data communications mode, and DTE mode) to connect the remote modem to the CPU
- An optional 9-pin to 25-pin adapter (if your modem connector requires it)

Note
The 4-switch PC/PPI cable does not support the 10-bit format.

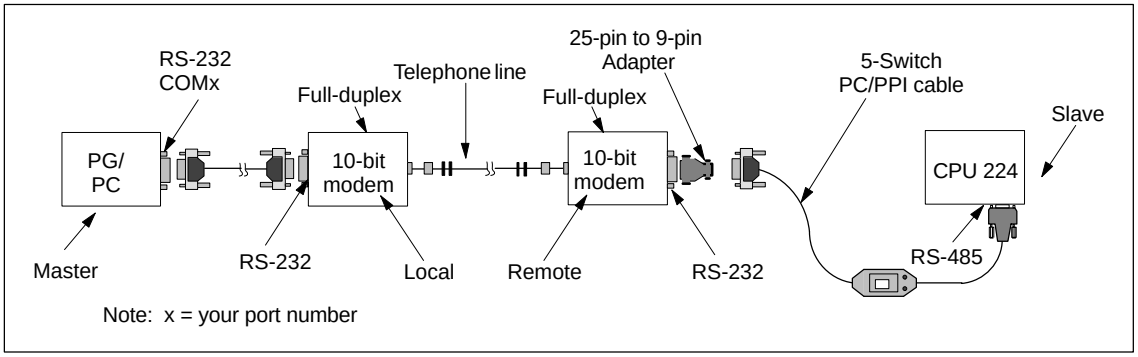


Figure 7-17 S7-200 Data Communications Using a 10-Bit Modem with a 5-Switch PC/PPI Cable

This configuration allows only one master device and one slave device. In this configuration, the S7-200 controller requires one start bit, eight data bits, no parity bit, one stop bit, asynchronous communication, and a transmission speed of 9600/19,200 baud. The modem requires the settings listed in Table 7-3. Figure 7-18 shows the pin assignments for a 25-pin to 9-pin Adapter.

Table 7-3 Modem Settings Required for a 10-Bit Modem

Modem	Data Format in Bits	Transmission Speed between Modem and PC	Transmission Speed on the Line	Other Features
10-Bit	8 data	9600 baud 19,200 baud	9600 baud 19,200 baud	Ignore DTR signal
	1 start			No hardware flow control
	1 stop			No software flow control
	no parity			

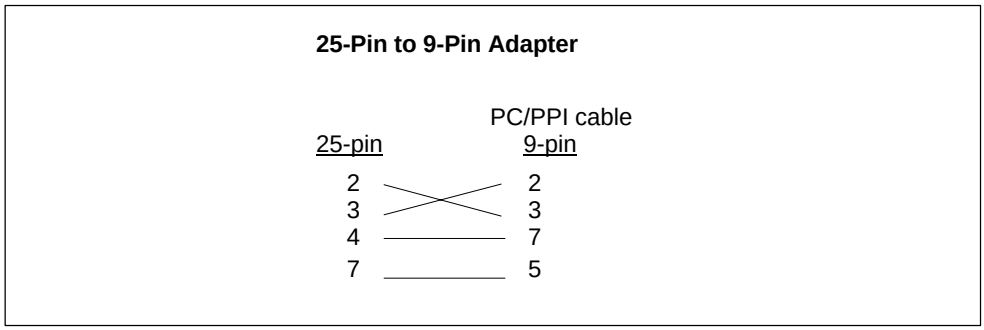


Figure 7-18 Pin Assignments for a 25-Pin to 9-Pin Adapter

Using an 11-Bit Modem to Connect an S7-200 CPU to a STEP 7-Micro/WIN 32 Master

Using STEP 7-Micro/WIN 32 on a PC with a Windows 95, Windows 98, or Windows NT operating system, or on a SIMATIC programming device (such as a PG 740) as a single-master device, you can connect to one or more S7-200 CPUs (slaves). Most modems are not capable of supporting the 11-bit protocol.

Depending on whether you want to connect to only one S7-200 CPU or to a network of them (see Figure 7-19), you need the following:

- A standard RS-232 cable to connect the PC or SIMATIC programming device to a full-duplex,11-bit local modem
- One of the following PC/PPI cables:
  - A 5-switch PC/PPI cable (set to the proper baud rate, the 11- bit data communications mode, and the DTE mode) to connect the remote modem to the CPU
  - A 4-switch PC/PPI cable (set to the proper baud rate) and a null modem adapter to connect the remote modem to the CPU
- If there are multiple CPUs connected to the remote modem, you will need a Siemens programming port connector on a PROFIBUS network (see Figure 7-24 for the bias and termination of interconnecting cables).

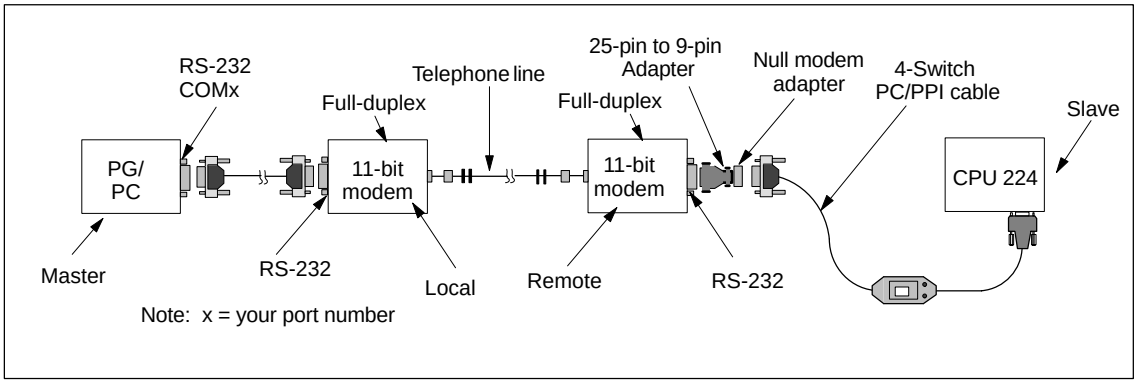


Figure 7-19 S7-200 Data Communications Using an 11-Bit Modem with a 4-Switch PC/PPI Cable

This configuration allows only one master device and supports only the PPI protocol. In order to communicate through the PPI interface, the S7-200 PLC requires that the modem use an 11-bit data string. In this mode, the S7-200 controller requires one start bit, eight data bits, one parity bit (even parity), one stop bit, asynchronous communication, and a transmission speed of 9600/19,200 baud. Many modems are not capable of supporting this data format. The modem requires the settings listed in Table 7-4.

Figure 7-20 shows the pin assignments for a null modem adapter and a 25-pin to 9-pin Adapter.

Table 7-4 Modem Settings Required for an 11-Bit Modem

Modem	Data Format in Bits	Transmission Speed between Modem and PC	Transmission Speed on the Line	Other Features
11-Bit	8 data	9600 baud 19,200 baud	9600 baud 19,200 baud	Ignore DTR signal
	1 start			No hardware flow control
	1 stop			No software flow control
	1 parity (even)			

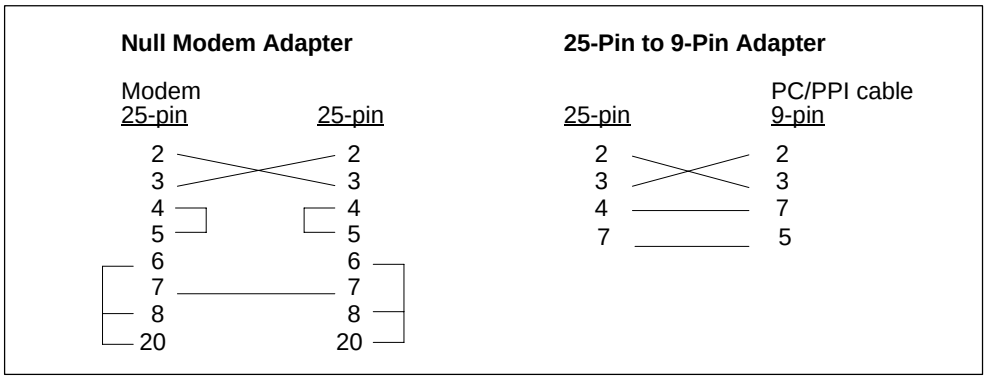


Figure 7-20 Pin Assignments for a Null Modem Adapter and a 25-Pin to 9-Pin Adapter

7.5 Network Overview

Network Masters

Figure 7-21 shows a configuration with a personal computer connected to several S7-200 CPUs. STEP 7-Micro/WIN 32 is designed to communicate with one S7-200 CPU at a time; however, you can access any CPU on the network. The CPUs in Figure 7-21 could be either slave or master devices. The TD 200 is a master device.

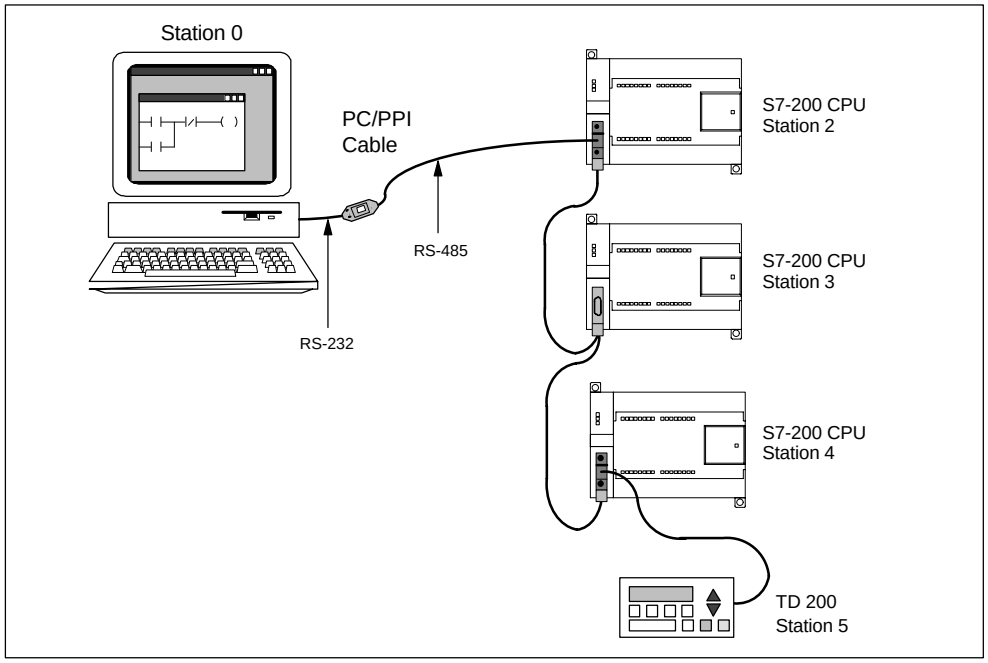


Figure 7-21 Using a PC/PPI Cable for Communicating with Several S7-200 CPUs with the Multiple Master Option Enabled

Figure 7-22 shows a more general network including multiple master devices. Higher baud rates and more connections are made possible by using the EM 277 PROFIBUS-DP module.

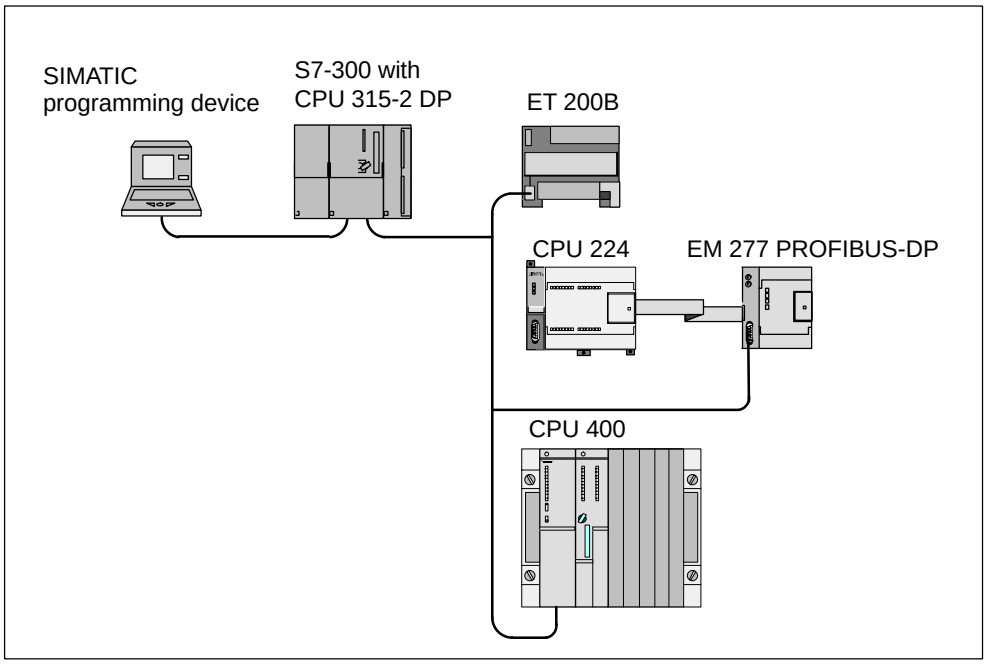


Figure 7-22 EM 277 PROFIBUS-DP Module and CPU 224 on a PROFIBUS Network

Network Communication Protocols

The S7-200 CPUs support a variety of communication capabilities. Depending on the S7-200 CPU that you use, your network can support one or more of the following communication protocols:

- Point-to-Point Interface (PPI)
- Multipoint Interface (MPI)
- PROFIBUS

These protocols are based upon the Open System Interconnection (OSI) seven-layer model of communications architecture. The PPI and MPI protocols are implemented on a token ring network which conforms to the Process Field Bus (PROFIBUS) standard as defined in the European Standard EN 50170.

These protocols are asynchronous, character-based protocols with one start bit, eight data bits, even parity, and one stop bit. Communication frames depend upon special start and stop characters, source and destination station addresses, frame length, and a checksum for data integrity. The three protocols can run on a network simultaneously without interfering with each other as long as the baud rate is the same for each of them.

The PROFIBUS network uses the RS-485 standard on twisted pair cables. This allows up to 32 devices to be connected together on a network segment. Network segments can be up to 1,200 m (3,936 ft.) in length, depending on the baud rate. Network segments can be connected with repeaters to allow more devices on a network and greater cable lengths. Networks can be up to 9,600 m (31,488 ft.) with up to 9 repeaters (depending on the baud rate). (See Table 7-7.) For more information about the EM 277 PROFIBUS-DP module, see the product specifications in Appendix A.

The protocols define two types of network devices: masters and slaves. Master devices can initiate a request to another device on the network. Slave devices can only respond to requests from master devices. Slaves never initiate a request on their own.

The protocols support 127 addresses (0 through 126) on a network. There can be up to 32 master devices on a network. All devices on a network must have different addresses in order to be able to communicate. SIMATIC programming devices and PCs running STEP 7-Micro/WIN 32 have the default address of 0. Operator panels such as the TD 200, OP3, and the OP7 default to address 1. The programmable controllers have the default address of 2.

PPI Protocol

PPI is a master/slave protocol. In this protocol the master devices (other CPUs, SIMATIC programming devices, or TD 200s) send requests to the slave devices and the slave devices respond. Slave devices do not initiate messages, but wait until a master sends them a request or polls them for a response. All S7-200 CPUs act as slave devices on the network.

Some S7-200 CPUs can act as master devices while they are in RUN mode, if you enable PPI master mode in the user program. (See the description of SMB30 in Appendix C.) Once PPI master mode has been enabled, you can read from or write to other CPUs by using the Network Read (NETR) and Network Write (NETW) instructions. See Section 9.15, SIMATIC Communications Instructions in Chapter 9 for a description of these instructions. While acting as a PPI master, the S7-200 CPU still responds as a slave to requests from other masters.

PPI has no limit on how many masters can communicate to any one slave CPU, but there can be no more than 32 masters on a network.

MPI Protocol

MPI may be either a Master/Master protocol or a Master/Slave protocol. Exactly how the protocol operates is based on the type of device. If the destination device is an S7-300 CPU, then a master/master connection is established because all S7-300 CPUs are network masters. If the destination device is an S7-200 CPU, then a master/slave connection is established because the S7-200 CPUs are slave devices.

MPI always establishes a connection between the two devices communicating with each other. A connection is like a private link between the two devices. Another master cannot interfere with a connection established between two devices. A master can establish a connection to use for a short period of time, or the connection can remain open indefinitely.

Because the connections are private links between devices and require resources in the CPU, each CPU can only support a finite number of connections. Each S7-200 CPU supports 4 connections on each of Port 0 and Port 1, and each EM 277 module supports 6 connections. Both the EM 277 and the S7-200 reserve two connections; one for a SIMATIC programming device or PC, and one for operator panels. The reserved connections enable you to always connect at least one programming device or PC and at least one operator panel to the S7-200 CPU or EM 277 PROFIBUS-DP module. These reserved connections cannot be used by other types of master devices (such as CPUs).

The S7-300 and S7-400 CPUs can communicate with the S7-200 CPUs by establishing a connection on the non-reserved connections of the S7-200 CPU or the EM 277 PROFIBUS-DP module. The S7-300s and S7-400s can read and write data to the S7-200s using the XGET and XPUT instructions (refer to your S7-300 or S7-400 programming manuals).

PROFIBUS Protocol

The PROFIBUS protocol is designed for high-speed communications with distributed I/O devices (remote I/O). There are many PROFIBUS devices available from a variety of manufacturers. These devices range from simple input or output modules to motor controllers and programmable controllers.

PROFIBUS networks usually have one master and several slave I/O devices. The master device is configured to know what types of I/O slaves are connected and at what addresses. The master initializes the network and verifies that the slave devices on the network match the configuration. The master writes output data to the slaves and reads input data from them continuously. When a DP master configures a slave device successfully, it then owns that slave device. If there is a second master device on the network, it has very limited access to the slaves owned by the first master.

For information about the EM 277 PROFIBUS-DP module and how to use it, see the product specifications in Appendix A.

User-Defined Protocols (Freeport)

Freeport communication is a mode of operation through which the user program can control the communication port of the S7-200 CPU. Using Freeport mode, you can implement user-defined communication protocols to interface to many types of intelligent devices.

The user program controls the operation of the communication port through the use of the receive interrupts, transmit interrupts, the transmit instruction (XMT) and the receive instruction (RCV). The communication protocol is controlled entirely by the user program while in Freeport mode. Freeport mode is enabled by means of SMB30 (port 0) and is only active when the CPU is in RUN mode. When the CPU returns to STOP mode, Freeport communications are halted and the communication port reverts to normal PPI protocol operation. See Section 9.15, SIMATIC Communications Instructions in Chapter 9 for a description of the Transmit and Receive instructions.

7.6 Network Components

The communication port on each S7-200 enables you to connect it to a network bus. The information below describes this port, the connectors for the network bus, the network cable, and repeaters used to extend the network.

Communication Port

The communication ports on the S7-200 CPUs are RS-485 compatible on a nine-pin subminiature D connector in accordance with the PROFIBUS standard as defined in the European Standard EN 50170. Figure 7-23 shows the connector that provides the physical connection for the communication port, and Table 7-5 describes the communication port pin assignments. See Appendix A for information about the EM 277 PROFIBUS-DP module.

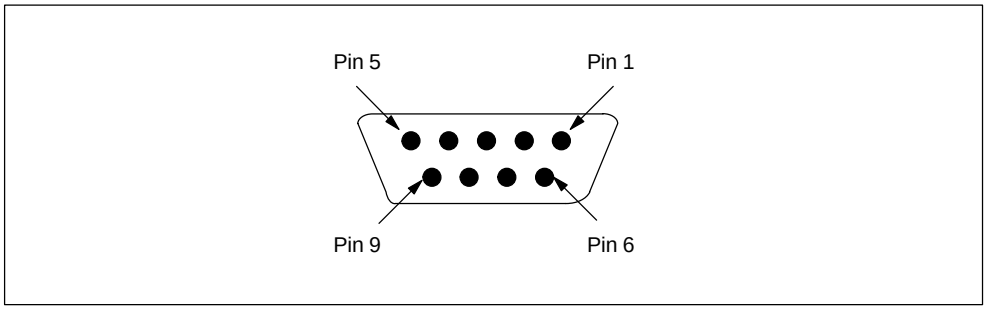


Figure 7-23 Pin Assignment for the S7-200 CPU Communication Port

Table 7-5 S7-200 Communication Port Pin Assignments

Pin Number	PROFIBUS Designation	Port 0/Port 1
1	Shield	Chassis ground
2	24 V Return	Logic common
3	RS-485 Signal B	RS-485 Signal B
4	Request-to-Send	RTS (TTL)
5	5 V Return	Logic common
6	+5 V	+5 V, 100 Ω series resistor
7	+24 V	+24 V
8	RS-485 Signal A	RS-485 Signal A
9	Not applicable	10-bit protocol select (input)
Connector shell	Shield	Chassis ground

Network Connectors

Siemens offers two types of networking connectors that you can use to connect multiple devices to a network easily. Both connectors have two sets of terminal screws to allow you to attach the incoming and outgoing network cables. Both connectors also have switches to bias and terminate the network selectively. One connector type provides only a connection to the CPU. The other adds a programming port (see Figure 7-24). See Appendix E for ordering information.

The connector with the programming port connection allows a SIMATIC programming device or operator panel to be added to the network without disturbing any existing network connections. The programming port connector passes all signals from the CPU through to the programming port. This connector is useful for connecting devices (such as a TD 200 or an OP3) which draw power from the CPU. The power pins on the communication port connector of the CPU are passed through to the programming port.

Caution

Interconnecting equipment with different reference potentials can cause unwanted currents to flow through the interconnecting cable.

These unwanted currents can cause communication errors or can damage equipment.

Be sure all equipment that you are about to connect with a communication cable either shares a common circuit reference or is isolated to prevent unwanted current flows. See “Grounding and Circuit Reference Point for Using Isolated Circuits” in Section 2.3.

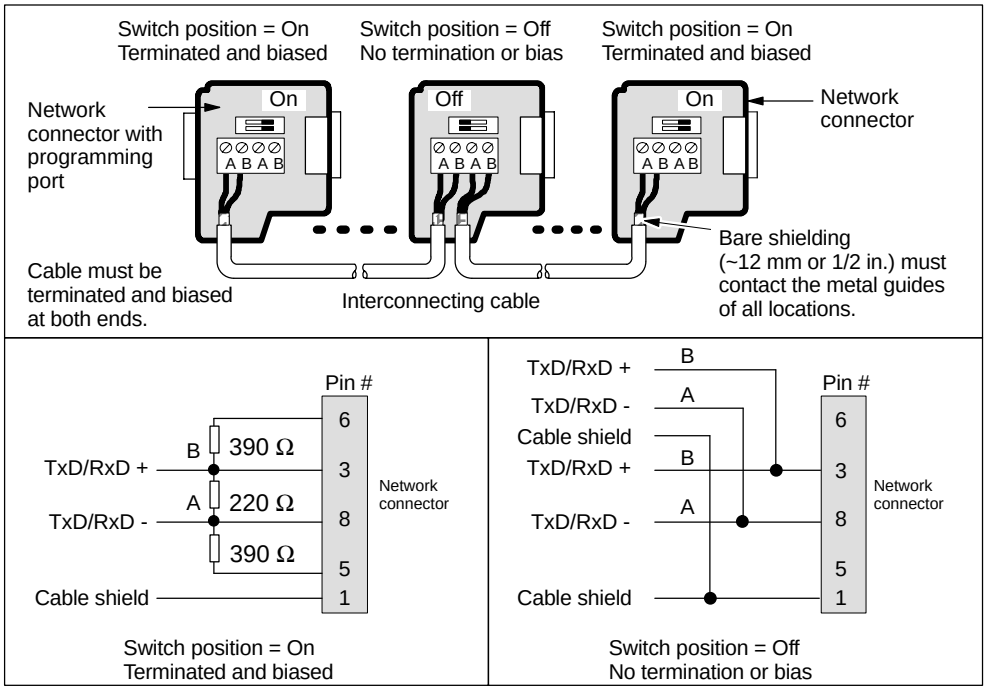


Figure 7-24 Bias and Termination of Interconnecting Cable

Cable for a PROFIBUS Network

Table 7-6 lists the general specifications for a PROFIBUS network cable. See Appendix E for the Siemens order number for PROFIBUS cable meeting these requirements.

Table 7-6 General Specifications for a PROFIBUS Network Cable

General Features	Specification
Type	Shielded, twisted pair
Conductor cross section	24 AWG (0.22 mm^2) or larger
Cable capacitance	< 60 pF/m
Nominal impedance	100 Ω to 120 Ω

The maximum length of a PROFIBUS network segment depends on the baud rate and the type of cable used. Table 7-7 lists the maximum segment lengths for cable matching the specifications listed in Table 7-6.

Table 7-7 Maximum Cable Length of a Segment in a PROFIBUS Network

Transmission Rate	Maximum Cable Length of a Segment
9.6 kbaud to 93.75 kbaud	1,200 m (3,936 ft.)
187.5 kbaud	1,000 m (3,280 ft.)
500 kbaud	400 m (1,312 ft.)
1 Mbaud to 1.5 Mbaud	200 m (656 ft.)
3 Mbaud to 12 Mbaud	100 m (328 ft.)

Network Repeaters

Siemens provides network repeaters to connect PROFIBUS network segments. See Figure 7-25. The use of repeaters extends the overall network length, allows you to add devices to a network, and/or provides a way to isolate different network segments. PROFIBUS allows a maximum of 32 devices on a network segment of up to 1,200 m (3,936 ft.) at 9600 baud. Each repeater allows you to add another 32 devices to the network and extend the network another 1,200 m (3,936 ft.) at 9600 baud. Up to 9 repeaters may be used in a network, but the total length of the network can be no more than 9600 meters. Each repeater provides bias and termination for the network segment. See Appendix E for ordering information.

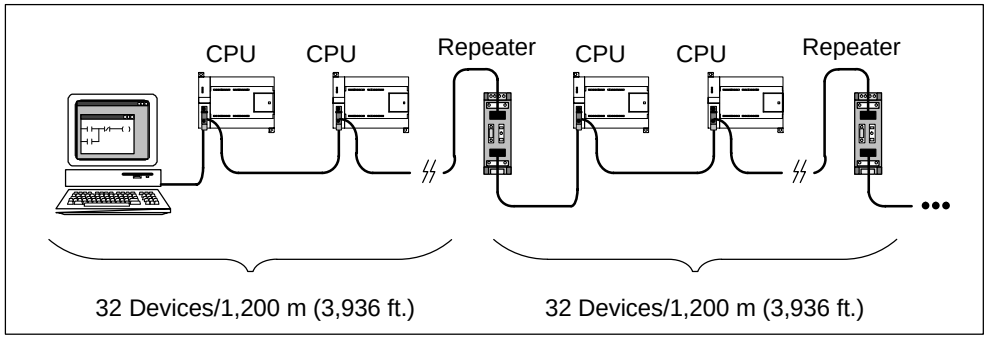


Figure 7-25 Network with Repeaters

7.7 Using the PC/PPI Cable with Other Devices and Freeport

You can use the PC/PPI cable and the Freeport communication functions to connect the S7-200 CPUs to many devices that are compatible with the RS-232 standard.

There are two different types of PC/PPI cables:

- An isolated PC/PPI cable with an RS-232 port that has 5 DIP switches for setting baud rate and other configuration items (see Figure 7-27). For technical specifications about the isolated PC/PPI cable, see Appendix A.
- A non-isolated PC/PPI cable with a RS-232 port that has 4 DIP switches for setting the baud rate. For technical specifications about the non-isolated PC/PPI cable, refer to the previous *S7-200 Programmable Controller System Manual* (model number 6ES7-298-8FA01-8BH0). This non-isolated PC/PPI cable is no longer available; the isolated PC/PPI cable is the replacement for the non-isolated cable.

Both PC/PPI cables support baud rates between 600 baud and 38,400 baud. Use the DIP switches on the housing of the PC/PPI cable to configure the cable for the correct baud rate. Table 7-8 shows the baud rates and switch positions.

Table 7-8 Baud Rate Switch Selections on the PC/PPI Cable

Baud Rate	Switch (1 = Up)
38400	000
19200	001
9600	010
4800	011
2400	100
1200	101
600	110

The PC/PPI cable is in the transmit mode when data is transmitted from the RS-232 port to the RS-485 port. The cable is in receive mode when it is idle or is transmitting data from the RS-485 port to the RS-232 port. The cable changes from receive to transmit mode immediately when it detects characters on the RS-232 transmit line. The cable switches back to receive mode when the RS-232 transmit line is in the idle state for a period of time defined as the turnaround time of the cable. This time depends on the baud rate selection made on the DIP switches of the cable (see Table 7-9).

If you are using the PC/PPI cable in a system where Freeport communication is used, the turnaround time must be comprehended by the user program in the S7-200 CPU for the following situations:

- The S7-200 CPU responds to messages transmitted by the RS-232 device.

  After receiving a request message from the RS-232 device, the transmission of a response message by the S7-200 CPU must be delayed for a period of time greater than or equal to the turnaround time of the cable.

- The RS-232 device responds to messages transmitted from the S7-200 CPU.

  After receiving a response message from the RS-232 device, the transmission of the next request message by the S7-200 CPU must be delayed for a period of time greater than or equal to the turnaround time of the cable.

In both situations, the delay allows the PC/PPI cable sufficient time to switch from transmit mode to receive mode so that data can be transmitted from the RS-485 port to the RS-232 port.

Table 7-9 PC/PPI Cable Turnaround Time (Transmit to Receive Mode)

Baud Rate	Turnaround Time (in Milliseconds)
38400	0.5
19200	1
9600	2
4800	4
2400	7
1200	14
600	28

Using a Modem with a 5-Switch PC/PPI Cable

You can use the 5-switch PC/PPI cable to connect the RS-232 communication port of a modem to an S7-200 CPU. Modems normally use the RS-232 control signals (such as RTS, CTS, and DTR) to allow a PC to control the modem. The PC/PPI cable does not monitor any of these signals, but does provide RTS in DTE mode. When you use a modem with a PC/PPI cable, the modem must be configured to operate without these signals. As a minimum, you must configure the modem to ignore DTR. Consult the operator manual supplied with the modem to determine the commands required to configure the modem.

The RS-232 port of the 5-switch PC/PPI cable can be set to either the Data Communications Equipment (DCE) or Data Terminal Equipment (DTE) mode. The only signals present on this port are transmit data, request to send, receive data, and ground. The 5-switch PC/PPI cable does not use or supply Clear to Send (CTS). See Table 7-10 and Table 7-11 for the PC/PPI cable pin-outs.

A modem is classified as Data Communications Equipment (DCE). When you connect a PC/PPI cable to a modem, the RS-232 port of the PC/PPI cable should be set to Data Terminal Equipment (DTE), as selected by the DIP switch 5 on the cable. This eliminates the need for a null modem adapter between the PC/PPI cable and the modem. You may still require a 9-pin to 25-pin adapter (depending on the connector on your modem). See Figure 7-26 for a typical setup and the pin assignment for a 25-pin to 9-pin adapter.

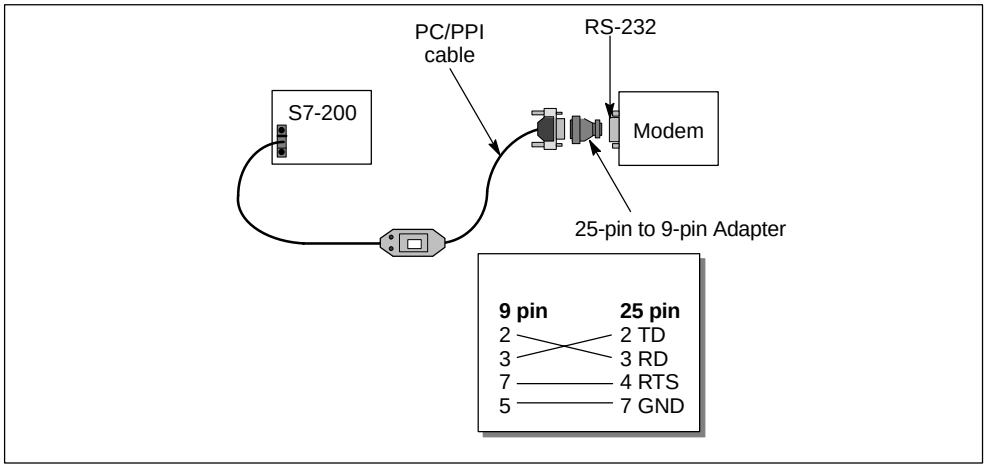


Figure 7-26 Pin Assignment for a 5-Switch PC/PPI cable With a Modem

To set the mode to Data Communications Equipment (DCE), you should set switch 5 to the 0 or down position (see Figure 7-27). To set the mode to Data Terminal Equipment (DTE), you should set switch 5 to the 1 or up position. Table 7-10 shows the pin numbers and functions for the RS-485 to RS-232 port of the PC/PPI cable in DTE mode. Table 7-11 shows the pin numbers and functions for the RS-485 to RS-232 port of the PC/PPI cable in DCE mode. You should note that the PC/PPI cable supplies RTS only when it is in DTE mode.

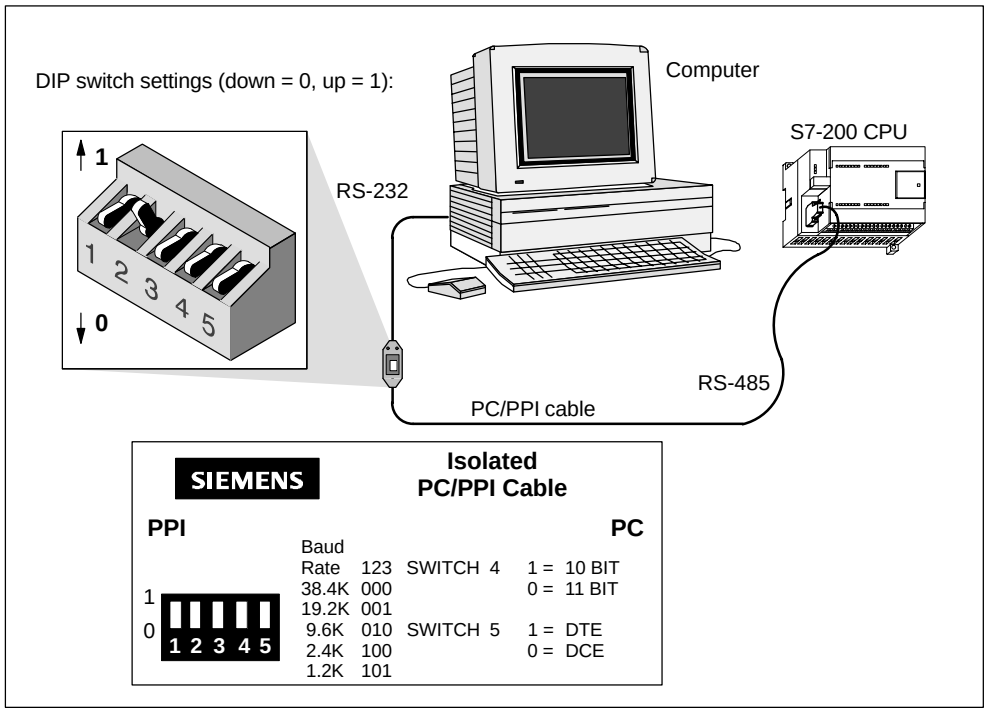


Figure 7-27 Communicating with a CPU in PPI Mode

Switch 4 of the PC/PPI cable tells the S7-200 CPU to use either a 10-bit protocol or the normal 11-bit PPI protocol. Switch 4 is used only when the CPU is communicating with STEP 7-Micro/WIN. If you are not using STEP 7-Micro/Win with a modem, switch 4 should be left in the 11-bit setting for proper operation with other devices.

Table 7-10 Pin-outs for RS-485 to RS-232 DTE Connector

RS-485 Connector Pin-out		RS-232 DTE Connector Pin-out[1]	
Pin Number	**Signal Description**	**Pin Number**	**Signal Description**
1	Ground (RS-485 logic ground)	1	Data Carrier Detect (DCD) (not used)
2	24 V Return (RS-485 logic ground)	2	Receive Data (RD) (input to PC/PPI cable)
3	Signal B (RxD/TxD+)	3	Transmit Data (TD) (output from PC/PPI cable)
4	RTS (TTL level)	4	Data Terminal Ready (DTR) (not used)
5	Ground (RS-485 logic ground)	5	Ground (RS-232 logic ground)
6	+5 V (with 100 Ω series resistor)	6	Data Set Ready (DSR) (not used)
7	24 V Supply	7	Request To Send (RTS) (output from PC/PPI cable)
8	Signal A (RxD/TxD-)	8	Clear To Send (CTS) (not used)
9	Protocol select	9	Ring Indicator (RI) (not used)
[1] A conversion from female to male, and a conversion from 9-pin to 25-pin is required for modems			

Table 7-11 Pin-outs for RS-485 to RS-232 DCE Connector

RS-485 Connector Pin-out		RS-232 DCE Connector Pin-out	
Pin Number	**Signal Description**	**Pin Number**	**Signal Description**
1	Ground (RS-485 logic ground)	1	Data Carrier Detect (DCD) (not used)
2	24 V Return (RS-485 logic ground)	2	Receive Data (RD) (output from PC/PPI cable)
3	Signal B (RxD/TxD+)	3	Transmit Data (TD) (input to PC/PPI cable)
4	RTS (TTL level)	4	Data Terminal Ready (DTR) (not used)
5	Ground (RS-485 logic ground)	5	Ground (RS-232 logic ground)
6	+5 V (with 100 Ω series resistor)	6	Data Set Ready (DSR) (not used)
7	24 V Supply	7	Request To Send (RTS) (not used)
8	Signal A (RxD/TxD-)	8	Clear To Send (CTS) (not used)
9	Protocol select	9	Ring Indicator (RI) (not used)

Using a Modem with a 4-Switch PC/PPI Cable

You can use a 4-switch PC/PPI cable to connect the RS-232 communication port of a modem to an S7-200 CPU. Modems normally use the RS-232 control signals (such as RTS, CTS, and DTR) to allow a PC to control the modem. This PC/PPI cable does not use any of these signals, so when you use a modem with a 4-switch PC/PPI cable, the modem must be configured to operate without these signals. As a minimum, you must configure the modem to ignore RTS and DTR. Consult the operator manual supplied with the modem to determine the commands required to configure the modem.

A modem is classified as Data Communications Equipment (DCE). The RS-232 port of the 4-switch PC/PPI cable is also classified as DCE. When you connect two devices of the same class (both DCE), the transmit data and receive data pins must be swapped. A null modem adapter swaps these lines. See Figure 7-28 for a typical setup and the pin assignment for a null modem adapter.

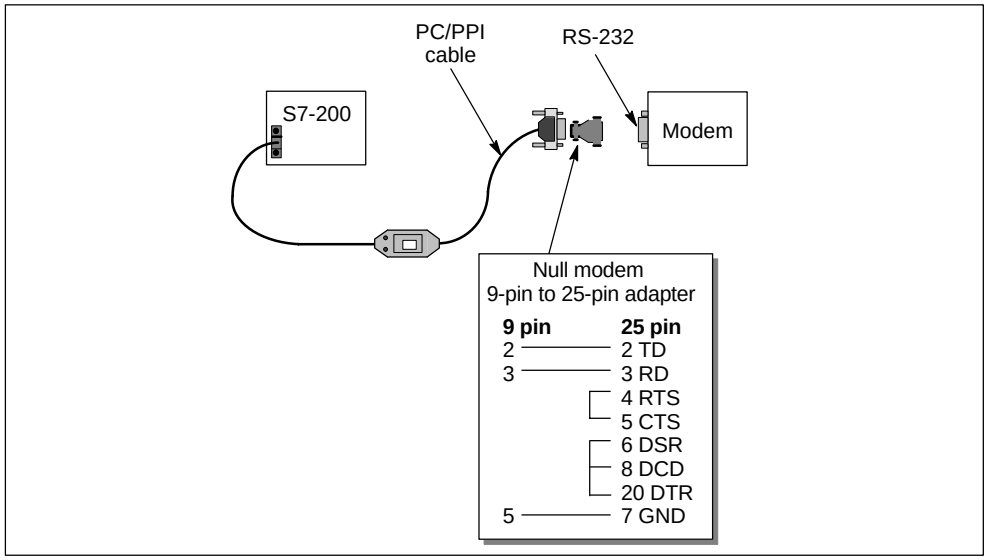


Figure 7-28 11-Bit Modem with a Combination Null Modem and a 9-pin to 25-pin Adapter

7.8 Network Performance

Optimizing Network Performance

The two factors which have the greatest effect on network performance are the baud rate and the number of masters. Operating the network at the highest baud rate supported by all devices has the greatest effect on the network. Minimizing the number of masters on a network also increases the performance of the network. Each master on the network increases the overhead requirements of the network. Fewer masters lessen the overhead.

The following factors also affect the performance of the network:

- Selection of master and slave addresses
- Gap update factor
- Highest station address

The addresses of the master devices should be set so that all of the masters are at sequential addresses with no gaps between addresses. Whenever there is an address gap between masters, the masters continually check the addresses in the gap to see if there is another master wanting to come online. This checking requires time and increases the overhead of the network. If there is no address gap between masters, no checking is done and so the overhead is minimized.

Slave addresses may be set to any value without affecting network performance as long as the slaves are not between masters. Slaves between masters increase the network overhead in the same way as having address gaps between masters.

The S7-200 CPUs can be configured to check address gaps only on a periodic basis. This checking is accomplished by setting the gap update factor (GUF) in the CPU configuration for a CPU port with STEP 7-Micro/WIN 32. The GUF tells the CPU how often to check the address gap for other masters. A GUF of one tells the CPU to check the address gap every time it holds the token. A GUF of two tells the CPU to check the address gap once every two times it holds the token. Setting a higher GUF reduces the network overhead if there are address gaps between masters. If there are no address gaps between masters, the GUF has no effect on performance. Setting a large number for the GUF causes long delays in bringing masters online since addresses are checked less frequently. The GUF is only used when a CPU is operating as a PPI master.

The highest station address (HSA) defines the highest address at which a master should look for another master. Setting an HSA limits the address gap which must be checked by the last master (highest address) in the network. Limiting the size of the address gap minimizes the time required to find and bring online another master. The highest station address has no effect on slave addresses. Masters can still communicate with slaves which have addresses greater than the HSA. The HSA is only used when a CPU is operating as a PPI master. The HSA can be set in the CPU configuration for a CPU port with STEP 7-Micro/WIN 32.

As a general rule, you should set the highest station address on all masters to the same value. This address should be greater than or equal to the highest master address. The S7-200 CPUs default to a value of 31 for the highest station address.

Token Rotation

In a token-passing network, the station that holds the token is the only station that has the right to initiate communication. Therefore, an important performance figure for a token-passing network is the token rotation time. This is the time required for the token to be circulated to each of the masters (token holders) in the logical ring. In order to illustrate the operation of a multiple-master network, consider the example shown in Figure 7-29.

The network in Figure 7-29 has four S7-200 CPUs, and each has its own TD 200. Two CPU 224 modules gather data from all the other CPUs.

Note

The example provided here is based on a network such as the one shown in Figure 7-29. The configuration includes TD 200 units. The CPU 224 modules are using the NETR and NETW instructions. The formulas for token hold time and token rotation time shown in Figure 7-30 are also based on such a configuration.

COM PROFIBUS provides an analyzer to determine network performance.

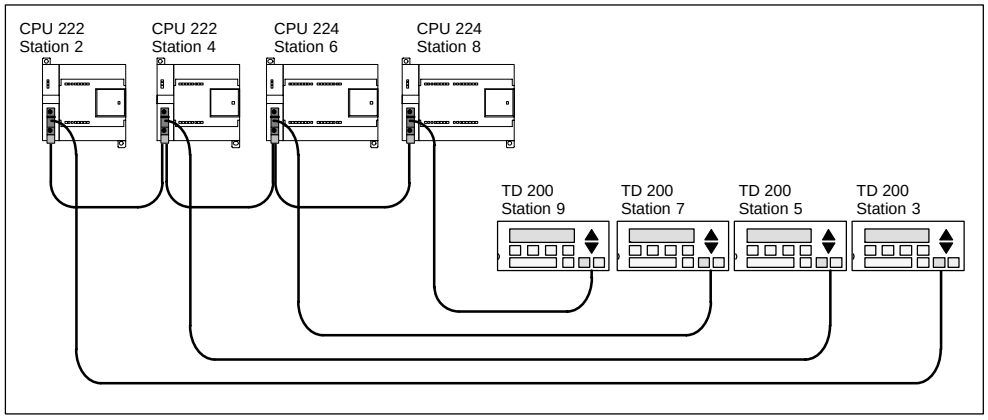


Figure 7-29 Example of a Token-Passing Network

In this configuration, the TD 200 (station 3) communicates with the CPU 222 (station 2), TD 200 (station 5) communicates with CPU 222 (station 4), and so on. Also, CPU 224 (station 6) is sending messages to stations 2, 4, and 8, and CPU 224 (station 8) is sending messages to stations 2, 4, and 6. In this network, there are six master stations (the four TD 200 units and the two CPU 224 modules) and two slave stations (the two CPU 222 modules).

Sending Messages

In order for a master to send a message, it must hold the token. For example: When station 3 has the token, it initiates a request message to station 2 and then it passes the token to station 5. Station 5 then initiates a request message to station 4 and then passes the token to station 6. Station 6 then initiates a message to station 2, 4, or 8, and passes the token to station 7. This process of initiating a message and passing the token continues around the logical ring from station 3 to station 5, station 6, station 7, station 8, station 9, and finally back to station 3. The token must rotate completely around the logical ring in order for a master to be able to send a request for information. For a logical ring of six stations, sending one request message per token hold to read or write one double-word value (four bytes of data), the token rotation time is approximately 900 ms at 9600 baud. Increasing the number of bytes of data accessed per message or increasing the number of stations increases the token rotation time.

Token Rotation Time

The token rotation time is determined by how long each station holds the token. You can determine the token rotation time for your S7-200 multiple-master network by adding the times that each master holds the token. If the PPI master mode has been enabled (under the PPI protocol on your network), you can send messages to other CPUs by using the Network Read (NETR) and Network Write (NETW) instructions with the CPU. See the description of these instructions in Section 9.15, SIMATIC Communications Instructions in Chapter 9. If you send messages using these instructions, you can use the formula shown in Figure 7-30 to calculate the approximate token rotation time when the following assumptions are true:

- Each station sends one request per token hold.
- The request is either a read or write request for consecutive data locations.
- There is no conflict for use of the one communication buffer in the CPU.
- There is no CPU that has a scan time longer than about 10 ms.

Token hold time (T_{hold}) = (128 overhead + *n* data char) ∗ 11 bits/char ∗ 1/baud rate

Token rotation time (T_{rot}) = T_{hold} of master 1 + T_{hold} of master 2 + . . . + T_{hold} of master *m*

where *n* is the number of data characters (bytes)
and *m* is the number of masters

Solving for the token rotation time using the example shown above, where each of the six masters has the same token hold time, yields:

T (token hold time) = (128 + 4 char) ∗ 11 bits/char ∗ 1/9600 bit times/s
= 151.25 ms/master

T (token rotation time) = 151.25 ms/master ∗ 6 masters
= 907.5 ms

(One “bit time” equals the duration of one signaling period.)

Figure 7-30 Formulas for Token Hold Time, Token Rotation Time, Using NETR and NETW

Token Rotation Comparison

Table 7-12, Table 7-13, and Table 7-14 show comparisons of the token rotation time versus the number of stations and amount of data at 9.6 kbaud, 19.2 kbaud, and 187.5 kbaud, respectively. The times are figured for a case where you use the Network Read (NETR) and Network Write (NETW) instructions with the CPU or other master devices.

Table 7-12 Token Rotation Time versus Number of Stations and Amount of Data at 9.6 kbaud

Bytes Transferred per Station at 9.6 kbaud	Number of Stations, with Time in Seconds								
	2 stations	3 stations	4 stations	5 stations	6 stations	7 stations	8 stations	9 stations	10 stations
1	0.30	0.44	0.59	0.74	0.89	1.03	1.18	1.33	1.48
2	0.30	0.45	0.60	0.74	0.89	1.04	1.19	1.34	1.49
3	0.30	0.45	0.60	0.75	0.90	1.05	1.20	1.35	1.50
4	0.30	0.45	0.61	0.76	0.91	1.06	1.21	1.36	1.51
5	0.30	0.46	0.61	0.76	0.91	1.07	1.22	1.37	1.52
6	0.31	0.46	0.61	0.77	0.92	1.07	1.23	1.38	1.54
7	0.31	0.46	0.62	0.77	0.93	1.08	1.24	1.39	1.55
8	0.31	0.47	0.62	0.78	0.94	1.09	1.25	1.40	1.56
9	0.31	0.47	0.63	0.78	0.94	1.10	1.26	1.41	1.57
10	0.32	0.47	0.63	0.79	0.95	1.11	1.27	1.42	1.58
11	0.32	0.48	0.64	0.80	0.96	1.11	1.27	1.43	1.59
12	0.32	0.48	0.64	0.80	0.96	1.12	1.28	1.44	1.60
13	0.32	0.48	0.65	0.81	0.97	1.13	1.29	1.45	1.62
14	0.33	0.49	0.65	0.81	0.98	1.14	1.30	1.46	1.63
15	0.33	0.49	0.66	0.82	0.98	1.15	1.31	1.47	1.64
16	0.33	0.50	0.66	0.83	0.99	1.16	1.32	1.49	1.65

Table 7-13 Token Rotation Time versus Number of Stations and Amount of Data at 19.2 kbaud

Bytes Transferred per Station at 19.2 kbaud	Number of Stations, with Time in Seconds								
	2 stations	3 stations	4 stations	5 stations	6 stations	7 stations	8 stations	9 stations	10 stations
1	0.15	0.22	0.30	0.37	0.44	0.52	0.59	0.67	0.74
2	0.15	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.74
3	0.15	0.23	0.30	0.38	0.45	0.53	0.60	0.68	0.75
4	0.15	0.23	0.30	0.38	0.45	0.53	0.61	0.68	0.76
5	0.15	0.23	0.30	0.38	0.46	0.53	0.61	0.69	0.76
6	0.15	0.23	0.31	0.38	0.46	0.54	0.61	0.69	0.77
7	0.15	0.23	0.31	0.39	0.46	0.54	0.62	0.70	0.77
8	0.16	0.23	0.31	0.39	0.47	0.55	0.62	0.70	0.78
9	0.16	0.24	0.31	0.39	0.47	0.55	0.63	0.71	0.78
10	0.16	0.24	0.32	0.40	0.47	0.55	0.63	0.71	0.79
11	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80
12	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80
13	0.16	0.24	0.32	0.40	0.48	0.57	0.65	0.73	0.81
14	0.16	0.24	0.33	0.41	0.49	0.57	0.65	0.73	0.81
15	0.16	0.25	0.33	0.41	0.49	0.57	0.66	0.74	0.82
16	0.17	0.25	0.33	0.41	0.50	0.58	0.66	0.74	0.83

Table 7-14 Token Rotation Time versus Number of Stations and Amount of Data at 187.5 kbytes

Bytes Transferred per Station at 187.5 kbaud	Number of Stations, with Time in Milliseconds								
	2 stations	3 stations	4 stations	5 stations	6 stations	7 stations	8 stations	9 stations	10 stations
1	8.68	13.02	17.37	21.71	26.05	30.39	34.73	39.07	43.41
2	8.80	13.20	17.60	22.00	26.40	30.80	35.20	39.60	44.00
3	8.92	13.38	17.83	22.29	26.75	31.21	35.67	40.13	44.59
4	9.03	13.55	18.07	22.59	27.10	31.62	36.14	40.66	45.17
5	9.15	13.73	18.30	22.88	27.46	32.03	36.61	41.18	45.76
6	9.27	13.90	18.54	23.17	27.81	32.44	37.08	41.71	46.35
7	9.39	14.08	18.77	23.47	28.16	32.85	37.55	42.24	46.93
8	9.50	14.26	19.01	23.76	28.51	33.26	38.02	42.77	47.52
9	9.62	14.43	19.24	24.05	28.86	33.67	38.49	43.30	48.11
10	9.74	14.61	19.48	24.35	29.22	34.09	38.95	43.82	48.69
11	9.86	14.78	19.71	24.64	29.57	34.50	39.42	44.35	49.28
12	9.97	14.96	19.95	24.93	29.92	34.91	39.89	44.88	49.87
13	10.09	15.14	20.18	25.23	30.27	35.32	40.36	45.41	50.45
14	10.21	15.31	20.42	25.52	30.62	35.73	40.83	45.84	51.04
15	10.33	15.49	20.65	25.81	30.98	36.14	41.30	46.46	51.63

Conventions for S7-200 Instructions

8

The following conventions are used in this chapter to illustrate the equivalent ladder logic, function block diagram, and statement list instructions and the CPUs in which the instructions are available.

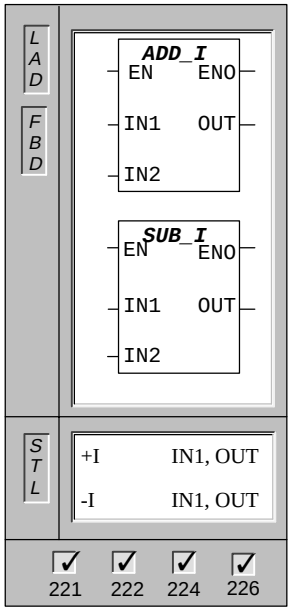
Chapter Overview

Section	Description	Page
8.1	Concepts and Conventions for STEP 7-Micro/WIN 32 Programming	8-2
8.2	Valid Ranges for the S7-200 CPUs	8-7

8.1 Concepts and Conventions For STEP 7-Micro/WIN 32 Programming

The following diagram shows the STEP 7-Micro/WIN 32 instruction format as used throughout this chapter. A description of the components of the instruction format follows the diagram.

Add Integer and Subtract Integer



The **Add Integer** and **Subtract Integer** instructions add or subtract two 16-bit integers and produce a 16-bit result (OUT).

In LAD and FBD: IN1 + IN2 = OUT
IN1 - IN2 = OUT

In STL: IN1 + OUT = OUT
OUT - IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, AC, Constant, *VD, *AC, *LD	INT
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	INT

Title of the Instruction or Instruction Group: In this example **Add Integer and Subtract Integer** is the title.

Figure Showing the STEP 7-Micro/WIN 32 Instruction: The figure below the instruction title contains a picture of the LAD instruction element, the FBD instruction element and for SIMATIC instructions, the STL instruction mnemonics and operands. In some cases, the picture of the LAD and FBD instructions are the same, and only one box containing both the LAD and FBD picture is shown (this is the case in this example). The SIMATIC STL instruction mnemonics and operands always appear in a separate box.

In the example, the LAD/FBD pictures have three inputs (inputs are always on the left side of the picture) and two outputs (outputs are always on the right side of the picture). In LAD there are two basic types of inputs and outputs. The first type of input/output is a power flow input or output.

In LAD, which is patterned after Relay Ladder Logic Electrical Drawings, there is a left power rail that is energized. In LAD, contacts that are closed allow energy to flow through them to the next element and contacts that are open block that energy flow. Any LAD element that can be connected to the left or right power rail or to a contact has a power flow input and/or output.

In SIMATIC FBD, which does not use the concept of left and right power rails, the term “power flow” is used to express the analogous concept of control flow through the FBD logic blocks. The logic “1” path through FBD elements is called power flow.

In LAD a power flow input or output is always exclusively power flow and cannot be assigned to an operand. In FBD the origin of a power flow input and the destination of a power flow output can be assigned directly to an operand.

In addition to power flow many, but not all, instructions have one or more input and output operands. The allowed parameters for the operand inputs and outputs are provided in the Inputs/Outputs table beneath the LAD/FBD/STL figure.

CPU Type: The checked boxes at the bottom of the instruction figure show the CPUs that support the instruction. In this example, the instruction is supported by the CPU 221, CPU 222, CPU 224, and CPU 226.

Instruction Description: The text to the right of the instruction figure on page 8-2 describes the operation of the instruction(s). In some cases there is a description of the operation of the instruction for each language and in other cases there will be a single description that applies to all three programming languages. Note that IEC terminology is slightly different from SIMATIC terminology. For example, a SIMATIC Count Up (CTU) is called an instruction; an IEC CTU is called a function block.

Error Conditions that Set ENO = 0: If the LAD/FBD instructions have an ENO output, this section lists the error conditions that result in ENO being set to a zero.

SM Bits Affected: If the instruction affects SM bits as a normal part of executing the instruction, the bits affected and how they are affected are listed in this section.

Operand Table: Beneath the LAD/FBD/STL figure is a table that lists the allowed operands for each of the inputs and outputs, along with the data types of each operand. The memory ranges of the operands for each CPU are shown in Table 8-3.

EN/ENO operands and data types are not shown in the instruction operand table because the operands are the same for all LAD and FBD instructions. Table 8-1 lists these operands and data types for LAD and FBD. These operands apply to all LAD and FBD instructions shown in this manual.

Table 8-1 EN/ENO Operands and Data Types for LAD and FBD

Language Editor	Inputs/Outputs	Operands	Data Types
LAD	EN	Power Flow	BOOL
	ENO	Power Flow	BOOL
FBD	EN	I, Q, M, S, SM, T, C, V, L, Power Flow	BOOL
	ENO	I, Q, M, S, SM, T, C, V, L, Power Flow	BOOL

General Conventions of Programming

Network: In LAD the program is divided into segments called networks. A network is an ordered arrangement of contacts, coils, and boxes that are all connected to form a complete circuit between the left power rail and the right power rail (no short circuits, no open circuits, and no reverse power flow conditions exist).
STEP 7-Micro/WIN 32 allows you to create comments for your LAD program on a network by network basis.

FBD programming uses the network concept for segmenting and commenting your program. STL programs do not use networks; however, you can use the NETWORK keyword to segment your program. If you do this, your program can be converted to either LAD or to FBD.

Execution Subsections: In LAD, FBD, or STL a program consists of at least one mandatory section and other optional sections. The mandatory section is the Main Program. Optional sections can include one or more subroutines and/or interrupt routines. You can easily move between subsections of the program by selecting or clicking on the subsection tabs displayed by STEP 7-Micro/WIN 32.

EN/ENO Definition: EN (Enable IN) is a Boolean input for boxes in LAD and FBD. Power flow must be present at this input for the box instruction to be executed. In STL the instructions do not have an EN input, but the top of stack value must be a logic “1” for the corresponding STL instruction to be executed.

ENO (Enable Out) is a Boolean output for boxes in LAD and FBD. If the box has power flow at the EN input and the box executes its function without error, then the ENO output will pass power flow to the next element. If an error is detected in the execution of the box, then power flow is terminated at the box that generated the error.

In SIMATIC STL, there is no ENO output, but the STL instructions that correspond to the LAD and FBD instructions with ENO outputs do set a special ENO bit. This bit is accessible with the STL instruction AENO (AND ENO), and may be used to generate the same effect as the ENO bit of a box.

Conditional/Unconditional Inputs: In LAD and FBD, a box or a coil that is dependent upon power flow is shown without a connection to any element on the left side. A coil or box that is independent of power flow is shown with a connection directly to the left power rail. Both conditional and unconditional inputs are shown in Figure 8-1.

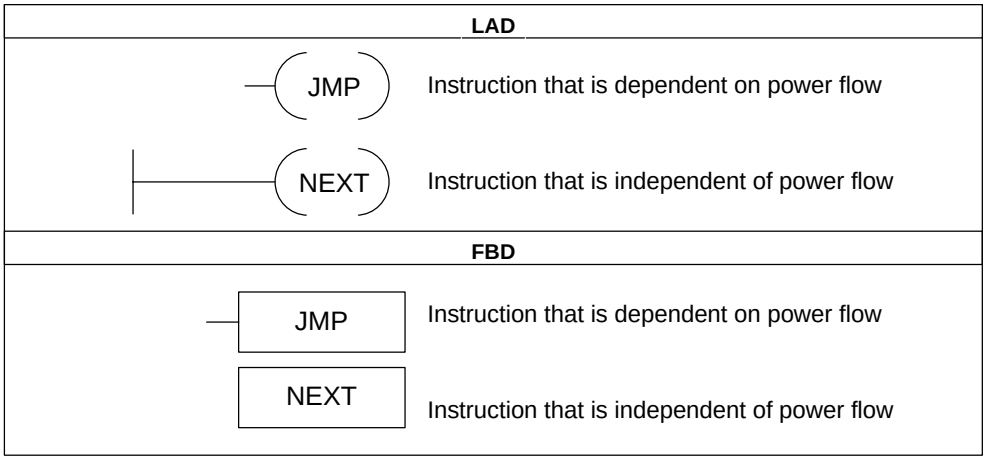


Figure 8-1 LAD Diagram of Conditional and Unconditional Inputs

Instructions without Outputs: Boxes that cannot cascade are drawn with no Boolean outputs. These include subroutine calls, JMP, CRET, etc. There are also ladder coils that can only be placed on the left power rail. These include LBL, NEXT, SCR, SCRE, etc. These are shown in FBD as boxes and are distinguished with unlabeled power inputs and no outputs.

Compare Instructions: SIMATIC FBD, IEC Ladder, and IEC FBD compare instructions are shown as boxes although the operation is performed as a contact.

The compare instruction is executed regardless of the state of power flow. If power flow is false, the output is false. If power flow is true, the output is set depending upon the result of the compare.

STEP 7-Micro/WIN 32 Conventions: In STEP 7-Micro/WIN 32, the following conventions apply in all editors:

- Capital letters used for a symbol (ABC) indicate that it is a global symbol.
- The pound character in front of a symbol name (#var1) indicates that the symbol is of local scope.
- The % symbol indicates a direct address.
- The operand symbol “?” or “????” indicates that an operand configuration is required.

Ladder Logic Conventions: In the LAD editor, you can use the F4, F6, and F9 keys on your keyboard to access contact, box, and coil instructions. The following conventions are used in the Ladder Logic editor.

- The symbol “--->>” is an open circuit, or required power flow connection.
- The $\rightarrow|$ indicates that the output is an optional powerflow for an instruction that can be cascaded or connected in series.
- The symbols “<<” or “>>” indicate that you can use either a value or power flow.
- A contact connected to the power rail indicates that the instruction is independent of powerflow (Figure 8-1).

- The logical NOT condition of the state of the operand or power flow driving the input is shown by the small circle on the input to an FBD instruction. In Figure 8-2, Q0.0 is equal to the NOT of I0.0 AND I0.1.

Function Block Conventions: In the FBD editor, you can use the F4, F6, and F9 keys on your keyboard to access AND, OR and box instructions. The following conventions are used in the Ladder Logic editor.

- The ladder editor symbol "--->>" on an EN operand is a powerflow or operand indicator. It can also depict an open circuit, or required power flow connection.
- The ⟶| indicates that the output is an optional powerflow for an instruction that can be cascaded or connected in series.
- Negation bubbles: The logical NOT condition or inverted condition of the operand or power flow is shown by the small circle on the input. In Figure 8-2, Q0.0 is equal to the NOT of I0.0 AND I0.1. Negation bubbles are only valid for Boolean signals, which can be specified as parameters or powerflow.

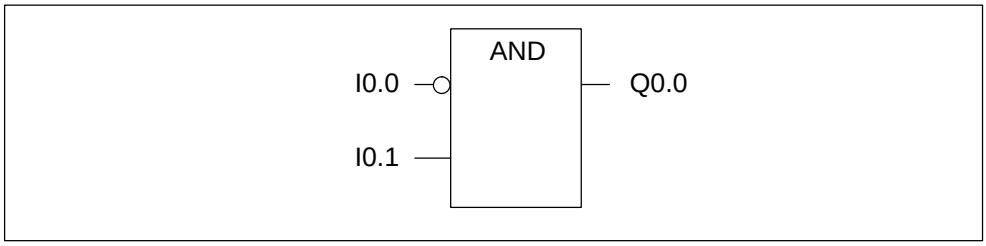


Figure 8-2 FBD Diagram of the Logical NOT Condition

- Immediate indicators: The immediate condition of of a Boolean operand is shown by the vertical line on the input to an FBD instruction (Figure 8-3). The immediate indicator causes an immediate read from the specified physical input. Immediate operators are only valid for physical inputs.

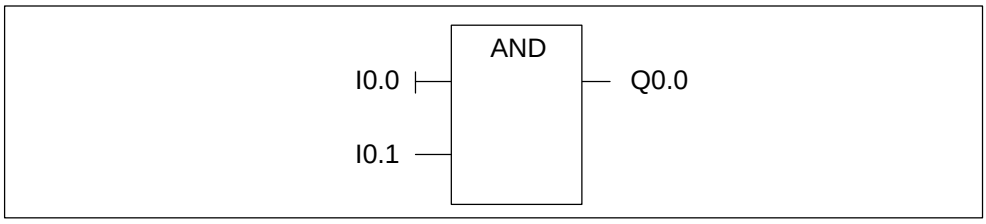


Figure 8-3 FBD Diagram of the Immediate Condition

- Tab key: The tab key moves the cursor from one input to another. The input currently selected becomes red. Movement is circular beginning with the first input through the output.
- Box with no input: A box with no input or output indicates an instruction that is independent of powerflow (Figure 8-1).
- Operand tics: The number of operands can be expanded up to 32 inputs for AND and OR instructions. To add or subtract operand tics, use the "+" and "-" keys on your keyboard.

8.2 Valid Ranges for the S7-200 CPUs

Table 8-2 Summary of S7-200 CPU Memory Ranges and Features

Description	CPU 221	CPU 222	CPU 224	CPU 226
User program size	2 Kwords	2 Kwords	4 Kwords	4 Kwords
User data size	1 Kwords	1 Kwords	2.5 Kwords	2.5 Kwords
Process-image input register	I0.0 to I15.7	I0.0 to I15.7	I0.0 to I15.7	I0.0 to I15.7
Process-image output register	Q0.0 to Q15.7	Q0.0 to Q15.7	Q0.0 to Q15.7	Q0.0 to Q15.7
Analog inputs (read only)	--	AIW0 to AIW30	AIW0 to AIW62	AIW0 to AIW62
Analog outputs (write only)	--	AQW0 to AQW30	AQW0 to AQW62	AQW0 to AQW62
Variable memory (V)[1]	VB0.0 to VB2047.7	VB0.0 to VB2047.7	VB0.0 to VB5119.7	VB0.0 to VB5119.7
Local memory (L)[2]	LB0.0 to LB63.7	LB0.0 to LB63.7	LB0.0 to LB63.7	LB0.0 to LB63.7
Bit memory (M)	M0.0 to M31.7	M0.0 to M31.7	M0.0 to M31.7	M0.0 to M31.7
Special Memory (SM)	SM0.0 to SM179.7	SM0.0 to SM179.7	SM0.0 to SM179.7	SM0.0 to SM179.7
Read only	SM0.0 to SM29.7	SM0.0 to SM29.7	SM0.0 to SM29.7	SM0.0 to SM29.7
Timers	256 (T0 to T255)	256 (T0 to T255)	256 (T0 to T255)	256 (T0 to T255)
Retentive on-delay 1 ms	T0, T64	T0, T64	T0, T64	T0, T64
Retentive on-delay 10 ms	T1 to T4, T65 to T68	T1 to T4, T65 to T68	T1 to T4, T65 to T68	T1 to T4, T65 to T68
Retentive on-delay 100 ms	T5 to T31, T69 to T95	T5 to T31, T69 to T95	T5 to T31, T69 to T95	T5 to T31, T69 to T95
On/Off delay 1 ms	T32, T96	T32, T96	T32, T96	T32, T96
On/Off delay 10 ms	T33 to T36, T97 to T100	T33 to T36, T97 to T100	T33 to T36, T97 to T100	T33 to T36, T97 to T100
On/Off delay 100 ms	T37 to T63, T101 to T255	T37 to T63, T101 to T255	T37 to T63, T101 to T255	T37 to T63, T101 to T255
Counters	C0 to C255	C0 to C255	C0 to C255	C0 to C255
High-speed counter	HC0, HC3, HC4, HC5	HC0, HC3, HC4, HC5	HC0 to HC5	HC0 to HC5
Sequential control relays (S)	S0.0 to S31.7	S0.0 to S31.7	S0.0 to S31.7	S0.0 to S31.7
Accumulator registers	AC0 to AC3	AC0 to AC3	AC0 to AC3	AC0 to AC3
Jumps/Labels	0 to 255	0 to 255	0 to 255	0 to 255
Call/Subroutine	0 to 63	0 to 63	0 to 63	0 to 63
Interrupt routines	0 to 127	0 to 127	0 to 127	0 to 127
PID loops	0 to 7	0 to 7	0 to 7	0 to 7
Port	Port 0	Port 0	Port 0	Port 0, Port 1

[1] All V memory can be saved to permanent memory.
[2] LB60 to LB63 are reserved by STEP 7-Micro/WIN 32, version 3.0 or later.

Table 8-3 S7-200 CPU Operand Ranges

Access Method	CPU 221	CPU 222	CPU 224, CPU 226
Bit access (byte.bit)	V 0.0 to 2047.7 I 0.0 to 15.7 Q 0.0 to 15.7 M 0.0 to 31.7 SM 0.0 to 179.7 S 0.0 to 31.7 T 0 to 255 C 0 to 255 L 0.0 to 63.7	V 0.0 to 2047.7 I 0.0 to 15.7 Q 0.0 to 15.7 M 0.0 to 31.7 SM 0.0 to 179.7 S 0.0 to 31.7 T 0 to 255 C 0 to 255 L 0.0 to 63.7	V 0.0 to 5119.7 I 0.0 to 15.7 Q 0.0 to 15.7 M 0.0 to 31.7 SM 0.0 to 179.7 S 0.0 to 31.7 T 0 to 255 C 0 to 255 L 0.0 to 63.7
Byte access	VB 0 to 2047 IB 0 to 15 QB 0 to 15 MB 0 to 31 SMB 0 to 179 SB 0 to 31 LB 0 to 63 AC 0 to 3 Constant	VB 0 to 2047 IB 0 to 15 QB 0 to 15 MB 0 to 31 SMB 0 to 179 SB 0 to 31 LB 0 to 63 AC 0 to 3 Constant	VB 0 to 5119 IB 0 to 15 QB 0 to 15 MB 0 to 31 SMB 0 to 179 SB 0 to 31 LB 0 to 63 AC 0 to 3 Constant
Word access	VW 0 to 2046 IW 0 to 14 QW 0 to 14 MW 0 to 30 SMW 0 to 178 SW 0 to 30 T 0 to 255 C 0 to 255 LW 0 to 62 AC 0 to 3 Constant	VW 0 to 2046 IW 0 to 14 QW 0 to 14 MW 0 to 30 SMW 0 to 178 SW 0 to 30 T 0 to 255 C 0 to 255 LW 0 to 62 AC 0 to 3 AIW 0 to 30 AQW 0 to 30 Constant	VW 0 to 5118 IW 0 to14 QW 0 to 14 MW 0 to 30 SMW 0 to 178 SW 0 to 30 T 0 to 255 C 0 to 255 LW 0 to 62 AC 0 to 3 AIW 0 to 62 AQW 0 to 62 Constant
Double word access	VD 0 to 2044 ID 0 to 12 QD 0 to 12 MD 0 to 28 SMD 0 to 176 SD 0 to 28 LD 0 to 60 AC 0 to 3 HC 0, 3, 4, 5 Constant	VD 0 to 2044 ID 0 to 12 QD 0 to 12 MD 0 to 28 SMD 0 to 176 SD 0 to 28 LD 0 to 60 AC 0 to 3 HC 0, 3, 4, 5 Constant	VD 0 to 5116 ID 0 to 12 QD 0 to 12 MD 0 to 28 SMD 0 to 176 SD 0 to 28 LD 0 to 60 AC 0 to 3 HC 0 to 5 Constant

SIMATIC Instructions

9

This chapter describes the SIMATIC instruction set for the S7-200.

Chapter Overview

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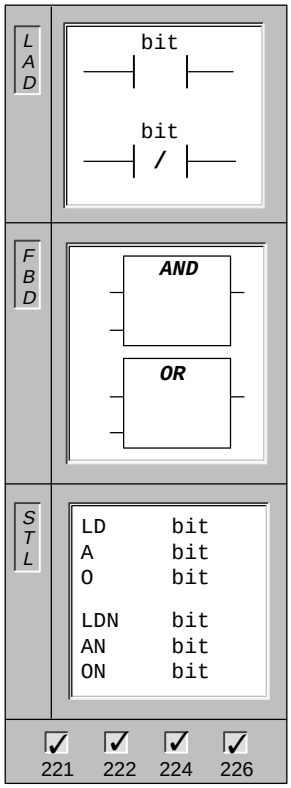
9.1 SIMATIC Bit Logic Instructions

Standard Contacts



These instructions obtain the referenced value from the memory or process-image register if the data type is I or Q. You can use a maximum of seven inputs to both the AND and the OR boxes.

The **Normally Open** contact is closed (on) when the bit is equal to 1.

The **Normally Closed** contact is closed (on) when the bit is equal to 0.

In LAD, normally open and normally closed instructions are represented by contacts.

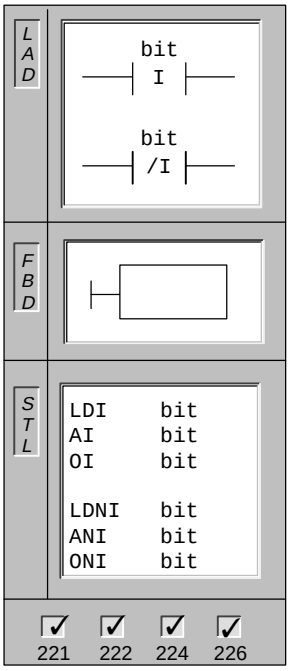
In FBD, normally open instructions are represented by AND/OR boxes. These instructions can be used to manipulate Boolean signals in the same manner as ladder contacts. Normally closed instructions are also represented by boxes. A normally closed instruction is constructed by placing the negation symbol on the stem of the input signal. Inputs to both the AND and OR boxes can be expanded to a maximum of seven inputs.

In STL, the Normally Open contact is represented by the **Load**, **And**, and **Or** instructions. These instructions Load, AND, or OR the bit value of the address bit to the top of the stack.

In STL, the Normally Closed contact is represented by the **Load Not**, **And Not**, and **Or Not** instructions. These instructions Load, AND, or OR the logical NOT of the bit value of the address bit to the top of the stack.

Inputs/Outputs	Operands	Data Types
bit (LAD, STL)	I, Q, M, SM, T, C, V, S, L	BOOL
Inputs (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
Output (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Immediate Contacts



The immediate instruction obtains the physical input value when the instruction is executed, but the process-image register is not updated.

The **Normally Open Immediate** contact is closed (on) when the physical input point (bit) is 1.

The **Normally Closed Immediate** contact is closed (on) when the physical input point (bit) is 0.

In LAD, normally open and normally closed immediate instructions are represented by contacts.

In FBD, normally open immediate instructions are represented by the immediate indicator in front of the operand tic. The immediate indicator may not be present when power flow is used. The instruction can be used to manipulate physical signals in the same manner as ladder contacts.

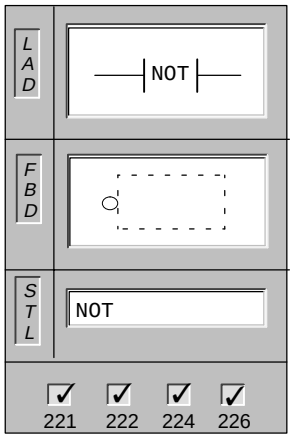
In FBD, normally closed immediate instructions are also represented by the immediate indicator and negation symbol in front of the operand tic. The immediate indicator cannot be present when power flow is used. The normally closed instruction is constructed by placing the negation symbol on the stem of the input signal.

In STL, the Normally Open Immediate contact is represented by the **Load Immediate**, **And Immediate**, and **Or Immediate** instructions. These instructions Load, AND, or OR the physical input value to the top of the stack immediately.

In STL, the Normally Closed Immediate contact is represented by the **Load Not Immediate**, **And Not Immediate**, and **Or Not Immediate** instructions. These instructions immediately Load, AND, or OR the logical NOT of the value of the physical input point to the top of the stack.

Inputs/Outputs	Operands	Data Types
bit (LAD, STL)	I	BOOL
Input (FBD)	I	BOOL

Not



The **NOT** contact changes the state of power flow input. When power flow reaches the Not contact, it stops. When power flow does not reach the Not contact, it supplies power flow.

In LAD, the **NOT** instruction is shown as a contact.

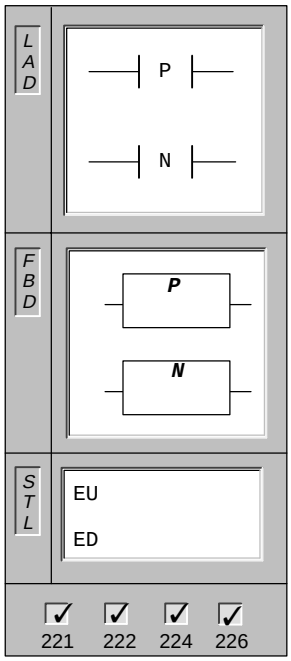
In FBD, the **NOT** instruction uses the graphical negation symbol with Boolean box inputs.

In STL, the **NOT** instruction changes the value on the top of the stack from 0 to 1, or from 1 to 0.

Operands: None

Data Types: None

Positive, Negative Transition



The **Positive Transition** contact allows power to flow for one scan for each off-to-on transition.

The **Negative Transition** contact allows power to flow for one scan for each on-to-off transition.

In LAD, the Positive and Negative Transition instructions are represented by contacts.

In FBD, the instructions are represented by the P and N boxes.

In STL, the Positive Transition contact is represented by the **Edge Up** instruction. Upon detection of a 0-to-1 transition in the value on the top of the stack, the top of the stack value is set to 1; otherwise, it is set to 0.

In STL, the Negative Transition contact is represented by the **Edge Down** instruction. Upon detection of a 1-to-0 transition in the value on the top of the stack, the top of the stack value is set to 1; otherwise, it is set to 0.

Inputs/Outputs	Operands	Data Types
IN (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
OUT (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Contact Examples

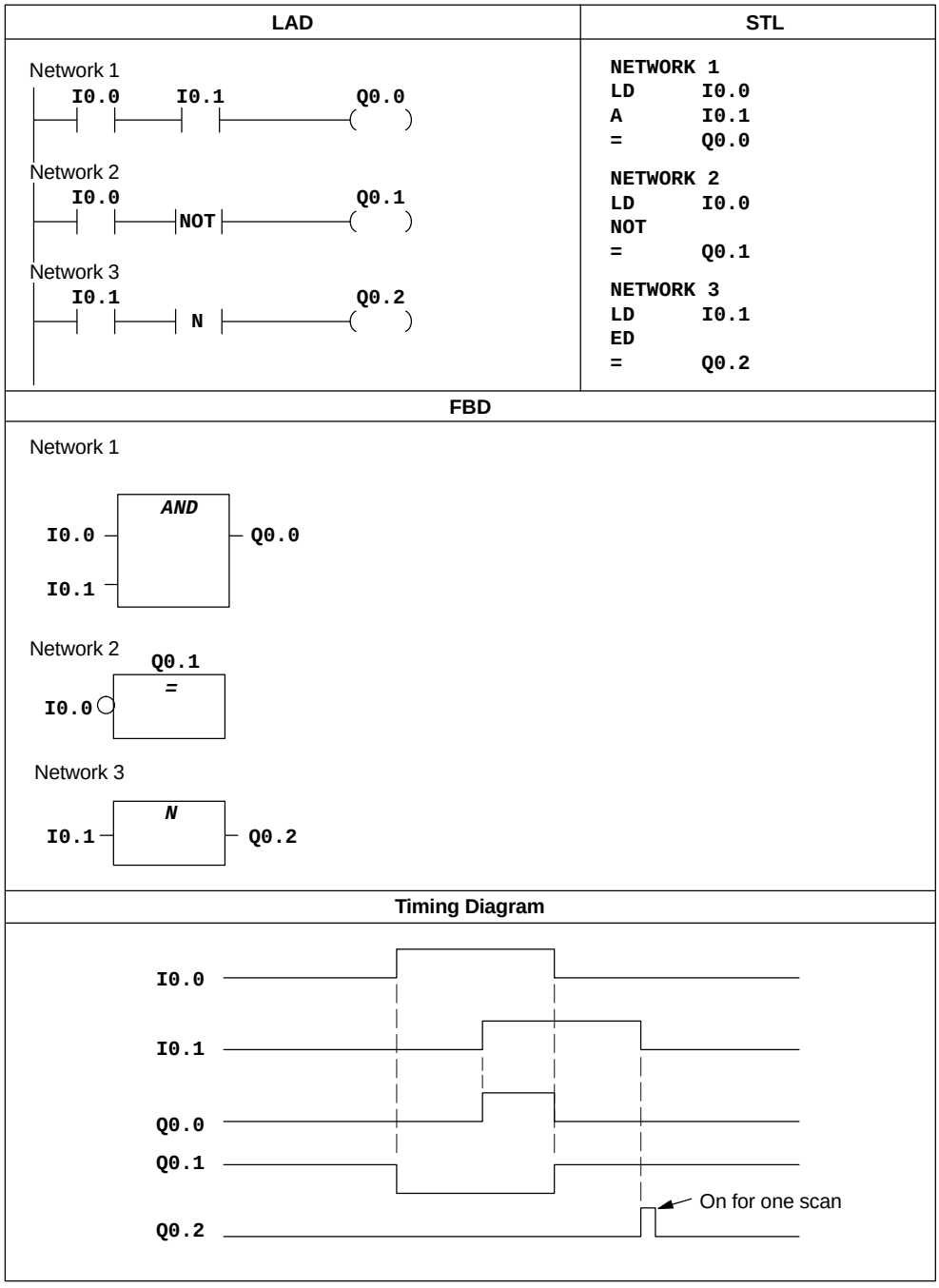
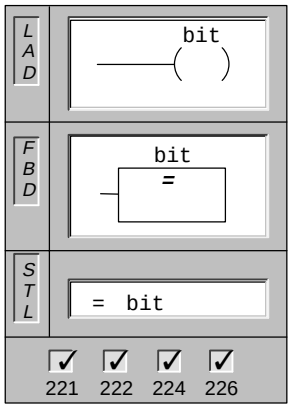


Figure 9-1 Examples of Boolean Contact Instructions for SIMATIC LAD, STL, and FBD

Output



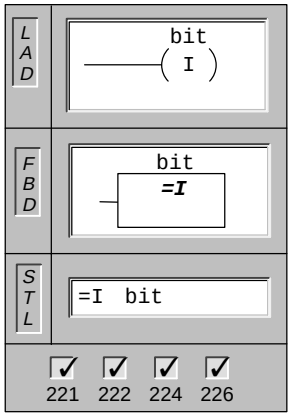
When the **Output** instruction is executed, the output bit in the process image register is turned on.

In LAD and FBD, when the output instruction is executed, the specified bit is set to equal to power flow.

In STL, the output instruction copies the top of the stack to the specified bit.

Inputs/Outputs	Operands	Data Types
bit	I, Q, M, SM, T, C, V, S, L	BOOL
Input (LAD)	Power Flow	BOOL
Input (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Output Immediate



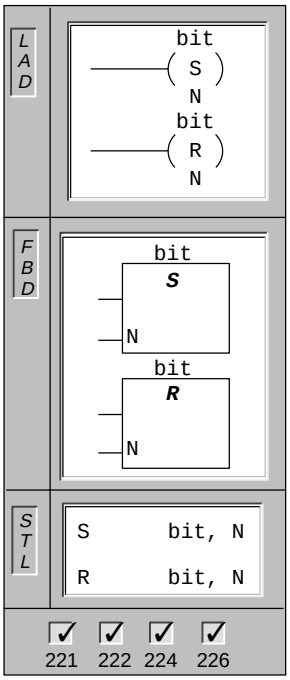
When the **Output Immediate** instruction is executed, the physical output point (bit or OUT) is set equal to power flow.

The "I" indicates an immediate reference; the new value is written to both the physical output and the corresponding process-image register location when the instruction is executed. This differs from the non-immediate references, which write the new value to the process-image register only.

In STL, the output immediate instruction copies the top of the stack to the specified physical output point (bit) immediately.

Inputs/Outputs	Operands	Data Types
bit	Q	BOOL
Input (LAD)	Power Flow	BOOL
Input (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Set, Reset (N Bits)



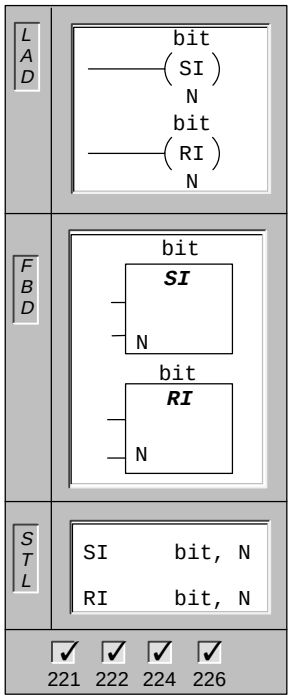
When the **Set** and **Reset** instructions are executed, the specified number of points (N) starting at the value specified by the bit or OUT parameter are set (turned on) or reset (turned off).

The range of points that can be set or reset is 1 to 255. When using the Reset instruction, if the bit is specified to be either a T- or C-bit, then either the timer or counter bit is reset and the timer/counter current value is cleared.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

Inputs/Outputs	Operands	Data Types
bit	I, Q, M, SM, T, C, V, S, L	BOOL
N	VB, IB, QB, MB, SMB, SB, LB, AC, Constant, *VD, *AC, *LD	BYTE

Set Immediate, Reset Immediate (N Bits)



When the **Set Immediate** and **Reset Immediate** instructions are executed, the specified number of physical output points (N) starting at the bit or OUT are immediately set (turned on) or immediately reset (turned off).

The range of points that can be set or reset is 1 to 128.

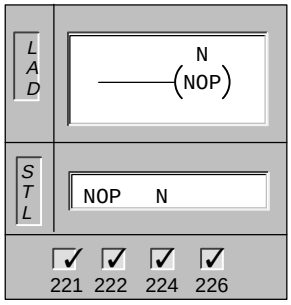
The "I" indicates an immediate reference; the new value is written to both the physical output point and the corresponding process-image register location when the instruction is executed. This differs from the non-immediate references, which write the new value to the process-image register only.

Error conditions that set ENO = 0:

SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

Inputs/Outputs	Operands	Data Types
bit	Q	BOOL
N	VB, IB, QB, MB, SMB, SB, LB, AC, Constant, *VD, *AC, *LD	BYTE

No Operation



The **No Operation** instruction has no effect on the user program execution. This instruction is not available in FBD mode. The operand N is a number from 0 to 255.

Operands: N: Constant (0 to 255)

Data Types: BYTE

Output, Set, and Reset Examples

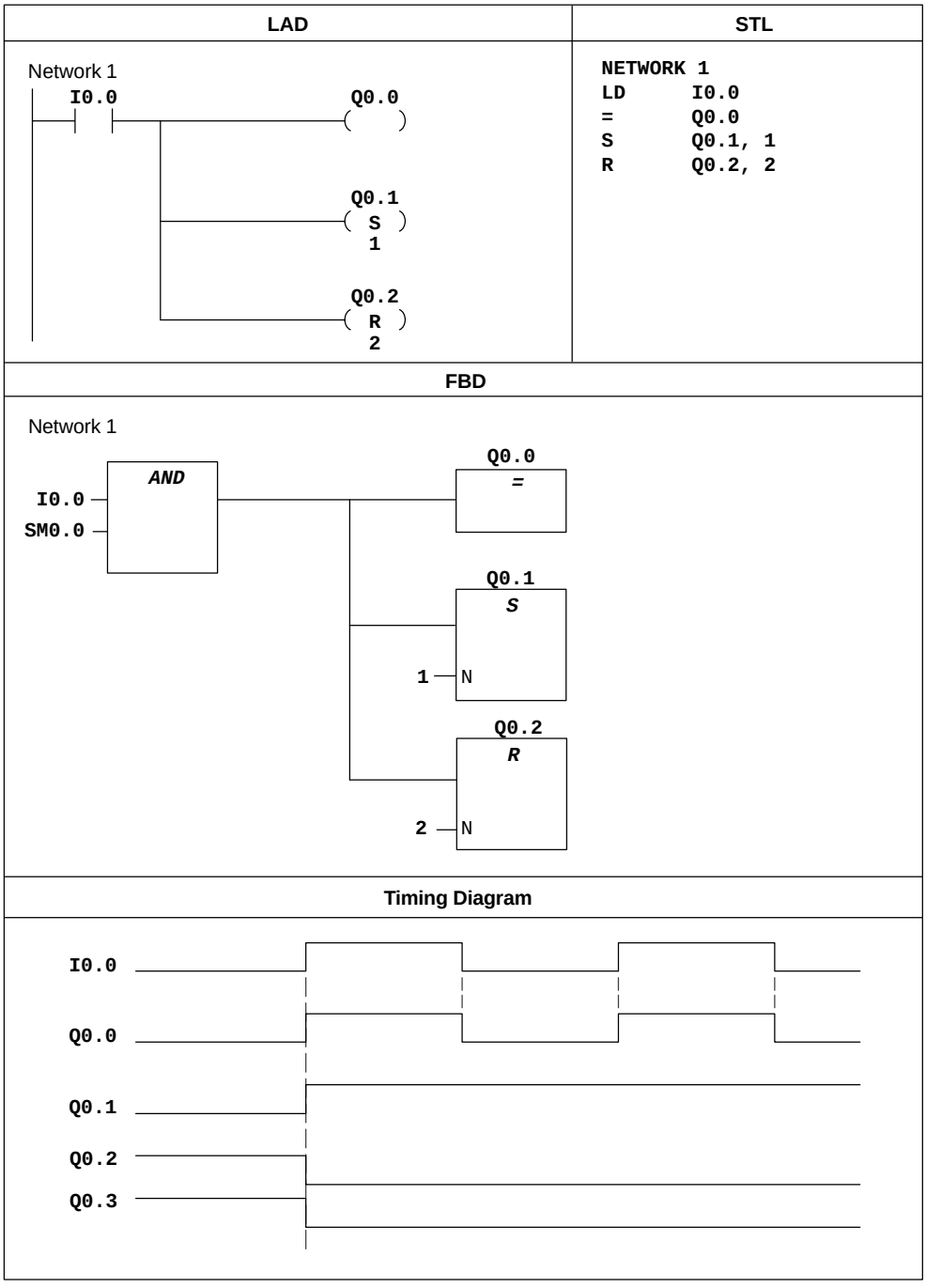
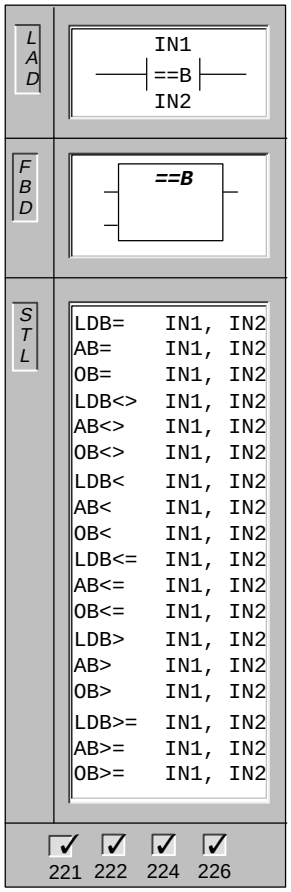


Figure 9-2 Examples of Output, Set, and Reset Instructions for SIMATIC LAD, STL, and FBD

9.2 SIMATIC Compare Instructions

Compare Byte



The **Compare Byte** instruction is used to compare two values: IN1 to IN2. Comparisons include: IN1 = IN2, IN1 >= IN2, IN1 <= IN2, IN1 > IN2, IN1 < IN2, or IN1 <> IN2.

Byte comparisons are unsigned.

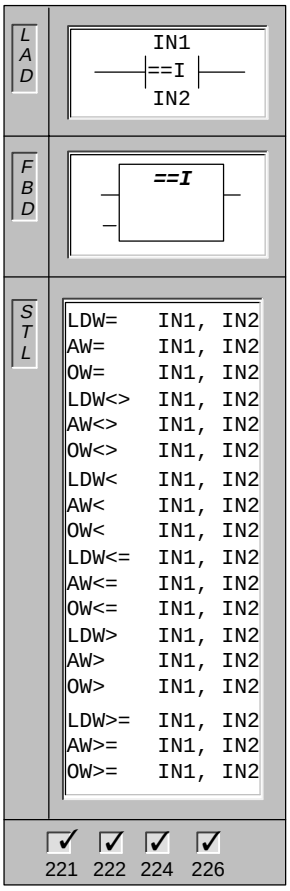
In LAD, the contact is on when the comparison is true.

In FBD, the output is on when the comparison is true.

In STL, the instructions Load, AND, or OR, a 1 with the top of stack when the comparison is true.

Inputs/Outputs	Operands	Data Types
Inputs	IB, QB, MB, SMB, VB, SB, LB, AC, Constant, *VD, *AC,*LD	BYTE
Outputs (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Compare Integer



The **Compare Integer** instruction is used to compare two values: IN1 to IN2. Comparisons include: IN1 = IN2, IN1 >= IN2, IN1 <= IN2, IN1 > IN2, IN1 < IN2, or IN1 <> IN2.

Integer comparisons are signed (16#7FFF > 16#8000).

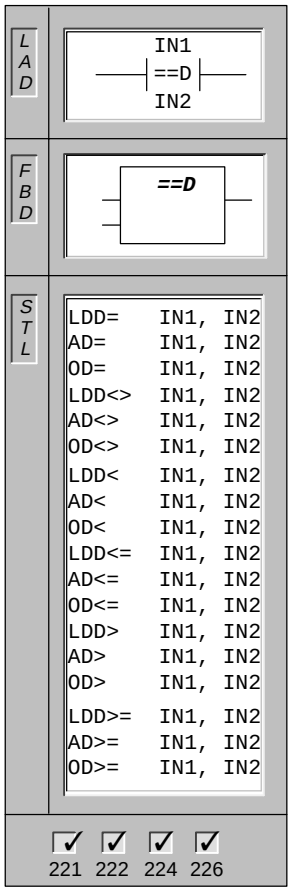
In LAD, the contact is on when the comparison is true.

In FBD, the output is on when the comparison is true.

In STL, the instructions Load, AND, or OR a 1 with the top of stack when the comparison is true.

Inputs/Outputs	Operands	Data Types
Inputs	IW, QW, MW, SW, SMW, T, C, VW, LW, AIW, AC, Constant, *VD, *AC,*LD	INT
Outputs (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Compare Double Word



The **Compare Double Word** instruction is used to compare two values: IN1 to IN2. Comparisons include: IN1 = IN2, IN1 >= IN2, IN1 <= IN2, IN1 > IN2, IN1 < IN2, or IN1 <> IN2.

Double word comparisons are signed (16#7FFFFFFF > 16#80000000).

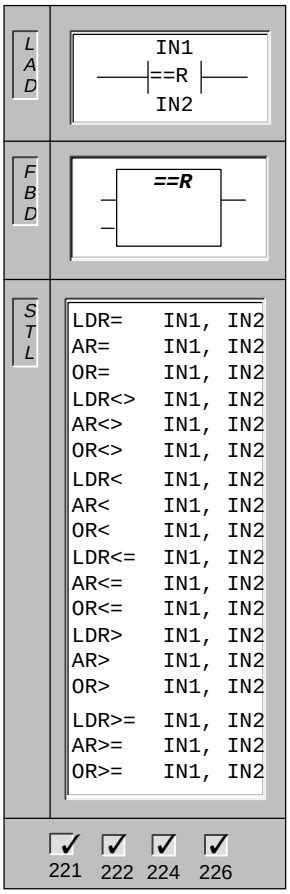
In LAD, the contact is on when the comparison is true.

In FBD, the output is on when the comparison is true.

In STL, the instructions Load, AND, or OR a 1 with the top of stack when the comparison is true.

Inputs/Outputs	Operands	Data Types
Inputs	ID, QD, MD, SD, SMD, VD, LD, HC, AC, Constant, *VD, *AC, *LD	DINT
Outputs (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Compare Real



Compare Real instruction is used to compare two values: IN1 to IN2. Comparisons include: IN1 = IN2, IN1 >= IN2, IN1 <= IN2, IN1 > IN2, IN1 < IN2, or IN1 <> IN2.

Real comparisons are signed.

In LAD, the contact is on when the comparison is true.

In FBD, the output is on when the comparison is true.

In STL, the instructions Load, AND, or OR a 1 with the top of stack when the comparison is true.

Inputs/Outputs	Operands	Data Types
Inputs	ID, QD, MD,SD, SMD, VD, LD, AC, Constant, *VD, *AC, *LD	REAL
Outputs (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Comparison Contact Examples

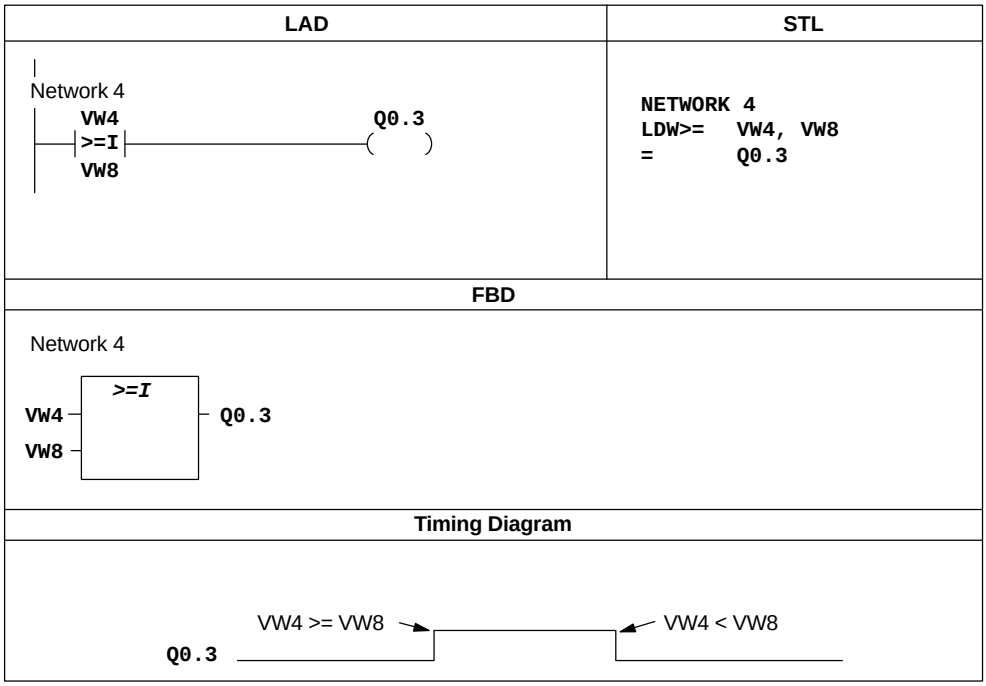
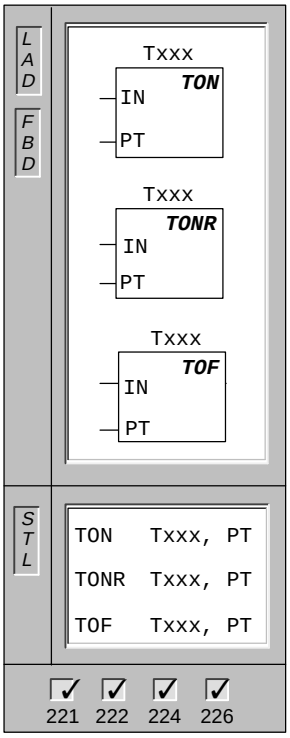


Figure 9-3 Examples of Comparison Contact Instructions for SIMATIC LAD. STL, and FBD

9.3 SIMATIC Timer Instructions

On-Delay Timer, Retentive On-Delay Timer, Off-Delay Timer



The **On-Delay Timer** and **Retentive On-Delay Timer** instructions count time when the enabling input is ON. When the current value (Txxx) is greater than or equal to the preset time (PT), the timer bit is ON.

The On-Delay timer current value is cleared when the enabling input is OFF, while the current value of the Retentive On-Delay Timer is maintained when the input is OFF. You can use the Retentive On-Delay Timer to accumulate time for multiple periods of the input ON. A Reset instruction (R) is used to clear the current value of the Retentive On-Delay Timer.

Both the On-Delay Timer and the Retentive On-Delay Timer continue counting after the Preset is reached, and they stop counting at the maximum value of 32767.

The **Off-Delay Timer** is used to delay turning an output OFF for a fixed period of time after the input turns OFF. When the enabling input turns ON, the timer bit turns ON immediately, and the current value is set to 0. When the input turns OFF, the timer counts until the elapsed time reaches the preset time. When the preset is reached, the timer bit turns OFF and the current value stops counting. If the input is OFF for a time shorter than the preset value, the timer bit remains ON. The TOF instruction must see an ON to OFF transition to begin counting.

If the TOF timer is inside an SCR region and the SCR region is inactive, then the current value is set to 0, the timer bit is turned OFF, and the current value does not count.

Inputs/Outputs	Operands	Data Types
Txxx	Constant	WORD
IN (LAD)	Power Flow	BOOL
IN (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
PT	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, AC, Constant, *VD, *AC, *LD	INT

TON, TONR, and TOF timers are available in three resolutions. The resolution is determined by the timer number as shown in Table 9-1. Each count of the current value is a multiple of the time base. For example, a count of 50 on a 10-ms timer represents 500 ms.

Table 9-1 Timer Numbers and Resolutions

Timer Type	Resolution in milliseconds (ms)	Maximum Value in seconds (s)	Timer Number
TONR (retentive)	1 ms	32.767 s (0.546 min.)	T0, T64
	10 ms	327.67 s (0.546 min.)	T1 to T4, T65 to T68
	100 ms	3276.7 s (0.546 min.)	T5 to T31, T69 to T95
TON, TOF (non-retentive)	1 ms	32.767 s (0.546 min.)	T32, T96
	10 ms	327.67 s (0.546 min.)	T33 to T36, T97 to T100
	100 ms	3276.7 s (0.546 min.)	T37 to T63, T101 to T255

Note

You cannot share the same timer numbers for TOF and TON. For example, you cannot have both a TON T32 and a TOF T32.

Understanding the S7-200 Timer Instructions

You can use timers to implement time-based counting functions. The S7-200 instruction set provides three types of timers as shown below. Table 9-2 shows the actions of the different timers.

- On-Delay Timer (TON) for timing a single interval
- Retentive On-Delay Timer (TONR) for accumulating a number of timed intervals
- Off-Delay Timer (TOF) for extending time past a false condition, such as cooling a motor after it is turned off

Table 9-2 Timer Actions

Timer Type	Current >= Preset	Enabling Input ON	Enabling Input OFF	Power Cycle/ First Scan
TON	Timer bit ON, Current continues counting to 32,767	Current value counts time	Timer bit OFF, Current value = 0	Timer bit OFF, Current value = 0
TONR	Timer bit ON, Current continues counting to 32,767	Current value counts time	Timer bit and current value maintain last state	Timer bit OFF, Current value may be maintained[1]
TOF	Timer bit OFF, Current = Preset, stops counting	Timer bit ON, Current value = 0	Timer counts after ON to OFF transition	Timer bit OFF, Current value = 0

[1] The retentive timer current value can be selected for retention through a power cycle. See Section 5.3 for information about memory retention for the S7-200 CPU.

Note

The Reset (R) instruction can be used to reset any timer. The Reset instruction performs the following operations:

Timer Bit = OFF
Timer Current = 0

The TONR timer can only be reset by the Reset instruction.

After a reset, TOF timers require the enabling input to make the transition from ON to OFF in order to restart.

The actions of the timers at different resolutions are explained below.

1-Millisecond Resolution

The 1-ms timers count the number of 1-ms timer intervals that have elapsed since the active 1-ms timer was enabled. The execution of the timer instruction starts the timing; however, the 1-ms timers are updated (timer bit and timer current) every millisecond asynchronous to the scan cycle. In other words, the timer bit and timer current are updated multiple times throughout any scan that is greater than 1 ms.

The timer instruction is used to turn the timer on, reset the timer, or, in the case of the TONR timer, to turn the timer off.

Since the timer can be started anywhere within a millisecond, the preset must be set to one time interval greater than the minimum desired timer interval. For example, to guarantee a timed interval of at least 56 ms using a 1-ms timer, the preset time value should be set to 57.

10-Millisecond Resolution

The 10-ms timers count the number of 10-ms timer intervals that have elapsed since the active 10-ms timer was enabled. The execution of the timer instruction starts the timing; however, the 10-ms timers are updated at the beginning of each scan cycle (in other words, the timer current and timer bit remain constant throughout the scan), by adding the accumulated number of 10-ms intervals (since the beginning of the previous scan) to the current value for the active timer.

Since the timer can be started anywhere within a 10-ms interval, the preset must be set to one time interval greater than the minimum desired timer interval. For example, to guarantee a timed interval of at least 140 ms using a 10-ms timer, the preset time value should be set to 15.

100-Millisecond Resolution

The 100-ms timers count the number of 100-ms timer intervals that have elapsed since the active 100-ms timer was last updated. These timers are updated by adding the accumulated number of 100-ms intervals (since the previous scan cycle) to the timer's current value when the timer instruction is executed.

The current value of a 100-ms timer is updated only if the timer instruction is executed. Consequently, if a 100-ms timer is enabled but the timer instruction is not executed each scan cycle, the current value for that timer is not updated and it loses time. Likewise, if the same 100-ms timer instruction is executed multiple times in a single scan cycle, the number of 100-ms intervals are added to the timer's current value multiple times, and it gains time. 100-ms timers should only be used where the timer instruction is executed exactly once per scan cycle.

Since the timer can be started anywhere within a 100-ms interval, the preset must be set to one time interval greater than the minimum desired timer interval. For example, to guarantee a timed interval of at least 2100 ms using a 100-ms timer, the preset time value should be set to 22.

Updating the Timer Current Value

The effect of the various ways in which current time values are updated depends upon how the timers are used. For example, consider the timer operation shown in Figure 9-4.

- In the case where the 1-ms timer is used (1), Q0.0 is turned on for one scan whenever the timer's current value is updated after the normally closed contact T32 is executed and before the normally open contact T32 is executed.
- In the case where the 10-ms timer is used (2), Q0.0 is never turned on, because the timer bit T33 is turned on from the top of the scan to the point where the timer box is executed. Once the timer box has been executed, the timer's current value and its T-bit is set to zero. When the normally open contact T33 is executed, T33 is off and Q0.0 is turned off.
- In the case where the 100-ms timer is used (3), Q0.0 is always turned on for one scan whenever the timer's current value reaches the preset value.

By using the normally closed contact Q0.0 instead of the timer bit as the enabling input to the timer box, the output Q0.0 is guaranteed to be turned on for one scan each time the timer reaches the preset value.

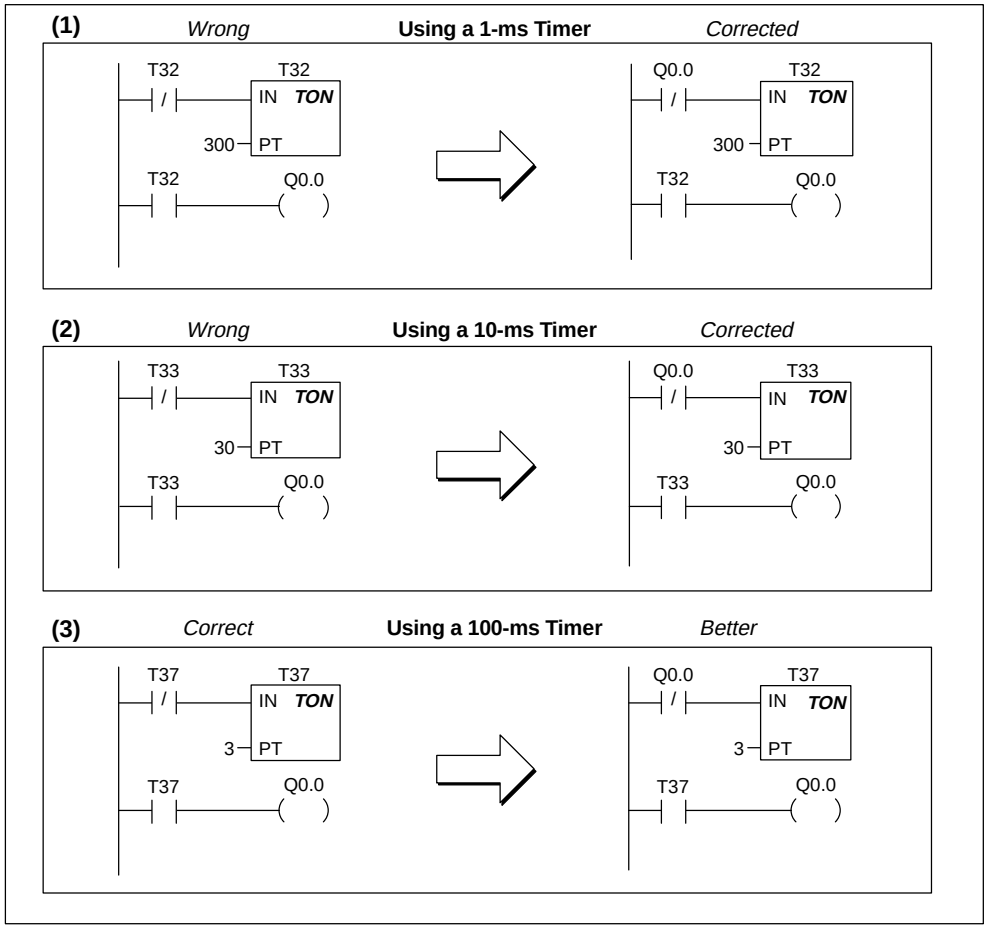


Figure 9-4 Example of Automatically Retriggered One Shot Timer

On-Delay Timer Example

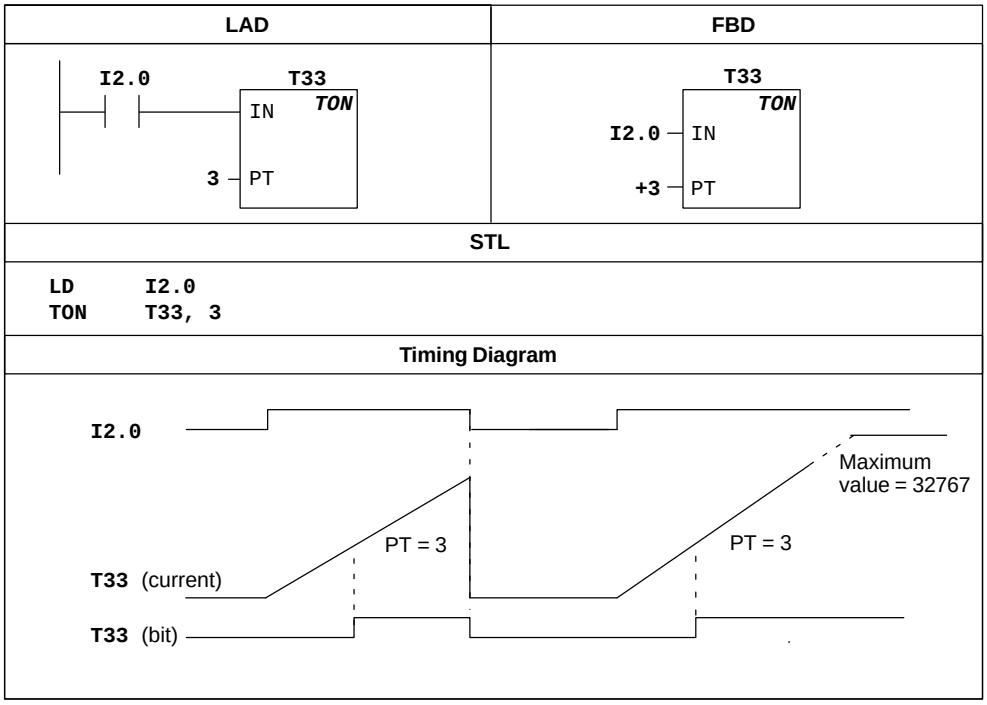


Figure 9-5 Example of On-Delay Timer Instruction for SIMATIC LAD, FBD, and STL

Retentive On-Delay Timer Example

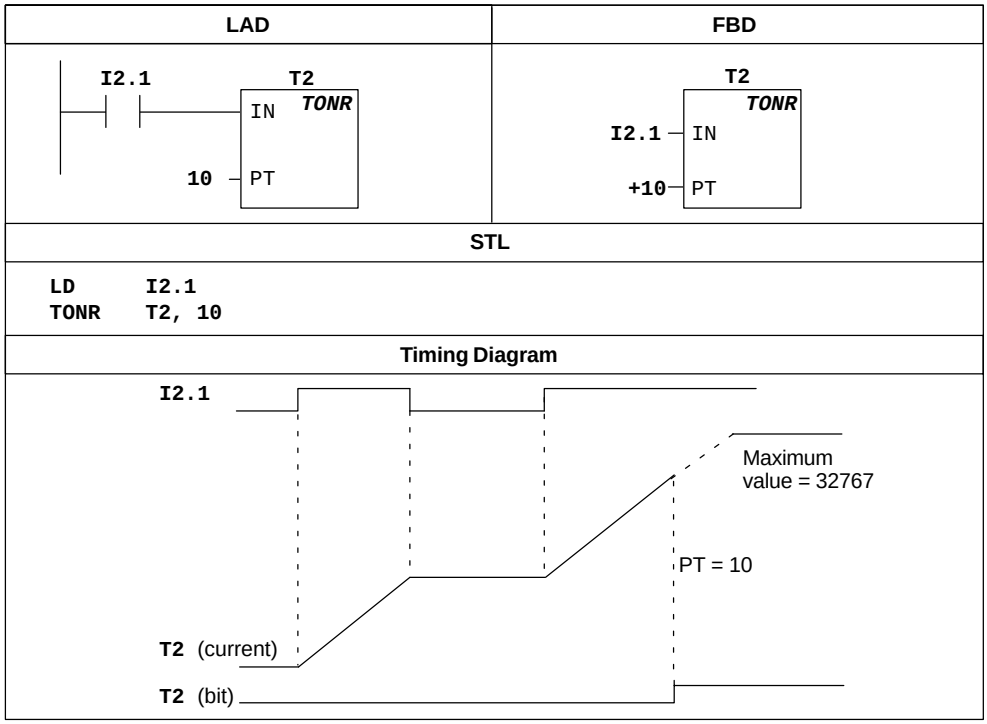


Figure 9-6 Example of Retentive On-Delay Timer Instruction for SIMATIC LAD, FBD, and STL

Off-Delay Timer Example

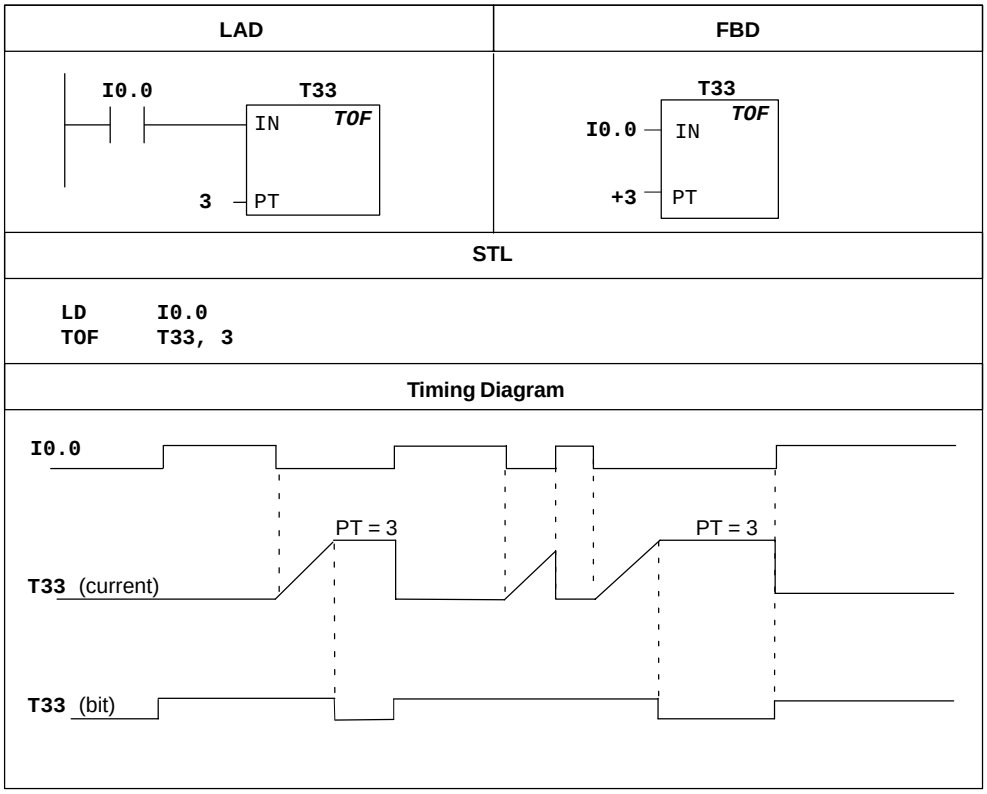
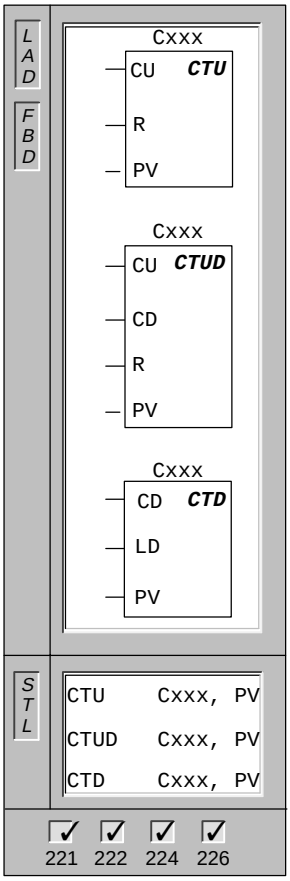


Figure 9-7 Example of Off-Delay Timer Instruction for SIMATIC LAD, FBD, and STL

9.4 SIMATIC Counter Instructions

Count Up, Count Up/Down, Count Down



The **Count Up** instruction counts up to the maximum value on the rising edges of the Count Up (CU) input. When the current value (Cxxx) is greater than or equal to the Preset Value (PV), the counter bit (Cxxx) turns on. The counter is reset when the Reset (R) input turns on. It stops counting when it reaches PV.

The **Count Up/Down** instruction counts up on rising edges of the Count Up (CU) input. It counts down on the rising edges of the Count Down (CD) input. When the current value (Cxxx) is greater than or equal to the Preset Value (PV), the counter bit (Cxxx) turns on. The counter is reset when the Reset (R) input turns on.

The **Count Down Counter** counts down from the preset value on the rising edges of the Count Down (CD) input . When the current value is equal to zero, the counter bit (Cxxx) turns on. The counter resets the counter bit (Cxxx) and loads the current value with the preset value (PV) when the load input (LD) turns on. The Down Counter stops counting when it reaches zero.

Counter ranges: Cxxx=C0 through C255

In STL, the CTU Reset input is the top of the stack value, while the Count Up input is the value loaded in the second stack location.

In STL, the CTUD Reset input is the top of the stack value, the Count Down input is the value loaded in the second stack location, and the Count Up input is the value loaded in the third stack location.

In STL, the CTD Load input is the top of stack, and the Count Down input is the value loaded in the second stack location.

Inputs/Outputs	Operands	Data Types
Cxxx	Constant	WORD
CU, CD, LD, R (LAD)	Power Flow	BOOL
CU, CD, R, LD (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
PV	VW, IW, QW, MW, SMW, LW, SW, AIW, AC, T, C, Constant, *VD, *AC, *LD	INT

Understanding the S7-200 Counter Instructions

The Up Counter (CTU) counts up from the current value of that counter each time the count-up input makes the transition from off to on. The counter is reset when the reset input turns on, or when the Reset instruction is executed. The counter stops upon reaching the maximum value (32,767).

The Up/Down Counter (CTUD) counts up each time the count-up input makes the transition from off to on, and counts down each time the count-down input makes the transition from off to on. The counter is reset when the reset input turns on, or when the Reset instruction is executed. Upon reaching maximum value (32,767), the next rising edge at the count-up input causes the current count to wrap around to the minimum value (-32,768). Likewise on reaching the minimum value (-32,768), the next rising edge at the count-down input causes the current count to wrap around to the maximum value (32,767).

The Up and Up/Down counters have a current value that maintains the current count. They also have a preset value (PV) that is compared to the current value whenever the counter instruction is executed. When the current value is greater than or equal to the preset value, the counter bit (C-bit) turns on. Otherwise, the C-bit turns off.

The Down counter counts down from the current value of that counter each time the count down input makes the transition from off to on. The counter resets the counter bit and loads the current value with the preset value when the load input turns on. The counter stops upon reaching zero, and the counter bit (C-bit) turns on.

When you reset a counter using the Reset instruction, the counter bit is reset and the counter current value is set to zero. Use the counter number to reference both the current value and the C-bit of that counter.

Note

Since there is one current value for each counter, do not assign the same number to more than one counter. (Up Counters, Up/Down Counters, and Down counters with the same number access the same current value.)

Counter Examples

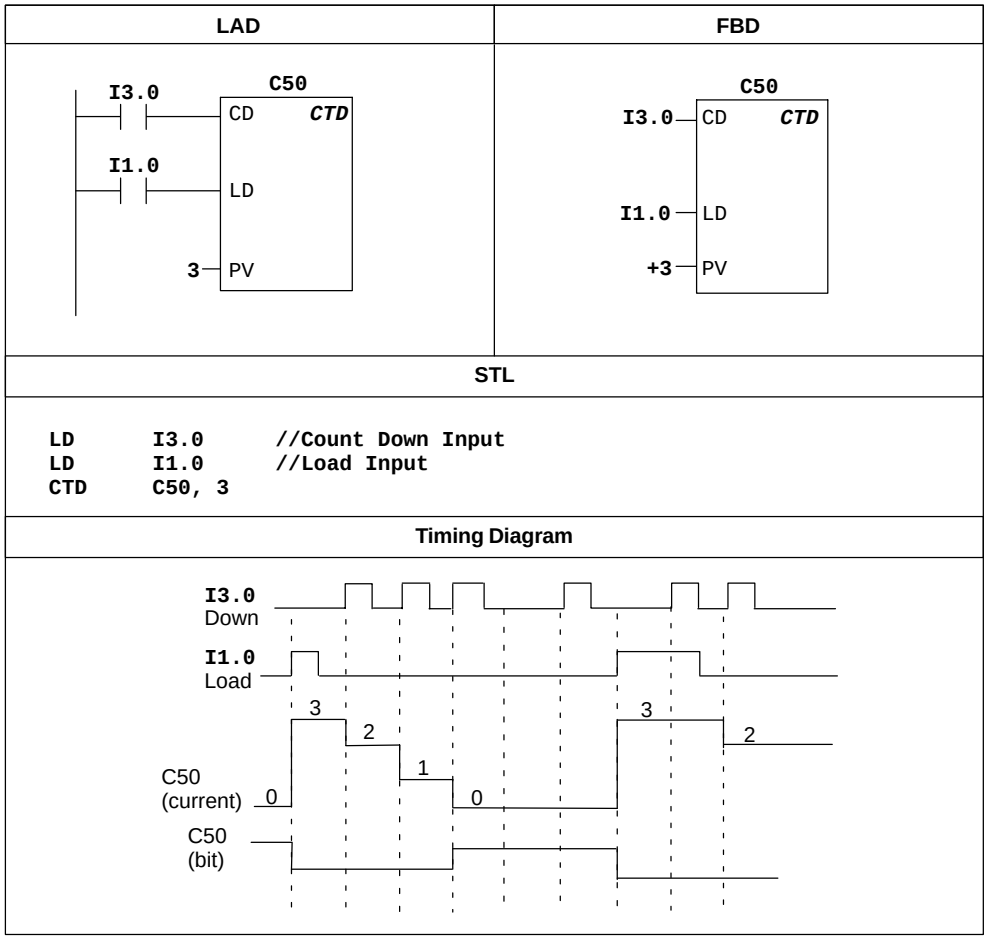


Figure 9-8 Example of CTD Counter Instruction for SIMATIC LAD, FBD, and STL

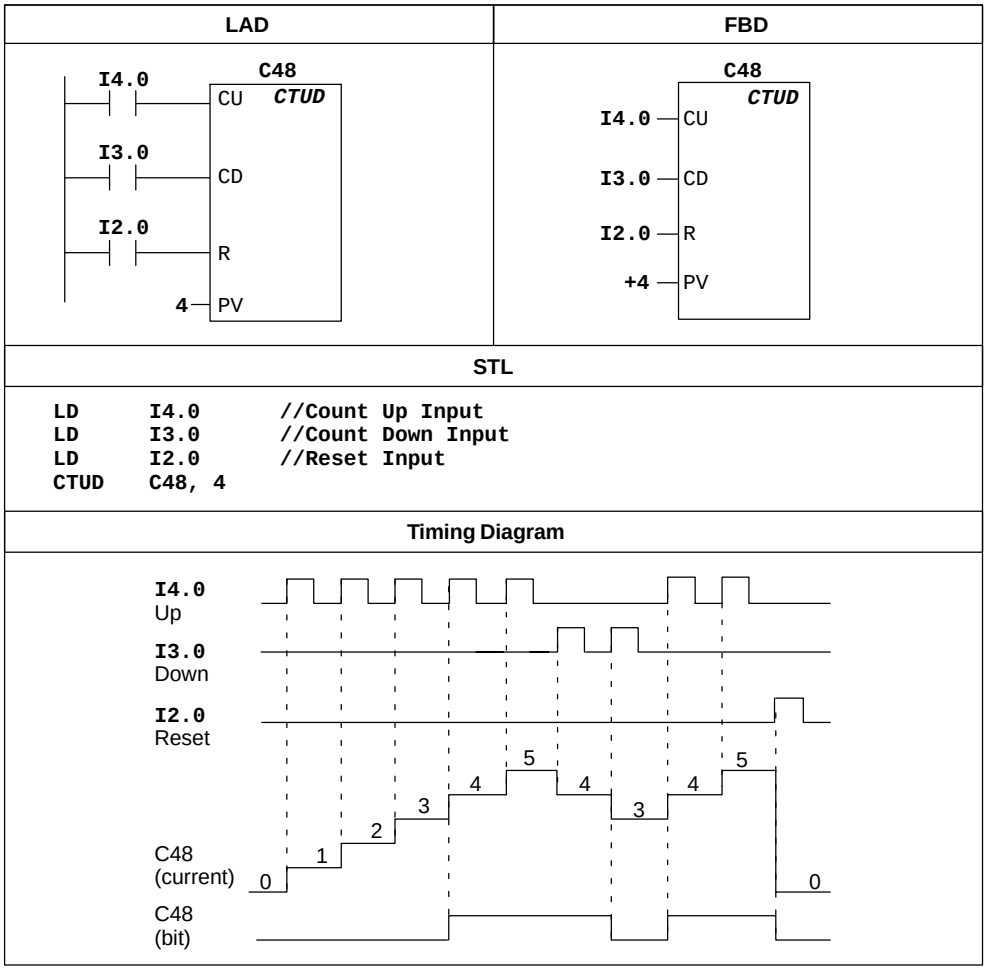
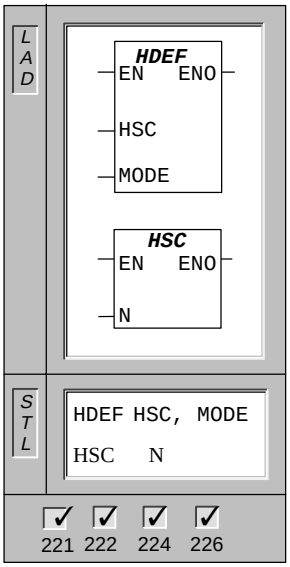


Figure 9-9 Example of CTUD Counter Instruction for SIMATIC LAD, FBD, and STL

High-Speed Counter Definition, High-Speed Counter



The **High-Speed Counter Definition** instruction assigns a MODE to the referenced high-speed counter (HSC). See Table 9-5 on page 9-33.

The **High-Speed Counter** instruction, when executed, configures and controls the operational mode of the high-speed counter, based on the state of the HSC special memory bits. The parameter N specifies the high-speed counter number.

CPU 221 and CPU 222 do not support HSC1 and HSC2.

Only one HDEF box may be used per counter.

HDEF: Error conditions that set ENO = 0:

SM4.3 (run-time), 0003 (input point conflict), 0004 (illegal instruction in interrupt), 000A (HSC redefinition)

HSC: Error conditions that set ENO = 0:

SM4.3 (run-time), 0001 (HSC before HDEF), 0005 (simultaneous HSC/PLS)

Inputs/Outputs	Operands	Data Types
HSC	Constant	BYTE
MODE	Constant	BYTE
N	Constant	WORD

Understanding the High-Speed Counter Instructions

High-speed counters count high-speed events that cannot be controlled at CPU scan rates, and can be configured for up to twelve different modes of operation. The counter modes are listed in Table 9-5. The maximum counting frequency of a high-speed counter is dependent upon your CPU type. See Appendix A for more information about your CPU.

Each counter has dedicated inputs for clocks, direction control, reset, and start, where these functions are supported. For the two-phase counters, both clocks may run at their maximum rates. In quadrature modes, an option is provided to select one times (1x) or four times (4x) the maximum counting rates. All counters run at maximum rates without interfering with one another.

Using the High-Speed Counter

Typically, a high-speed counter is used as the drive for a drum timer, where a shaft rotating at a constant speed is fitted with an incremental shaft encoder. The shaft encoder provides a specified number of counts per revolution and a reset pulse that occurs once per revolution. The clock(s) and the reset pulse from the shaft encoder provide the inputs to the high-speed counter. The high-speed counter is loaded with the first of several presets, and the desired outputs are activated for the time period where the current count is less than the current preset. The counter is set up to provide an interrupt when the current count is equal to preset and also when reset occurs.

As each current-count-value-equals-preset-value interrupt event occurs, a new preset is loaded and the next state for the outputs is set. When the reset interrupt event occurs, the first preset and the first output states are set, and the cycle is repeated.

Since the interrupts occur at a much lower rate than the counting rates of the high-speed counters, precise control of high-speed operations can be implemented with relatively minor impact to the overall scan cycle of the programmable logic controller. The method of interrupt attachment allows each load of a new preset to be performed in a separate interrupt routine for easy state control, making the program very straightforward and easy to follow. Of course, all interrupt events can be processed in a single interrupt routine. For more information about the interrupt instructions, see Section 9.15.

Understanding the Detailed Timing for the High-Speed Counters

The following timing diagrams (Figure 9-10 through Figure 9-16) show how each counter functions according to mode. The operation of the reset and start inputs is shown in a separate timing diagram and applies to all modes that use reset and start inputs. In the diagrams for the reset and start inputs, both reset and start are shown with the active state programmed to a high level.

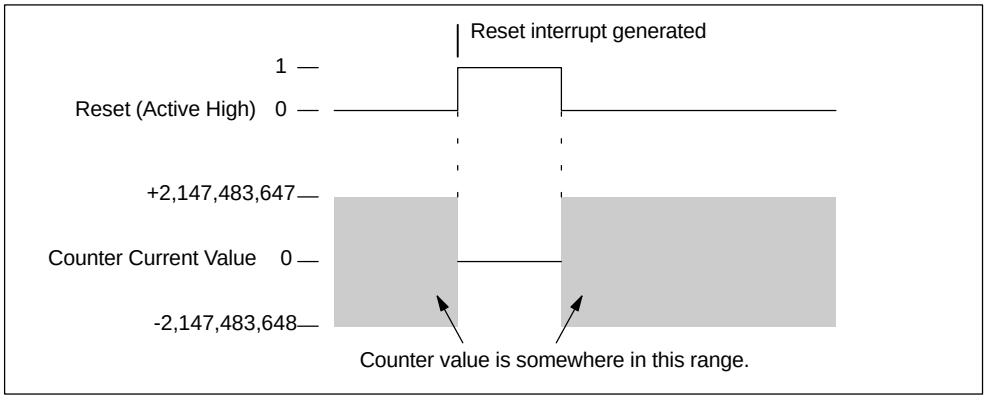


Figure 9-10 Operation Example with Reset and without Start

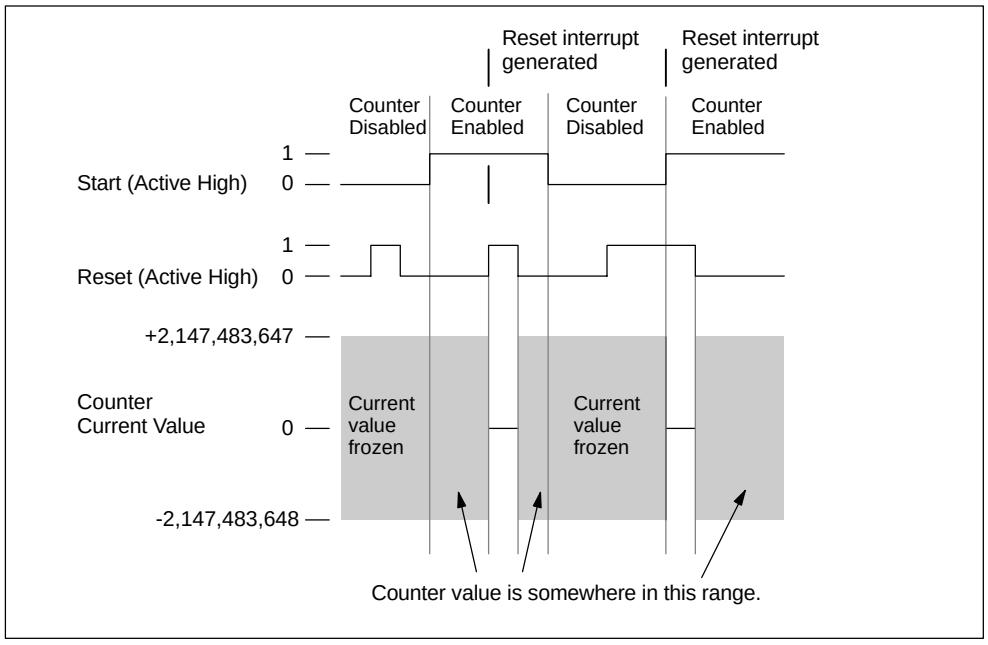


Figure 9-11 Operation Example with Reset and Start

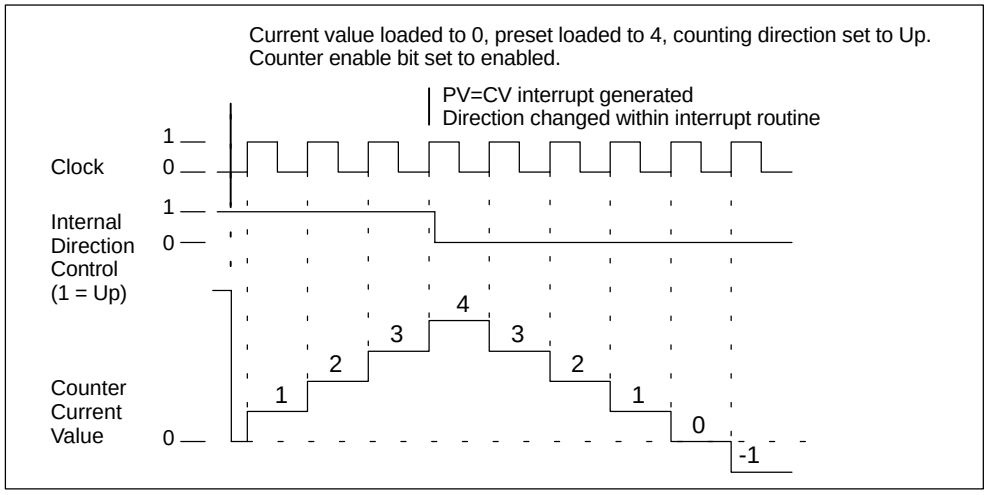


Figure 9-12 Operation Example of Modes 0, 1, or 2

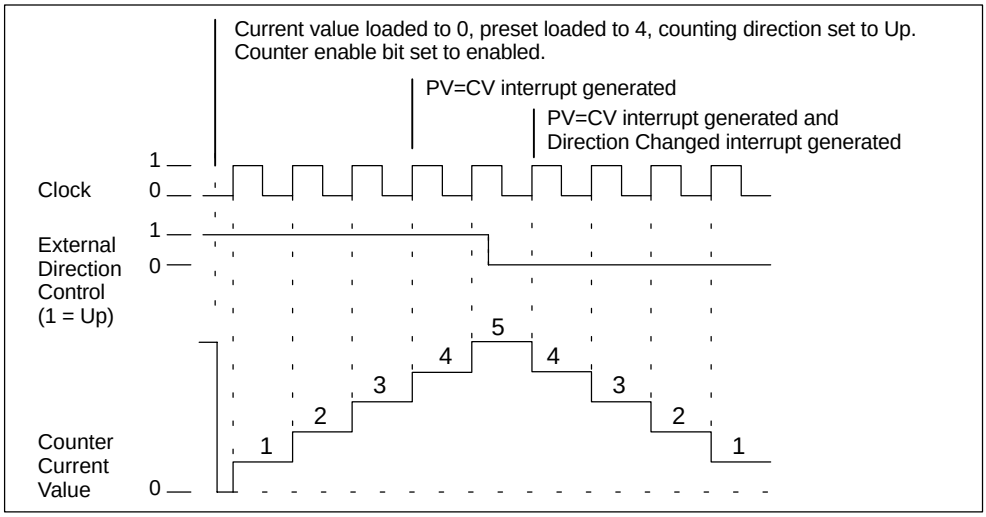


Figure 9-13 Operation Example of Modes 3, 4, or 5

When you use counting modes 6, 7, or 8 and a rising edge on both the up clock and down clock inputs occurs within 0.3 microseconds of each other, the high-speed counter may see these events as happening simultaneously. If this happens, the current value is unchanged and no change in counting direction is indicated. As long as the separation between rising edges of the up and down clock inputs is greater than this time period, the high-speed counter captures each event separately. In either case, no error is generated and the counter maintains the correct count value. See Figure 9-14, Figure 9-15, and Figure 9-16.

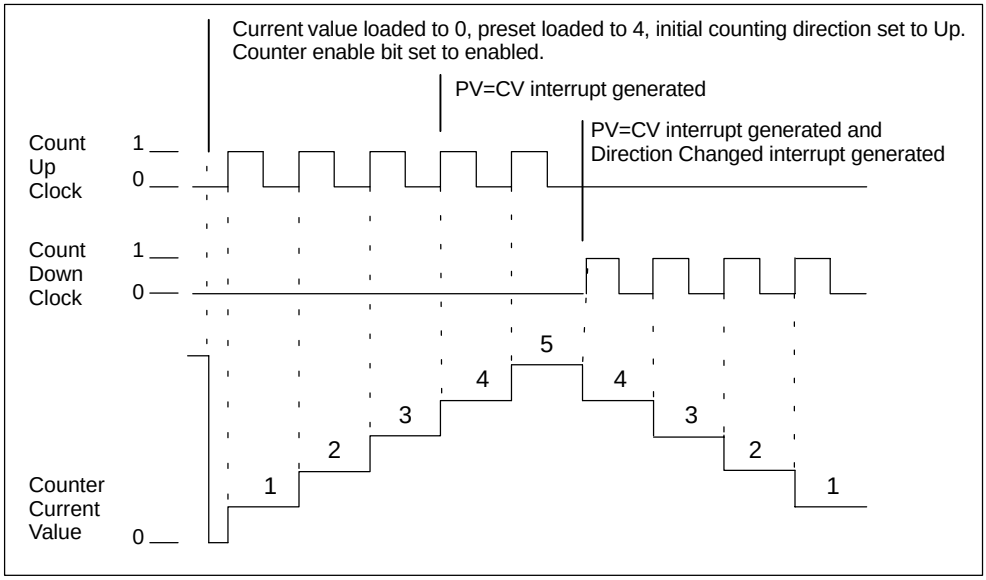


Figure 9-14 Operation Example of Modes 6, 7, or 8

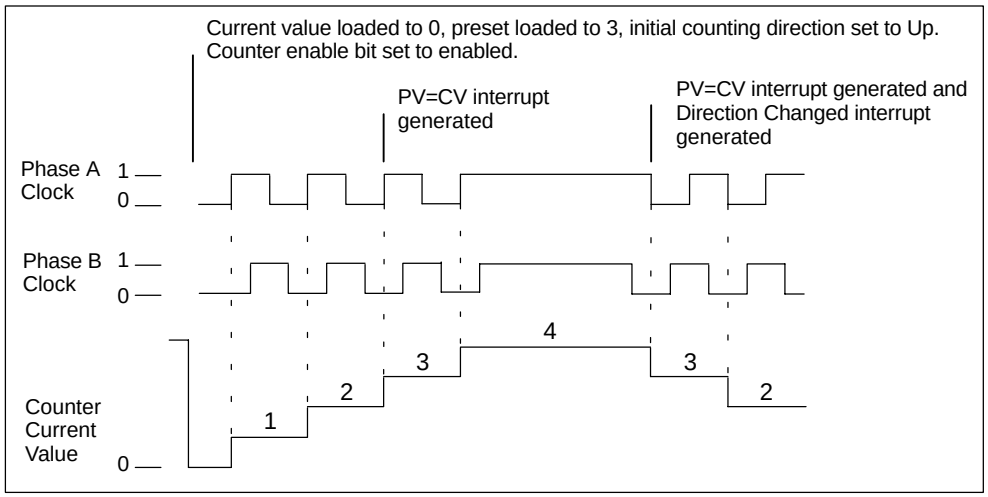


Figure 9-15 Operation Example of Modes 9, 10, or 11 (Quadrature 1x Mode)

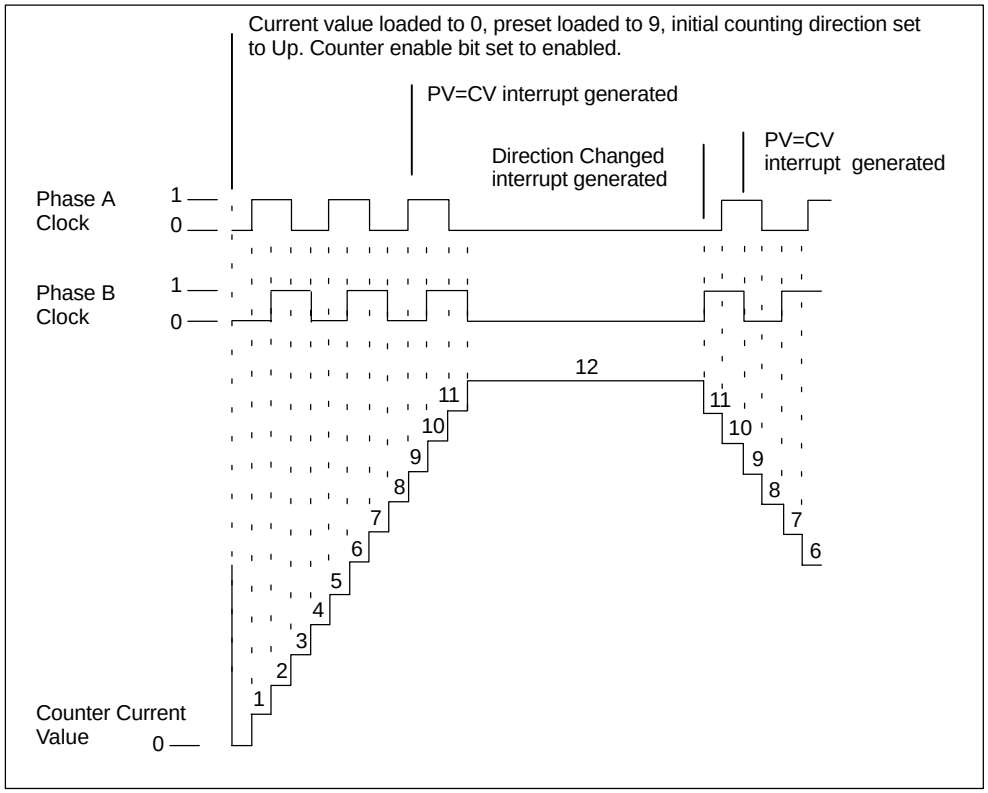


Figure 9-16 Operation Example of Modes 9, 10, or 11 (Quadrature 4x Mode)

Connecting the Input Wiring for the High-Speed Counters

Table 9-3 shows the inputs used for the clock, direction control, reset, and start functions associated with the high-speed counters. These input functions and the HSC modes of operation are described in Table 9-5 through Table 9-10.

Table 9-3 Dedicated Inputs for High-Speed Counters

High-Speed Counter	Inputs Used
HSC0	I0.0, I0.1, 0.2
HSC1	I0.6, I0.7, I1.0, I1.1
HSC2	I1.2, I1.3, I1.4, I1.5
HSC3	I0.1
HSC4	I0.3, I0.4, I0.5
HSC5	I0.4

There is some overlap in the input point assignments for some high-speed counters and edge interrupts, as shown in the shaded area of Table 9-4. The same input cannot be used for two different functions, however, any input not being used by the present mode of its high-speed counter can be used for another purpose. For example, if HSC0 is being used in mode 2 which uses I0.0 and I0.2, I0.1 can be used for edge interrupts or for HSC3.

If a mode of HSC0 is used that does not use input I0.1, then this input is available for use as either HSC3 or edge interrupts. Similarly, if I0.2 is not used in the selected HSC0 mode, this input is available for edge interrupts; and if I0.4 is not used in the selected HSC4 mode, this input is available for HSC5. Note that all modes of HSC0 always use I0.0 and all modes of HSC4 always use I0.3, so these points are never available for other uses when these counters are in use.

Table 9-4 Input Point Assignments for High-Speed Counters and Edge Interrupts

	Input Point (I)													
Element	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**
HSC0	x	x	x											
HSC1							x	x	x	x				
HSC2											x	x	x	x
HSC3		x												
HSC4				x	x	x								
HSC5					x									
Edge Interrupts	x	x	x	x										

Table 9-5 HSC0 Modes of Operation (CPU 221, CPU 222, CPU 224, and CPU 226)

HSC0					
Mode	**Description**	**I0.0**	**I0.1**	**I0.2**	
0	Single phase up/down counter with internal direction control SM37.3 = 0, count down SM37.3 = 1, count up	Clock			
1				Reset	
3	Single phase up/down counter with external direction control I0.1 = 0, count down I0.1 = 1, count up	Clock	Dir.		
4				Reset	
6	Two-phase counter with count up and count down clock inputs	Clock (Up)	Clock (Dn)		
7				Reset	
9	A/B phase quadrature counter, phase A leads B by 90 degrees for clockwise rotation, phase B leads A by 90 degrees for counterclockwise rotation	Clock Phase A	Clock Phase B		
10				Reset	

Table 9-6 HSC1 Modes of Operation (CPU 224 and CPU 226)

HSC1					
Mode	**Description**	**I0.6**	**I0.7**	**I1.0**	**I1.1**
0	Single phase up/down counter with internal direction control SM47.3 = 0, count down SM47.3 = 1, count up	Clock			
1				Reset	
2					Start
3	Single phase up/down counter with external direction control I0.7 = 0, count down I0.7 = 1, count up	Clock	Dir.		
4				Reset	
5					Start
6	Two-phase counter with count up and count down clock inputs	Clock (Up)	Clock (Dn)		
7				Reset	
8					Start
9	A/B phase quadrature counter, phase A leads B by 90 degrees for clockwise rotation, phase B leads A by 90 degrees for counterclockwise rotation	Clock Phase A	Clock Phase B		
10				Reset	
11					Start

Table 9-7 HSC2 Modes of Operation (CPU 224 and CPU 226)

HSC2					
Mode	**Description**	**I1.2**	**I1.3**	**I1.4**	**I1.5**
0	Single phase up/down counter with internal direction control SM57.3 = 0, count down SM57.3 = 1, count up	Clock			
1				Reset	
2					Start
3	Single phase up/down counter with external direction control I1.3 = 0, count down I1.3 = 1, count up	Clock	Dir.		
4				Reset	
5					Start
6	Two-phase counter with count up and count down clock inputs	Clock (Up)	Clock (Dn)		
7				Reset	
8					Start
9	A/B phase quadrature counter, phase A leads B by 90 degrees for clockwise rotation, phase B leads A by 90 degrees for counterclockwise rotation	Clock Phase A	Clock Phase B		
10				Reset	
11					Start

Table 9-8 HSC3 Modes of Operation (CPU 221, CPU 222, CPU 224, and CPU 226)

HSC3					
Mode	**Description**	**I0.1**			
0	Single phase up/down counter with internal direction control SM137.3 = 0, count down SM137.3 = 1, count up	Clock			

Table 9-9 HSC4 Modes of Operation (CPU 221, CPU 222, CPU 224, and CPU 226)

HSC4					
Mode	**Description**	**I0.3**	**I0.4**	**I0.5**	
0	Single phase up/down counter with internal direction control SM147.3 = 0, count down SM147.3 = 1, count up	Clock			
1				Reset	
3	Single phase up/down counter with external direction control I0.4 = 0, count down I0.4 = 1, count up	Clock	Dir.		
4				Reset	
6	Two-phase counter with count up and count down clock inputs	Clock (Up)	Clock (Dn)		
7				Reset	
9	A/B phase quadrature counter, phase A leads B by 90 degrees for clockwise rotation, phase B leads A by 90 degrees for counterclockwise rotation	Clock Phase A	Clock Phase B		
10				Reset	

Table 9-10 HSC5 Modes of Operation (CPU 221, CPU 222, CPU 224, and CPU 226)

HSC5					
Mode	**Description**	**I0.4**			
0	Single phase up/down counter with internal direction control SM157.3 = 0, count down SM157.3 = 1, count up	Clock			

Addressing the High-Speed Counters (HC)

To access the count value for the high-speed counter, you specify the address of the high-speed counter, using the memory type (HC) and the counter number (such as HC0). The current value of the high-speed counter is a read-only value and can be addressed only as a double word (32 bits), as shown in Figure 9-17.

Format: **HC*[high-speed counter number]*** **HC2**

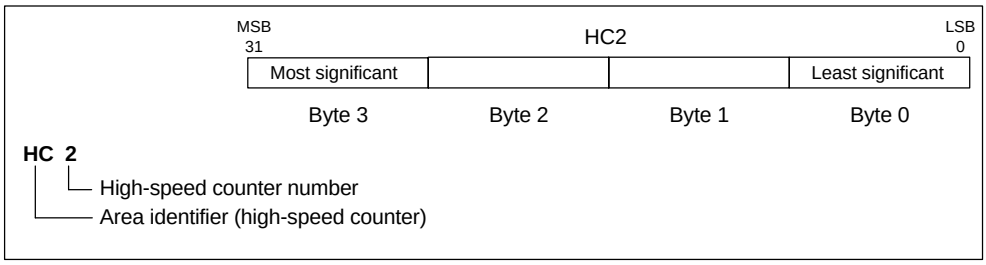


Figure 9-17 Accessing the High-Speed Counter Current Values

Understanding the Different High-Speed Counters

All counters function the same way for the same counter mode of operation. There are four basic types of counter modes as shown in Table 9-5. Note that every mode is not supported by every counter. You can use each type: without reset or start inputs, with reset and without start, or with both start and reset inputs.

When you activate the reset input, it clears the current value and holds it cleared until you de-activate reset. When you activate the start input, it allows the counter to count. While start is de-activated, the current value of the counter is held constant and clocking events are ignored. If reset is activated while start is inactive, the reset is ignored and the current value is not changed. If the start input becomes active while the reset input is active, the current value is cleared.

You must select the counter mode before a high-speed counter can be used. You can do this with the HDEF instruction (High-Speed Counter Definition). HDEF provides the association between a high-speed counter (HSCx) and a counter mode. You can only use one HDEF instruction for each high-speed counter. Define a high-speed counter by using the first scan memory bit, SM0.1 (this bit is turned on for the first scan and is then turned off), to call a subroutine that contains the HDEF instruction.

Selecting the Active State and 1x/4x Mode

Four counters have three control bits that are used to configure the active state of the reset and start inputs and to select 1x or 4x counting modes (quadrature counters only). These bits are located in the control byte for the respective counter and are only used when the HDEF instruction is executed. These bits are defined in Table 9-11.

You must set these control bits to the desired state before the HDEF instruction is executed. Otherwise, the counter takes on the default configuration for the counter mode selected. The default setting of the reset input and the start input are active high, and the quadrature counting rate is 4x (or four times the input clock frequency). Once the HDEF instruction has been executed, you cannot change the counter setup unless you first place the CPU in the STOP mode.

Table 9-11 Active Level for Reset, Start, and 1x/4x Control Bits

HSC0	HSC1	HSC2	HSC4	Description (used only when HDEF is executed)
SM37.0	SM47.0	SM57.0	SM147.0	Active level control bit for Reset: 0 = Reset is active high; 1 = Reset is active low
--	SM47.1	SM57.1	--	Active level control bit for Start: 0 = Start is active high; 1 = Start is active low
SM37.2	SM47.2	SM57.2	SM147.2	Counting rate selection for Quadrature counters: 0 = 4X counting rate; 1 = 1X counting rate

Control Byte

Once you have defined the counter and the counter mode, you can program the dynamic parameters of the counter. Each high-speed counter has a control byte that allows the counter to be enabled or disabled; the direction to be controlled (modes 0, 1, and 2 only), or the initial counting direction for all other modes; the current value to be loaded; and the preset value to be loaded. Examination of the control byte and associated current and preset values is invoked by the execution of the HSC instruction. Table 9-12 describes each of these control bits.

Table 9-12 Control Bits for HSC0, HSC1, and HSC2

HSC0	HSC1	HSC2	HSC3	HSC4	HSC5	Description
SM37.3	SM47.3	SM57.3	SM137.3	SM147.3	SM157.3	Counting direction control bit: 0 = count down; 1 = count up
SM37.4	SM47.4	SM57.4	SM137.4	SM147.4	SM157.4	Write the counting direction to the HSC: 0 = no update; 1 = update direction
SM37.5	SM47.5	SM57.5	SM137.5	SM147.5	SM157.5	Write the new preset value to the HSC: 0 = no update; 1 = update preset
SM37.6	SM47.6	SM57.6	SM137.6	SM147.6	SM157.6	Write the new current value to the HSC: 0 = no update; 1 = update current value
SM37.7	SM47.7	SM57.7	SM137.7	SM147.7	SM157.7	Enable the HSC: 0 = disable the HSC; 1 = enable the HSC

Setting Current Values and Preset Values

Each high-speed counter has a 32-bit current value and a 32-bit preset value. Both the current and the preset values are signed integer values. To load a new current or preset value into the high-speed counter, you must set up the control byte and the special memory bytes that hold the current and/or preset values. You must then execute the HSC instruction to cause the new values to be transferred to the high-speed counter. Table 9-13 describes the special memory bytes used to hold the new current and preset values.

In addition to the control bytes and the new preset and current holding bytes, the current value of each high-speed counter can be read using the data type HC (High-Speed Counter Current) followed by the number (0, 1, 2, 3, 4, or 5) of the counter. Thus, the current value is directly accessible for read operations, but can only be written with the HSC instruction described above.

Table 9-13 Current and Preset Values of HSC0, HSC1, HSC2, HSC3, HSC4, and HSC5

Value to be Loaded	HSC0	HSC1	HSC2	HSC3	HSC4	HSC5
New current	SMD38	SMD48	SMD58	SMD138	SMD148	SMD158
New preset	SMD42	SMD52	SMD62	SMD142	SMD152	SMD162

Status Byte

A status byte is provided for each high-speed counter that provides status memory bits that indicate the current counting direction, and whether the current value is greater or equal to the preset value. Table 9-14 defines these status bits for each high-speed counter.

Table 9-14 Status Bits for HSC0, HSC1, HSC2, HSC3, HSC4, and HSC5

HSC0	HSC1	HSC2	HSC3	HSC4	HSC5	Description
SM36.0	SM46.0	SM56.0	SM136.0	SM146.0	SM156.0	Not used
SM36.1	SM46.1	SM56.1	SM136.1	SM146.1	SM156.1	Not used
SM36.2	SM46.2	SM56.2	SM136.2	SM146.2	SM156.2	Not used
SM36.3	SM46.3	SM56.3	SM136.3	SM146.3	SM156.3	Not used
SM36.4	SM46.4	SM56.4	SM136.4	SM146.4	SM156.4	Not used
SM36.5	SM46.5	SM56.5	SM136.5	SM146.5	SM156.5	Current counting direction status bit: 0 = counting down; 1 = counting up
SM36.6	SM46.6	SM56.6	SM136.6	SM146.6	SM156.6	Current value equals preset value status bit: 0 = not equal; 1 = equal
SM36.7	SM46.7	SM56.7	SM136.7	SM146.7	SM156.7	Current value greater than preset value status bit: 0 = less than or equal; 1 = greater than

Note

Status bits are valid only while the high-speed counter interrupt routine is being executed. The purpose of monitoring the state of the high-speed counter is to enable interrupts for the events that are of consequence to the operation being performed.

HSC Interrupts

All counter modes support an interrupt on current value equal to the preset value. Counter modes that use an external reset input support an interrupt on external reset activated. All counter modes except modes 0, 1, and 2 support an interrupt on a counting direction change. Each of these interrupt conditions may be enabled or disabled separately. For a complete discussion on the use of interrupts, see Section 9.15.

Note

When you are using the external reset interrupt, do not attempt to load a new current value or disable, then re-enable the high-speed counter from within the interrupt routine attached to that event. A fatal error condition can result.

To help you understand the operation of high-speed counters, the following descriptions of the initialization and operation sequences are provided. HSC1 is used as the model counter throughout these sequence descriptions. The initialization descriptions make the assumption that the S7-200 has just been placed in the RUN mode, and for that reason, the first scan memory bit is true. If this is not the case, remember that the HDEF instruction can be executed only one time for each high-speed counter after entering RUN mode. Executing HDEF for a high-speed counter a second time generates a run-time error and does not change the counter setup from the way it was set up on the first execution of HDEF for that counter.

Initialization Modes 0, 1, or 2

The following steps describe how to initialize HSC1 for Single Phase Up/Down Counter with Internal Direction (Modes 0, 1, or 2).

1. Use the first scan memory bit to call a subroutine in which the initialization operation is performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SMB47 according to the desired control operation. For example:

   SMB47 = 16#F8 produces the following results:
   Enables the counter
   Writes a new current value
   Writes a new preset value
   Sets the direction to count up
   Sets the start and reset inputs to be active high
3. Execute the HDEF instruction with the HSC input set to 1 and the MODE input set to 0 for no external reset or start, to 1 for external reset and no start, or to 2 for both external reset and start.
4. Load SMD48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SMD52 (double word size value) with the desired preset value.
6. In order to capture the current value equal to preset event, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See Section 9.15 for complete details on interrupt processing.
7. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
8. Execute the global interrupt enable instruction (ENI) to enable interrupts.
9. Execute the HSC instruction to cause the S7-200 to program HSC1.
10. Exit the subroutine.

Initialization Modes 3, 4, or 5

The following steps describe how to initialize HSC1 for Single Phase Up/Down Counter with External Direction (Modes 3, 4, or 5):

1. Use the first scan memory bit to call a subroutine in which the initialization operation is performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SMB47 according to the desired control operation. For example:

   SMB47 = 16#F8 produces the following results:
   Enables the counter
   Writes a new current value
   Writes a new preset value
   Sets the initial direction of the HSC to count up
   Sets the start and reset inputs to be active high
3. Execute the HDEF instruction with the HSC input set to 1 and the MODE input set to 3 for no external reset or start, 4 for external reset and no start, or 5 for both external reset and start.
4. Load SMD48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SMD52 (double word size value) with the desired preset value.
6. In order to capture the current value equal to preset event, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See Section 9.15 for complete details on interrupt processing.
7. In order to capture direction changes, program an interrupt by attaching the direction changed interrupt event (event 14) to an interrupt routine.
8. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
9. Execute the global interrupt enable instruction (ENI) to enable interrupts.
10. Execute the HSC instruction to cause the S7-200 to program HSC1.
11. Exit the subroutine.

Initialization Modes 6, 7, or 8

The following steps describe how to initialize HSC1 for Two Phase Up/Down Counter with Up/Down Clocks (Modes 6, 7, or 8):

1. Use the first scan memory bit to call a subroutine in which the initialization operations are performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SMB47 according to the desired control operation. For example:

   SMB47 = 16#F8 produces the following results:
   Enables the counter
   Writes a new current value
   Writes a new preset value
   Sets the initial direction of the HSC to count up
   Sets the start and reset inputs to be active high
3. Execute the HDEF instruction with the HSC input set to 1 and the MODE set to 6 for no external reset or start, 7 for external reset and no start, or 8 for both external reset and start.
4. Load SMD48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SMD52 (double word size value) with the desired preset value.
6. In order to capture the current value equal to preset event, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See Section 9.15 for complete details on interrupt processing.
7. In order to capture direction changes, program an interrupt by attaching the direction changed interrupt event (event 14) to an interrupt routine.
8. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
9. Execute the global interrupt enable instruction (ENI) to enable interrupts.
10. Execute the HSC instruction to cause the S7-200 to program HSC1.
11. Exit the subroutine.

Initialization Modes 9, 10, or 11

The following steps describe how to initialize HSC1 for A/B Phase Quadrature Counter (Modes 9, 10, or 11):

1. Use the first scan memory bit to call a subroutine in which the initialization operations are performed. Since you use a subroutine call, subsequent scans do not make the call to the subroutine, which reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SMB47 according to the desired control operation.

   For example (1x counting mode):
   SMB47 = 16#FC produces the following results:
   Enables the counter
   Writes a new current value
   Writes a new preset value
   Sets the initial direction of the HSC to count up
   Sets the start and reset inputs to be active high

   For example (4x counting mode):
   SMB47 = 16#F8 produces the following results:
   Enables the counter
   Writes a new current value
   Writes a new preset value
   Sets the initial direction of the HSC to count up
   Sets the start and reset inputs to be active high
3. Execute the HDEF instruction with the HSC input set to 1 and the MODE input set to 9 for no external reset or start, 10 for external reset and no start, or 11 for both external reset and start.
4. Load SMD48 (double word size value) with the desired current value (load with 0 to clear it).
5. Load SMD52 (double word size value) with the desired preset value.
6. In order to capture the current value equal to preset event, program an interrupt by attaching the CV = PV interrupt event (event 13) to an interrupt routine. See Section 9.15 for complete details on interrupt processing.
7. In order to capture direction changes, program an interrupt by attaching the direction changed interrupt event (event 14) to an interrupt routine.
8. In order to capture an external reset event, program an interrupt by attaching the external reset interrupt event (event 15) to an interrupt routine.
9. Execute the global interrupt enable instruction (ENI) to enable interrupts.
10. Execute the HSC instruction to cause the S7-200 to program HSC1.
11. Exit the subroutine.

Change Direction in Modes 0, 1, or 2

The following steps describe how to configure HSC1 for Change Direction for Single Phase Counter with Internal Direction (Modes 0, 1, or 2):

1. Load SMB47 to write the desired direction:

   SMB47 = 16#90 Enables the counter
   Sets the direction of the HSC to count down

   SMB47 = 16#98 Enables the counter
   Sets the direction of the HSC to count up

2. Execute the HSC instruction to cause the S7-200 to program HSC1.

Load a New Current Value (Any Mode)

Changing the current value forces the counter to be disabled while the change is made. While the counter is disabled, it does not count or generate interrupts.

The following steps describe how to change the counter current value of HSC1 (any mode):

1. Load SMB47 to write the desired current value:

   SMB47 = 16#C0 Enables the counter
   Writes the new current value

2. Load SMD48 (double word size) with the desired current value (load with 0 to clear it).

3. Execute the HSC instruction to cause the S7-200 to program HSC1.

Load a New Preset Value (Any Mode)

The following steps describe how to change the preset value of HSC1 (any mode):

1. Load SMB47 to write the desired preset value:

   SMB47 = 16#A0 Enables the counter
   Writes the new preset value

2. Load SMD52 (double word size value) with the desired preset value.
3. Execute the HSC instruction to cause the S7-200 to program HSC1.

Disable a High-Speed Counter (Any Mode)

The following steps describe how to disable the HSC1 high-speed counter (any mode):

1. Load SMB47 to disable the counter:

   SMB47 = 16#00 Disables the counter

2. Execute the HSC instruction to disable the counter.

Although the above sequences show how to change direction, current value, and preset value individually, you may change all or any combination of them in the same sequence by setting the value of SMB47 appropriately and then executing the HSC instruction.

High-Speed Counter Example

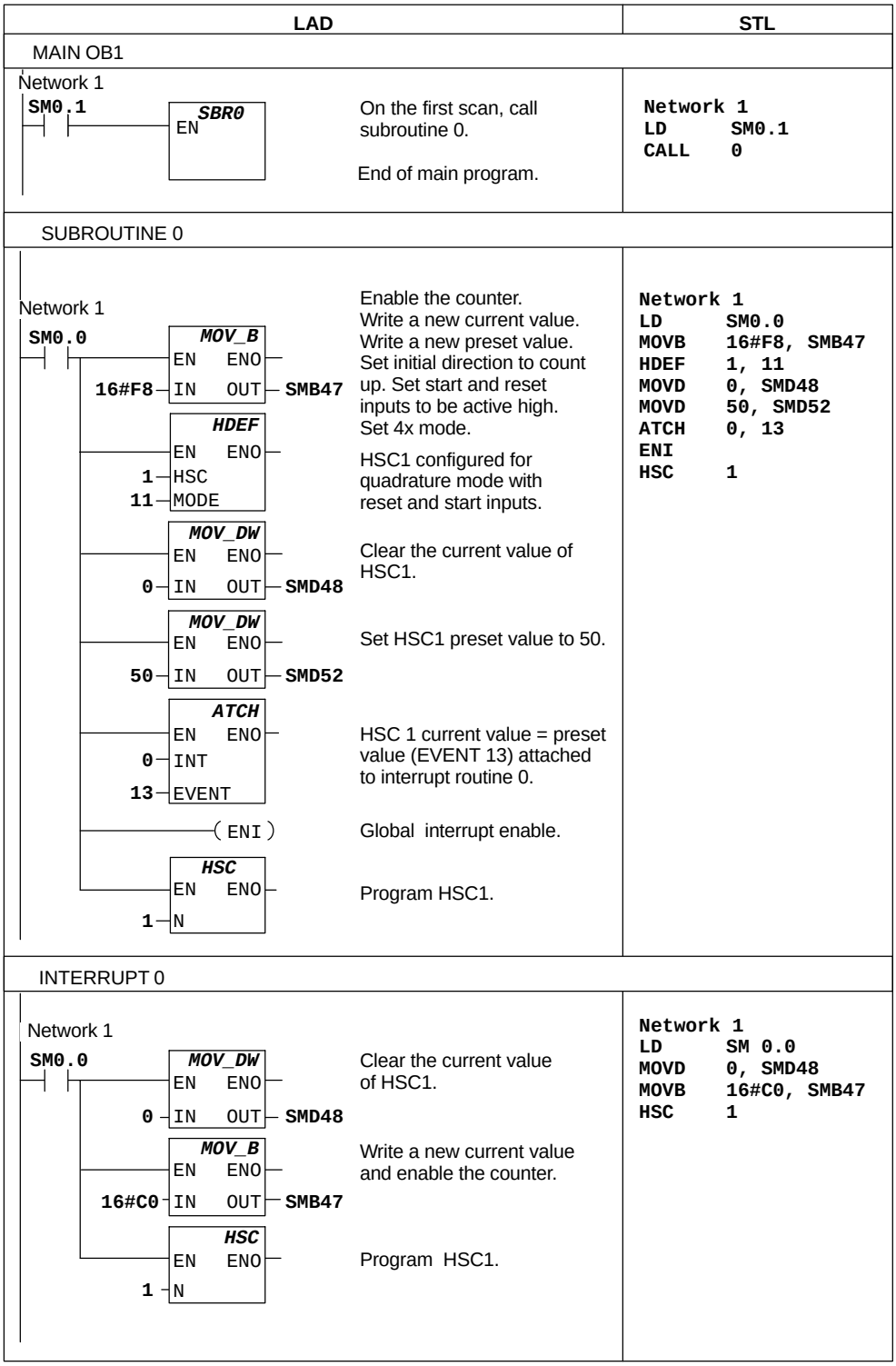


Figure 9-18 Example of Initialization of HSC1 (SIMATIC LAD and STL)

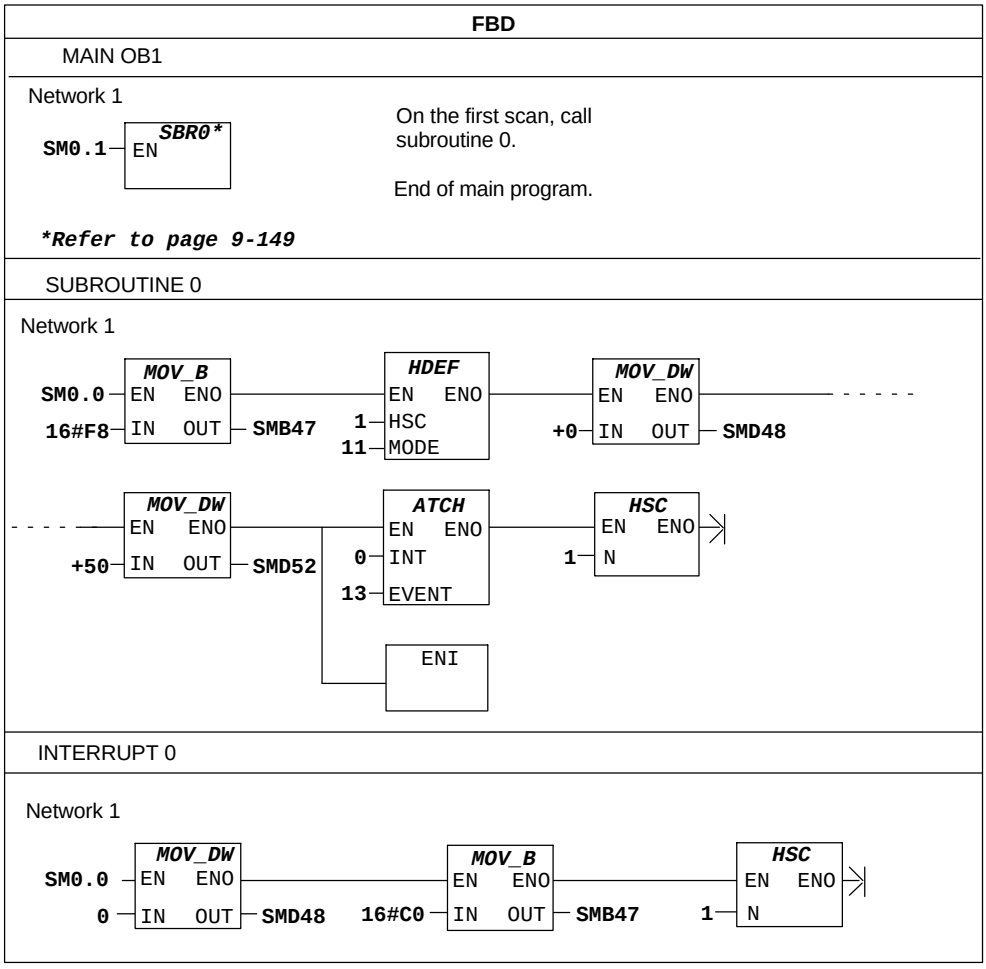
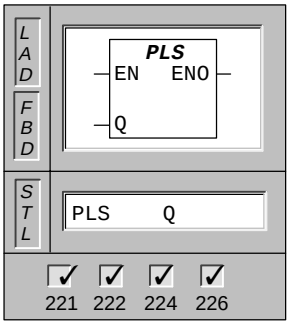


Figure 9-19 Example of Initialization of HSC1 (SIMATIC FBD)

Pulse Output



The **Pulse Output** instruction examines the special memory bits for the pulse output (Q0.0 or Q0.1). The pulse operation defined by the special memory bits is then invoked.

Operands:	Q	Constant (0 or 1)
Data Types:	WORD	
Pulse Output Ranges		Q0.0 through Q0.1

Understanding the S7-200 High-Speed Output Instructions

The CPUs each have two PTO/PWM generators to output high-speed pulse train and pulse width modulated waveforms. One generator is assigned to digital output point Q0.0 and the other generator is assigned to digital output point Q0.1.

The PTO/PWM generators and the process-image register share the use of Q0.0 and Q0.1. When a PTO or PWM function is active on Q0.0 or Q0.1, the PTO/PWM generator has control of the output, and normal use of the output point is inhibited. The output waveform is not affected by the state of the process-image register, the forced value of the point, or execution of immediate output instructions. When the PTO/PWM generator is inactive, control of the output reverts to the process-image register. The process-image register determines the initial and final state of the output waveform, causing the waveform to start and end at a high or low level.

Note

It is recommended that the process-image register for Q0.0 and Q0.1 be set to a value of zero before enabling PTO or PWM operation.

The pulse train (PTO) function provides a square wave (50% duty cycle) output with user control of the cycle time and the number of pulses. The pulse width modulation (PWM) function provides a continuous, variable duty cycle output with user control of the cycle time and the pulse width.

Each PTO/PWM generator has a control byte (8 bits), a cycle time value and pulse width value (unsigned 16-bit values), and a pulse count value (unsigned 32-bit value). These values are all stored in designated locations of the special memory (SM) area. Once these special memory bit locations have been set up to select the desired operation, the operation is invoked by executing the Pulse Output instruction (PLS). This instruction causes the S7-200 to read the SM locations and program the PTO/PWM generator accordingly.

You can change the characteristics of a PTO or PWM waveform by modifying the desired locations in the SM area (including the control byte), and then executing the PLS instruction.

You can disable the generation of a PTO or PWM waveform at any time by writing zero to the PTO/PWM enable bit of the control byte (SM67.7 or SM77.7), and then executing the PLS instruction.

Note

Default values for all control bits, cycle time, pulse width, and pulse count values are zero.

Note

The PTO/PWM outputs must have a minimum load of at least 10% of rated load to provide crisp transitions from off to on, and from on to off.

PWM Operation

The PWM function provides for variable duty cycle output. The cycle time and the pulse width can be specified in a time base of either microseconds or milliseconds. The cycle time has a range either from 50 microseconds to 65,535 microseconds, or from 2 milliseconds to 65,535 milliseconds. The pulse width time has a range either from 0 microseconds to 65,535 microseconds, or from 0 milliseconds to 65,535 milliseconds. When the pulse width is specified to have a value greater or equal to the cycle time value, the duty cycle of the waveform is 100% and the output is turned on continuously. When the pulse width is specified as 0, the duty cycle of the waveform is 0% and the output is turned off. If a cycle time of less than two time units is specified, the cycle time defaults to two time units.

There are two different ways to change the characteristics of a PWM waveform: with a synchronous update and with an asynchronous update.

- Synchronous Update: If no time base changes are required, then a synchronous update can be performed. With a synchronous update, the change in the waveform characteristics occurs on a cycle boundary, providing for a smooth transition.
- Asynchronous Update: Typically with PWM operation, the pulse width is varied while the cycle time remains constant. Therefore, time base changes are not required. However, if a change in the time base of the PTO/PWM generator is required, then an asynchronous update is used. An asynchronous update causes the PTO/PWM generator to be disabled momentarily, asynchronous to the PWM waveform. This can cause undesirable jitter in the controlled device. For that reason, synchronous PWM updates are recommended. Choose a time base that will work for all of your anticipated cycle time values.

The PWM Update Method bit (SM67.4 or SM77.4) in the control byte is used to specify the update type. Execute the PLS instruction to invoke the changes. Be aware that if the time base is changed, an asynchronous update will occur regardless of the state of the PWM Update Method bit.

PTO Operation

The PTO function provides for the generation of a square wave (50% duty cycle) pulse train with a specified number of pulses. The cycle time can be specified in either microsecond or millisecond increments. The cycle time has a range either from 50 microseconds to 65,535 microseconds, or from 2 milliseconds to 65,535 milliseconds. If the specified cycle time is an odd number, some duty cycle distortion will result. The pulse count has a range from 1 to 4,294,967,295 pulses.

If a cycle time of less than two time units is specified, the cycle time defaults to two time units. If a pulse count of zero is specified, the pulse count defaults to one pulse.

The PTO Idle bit in the status byte (SM66.7 or SM76.7) is provided to indicate the completion of the programmed pulse train. In addition, an interrupt routine can be invoked upon the completion of a pulse train (see Section 9.15 for information about the interrupt and communication instructions). If you are using the multiple segment operation, the interrupt routine will be invoked upon completion of the profile table. See Multiple Segment Pipelining below.

The PTO function allows the chaining or pipelining of pulse trains. When the active pulse train is complete, the output of a new pulse train begins immediately. This allows continuity between subsequent output pulse trains.

This pipelining can be done in one of two ways: in single segment pipelining or in multiple segment pipelining.

Single Segment Pipelining In single segment pipelining, you are responsible for updating the SM locations for the next pulse train. Once the initial PTO segment has been started, you must modify immediately the SM locations as required for the second waveform, and execute the PLS instruction again. The attributes of the second pulse train will be held in a pipeline until the first pulse train is completed. Only one entry at a time can be stored in the pipeline. Once the first pulse train is completed, the output of the second waveform will begin and the pipeline is made available for a new pulse train specification. You can then repeat this process to set up the characteristics of the next pulse train.

Smooth transitions between pulse trains will occur except in the following situations:

- If a change in time base is performed
- If the active pulse train is completed before a new pulse train setup is captured by the execution of the PLS instruction.

If you attempt to load the pipeline while it is full, the PTO overflow bit in the status register (SM66.6 or SM76.6) is set. This bit is initialized to zero on entry to RUN mode. If you want to detect subsequent overflows, you must clear this bit manually after an overflow is detected.

Multiple Segment Pipelining In multiple segment pipelining, the characteristics of each pulse train segment are read automatically by the CPU from a profile table located in V memory. The only SM locations used in this mode are the control byte and the status byte. To select multiple segment operation, the starting V memory offset of the profile table must be loaded (SMW168 or SMW178). The time base can be specified to be either microseconds or milliseconds, but the selection applies to all cycle time values in the profile table, and cannot be changed while the profile is running. Multiple segment operation can then be started by executing the PLS instruction.

Each segment entry is 8 bytes in length, and is composed of a 16-bit cycle time value, a 16-bit cycle time delta value, and a 32-bit pulse count value.

The format of the profile table is shown in Table 9-15. An additional feature available with multiple segment PTO operation is the ability to increase or decrease the cycle time automatically by a specified amount for each pulse. Programming a positive value in the cycle time delta field increases cycle time. Programming a negative value in the cycle time delta field decreases cycle time. A value of zero results in an unchanging cycle time.

If you specify a cycle time delta value that results in an illegal cycle time after a number of pulses, a mathematical overflow condition occurs. The PTO function is terminated, and the output reverts to image register control. In addition, the delta calculation error bit in the status byte (SM66.4 or SM76.4) is set to a one.

If you manually abort a PTO profile in progress, the user abort bit in the status byte (SM66.5 or SM76.5) will be set to one as a result.

While the PTO profile is operating, the number of the currently active segment is available in SMB166 (or SMB176).

Table 9-15 Profile Table Format for Multiple Segment PTO Operation

Byte Offset From Profile Table Start	Profile Segment Number	Description of Table Entries
0		Number of segments (1 to 255); a value of 0 generates a non-fatal error and no PTO output is generated.
1	#1	Initial cycle time (2 to 65535 units of the time base)
3		Cycle time delta per pulse (signed value) (-32768 to 32767 units of the time base)
5		Pulse count (1 to 4294967295)
9	#2	Initial cycle time (2 to 65535 units of the time base)
11		Cycle time delta per pulse (signed value) (-32768 to 32767 units of the time base)
13		Pulse count (1 to 4294967295)
: :	: :	: :

Calculating Profile Table Values

The multiple segment pipelining capability of the PTO/PWM generators can be useful in many applications, particularly in stepper motor control.

The example shown in Figure 9-20 illustrates how to determine the profile table values required to generate an output waveform that accelerates a stepper motor, operates the motor at a constant speed, and then decelerates the motor.

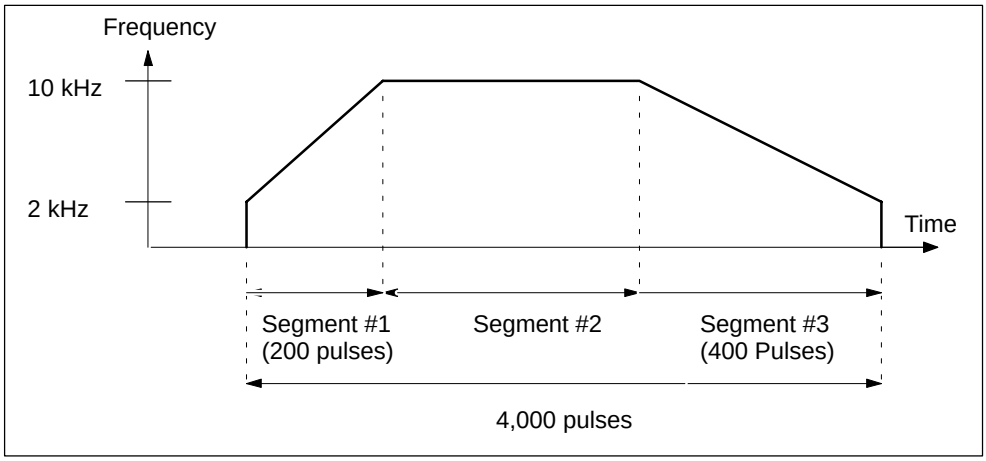


Figure 9-20 Example Frequency vs. Time Diagram for Simple Stepper Motor Application

For this example, it is assumed that 4,000 pulses are required to achieve the desired number of motor revolutions. The starting and final pulse frequency is 2 kHz and the maximum pulse frequency is 10 kHz. Since profile table values are expressed in terms of period (cycle time) instead of frequency, convert the given frequency values into cycle time values. Therefore, the starting (initial) and final (ending) cycle time is 500 µs and the cycle time corresponding to the maximum frequency is 100 µs.

During the acceleration portion of the output profile, it is desired that the maximum pulse frequency be reached in approximately 200 pulses. It is also assumed that the deceleration portion of the profile should be completed in around 400 pulses.

In the Figure 9-20 example, a simple formula (shown below) can be used to determine the delta cycle time value for a given segment that the PTO/PWM generator uses to adjust the cycle time of each pulse:

```
delta cycle time for a given segment  = | ECT - ICT | / Q
  where, ECT =  ending cycle time for this segment
         ICT  =  initial cycle time for this segment
         Q    =  quantity of pulses in this segment
```

Using this formula, the delta cycle time for the acceleration portion (or segment #1) is calculated to be -2. Likewise, the delta cycle time for the deceleration portion (or segment #3) is calculated to be 1. Since segment #2 is the constant speed portion of the output waveform, the delta cycle time value for that segment is zero.

Assuming that the profile table is located in V memory starting at V500, the table values used to generate the desired waveform are shown in Table 9-16.

Table 9-16 Profile Table Values

V Memory Address	Value
VB500	3 (total number of segments)
VW501	500 (initial cycle time - segment #1)
VW503	-2 (initial cycle time - segment #1)
VD505	200 (number of pulses - segment #1)
VW509	100 (initial cycle time - segment #2)
VW511	0 (delta cycle time - segment #2)
VD513	3400 (number of pulses - segment #2)
VW517	100 (initial cycle time - segment #3)
VW519	1 (delta cycle time - segment #3)
VD521	400 (number of pulses - segment #3)

The values of this table can be placed in V memory by using instructions in your program. An alternate method is to define the values of the profile in the data block. An example containing the program instructions to use the multiple segment PTO operation is shown in Figure 9-23.

The cycle time of the last pulse of a segment is not directly specified in the profile, but instead must be calculated (except of course for the case in which the delta cycle time is zero). Knowing the cycle time of a segment's last pulse is useful to determine if the transitions between waveform segments are acceptable. The formula for calculating the cycle time of a segment's last pulse is shown below:

cycle time of segment's last pulse = ICT + (DEL * (Q-1))
where, ICT = initial cycle time for this segment
DEL = delta cycle time for this segment
Q = quantity of pulses in this segment

While the simplified example above is useful as an introduction, real applications may require more complicated waveform profiles. Remember that:

- The delta cycle time can be specified only as an integer number of microseconds or milliseconds
- The cycle time modification is performed on each pulse

The effect of these two items is that calculation of the delta cycle time value for a given segment may require an iterative approach. Some flexibility in the value of the ending cycle time or the number of pulses for a given segment may be required.

The duration of a given profile segment can be useful in the process of determining correct profile table values. The length of time to complete a given profile segment can be calculated using the following formula:

```
duration of segment = Q * ( ICT + ( ( DEL/2 ) * ( Q-1 ) ) )
  where, Q   =  quantity of pulses in this segment
         ICT =  initial cycle time for this segment
         DEL =  delta cycle time for this segment
```

PTO/PWM Control Registers

Table 9-17 describes the registers used to control the PTO/PWM operation. You can use Table 9-18 as a quick reference to determine the value to place in the PTO/PWM control register to invoke the desired operation. Use SMB67 for PTO/PWM 0, and SMB77 for PTO/PWM 1. If you are going to load the new pulse count (SMD72 or SMD82), pulse width (SMW70 or SMW80), or cycle time (SMW68 or SMW78), you should load these values as well as the control register before you execute the PLS instruction. If you are using the multiple segment pulse train operation, you also need to load the starting offset (SMW168 or SMW178) of the profile table and the profile table values before you execute the PLS instruction.

Table 9-17 PTO /PWM Control Registers

Q0.0	Q0.1	Status Bits
SM66.4	SM76.4	PTO profile aborted due to delta calculation error 0 = no error; 1 = aborted
SM66.5	SM76.5	PTO profile aborted due to user command 0 = no abort; 1 = aborted
SM66.6	SM76.6	PTO pipeline overflow/underflow 0 = no overflow; 1 = overflow/underflow
SM66.7	SM76.7	PTO idle 0 = in progress; 1 = PTO idle
Q0.0	**Q0.1**	**Control Bits**
SM67.0	SM77.0	PTO/PWM update cycle time value 0 = no update; 1 = update cycle time
SM67.1	SM77.1	PWM update pulse width time value 0 = no update; 1 = update pulse width
SM67.2	SM77.2	PTO update pulse count value 0 = no update; 1 = update pulse count
SM67.3	SM77.3	PTO/PWM time base select 0 = 1 µs/tick; 1 = 1ms/tick
SM67.4	SM77.4	PWM update method: 0 = asynchronous update, 1 = synchronous update
SM67.5	SM77.5	PTO operation: 0 = single segment operation 1 = multiple segment operation
SM67.6	SM77.6	PTO/PWM mode select 0 = selects PTO; 1 = selects PWM
SM67.7	SM77.7	PTO/PWM enable 0 = disables PTO/PWM; 1 = enables PTO/PWM
Q0.0	**Q0.1**	**Other PTO/PWM Registers**
SMW68	SMW78	PTO/PWM cycle time value (range: 2 to 65535)
SMW70	SMW80	PWM pulse width value (range: 0 to 65535)
SMD72	SMD82	PTO pulse count value (range: 1 to 4294967295)
SMB166	SMB176	Number of segment in progress (used only in multiple segment PTO operation)
SMW168	SMW178	Starting location of profile table, expressed as a byte offset from V0 (used only in multiple segment PTO operation)

Table 9-18 PTO/PWM Control Byte Reference

Control Register (Hex Value)	Result of executing the PLS instruction							
	Enable	Select Mode	PTO Segment Operation	PWM Update Method	Time Base	Pulse Count	Pulse Width	Cycle Time
16#81	Yes	PTO	Single		1 µs/cycle			Load
16#84	Yes	PTO	Single		1 µs/cycle	Load		
16#85	Yes	PTO	Single		1 µs/cycle	Load		Load
16#89	Yes	PTO	Single		1 ms/cycle			Load
16#8C	Yes	PTO	Single		1 ms/cycle	Load		
16#8D	Yes	PTO	Single		1 ms/cycle	Load		Load
16#A0	Yes	PTO	Multiple		1 µs/cycle			
16#A8	Yes	PTO	Multiple		1 ms/cycle			
16#D1	Yes	PWM		Synchronous	1 µs/cycle			Load
16#D2	Yes	PWM		Synchronous	1 µs/cycle		Load	
16#D3	Yes	PWM		Synchronous	1 µs/cycle		Load	Load
16#D9	Yes	PWM		Synchronous	1 ms/cycle			Load
16#DA	Yes	PWM		Synchronous	1 ms/cycle		Load	
16#DB	Yes	PWM		Synchronous	1 ms/cycle		Load	Load

PTO/PWM Initialization and Operation Sequences

Descriptions of the initialization and operation sequences follow. They can help you better understand the operation of PTO and PWM functions. The pulse output Q0.0 is used throughout these sequence descriptions. The initialization descriptions assume that the S7-200 has just been placed in RUN mode, and for that reason the first scan memory bit is true. If this is not the case, or if the PTO/PWM function must be re-initialized, you can call the initialization routine using a condition other than the first scan memory bit.

PWM Initialization

To initialize the PWM for Q0.0, follow these steps:

1. Use the first scan memory bit (SM0.1) to initialize the output to 0, and call the subroutine that you need in order to perform the initialization operations. When you use the subroutine call, subsequent scans do not make the call to the subroutine. This reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SMB67 with a value of 16#D3 for PWM using microsecond increments (or 16#DB for PWM using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PWM operation, select either microsecond or millisecond increments, and set the update pulse width and cycle time values.
3. Load SMW68 (word size value) with the desired cycle time.
4. Load SMW70 (word size value) with the desired pulse width.
5. Execute the PLS instruction so that the S7-200 programs the PTO/PWM generator.
6. Load SMB67 with a value of 16#D2 for microsecond increments (or 16#DA for millisecond increments). This preloads a new control byte value for subsequent pulse width changes.
7. Exit the subroutine.

Changing the Pulse Width for PWM Outputs

To change the pulse width for PWM outputs in a subroutine, follow these steps. (It is assumed that SMB67 was preloaded with a value of 16#D2 or 16#DA.)

1. Call a subroutine to load SMW70 (word size value) with the desired pulse width.
2. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator.
3. Exit the subroutine.

PTO Initialization - Single Segment Operation

To initialize the PTO, follow these steps:

1. Use the first scan memory bit (SM0.1) to initialize the output to 0, and call the subroutine that you need to perform the initialization operations. This reduces scan time execution and provides a more structured program.
2. In the initialization subroutine, load SMB67 with a value of 16#85 for PTO using microsecond increments (or 16#8D for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update pulse count and cycle time values.
3. Load SMW68 (word size value) with the desired cycle time.
4. Load SMD72 (double word size value) with the desired pulse count.
5. This is an optional step. If you want to perform a related function as soon as the pulse train output is complete, you can program an interrupt by attaching the pulse train complete event (Interrupt Category 19) to an interrupt subroutine, using the ATCH instruction, and executing the global interrupt enable instruction ENI. Refer to Section 9.15 for complete details on interrupt processing.
6. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator.
7. Exit the subroutine.

Changing the PTO Cycle Time - Single Segment Operation

To change the PTO Cycle Time in an interrupt routine or subroutine when using single segment PTO operation, follow these steps:

1. Load SMB67 with a value of 16#81 for PTO using microsecond increments (or 16#89 for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update cycle time value.
2. Load SMW68 (word size value) with the desired cycle time.
3. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator. The CPU must complete any PTO that is in process before output of the PTO waveform with the updated cycle time begins.
4. Exit the interrupt routine or the subroutine.

Changing the PTO Pulse Count - Single Segment Operation

To change the PTO Pulse Count in an interrupt routine or a subroutine when using single segment PTO operation, follow these steps:

1. Load SMB67 with a value of 16#84 for PTO using microsecond increments (or 16#8C for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update pulse count value.
2. Load SMD72 (double word size value) with the desired pulse count.
3. Execute the PLS instruction to cause the S7-200 to program the PTO/PWM generator. The CPU must complete any PTO that is in process before output of the waveform with the updated pulse count begins.
4. Exit the interrupt routine or the subroutine.

Changing the PTO Cycle Time and the Pulse Count - Single Segment Operation

To change the PTO Cycle Time and Pulse Count in an interrupt routine or a subroutine when using single segment PTO operation, follow these steps:

1. Load SMB67 with a value of 16#85 for PTO using microsecond increments (or 16#8D for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO operation, select either microsecond or millisecond increments, and set the update cycle time and pulse count values.
2. Load SMW68 (word size value) with the desired cycle time.
3. Load SMD72 (double word size value) with the desired pulse count.
4. Execute the PLS instruction so that the S7-200 programs the PTO/PWM generator. The CPU must complete any PTO that is in process before output of the waveform with the updated pulse count and cycle time begins.
5. Exit the interrupt routine or the subroutine.

PTO Initialization - Multiple Segment Operation

To initialize the PTO, follow these steps:

1. Use the first scan memory bit (SM0.1) to initialize the output to 0, and call the subroutine that you need to perform the initialization operations. This reduces the scan time execution and provides a more structured program.
2. In the initialization subroutine, load SMB67 with a value of 16#A0 for PTO using microsecond increments (or 16#A8 for PTO using millisecond increments). These values set the control byte to enable the PTO/PWM function, select PTO and multiple segment operation, and select either microsecond or millisecond increments
3. Load SMW168 (word size value) with the starting V memory offset of the profile table.
4. Set up the segment values in the profile table. Ensure that the Number of Segment field (the first byte of the table) is correct.
5. This is an optional step. If you want to perform a related function as soon as the PTO profile is complete, you can program an interrupt by attaching the pulse train complete event (Interrupt Category 19) to an interrupt subroutine. Use the ATCH instruction, and execute the global interrupt enable instruction ENI. Refer to Section 9.15 for complete details on interrupt processing.
6. Execute the PLS instruction. The S7-200 programs the PTO/PWM generator.
7. Exit the subroutine.

Example of Pulse Width Modulation

Figure 9-21 shows an example of the Pulse Width Modulation.

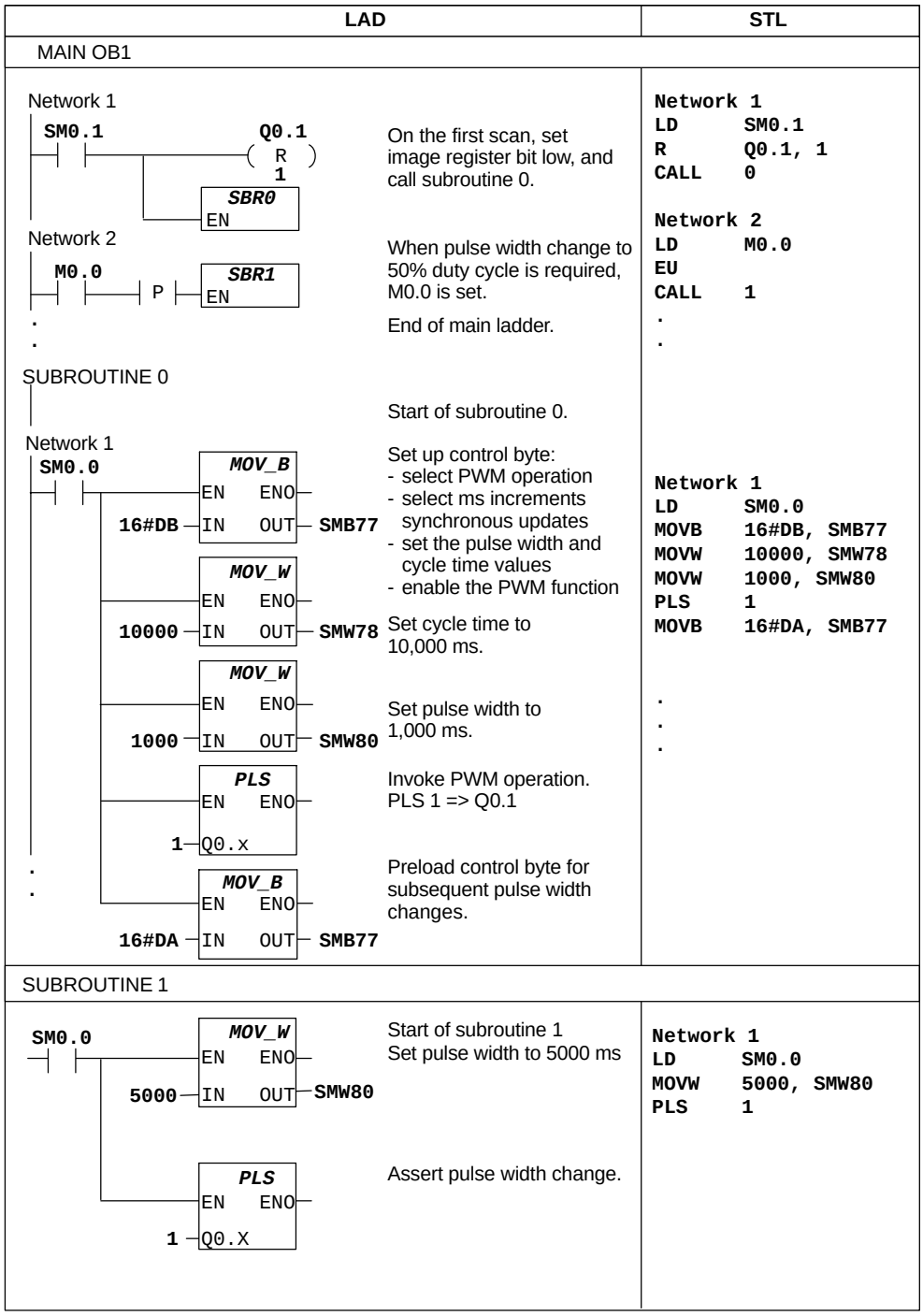


Figure 9-21 Example of High-Speed Output Using Pulse Width Modulation

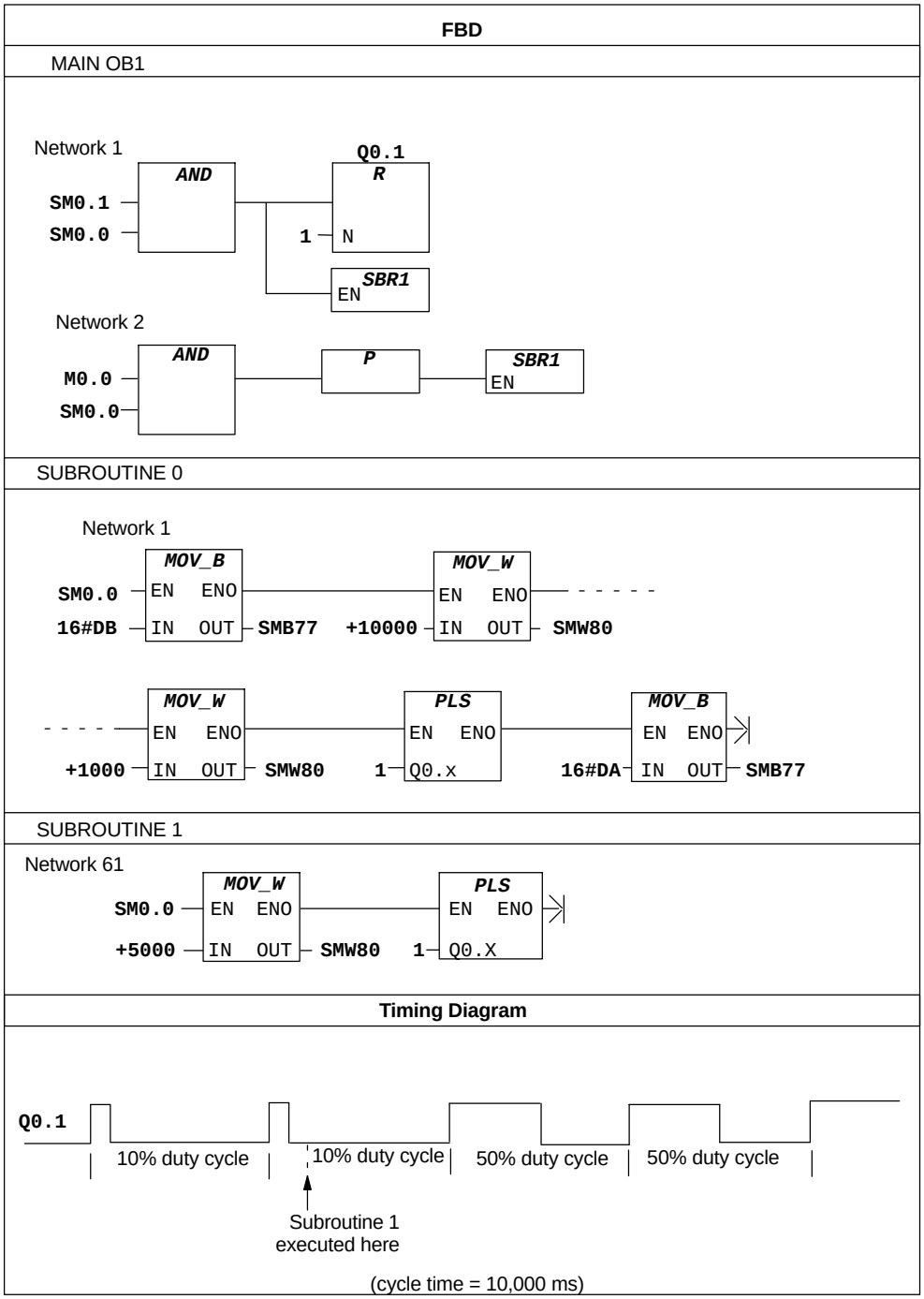


Figure 9-21 Example of High-Speed Output Using Pulse Width Modulation (continued)

Example of Pulse Train Output Using Single Segment Operation

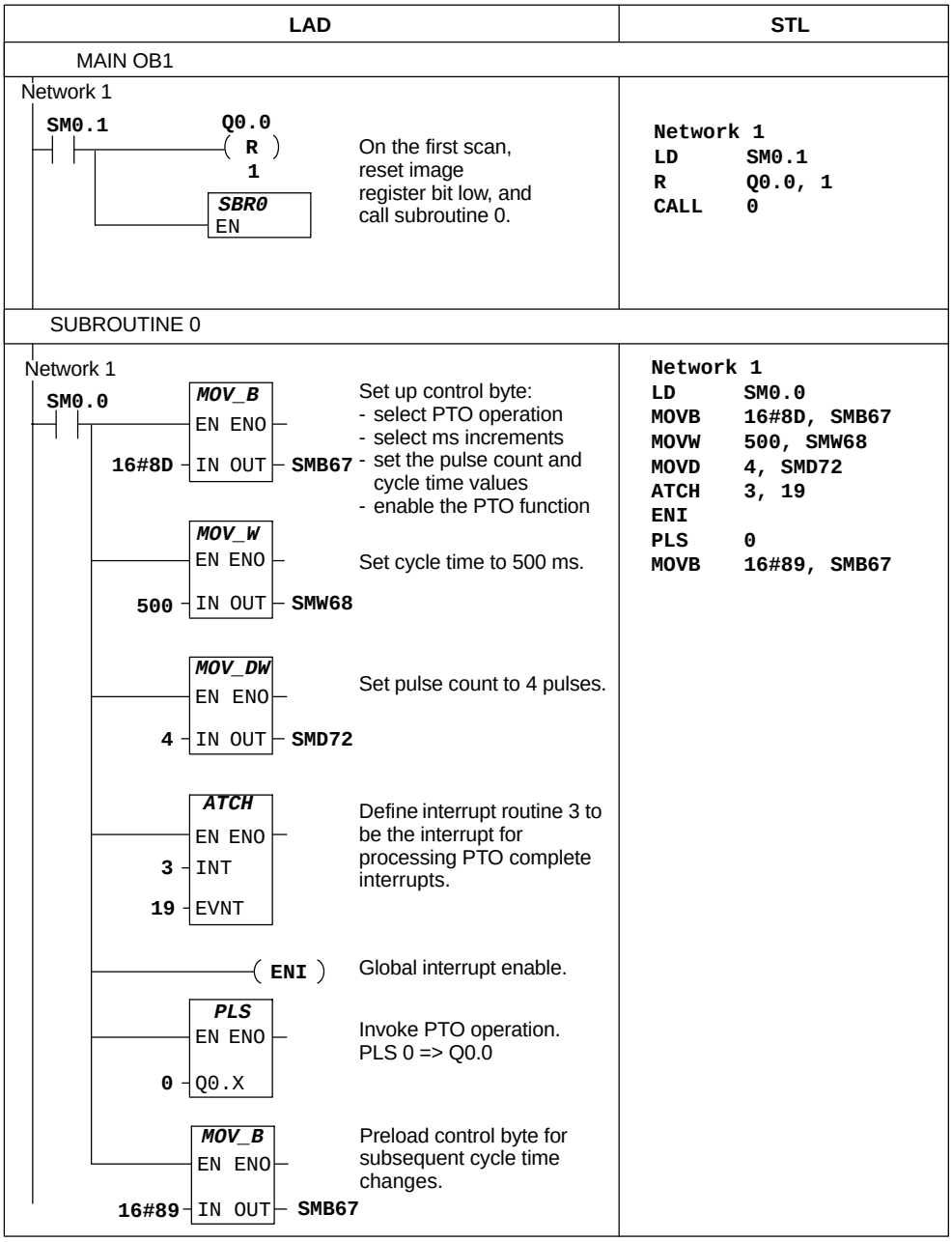


Figure 9-22 Example of a Pulse Train Output Using Single Segment Operation in SM Memory

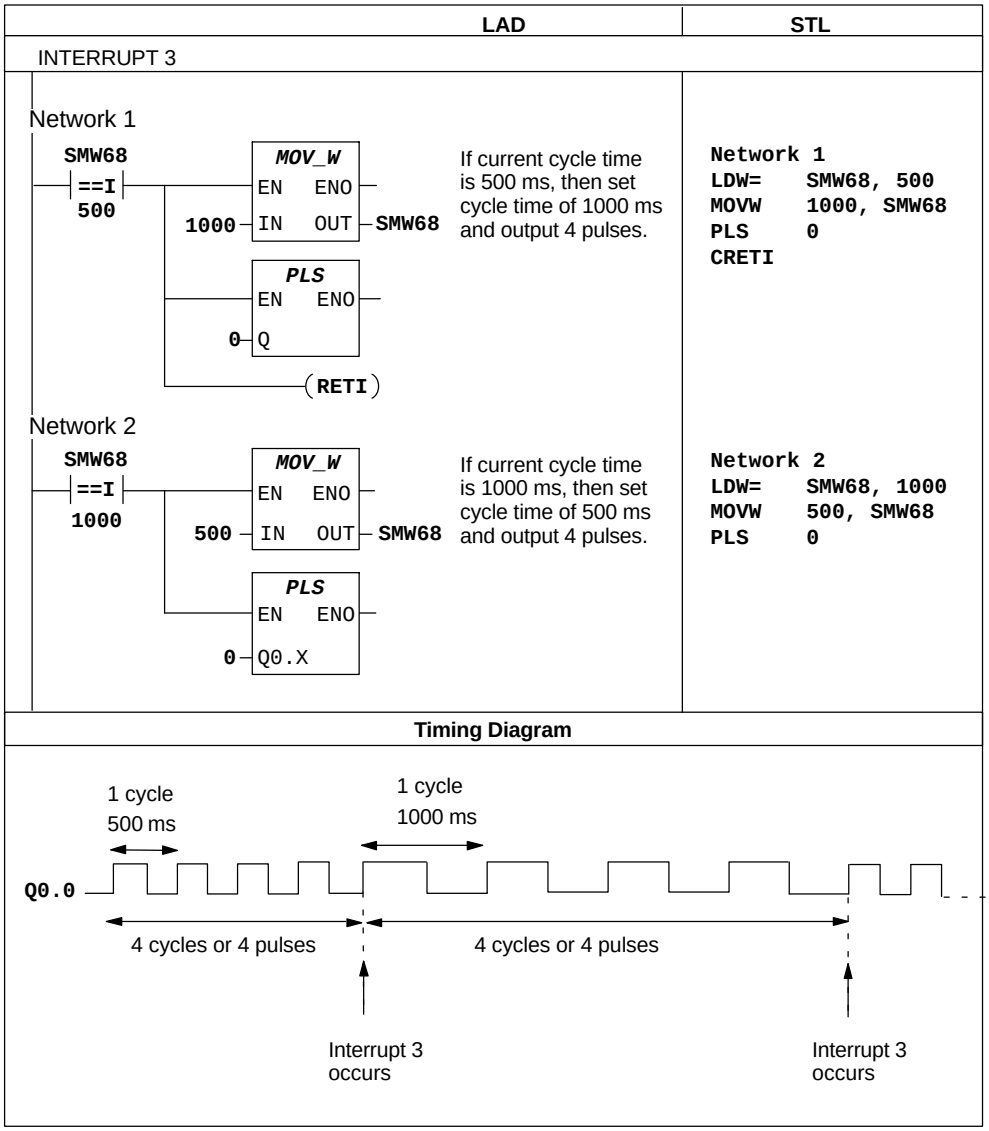


Figure 9-22 Example of a Pulse Train Output Using Single Segment Operation (continued)

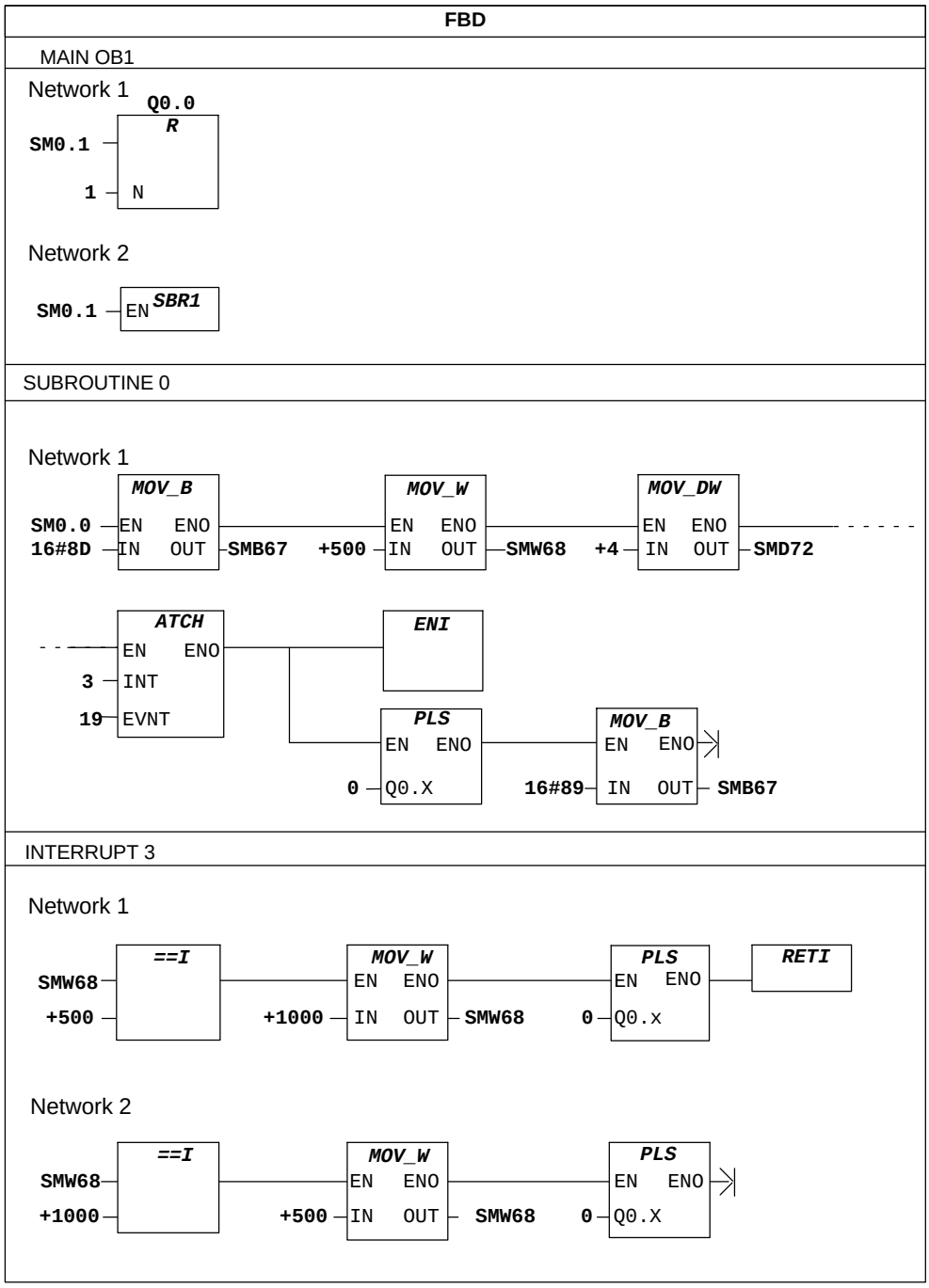


Figure 9-22 Example of a Pulse Train Output Using Single Segment Operation (continued)

Example of Pulse Train Output Using Multiple Segment Operation

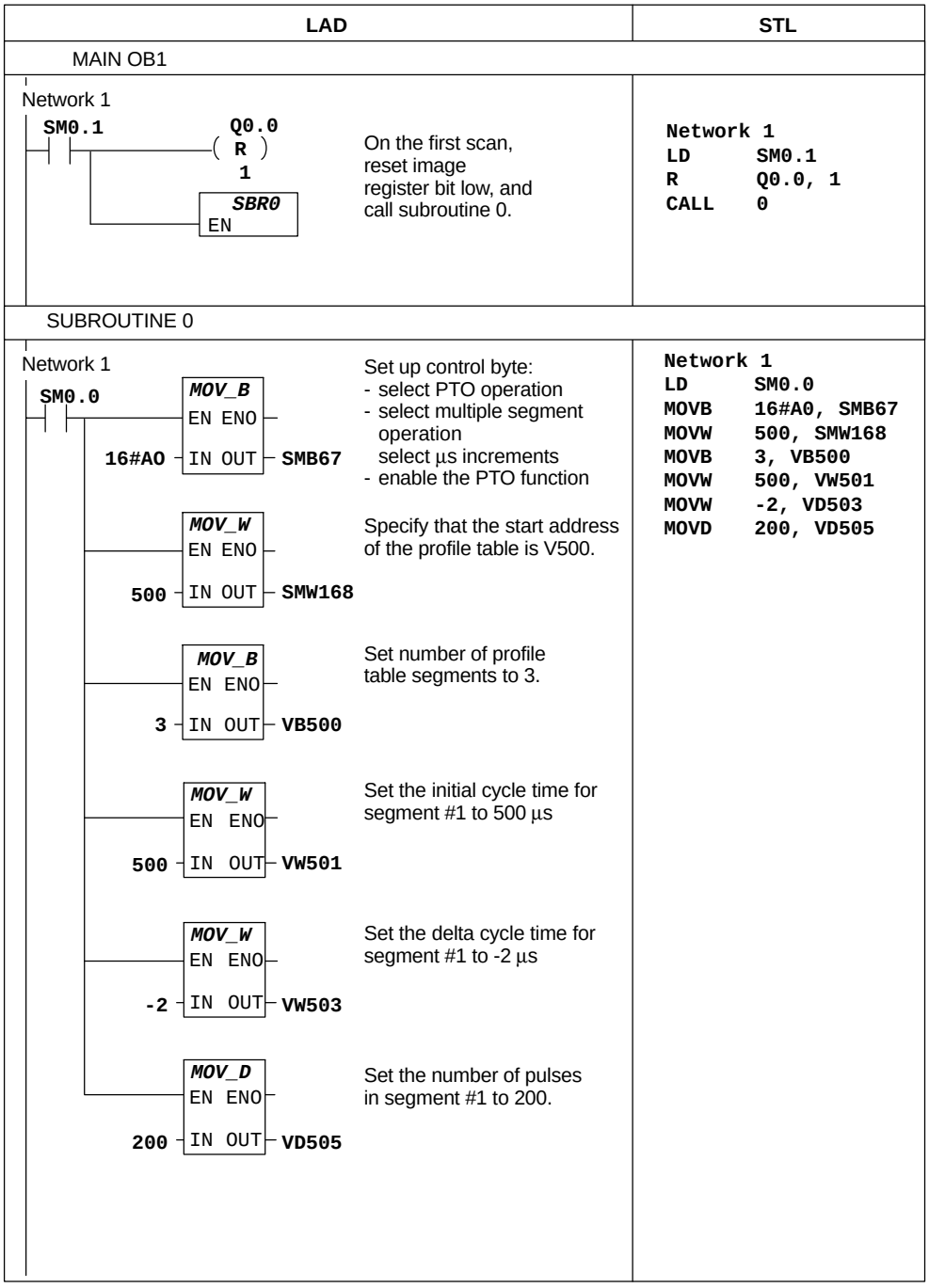


Figure 9-23 Example of a Pulse Train Output Using Multiple Segment Operation

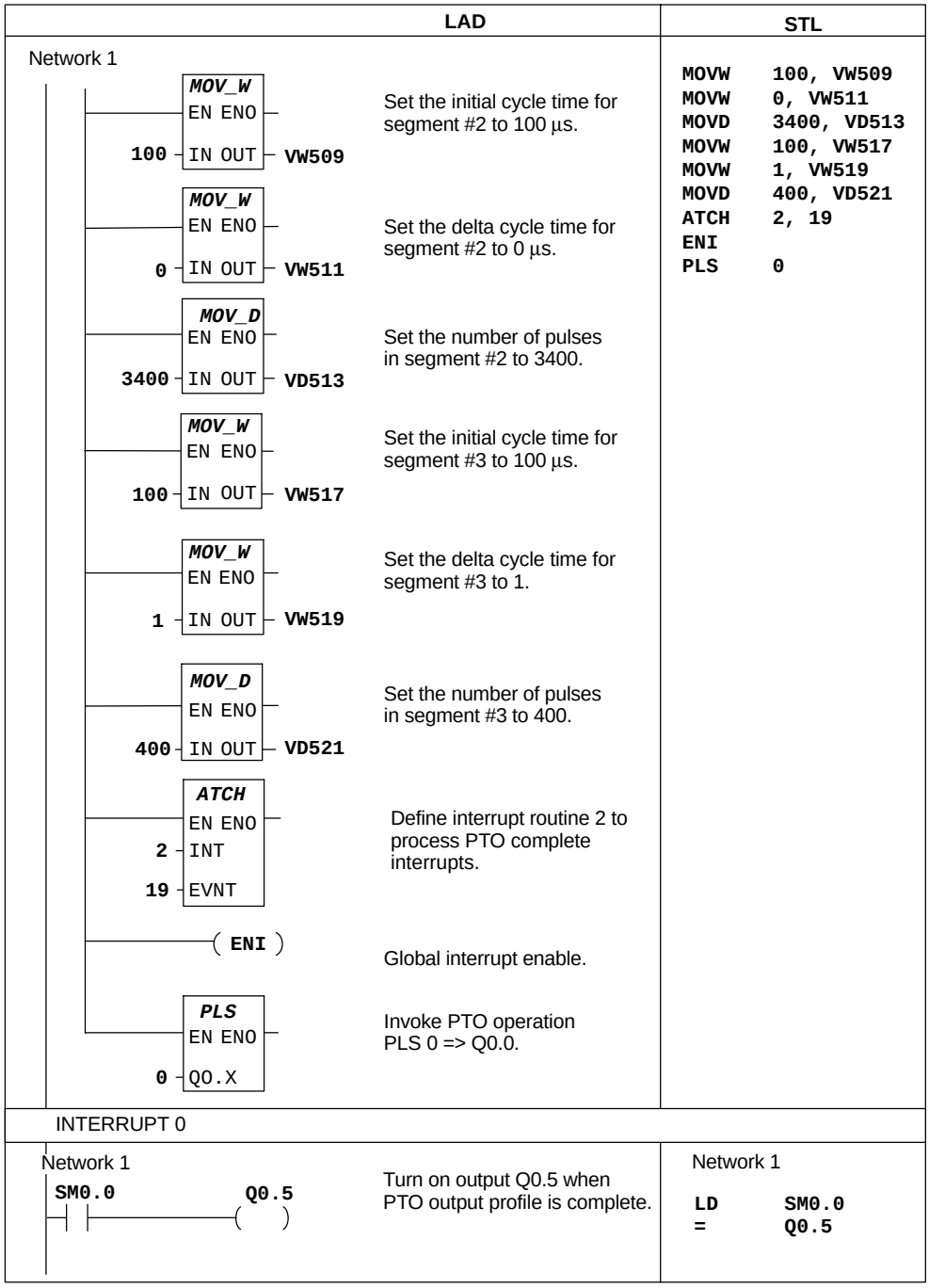


Figure 9-23 Example of Pulse Train Output Using Multiple Segment Operation (continued)

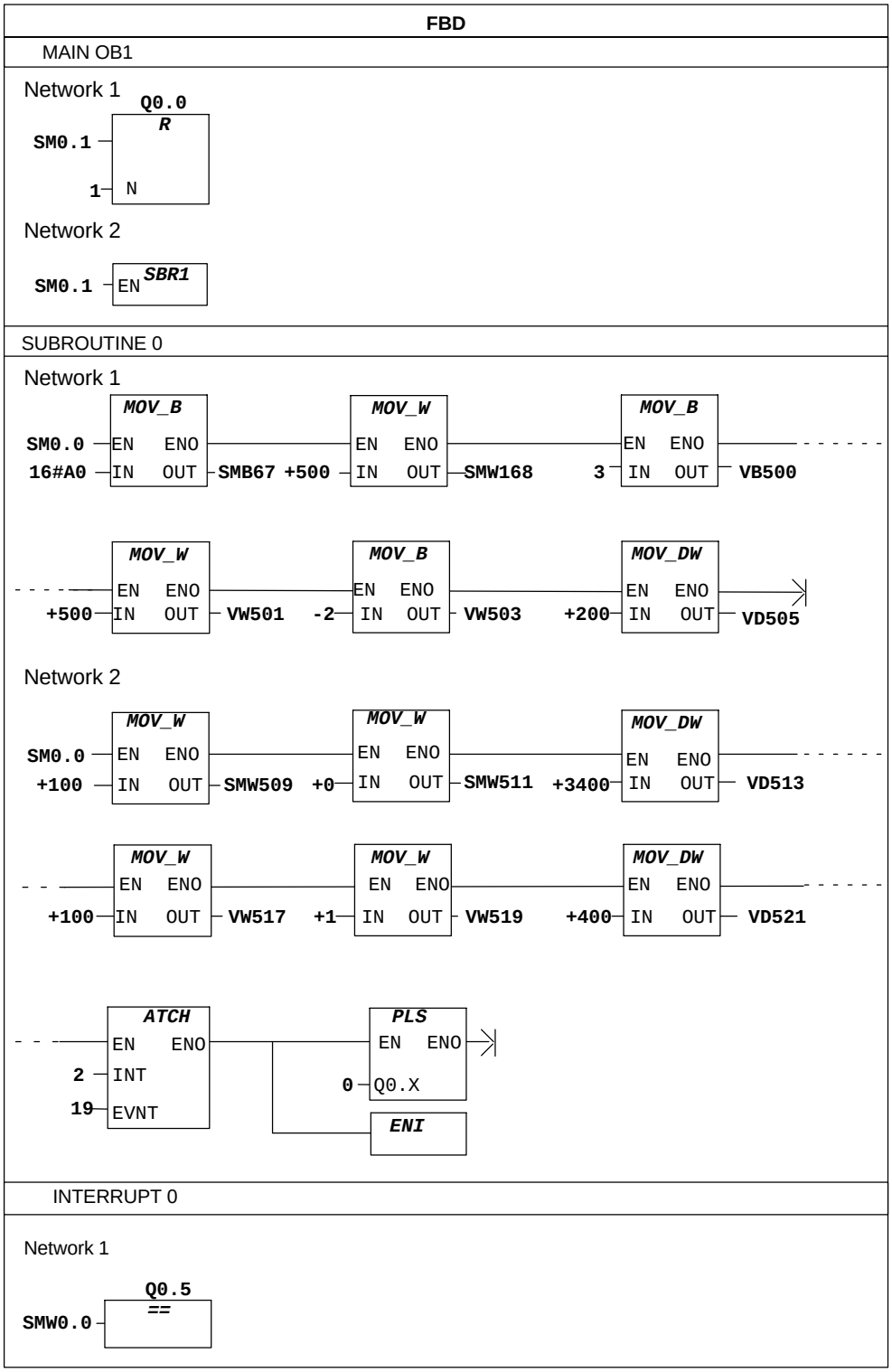
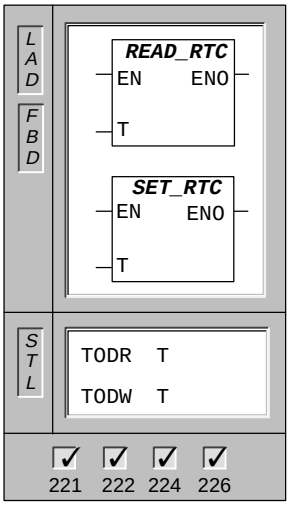


Figure 9-23 Example of Pulse Train Output Using Multiple Segment Operation (continued)

9.5 SIMATIC Clock Instructions

Read Real-Time Clock, Set Real-Time Clock



The **Read Real-Time Clock** instruction reads the current time and date from the clock and loads it in an 8-byte buffer starting at address T.

The **Set Real-Time Clock** instruction writes the current time and date to the clock beginning at the 8-byte buffer address specified by T.

In STL, the TODR and TODW instructions are represented as Time of Day Read (TODR) and Time of Day Write (TODW).

TODR: Error conditions that set ENO = 0:
SM4.3 (run-time), 0006 (indirect address),
000C (clock cartridge not present)

TODW: Error conditions that set ENO = 0:
SM 4.3 (run-time), 0006 (indirect address),
0007 (TOD data error), 000C (clock cartridge not present)

Inputs/Outputs	Operands	Data Types
T	VB, IB, QB, MB, SMB, SB, LB, *VD, *AC, *LD	BYTE

Figure 9-24 shows the format of the time buffer (T).

T	T+1	T+2	T+3	T+4	T+5	T+6	T+7
year	month	day	hour	minute	second	0	day of week

Figure 9-24 Format of the Time Buffer

The time-of-day clock initializes the following date and time after extended power outages or memory has been lost:

Date:	01-Jan-90
Time:	00:00:00
Day of Week	Sunday

The time-of-day clock in the S7-200 uses only the least significant two digits for the year, so for the year 2000, the year is represented as 00.

You must code all date and time values in BCD format (for example, 16#97 for the year 1997). Use the following data formats:

Year/Month	yymm	yy -	0 to 99	mm -	1 to 12
Day/Hour	ddhh	dd -	1 to 31	hh -	0 to 23
Minute/Second	mmss	mm -	0 to 59	ss -	0 to 59
Day of week	d	d -	0 to 7	1 =	Sunday
				0 =	disables day of week (remains 0)

Note

The S7-200 CPU does not perform a check to verify that the day of week is correct based upon the date. Invalid dates, such as February 30, may be accepted. You should ensure that the date you enter is correct.

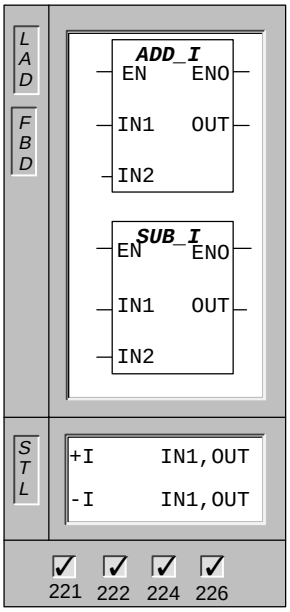
Do not use the TODR/TODW instruction in both the main program and in an interrupt routine. A TODR/TODW instruction in an interrupt routine which attempts to execute while another TODR/TODW instruction is in process will not be executed. SM4.3 is set indicating that two simultaneous accesses to the clock were attempted (non-fatal error 0007).

The S7-200 PLC does not use the year information in any way and is not affected by the century rollover (year 2000). However, user programs that use arithmetic or compares with the year's value must take into account the two-digit representation and the change in century.

Leap year is correctly handled through year 2096.

9.6 SIMATIC Integer Math Instructions

Add Integer and Subtract Integer



The **Add Integer** and **Subtract Integer** instructions add or subtract two 16-bit integers and produce a 16-bit result (OUT).

In LAD and FBD: IN1 + IN2 = OUT
IN1 - IN2 = OUT

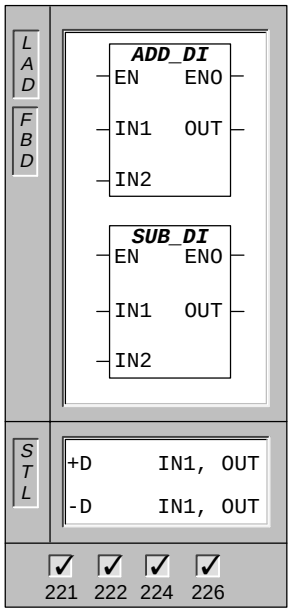
In STL: IN1 + OUT = OUT
OUT - IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, AC, Constant, *VD, *AC, *LD	INT
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	INT

Add Double Integer and Subtract Double Integer



The **Add Double Integer** and **Subtract Double Integer** instructions add or subtract two 32-bit integers, and produce a 32-bit result (OUT).

In LAD and FBD: IN1 + IN2 = OUT
IN1 - IN2 = OUT

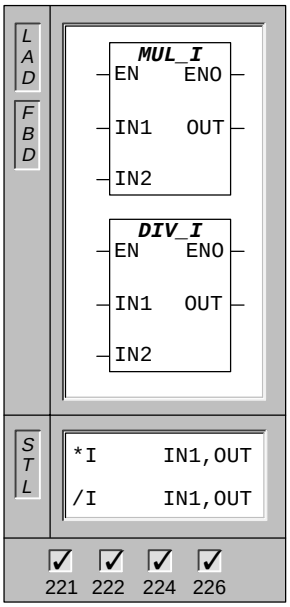
In STL: IN1 + OUT = OUT
OUT - IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VD, ID, QD, MD, SMD, SD, LD, AC, HC, Constant, *VD, *AC, *LD	DINT
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	DINT

Multiply Integer and Divide Integer



The **Multiply Integer** instruction multiplies two 16-bit integers and produces a 16-bit product.

The **Divide Integer** instruction divides two 16-bit integers and produces a 16-bit quotient. No remainder is kept.

The overflow bit is set if the result is greater than a word output.

In LAD and FBD: IN1 * IN2 = OUT
IN1 / IN2 = OUT

In STL: IN1 * OUT = OUT
OUT / IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM1.3 (divide-by-zero), SM4.3 (run-time), 0006 (indirect address)

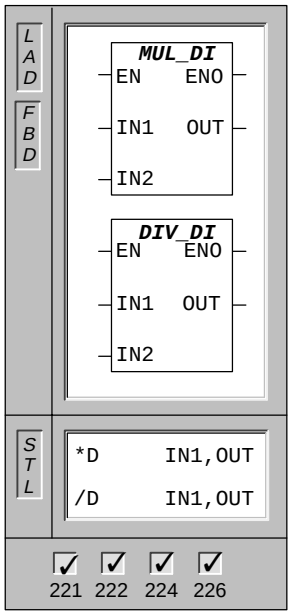
These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative); SM1.3 (divide-by-zero)

If SM1.1 (overflow) is set during a multiply or divide operation, the output is not written and all other math status bits are set to zero.

If SM1.3 (divide by zero) is set during a divide operation, then the other math status bits are left unchanged and the original input operands are not altered. Otherwise, all supported math status bits contain valid status upon completion of the math operation.

Inputs/Outputs	Operands	Data Types
IN1, IN2	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, AC, Constant, *VD, *AC, *LD	INT
OUT	VW, QW, IW, MW, SW, SMW, LW, T, C, AC, *VD, *LD, *AC	INT

Multiply Double Integer and Divide Double Integer



The **Multiply Double Integer** instruction multiplies two 32-bit integers and produces a 32-bit product.

The **Divide Double Integer** instruction divides two 32-bit integers and produces a 32-bit quotient. No remainder is kept.

In LAD and FBD: IN1 * IN2 = OUT
IN1 / IN2 = OUT

In STL: IN1 * OUT = OUT
OUT / IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM1.3 (divide-by-zero), SM4.3 (run-time), 0006 (indirect address)

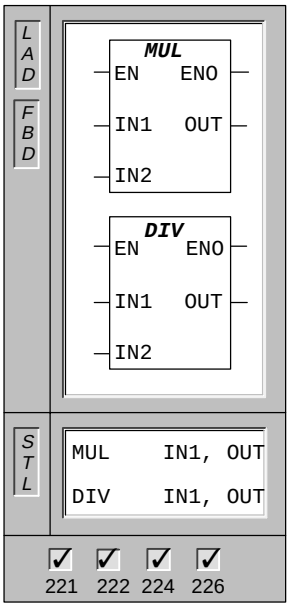
These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative); SM1.3 (divide-by-zero)

If SM1.1 (overflow) is set during a multiply or divide operation, the output is not written and all other math status bits are set to zero.

If SM1.3 (divide by zero) is set during a divide operation, then the other math status bits are left unchanged and the original input operands are not altered. Otherwise, all supported math status bits contain valid status upon completion of the math operation.

Inputs/Outputs	Operands	Data Types
IN1, IN2	VD, ID, QD, MD, SMD, SD, LD, HC, AC, Constant, *VD, *AC, *LD	DINT
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *LD, *AC	DINT

Multiply Integer To Double Integer and Divide Integer To Double Integer



The **Multiply Integer to Double Integer** instruction multiplies two 16-bit integers and produces a 32-bit product.

The **Divide Integer to Double Integer** instruction divides two 16-bit integers and produces a 32-bit result consisting of a 16-bit remainder (most-significant) and a 16-bit quotient (least-significant).

In the STL Multiply instruction, the least-significant word (16 bits) of the 32-bit OUT is used as one of the factors.

In the STL Divide instruction, the least-significant word (16 bits) of the 32-bit OUT is used as the dividend.

In LAD and FBD: IN1 * IN2 = OUT
IN1 / IN2 = OUT

In STL: IN1 * OUT = OUT
OUT / IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM1.3 (divide-by-zero), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative); SM1.3 (divide-by-zero)

If SM1.3 (divide by zero) is set during a divide operation, then the other math status bits are left unchanged and the original input operands are not altered. Otherwise, all supported math status bits contain valid status upon completion of the math operation.

Inputs/Outputs	Operands	Data Types
IN1, IN2	VW, IW, QW, MW, SW, SMW, LW, AC, AIW, T, C, Constant, *VD, *AC, *LD	INT
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *LD, *AC	DINT

Math Examples

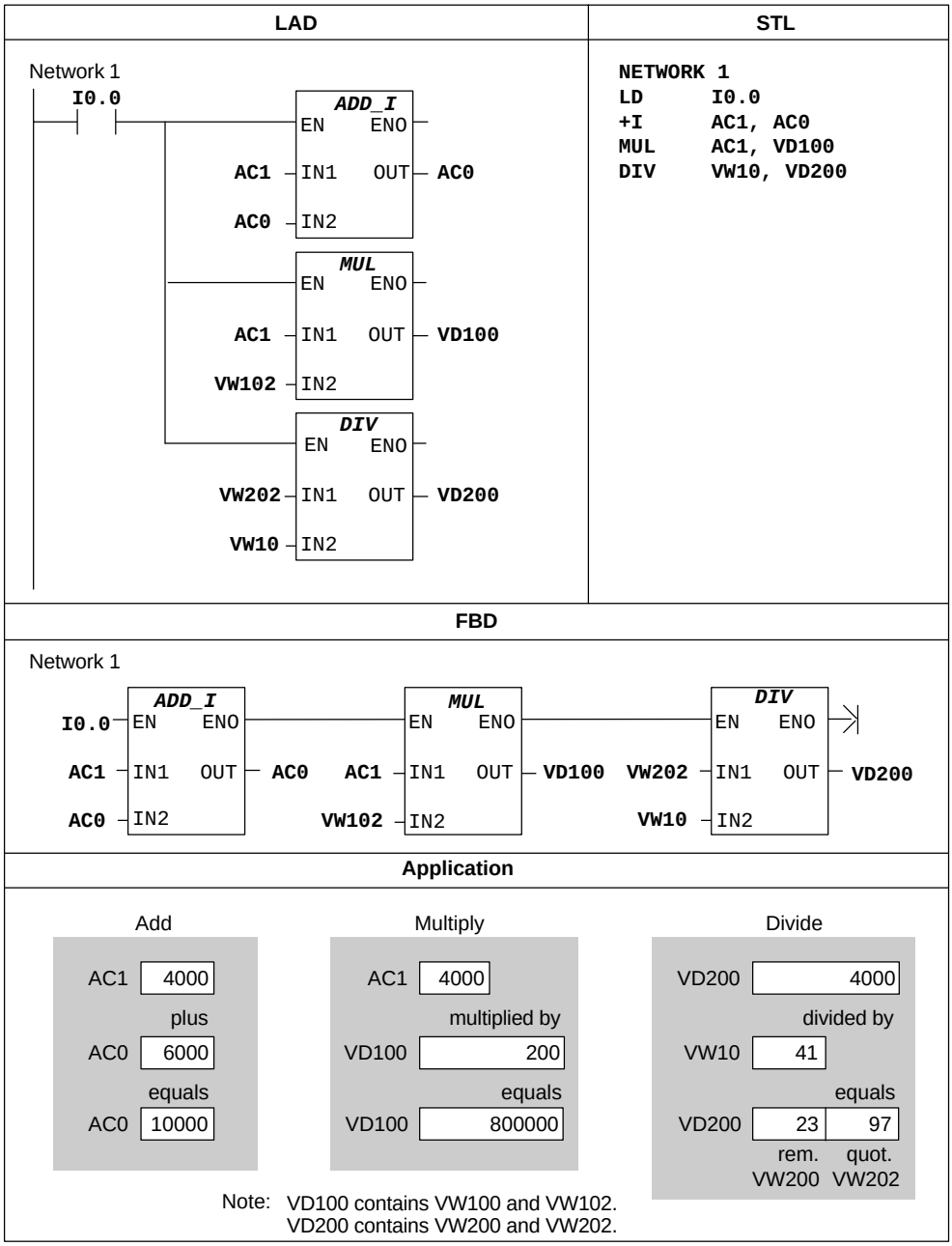
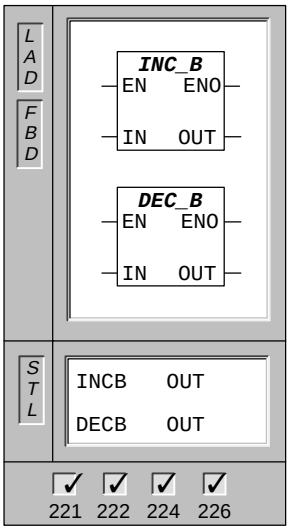


Figure 9-25 Examples of Integer Math Instructions for SIMATIC LAD, STL, and FBD

Increment Byte and Decrement Byte



The **Increment Byte** and **Decrement Byte** instructions add or subtract 1 to or from the input byte (IN) and place the result into the variable specified by OUT.

Increment and decrement byte operations are unsigned.

In LAD and FBD: IN + 1 = OUT
IN - 1 = OUT

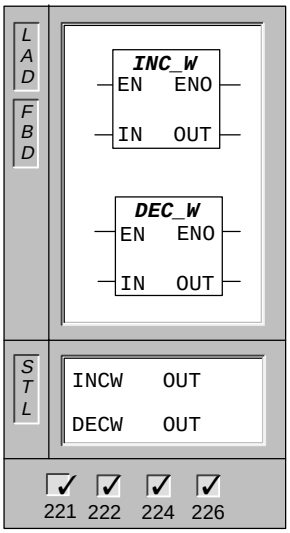
In STL: OUT+ 1 = OUT
OUT - 1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VB, IB, QB, MB, SB, SMB, LB, AC,*VD, *AC, *LD	BYTE

Increment Word and Decrement Word



The **Increment Word** and **Decrement Word** instructions add or subtract 1 to or from the input word (IN) and place the result in OUT.

Increment and decrement word operations are signed (16#7FFF > 16#8000).

In LAD and FBD: IN + 1 = OUT
IN - 1 = OUT

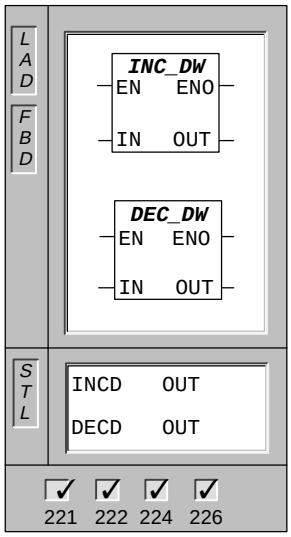
In STL: OUT + 1 = OUT
OUT - 1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, AC, AIW, LW, T, C, Constant, *VD, *AC, *LD	INT
OUT	VW, IW, QW, MW, SW, SMW, LW, AC, T, C, *VD, *AC, *LD	INT

Increment Double Word and Decrement Double Word



The **Increment Double Word** and **Decrement Double Word** instructions add or subtract 1 to or from the input double word (IN) and place the result in OUT.

In LAD and FBD: IN + 1 = OUT
IN - 1 = OUT

Increment and decrement double word operations are signed (16#7FFFFFFF > 16#80000000).

In STL: OUT + 1 = OUT
OUT - 1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SD, SMD, LD, AC, HC, Constant, *VD, *AC, *LD	DINT
OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	DINT

Increment, Decrement Example

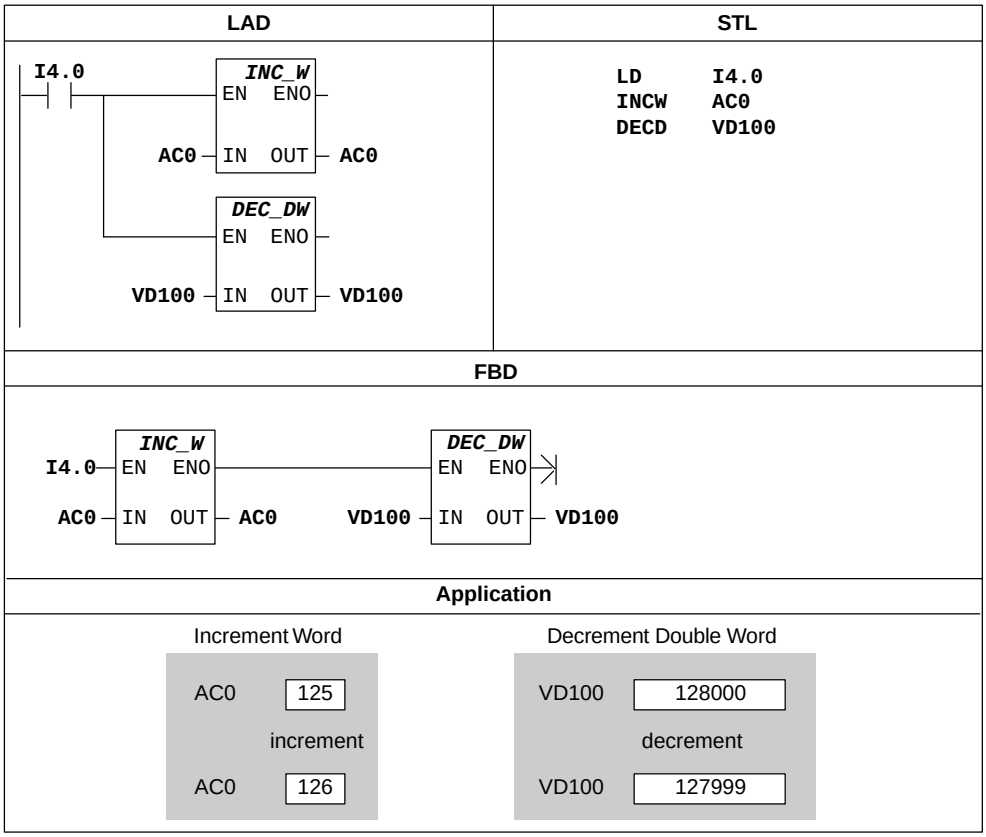
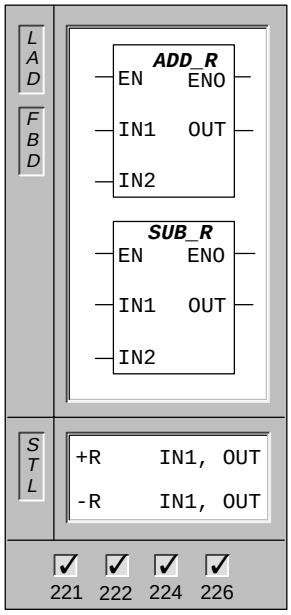


Figure 9-26 Example of Increment/Decrement Instructions for SIMATIC LAD, STL, and FBD

9.7 SIMATIC Real Math Instructions

Add Real, Subtract Real



The **Add Real** and **Subtract Real** instructions add or subtract two 32-bit real numbers and produce a 32-bit real number result (OUT).

In LAD and FBD: IN1 + IN2 = OUT
IN1 - IN2 = OUT

In STL: IN1 + OUT = OUT
OUT - IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

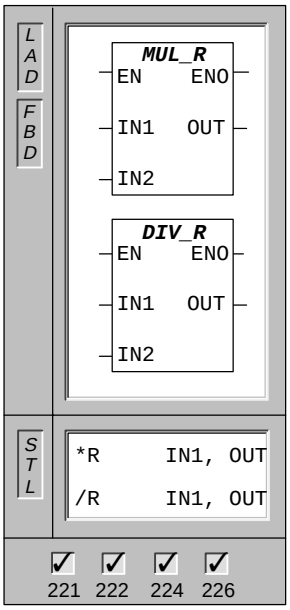
SM1.1 is used to indicate overflow errors and illegal values. If SM1.1 is set, then the status of SM1.0 and SM1.2 is not valid and the original input operands are not altered. If SM1.1 is not set, then the math operation has completed with a valid result and SM1.0 and SM1.2 contain valid status.

Inputs/Outputs	Operands	Data Types
IN1, IN2	VD, ID, QD, MD, SD, SMD, AC, LD, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SD, SMD, AC, LD, *VD, *AC, *LD	REAL

Note

Real or floating-point numbers are represented in the format described in the ANSI/IEEE 754-1985 standard (single-precision). Refer to the standard for more information.

Multiply Real, Divide Real



The **Multiply Real** instruction multiplies two 32-bit real numbers, and produces a 32-bit real number result (OUT).

The **Divide Real** instruction divides two 32-bit real numbers, and produces a 32-bit real number quotient.

In LAD and FBD:	IN1 ∗ IN2 = OUT IN1/ IN2 = OUT
In STL:	IN1 ∗ OUT = OUT OUT / IN1 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM1.3 (divide-by-zero), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow or illegal value generated during the operation or illegal input parameter found); SM1.2 (negative); SM1.3 (divide-by-zero)

If SM1.3 is set during a divide operation, then the other math status bits are left unchanged and the original input operands are not altered. SM1.1 is used to indicate overflow errors and illegal values. If SM1.1 is set, then the status of SM1.0 and SM1.2 is not valid and the original input operands are not altered. If SM1.1 and SM1.3 (during a divide operation) are not set, then the math operation has completed with a valid result and SM1.0 and SM1.2 contain valid status.

Inputs/Outputs	Operands	Data Types
IN1, IN2	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

Note

Real or floating-point numbers are represented in the format described in the ANSI/IEEE 754-1985 standard (single-precision). Refer to the standard for more information.

Math Examples

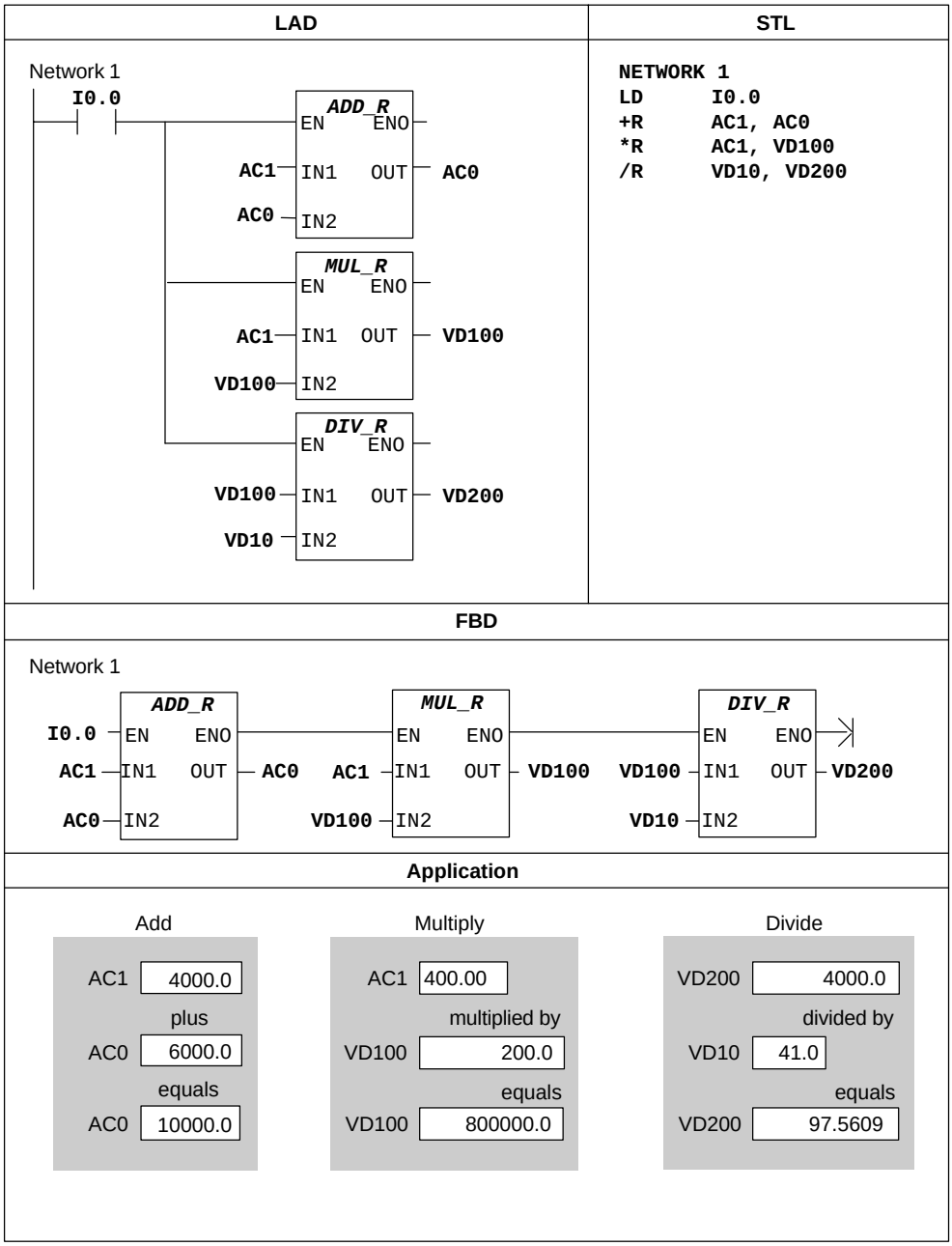
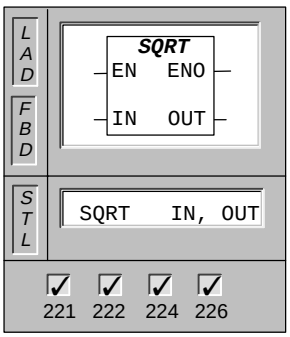


Figure 9-27 Examples of Real Math Instructions for SIMATIC LAD, STL, and FBD

9.8 SIMATIC Numerical Functions Instructions

Square Root



The **Square Root** instruction takes the square root of a 32-bit real number (IN) and produces a 32-bit real number result (OUT) as shown in the equation:

$\sqrt{\ }IN = OUT$

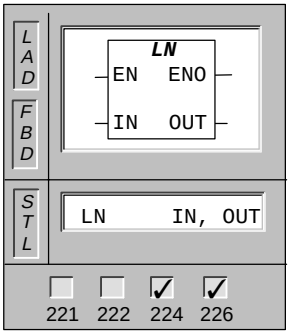
Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative).

SM1.1 is used to indicate overflow errors and illegal values. If SM1.1 is set, then the status of SM1.0 and SM1.2 is not valid and the original input operands are not altered. If SM1.1 is not set, then the math operation has completed with a valid result and SM1.0 and SM1.2 contain valid status. To obtain other roots, see Natural Exponential on page 9-86.

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

Natural Logarithm



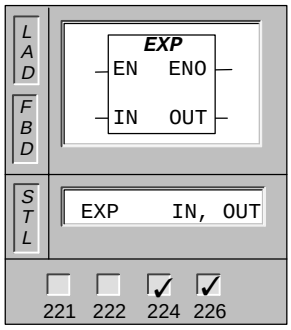
The **Natural Logarithm** instruction performs the natural logarithm of the value in IN and places the result in OUT. To obtain the base 10 logarithm from the natural logarithm, use DIV_R (/R) to divide the natural logarithm by 2.302585 (approximately the natural log of 10).

Error conditions that set ENO = 0: SM1.1 (overflow), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative), SM4.3 (run-time).

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

Natural Exponential



The **Natural Exponential** instruction performs the exponential operation of e raised to the power of the value in IN and places the result in OUT. The Natural Exponential can be used in combination with the Natural Logarithm to raise any real number to the power of another real number, including fractional exponents. That is, X raised to the Y power can be computed as EXP (Y * LNX).

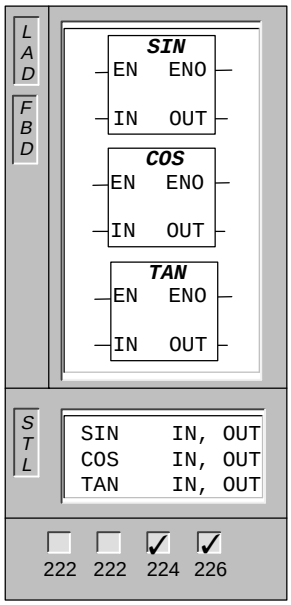
Examples:
5 cubed = 5^3=EXP(3*LN(5))=125
The cube root of 125=125^(1/3)= EXP(1/3)*LN(125))= 5
The square root of
5 cubed=5^(3/2)=EXP(3/2*LN(5))=11.18034 ...

Error conditions that set ENO = 0: SM1.1 (overflow), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative), SM4.3 (run-time).

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

Sine, Cosine, and Tangent



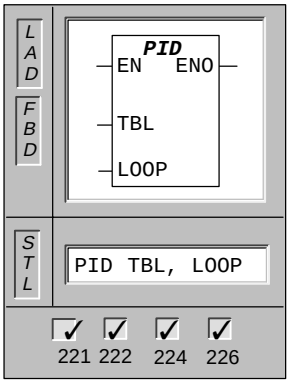
The **Sine, Cosine, and Tangent** instructions evaluate the trigonometric function of the angle value IN and place the result in OUT. The input angle value is in radians. To convert an angle from degrees to radians, use MUL_R (*R) to multiply the angle in degrees by 1.745329E-2 (approximately by π /180).

Error conditions that set ENO = 0: SM1.1 (overflow), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative), SM4.3 (run-time).

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

PID Loop



The **PID Loop** instruction executes a PID loop calculation on the referenced LOOP based on the input and configuration information in Table (TBL).

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
TBL	VB	BYTE
LOOP	Constant (0 to 7)	BYTE

The PID loop instruction (Proportional, Integral, Derivative Loop) is provided to perform the PID calculation. The top of the logic stack (TOS) must be ON (power flow) to enable the PID calculation. The instruction has two operands: a TABLE address which is the starting address of the loop table and a LOOP number which is a constant from 0 to 7. Eight PID instructions can be used in a program. If two or more PID instructions are used with the same loop number (even if they have different table addresses), the PID calculations will interfere with one another and the output will be unpredictable.

The loop table stores nine parameters used for controlling and monitoring the loop operation and includes the current and previous value of the process variable, the setpoint, output, gain, sample time, integral time (reset), derivative time (rate), and the integral sum (bias).

To perform the PID calculation at the desired sample rate, the PID instruction must be executed either from within a timed interrupt routine or from within the main program at a rate controlled by a timer. The sample time must be supplied as an input to the PID instruction via the loop table.

Using the PID Wizard in STEP 7-Micro/WIN 32

STEP 7-Micro/WIN 32 offers the PID Wizard to guide you in defining a PID algorithm for a closed-loop control process. Select the menu command **Tools > Instruction Wizard**, and then select PID from the Instruction Wizard window.

PID Algorithm

In steady state operation, a PID controller regulates the value of the output so as to drive the error (e) to zero. A measure of the error is given by the difference between the setpoint (SP) (the desired operating point) and the process variable (PV) (the actual operating point). The principle of PID control is based upon the following equation that expresses the output, M(t), as a function of a proportional term, an integral term, and a differential term:

$M(t)$	=	$K_C * e$	+	$K_C \int_0^t e\,dt + M_{initial}$	+	$K_C * de/dt$
output	=	proportional term	+	integral term	+	differential term

where:

$M(t)$ is the loop output as a function of time
K_C is the loop gain
e is the loop error (the difference between setpoint and process variable)
$M_{initial}$ is the initial value of the loop output

In order to implement this control function in a digital computer, the continuous function must be quantized into periodic samples of the error value with subsequent calculation of the output. The corresponding equation that is the basis for the digital computer solution is:

M_n	=	$K_C * e_n$	+	$K_I * \sum_1^n + M_{initial}$	+	$K_D * (e_n - e_{n-1})$
output	=	proportional term	+	integral term	+	differential term

where:

M_n is the calculated value of the loop output at sample time n
K_C is the loop gain
e_n is the value of the loop error at sample time n
e_{n-1} is the previous value of the loop error (at sample time n - 1)
K_I is the proportional constant of the integral term
$M_{initial}$ is the initial value of the loop output
K_D is the proportional constant of the differential term

From this equation, the integral term is shown to be a function of all the error terms from the first sample to the current sample. The differential term is a function of the current sample and the previous sample, while the proportional term is only a function of the current sample. In a digital computer it is not practical to store all samples of the error term, nor is it necessary.

Since the digital computer must calculate the output value each time the error is sampled beginning with the first sample, it is only necessary to store the previous value of the error and the previous value of the integral term. As a result of the repetitive nature of the digital computer solution, a simplification in the equation that must be solved at any sample time can be made. The simplified equation is:

M_n	=	$K_C * e_n$	+	$K_I * e_n + MX$	+	$K_D * (e_n - e_{n-1})$
output	=	proportional term	+	integral term	+	differential term

where:

M_n	is the calculated value of the loop output at sample time n
K_C	is the loop gain
e_n	is the value of the loop error at sample time n
e_{n-1}	is the previous value of the loop error (at sample time n - 1)
K_I	is the proportional constant of the integral term
MX	is the previous value of the integral term (at sample time n - 1)
K_D	is the proportional constant of the differential term

The CPU uses a modified form of the above simplified equation when calculating the loop output value. This modified equation is:

M_n	=	MP_n	+	MI_n	+	MD_n
output	=	proportional term	+	integral term	+	differential term

where:

M_n	is the calculated value of the loop output at sample time n
MP_n	is the value of the proportional term of the loop output at sample time n
MI_n	is the value of the integral term of the loop output at sample time n
MD_n	is the value of the differential term of the loop output at sample time n

Proportional Term

The proportional term MP is the product of the gain (K_C), which controls the sensitivity of the output calculation, and the error (e), which is the difference between the setpoint (SP) and the process variable (PV) at a given sample time. The equation for the proportional term as solved by the CPU is:

$$MP_n = K_C * (SP_n - PV_n)$$

where:

MP_n	is the value of the proportional term of the loop output at sample time n
K_C	is the loop gain
SP_n	is the value of the setpoint at sample time n
PV_n	is the value of the process variable at sample time n

Integral Term

The integral term MI is proportional to the sum of the error over time. The equation for the integral term as solved by the CPU is:

$$\mathbf{MI_n = K_C * T_S / T_I * (SP_n - PV_n) + MX}$$

where:

MI_n	is the value of the integral term of the loop output at sample time n
K_C	is the loop gain
T_S	is the loop sample time
T_I	is the integration period of the loop (also called the integral time or reset)
SP_n	is the value of the setpoint at sample time n
PV_n	is the value of the process variable at sample time n
MX	is the value of the integral term at sample time n - 1 (also called the integral sum or the bias)

The integral sum or bias (MX) is the running sum of all previous values of the integral term. After each calculation of MI_n, the bias is updated with the value of MI_n which may be adjusted or clamped (see the section “Variables and Ranges” on page 9-95 for details). The initial value of the bias is typically set to the output value ($M_{initial}$) just prior to the first loop output calculation. Several constants are also part of the integral term, the gain (K_C), the sample time (T_S), which is the cycle time at which the PID loop recalculates the output value, and the integral time or reset (T_I), which is a time used to control the influence of the integral term in the output calculation.

Differential Term

The differential term MD is proportional to the change in the error. The equation for the differential term is shown below:

$$\mathbf{MD_n = K_C * T_D / T_S * ((SP_n - PV_n) - (SP_{n-1} - PV_{n-1}))}$$

To avoid step changes or bumps in the output due to derivative action on setpoint changes, this equation is modified to assume that the setpoint is a constant ($SP_n = SP_{n-1}$). This results in the calculation of the change in the process variable instead of the change in the error as shown:

$$\mathbf{MD_n = K_C * T_D / T_S * (SP_n - PV_n - SP_n + PV_{n-1})}$$

or just:

$$\mathbf{MD_n = K_C * T_D / T_S * (PV_{n-1} - PV_n)}$$

where:

MD_n	is the value of the differential term of the loop output at sample time n
K_C	is the loop gain
T_S	is the loop sample time
T_D	is the differentiation period of the loop (also called the derivative time or rate)
SP_n	is the value of the setpoint at sample time n
SP_{n-1}	is the value of the setpoint at sample time n - 1
PV_n	is the value of the process variable at sample time n
PV_{n-1}	is the value of the process variable at sample time n - 1

The process variable rather than the error must be saved for use in the next calculation of the differential term. At the time of the first sample, the value of PV_{n-1} is initialized to be equal to PV_n.

Selection of Loop Control

In many control systems it may be necessary to employ only one or two methods of loop control. For example, only proportional control or proportional and integral control may be required. The selection of the type of loop control desired is made by setting the value of the constant parameters.

If you do not want integral action (no “I” in the PID calculation), then a value of infinity should be specified for the integral time (reset). Even with no integral action, the value of the integral term may not be zero, due to the initial value of the integral sum MX.

If you do not want derivative action (no “D” in the PID calculation), then a value of 0.0 should be specified for the derivative time (rate).

If you do not want proportional action (no “P” in the PID calculation) and you want I or ID control, then a value of 0.0 should be specified for the gain. Since the loop gain is a factor in the equations for calculating the integral and differential terms, setting a value of 0.0 for the loop gain will result in a value of 1.0 being used for the loop gain in the calculation of the integral and differential terms.

Converting and Normalizing the Loop Inputs

A loop has two input variables, the setpoint and the process variable. The setpoint is generally a fixed value such as the speed setting on the cruise control in your automobile. The process variable is a value that is related to loop output and therefore measures the effect that the loop output has on the controlled system. In the example of the cruise control, the process variable would be a tachometer input that measures the rotational speed of the tires.

Both the setpoint and the process variable are real world values whose magnitude, range, and engineering units may be different. Before these real world values can be operated upon by the PID instruction, the values must be converted to normalized, floating-point representations.

The first step is to convert the real world value from a 16-bit integer value to a floating-point or real number value. The following instruction sequence is provided to show how to convert from an integer value to a real number.

```
XORD    AC0,  AC0              //Clear the accumulator.
MOVW    AIW0,  AC0             //Save the analog value in the accumulator.
LDW>=   AC0,  0                //If the analog value is positive,
JMP     0                      //then convert to a real number.
NOT                            //Else,
ORD     16#FFFF0000,  AC0      //sign extend the value in AC0.
LBL     0
DTR     AC0,  AC0              //Convert the 32-bit integer to a real number.
```

The next step is to convert the real number value representation of the real world value to a normalized value between 0.0 and 1.0. The following equation is used to normalize either the setpoint or process variable value:

$$\mathbf{R_{Norm} = ((R_{Raw} / Span) + Offset)}$$

where:

R_{Norm}	is the normalized, real number value representation of the real world value
R_{Raw}	is the un-normalized or raw, real number value representation of the real world value
Offset	is 0.0 for unipolar values is 0.5 for bipolar values
Span	is the maximum possible value minus the minimum possible value = 32,000 for unipolar values (typical) = 64,000 for bipolar values (typical)

The following instruction sequence shows how to normalize the bipolar value in AC0 (whose span is 64,000) as a continuation of the previous instruction sequence:

```
/R      64000.0,  AC0          //Normalize the value in the accumulator
+R      0.5,  AC0              //Offset the value to the range from 0.0 to 1.0
MOVR    AC0,  VD100            //Store the normalized value in the loop TABLE
```

Converting the Loop Output to a Scaled Integer Value

The loop output is the control variable, such as the throttle setting in the example of the cruise control on the automobile. The loop output is a normalized, real number value between 0.0 and 1.0. Before the loop output can be used to drive an analog output, the loop output must be converted to a 16-bit, scaled integer value. This process is the reverse of converting the PV and SP to a normalized value. The first step is to convert the loop output to a scaled, real number value using the formula given below:

$$\mathbf{R_{Scal} = (M_n - Offset) * Span}$$

where:

R_{Scal}	is the scaled, real number value of the loop output
M_n	is the normalized, real number value of the loop output
Offset	is 0.0 for unipolar values is 0.5 for bipolar values
Span	is the maximum possible value minus the minimum possible value = 32,000 for unipolar values (typical) = 64,000 for bipolar values (typical)

The following instruction sequence shows how to scale the loop output:

```
MOVR   VD108,  AC0      //Move the loop output to the accumulator.
-R     0.5,  AC0        //Include this statement only if the value is
                        //bipolar.
*R     64000.0,  AC0    //Scale the value in the accumulator.
```

Next, the scaled, real number value representing the loop output must be converted to a 16-bit integer. The following instruction sequence shows how to do this conversion:

```
ROUND  AC0   AC0        //Convert the real number to a 32-bit integer.
MOVW   AC0,  AQW0       //Write the 16-bit integer value to the analog
                        //output.
```

Forward- or Reverse-Acting Loops

The loop is forward-acting if the gain is positive and reverse-acting if the gain is negative. (For I or ID control, where the gain value is 0.0, specifying positive values for integral and derivative time will result in a forward-acting loop, and specifying negative values will result in a reverse-acting loop.)

Variables and Ranges

The process variable and setpoint are inputs to the PID calculation. Therefore the loop table fields for these variables are read but not altered by the PID instruction.

The output value is generated by the PID calculation, so the output value field in the loop table is updated at the completion of each PID calculation. The output value is clamped between 0.0 and 1.0. The output value field can be used as an input by the user to specify an initial output value when making the transition from manual control to PID instruction (auto) control of the output (see discussion in the “Modes” section below).

If integral control is being used, then the bias value is updated by the PID calculation and the updated value is used as an input in the next PID calculation. When the calculated output value goes out of range (output would be less than 0.0 or greater than 1.0), the bias is adjusted according to the following formulas:

$\mathbf{MX = 1.0 - (MP_n + MD_n)}$ when the calculated output, $M_n > 1.0$

or

$\mathbf{MX = - (MP_n + MD_n)}$ when the calculated output, $M_n < 0.0$

where:

MX	is the value of the adjusted bias
MP_n	is the value of the proportional term of the loop output at sample time n
MD_n	is the value of the differential term of the loop output at sample time n
M_n	is the value of the loop output at sample time n

By adjusting the bias as described, an improvement in system responsiveness is achieved once the calculated output comes back into the proper range. The calculated bias is also clamped between 0.0 and 1.0 and then is written to the bias field of the loop table at the completion of each PID calculation. The value stored in the loop table is used in the next PID calculation.

The bias value in the loop table can be modified by the user prior to execution of the PID instruction in order to address bias value problems in certain application situations. Care must be taken when manually adjusting the bias, and any bias value written into the loop table must be a real number between 0.0 and 1.0.

A comparison value of the process variable is maintained in the loop table for use in the derivative action part of the PID calculation. You should not modify this value.

Modes

There is no built-in mode control for S7-200 PID loops. The PID calculation is performed only when power flows to the PID box. Therefore, “automatic” or “auto” mode exists when the PID calculation is performed cyclically. “Manual” mode exists when the PID calculation is not performed.

The PID instruction has a power-flow history bit, similar to a counter instruction. The instruction uses this history bit to detect a 0-to-1 power flow transition. When the power flow transition is detected, it will cause the instruction to perform a series of actions to provide a bumpless change from manual control to auto control. In order for change to auto mode control to be bumpless, the value of the output as set by the manual control must be supplied as an input to the PID instruction (written to the loop table entry for M_n) before switching to auto control. The PID instruction performs the following actions to values in the loop table to ensure a bumpless change from manual to auto control when a 0-to-1 power flow transition is detected:

- Sets setpoint (SP_n) = process variable (PV_n)
- Sets old process variable (PV_{n-1}) = process variable (PV_n)
- Sets bias (MX) = output value (M_n)

The default state of the PID history bits is “set” and that state is established at CPU startup and on every STOP-to-RUN mode transition of the controller. If power flows to the PID box the first time that it is executed after entering RUN mode, then no power flow transition is detected and the bumpless mode change actions will not be performed.

Alarm Checking and Special Operations

The PID instruction is a simple but powerful instruction that performs the PID calculation. If other processing is required such as alarm checking or special calculations on loop variables, these must be implemented using the basic instructions supported by the CPU.

Error Conditions

When it is time to compile, the CPU will generate a compile error (range error) and the compilation will fail if the loop table start address or PID loop number operands specified in the instruction are out of range.

Certain loop table input values are not range checked by the PID instruction. You must take care to ensure that the process variable and setpoint (as well as the bias and previous process variable if used as inputs) are real numbers between 0.0 and 1.0.

If any error is encountered while performing the mathematical operations of the PID calculation, then SM1.1 (overflow or illegal value) will be set and execution of the PID instruction will be terminated. (Update of the output values in the loop table may be incomplete, so you should disregard these values and correct the input value causing the mathematical error before the next execution of the loop's PID instruction.)

Loop Table

The loop table is 36 bytes long and has the format shown in Table 9-19.

Table 9-19 Format of the Loop Table

Offset	Field	Format	Type	Description
0	Process variable (PV_n)	Double word - real	in	Contains the process variable, which must be scaled between 0.0 and 1.0.
4	Setpoint (SP_n)	Double word - real	in	Contains the setpoint, which must be scaled between 0.0 and 1.0.
8	Output (M_n)	Double word - real	in/out	Contains the calculated output, scaled between 0.0 and 1.0.
12	Gain (K_C)	Double word - real	in	Contains the gain, which is a proportional constant. Can be a positive or negative number.
16	Sample time (T_S)	Double word - real	in	Contains the sample time, in seconds. Must be a positive number.
20	Integral time or reset (T_I)	Double word - real	in	Contains the integral time or reset, in minutes. Must be a positive number.
24	Derivative time or rate (T_D)	Double word - real	in	Contains the derivative time or rate, in minutes. Must be a positive number.
28	Bias (MX)	Double word - real	in/out	Contains the bias or integral sum value between 0.0 and 1.0.
32	Previous process variable (PV_{n-1})	Double word - real	in/out	Contains the previous value of the process variable stored from the last execution of the PID instruction.

PID Program Example

In this example, a water tank is used to maintain a constant water pressure. Water is continuously being taken from the water tank at a varying rate. A variable speed pump is used to add water to the tank at a rate that will maintain adequate water pressure and also keep the tank from being emptied.

The setpoint for this system is a water level setting that is equivalent to the tank being 75% full. The process variable is supplied by a float gauge that provides an equivalent reading of how full the tank is and which can vary from 0% or empty to 100% or completely full. The output is a value of pump speed that allows the pump to run from 0% to 100% of maximum speed.

The setpoint is predetermined and will be entered directly into the loop table. The process variable will be supplied as a unipolar, analog value from the float gauge. The loop output will be written to a unipolar, analog output which is used to control the pump speed. The span of both the analog input and analog output is 32,000.

Only proportional and integral control will be employed in this example. The loop gain and time constants have been determined from engineering calculations and may be adjusted as required to achieve optimum control. The calculated values of the time constants are:

K_C is 0.25

T_S is 0.1 seconds

T_I is 30 minutes

The pump speed will be controlled manually until the water tank is 75% full, then the valve will be opened to allow water to be drained from the tank. At the same time, the pump will be switched from manual to auto control mode. A digital input will be used to switch the control from manual to auto. This input is described below:

I0.0 is manual/auto control; 0 is manual, 1 is auto

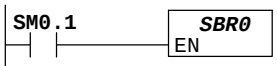
While in manual control mode, the pump speed will be written by the operator to VD108 as a real number value from 0.0 to 1.0.

Figure 9-28 shows the control program for this application.

LAD

MAIN OB1

Network 1

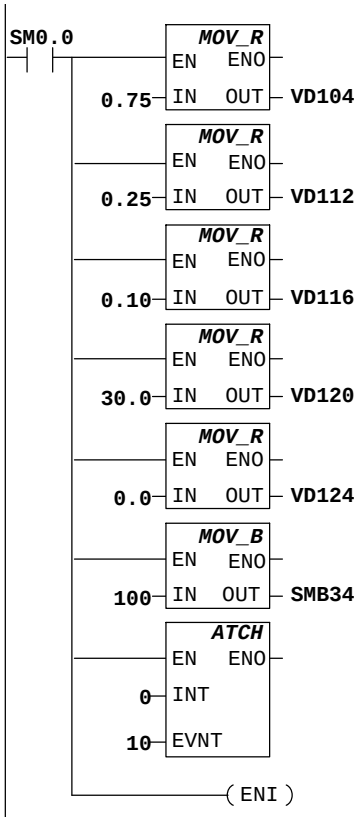


STL

```
Network 1
LD    SM0.1        //On the first scan call
CALL  0            //the initialization
                   //subroutine.
```

SUBROUTINE 0

Network 1




```
Network 1
LD    SM0.0
MOVR  0.75, VD104 //Load the loop setpoint.
                  // = 75% full.
MOVR  0.25, VD112 //Load the loop gain=0.25.
MOVR  0.10, VD116 //Load the loop sample
                  //time = 0.1 seconds.
MOVR  30.0, VD120 //Load the integral time
                  //= 30 minutes.
                  //
MOVR  0.0, VD124  //Set no derivative action.
MOVB  100, SMB34  //Set time interval
                  //(100 ms) for timed
                  //interrupt 0.
ATCH  0, 10       //Set up a timed
                  //interrupt to invoke
                  //PID execution.
ENI               //Enable interrupts.

                  //End of subroutine 0
```

Figure 9-28 Example of PID Loop Control for SIMATIC LAD, STL, and FBD

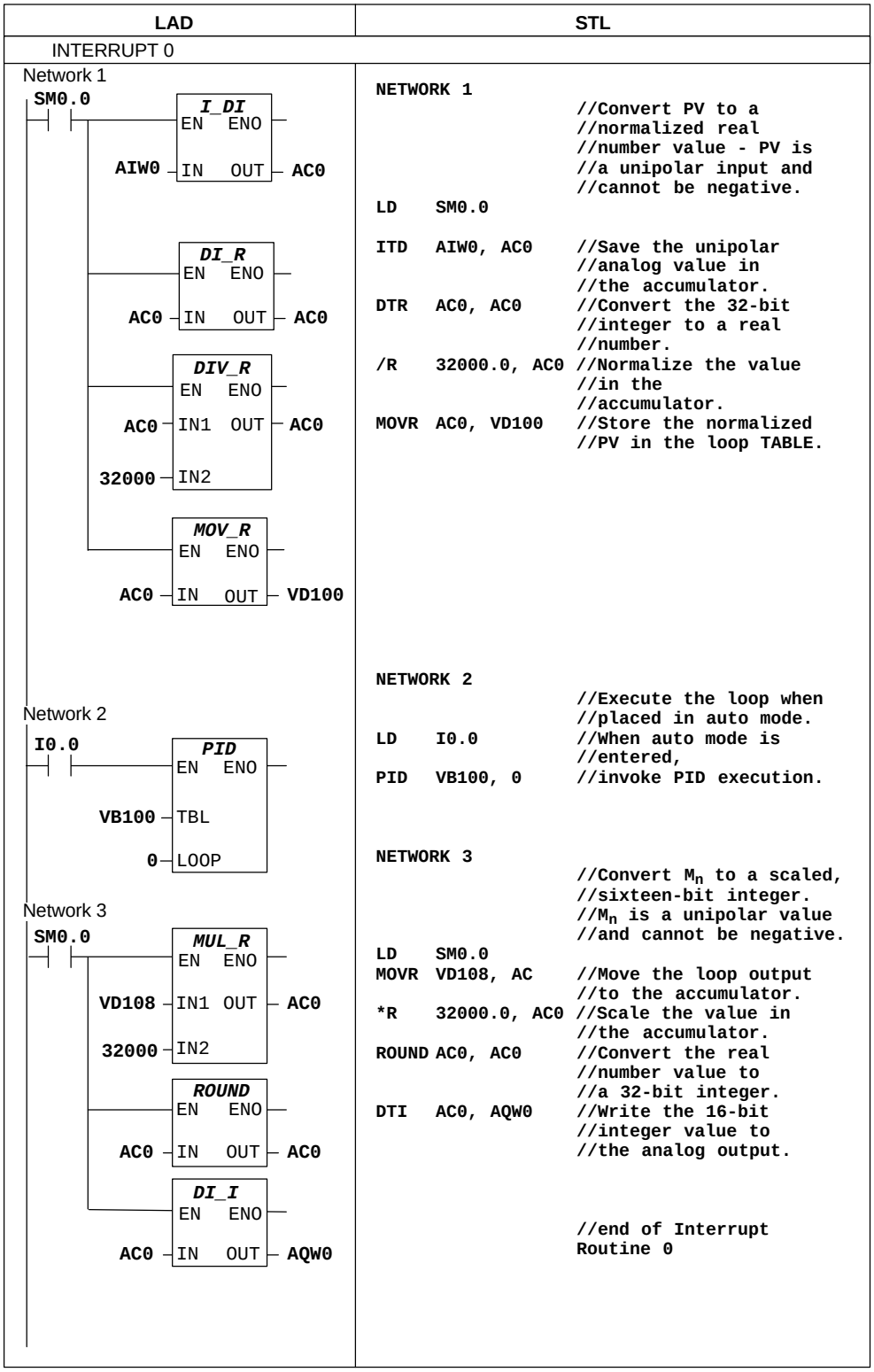


Figure 9-28 Example of PID Loop Control for SIMATIC LAD, STL, and FBD (continued)

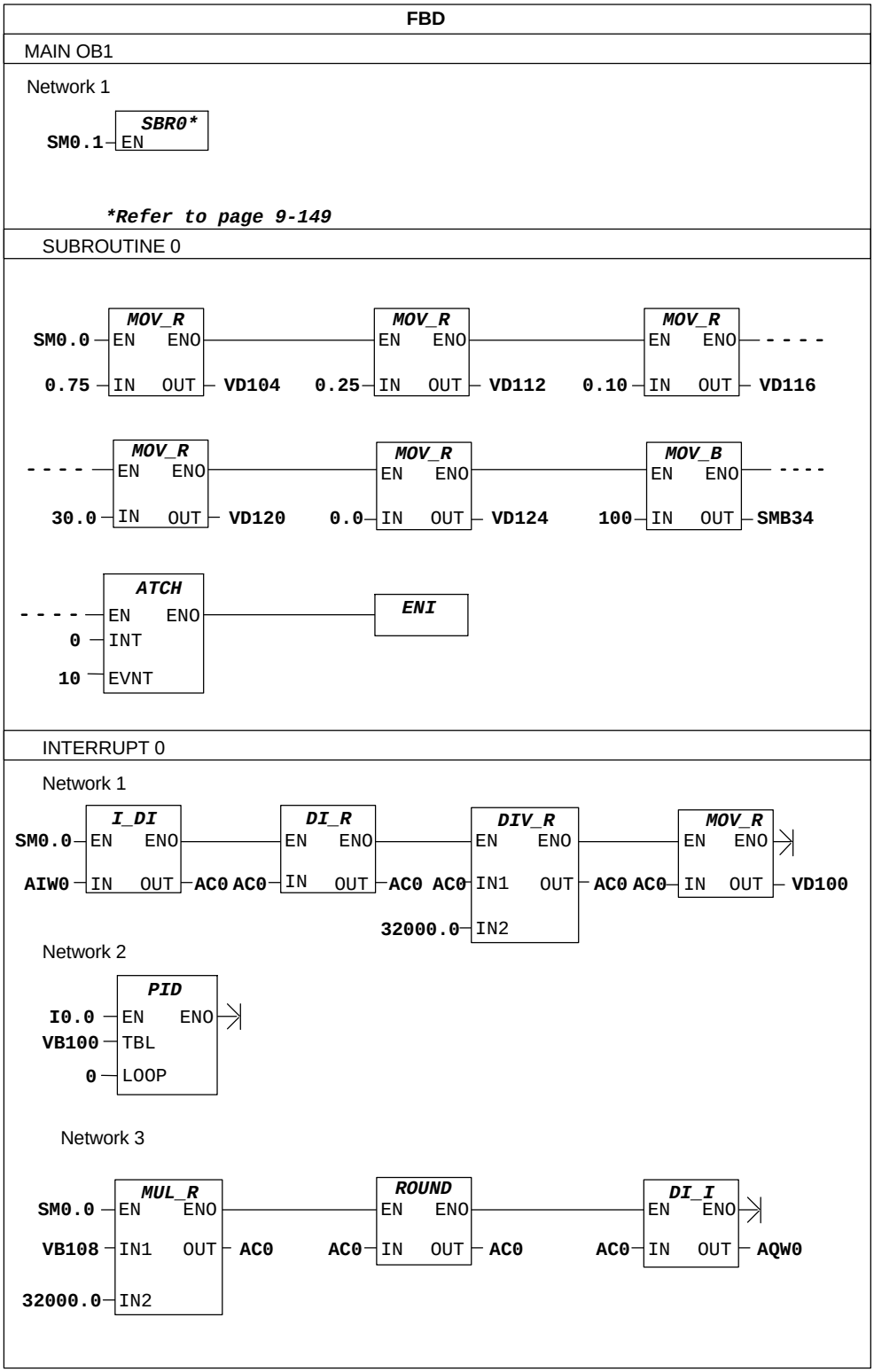
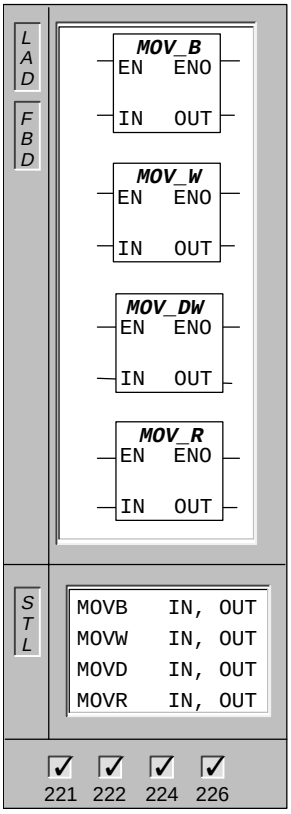


Figure 9-28 Example of PID Loop Control for SIMATIC LAD, STL, and FBD (continued)

9.9 SIMATIC Move Instructions

Move Byte, Move Word, Move Double Word, Move Real



The **Move Byte** instruction moves the input byte (IN) to the output byte (OUT). The input byte is not altered by the move.

The **Move Word** instruction moves the input word (IN) to the output word (OUT). The input word is not altered by the move.

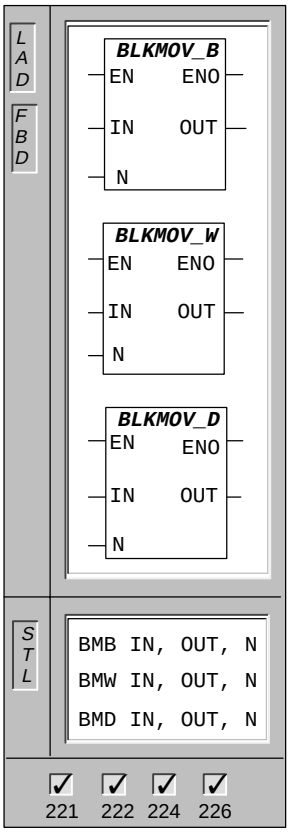
The **Move Double Word** instruction moves the input double word (IN) to the output double word (OUT). The input double word is not altered by the move.

The **Move Real** instruction moves a 32-bit, real input double word (IN) to the output double word (OUT). The input double word is not altered by the move.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Move...	Inputs/Outputs	Operands	Data Types
Byte	IN	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
	OUT	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD	BYTE
Word	IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, Constant, AC *VD, *AC, *LD	WORD, INT
	OUT	VW, T, C, IW, QW, SW, MW, SMW, LW, AC, AQW, *VD, *AC, *LD	WORD, INT
Double Word	IN	VD, ID, QD, MD, SD, SMD, LD, HC, &VB, &IB, &QB, &MB, &SB, &T, &C, AC, Constant, *VD, *AC, *LD	DWORD, DINT
	OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	DWORD, DINT
Real	IN	VD, ID, QD, MD, SD, SMD, LD, AC, Constant, *VD, *AC, *LD	REAL
	OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	REAL

Block Move Byte, Block Move Word, Block Move Double Word



The **Block Move Byte** instruction moves the number of bytes (N) from the input address IN to the output address OUT. N has a range of 1 to 255.

The **Block Move Word** instruction moves the number of words (N), from the input address IN to the output address OUT. N has a range of 1 to 255.

The **Block Move Double Word** instruction moves the number of double words (N), from the input address IN, to the output address OUT. N has a range of 1 to 255.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

Block Move...	Inputs/Outputs	Operands	Data Types
Byte	IN, OUT	VB, IB, QB, MB,SB, SMB, LB, *VD, *AC, *LD	BYTE
	N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
Word	IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, *VD, *AC, *LD	WORD
	N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
	OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AQW, *VD, *LD, *AC	WORD
Double Word	IN, OUT	VD, ID, QD, MD, SD, SMD, LD, *VD, *AC, *LD	DWORD
	N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE

Block Move Example

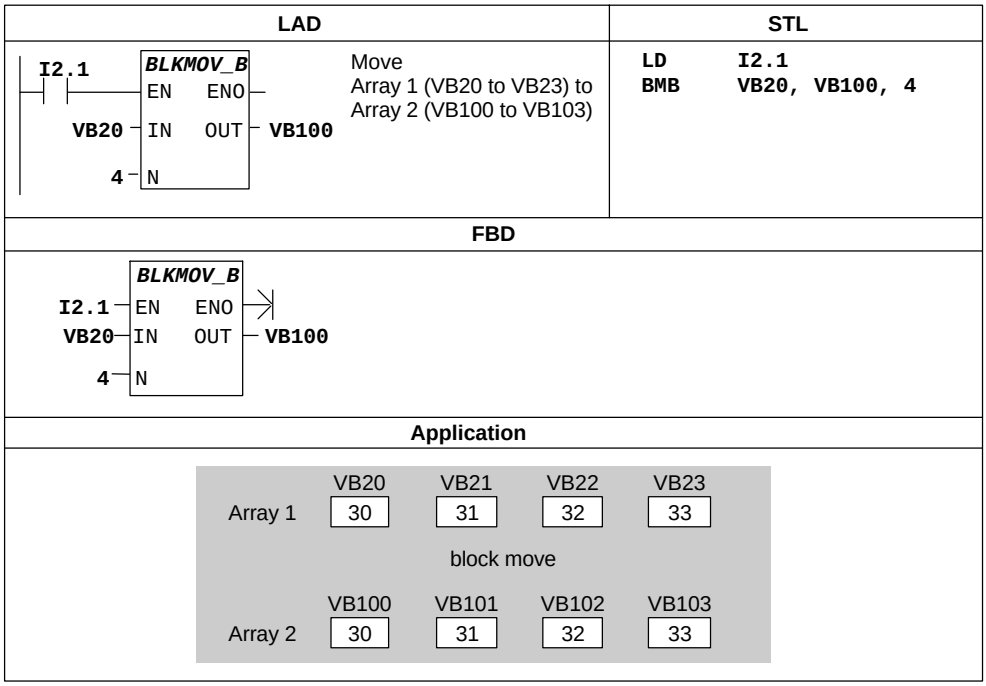
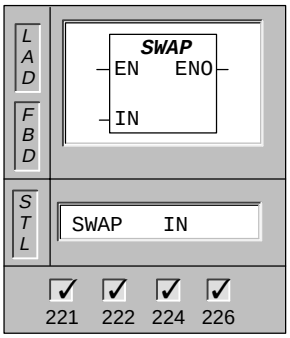


Figure 9-29 Example of Block Move Instructions for SIMATIC LAD, STL, and FBD

Swap Bytes



The **Swap Bytes** instruction exchanges the most significant byte with the least significant byte of the word (IN).

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	WORD

Move and Swap Examples

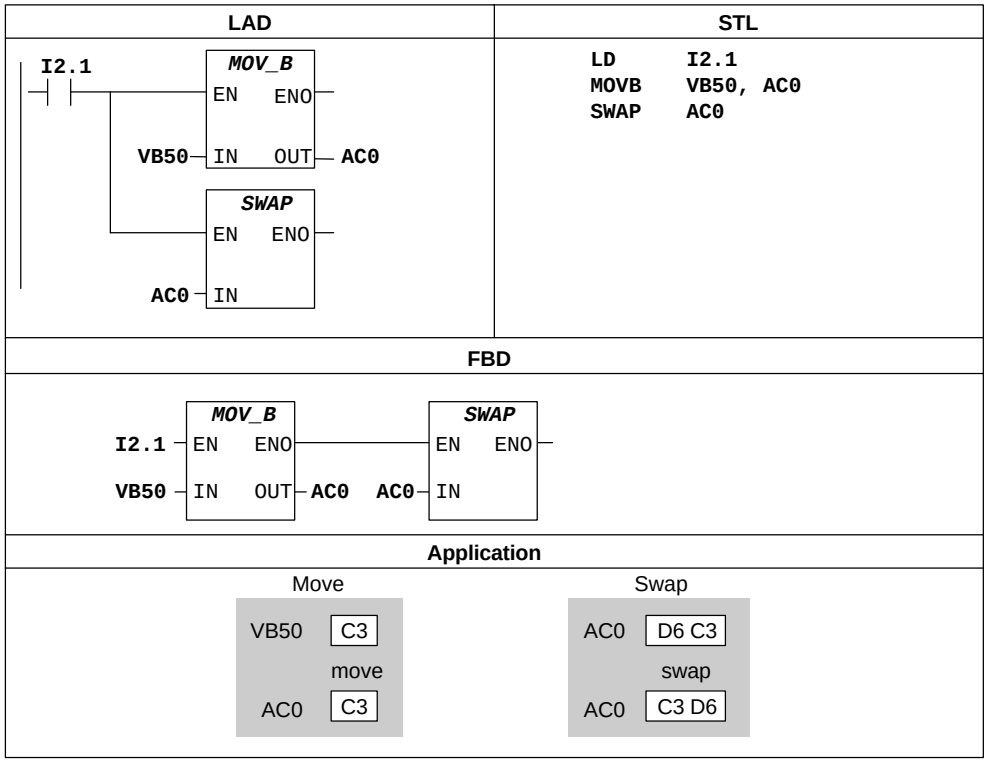
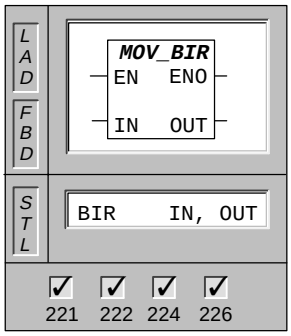


Figure 9-30 Example of Move and Swap Instructions for SIMATIC LAD, STL, and FBD

Move Byte Immediate Read

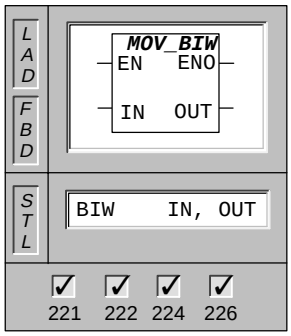


The **Move Byte Immediate Read** instruction reads physical input IN and writes the result in OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	IB	BYTE
OUT	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *LD, *AC	BYTE

Move Byte Immediate Write



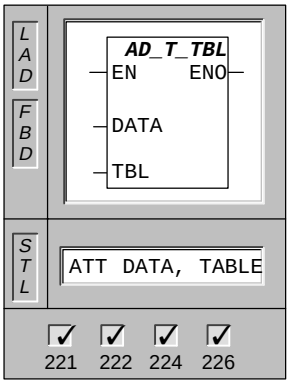
The **Move Byte Immediate Write** instruction reads from location IN and writes to physical output OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, AC, Constant,*VD, *LD, *AC	BYTE
OUT	QB	BYTE

9.10 SIMATIC Table Instructions

Add to Table



The **Add To Table** instruction adds word values (DATA) to the table (TBL).

The first value of the table is the maximum table length (TL). The second value is the entry count (EC), which specifies the number of entries in the table. (See Figure 9-31.) New data are added to the table after the last entry. Each time new data are added to the table, the entry count is incremented. A table may have up to 100 data entries.

Error conditions that set ENO = 0: SM1.4 (table overflow), SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

This instruction affects the following Special Memory bits: SM1.4 is set to 1 if you try to overfill the table.

Inputs/Outputs	Operands	Data Types
DATA	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, AC, Constant, *VD, *AC, *LD	INT
TBL	VW, IW, QW, MW, SW, SMW, LW, T, C, *VD, *AC, *LD	WORD

Add to Table Example

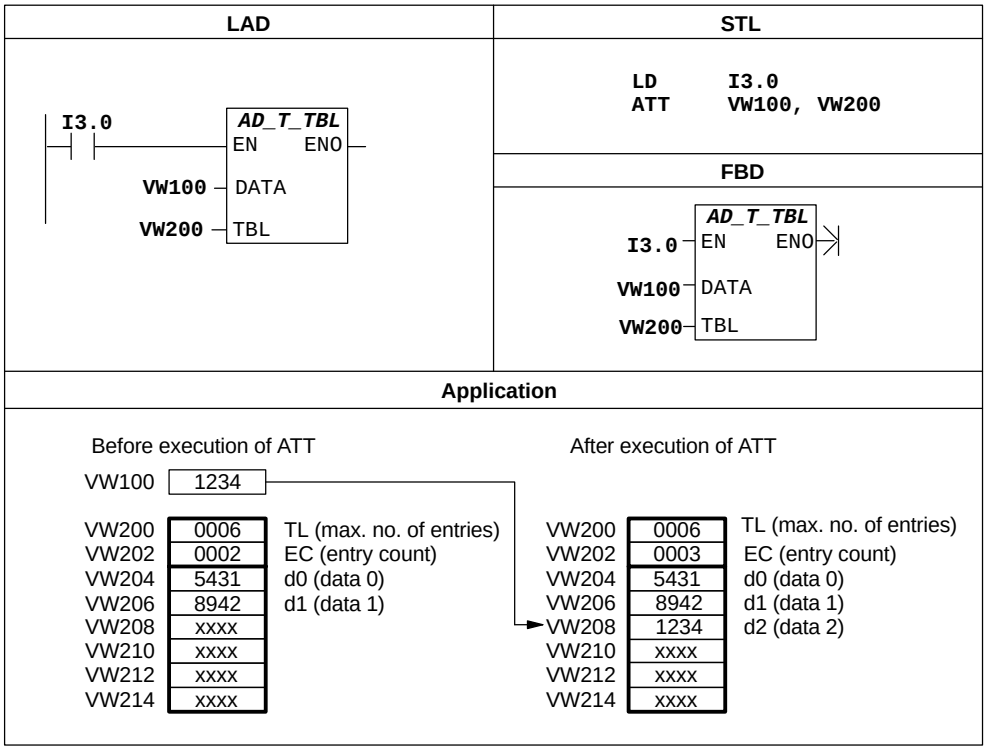
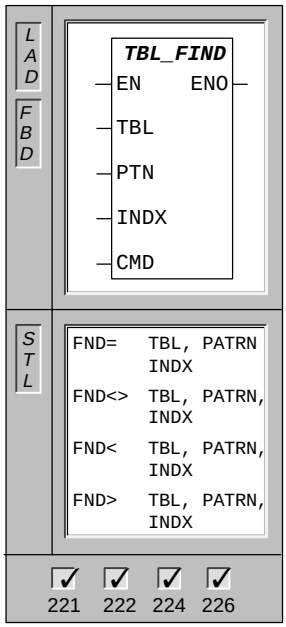


Figure 9-31 Example of Add To Table Instruction for SIMATIC LAD, STL, and FBD

Table Find



The **Table Find** instruction searches the table (TBL), starting with the table entry INDX, for the data value (PTN) that matches the search criteria defined by CMD. The command parameter CMD is given a numeric value of 1 to 4 that corresponds to =, <>, <, and >, respectively.

If a match is found, the INDX points to the matching entry in the table. To find the next matching entry, the INDX must be incremented before invoking the Table Find instruction again. If a match is not found, the INDX has a value equal to the entry count.

A table may have up to 100 data entries. The data entries (area to be searched) are numbered from 0 to a maximum value of 99.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

Inputs/Outputs	Operands	Data Types
SRC	VW, IW, QW, MW, SMW, LW, T, C, *VD, *AC, *LD	WORD
PTN	VW, IW, QW, MW, SW, SMW, AIW, LW, T, C, AC, Constant, *VD, *AC, *LD	INT
INDX	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	WORD
CMD	Constant	BYTE

Note

When you use the Find instructions with tables generated with ATT, LIFO, and FIFO instructions, the entry count and the data entries correspond directly. The maximum-number-of-entries word required for ATT, LIFO, and FIFO is not required by the Find instructions. Consequently, the SRC operand of a Find instruction is one word address (two bytes) higher than the TBL operand of a corresponding ATT, LIFO, or FIFO instruction, as shown in Figure 9-32.

Table format for ATT, LIFO, and FIFO

VW200	0006	TL (max. no. of entries)
VW202	0006	EC (entry count)
VW204	xxxx	d0 (data 0)
VW206	xxxx	d1 (data 1)
VW208	xxxx	d2 (data 2)
VW210	xxxx	d3 (data 3)
VW212	xxxx	d4 (data 4)
VW214	xxxx	d5 (data 5)

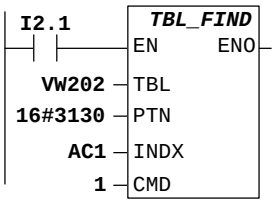
Table format for TBL_FIND

VW202	0006	EC (entry count)
VW204	xxxx	d0 (data 0)
VW206	xxxx	d1 (data 1)
VW208	xxxx	d2 (data 2)
VW210	xxxx	d3 (data 3)
VW212	xxxx	d4 (data 4)
VW214	xxxx	d5 (data 5)

Figure 9-32 Difference in Table Format between Find Instructions and ATT, LIFO, FIFO

Table Find Example

LAD

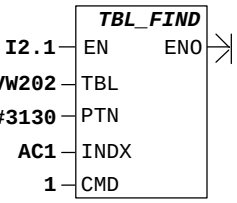


When **I2.1** is on, search the table for a value equal to 3130 HEX.

STL

```
LD      I2.1
FND=    VW202, 16#3130, AC1
```

FBD



Application

This is the table you are searching. If the table was created using ATT, LIFO, and FIFO instructions, VW200 contains the maximum number of allowed entries and is not required by the Find instructions.

VW202	0006	EC (entry count)
VW204	3133	d0 (data 0)
VW206	4142	d1 (data 1)
VW208	3130	d2 (data 2)
VW210	3030	d3 (data 3)
VW212	3130	d4 (data 4)
VW214	4541	d5 (data 5)

AC1 [0] AC1 must be set to 0 to search from the top of table.

Execute table search

AC1 [2] AC1 contains the data entry number corresponding to the first match found in the table (d2).

AC1 [3] Increment the INDX by one, before searching the remaining entries of the table.

Execute table search

AC1 [4] AC1 contains the data entry number corresponding to the second match found in the table (d4).

AC1 [5] Increment the INDX by one, before searching the remaining entries of the table.

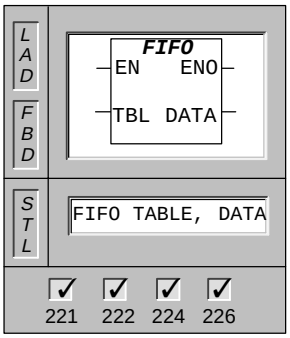
Execute table search

AC1 [6] AC1 contains a value equal to the entry count. The entire table has been searched without finding another match.

AC1 [0] Before the table can be searched again, the INDX value must be reset to 0.

Figure 9-33 Example of Find Instructions for SIMATIC LAD, STL, and FBD

First-In-First-Out



The **First-In-First-Out** instruction removes the first entry in the table (TBL), and moves the value to location DATA. All other entries of the table are shifted up one location. The entry count in the table is decremented for each instruction execution.

Error conditions that set ENO = 0: SM1.5 (empty table), SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

This instruction affects the following Special Memory bits: SM1.5 is set to 1 if you try to remove an entry from an empty table.

Inputs/Outputs	Operands	Data Types
TABLE	VW, IW, QW, MW, SW, SMW, LW, T, C, *VD, *AC, *LD	INT
DATA	VW, IW, QW, MW, SW, SMW, LW, AC, AQW, T, C, *VD, *AC, *LD	WORD

First-In-First-Out Example

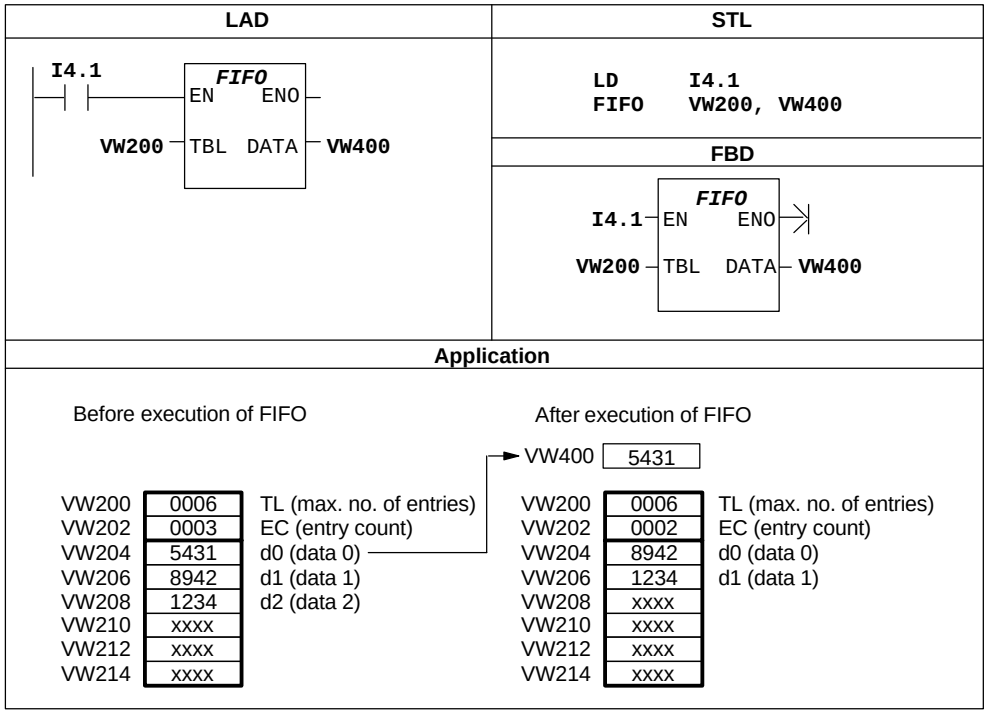
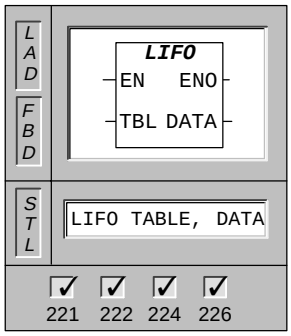


Figure 9-34 Example of First-In-First-Out Instruction for SIMATIC LAD, STL, and FBD

Last-In-First-Out



The **Last-In-First-Out** instruction removes the last entry in the table (TBL), and outputs the value to a location specified by DATA. The entry count in the table is decremented for each instruction execution.

Error conditions that set ENO = 0: SM1.5 (empty table), SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

This instruction affects the following Special Memory bits: SM1.5 is set to 1 if you try to remove an entry from an empty table.

Inputs/Outputs	Operands	Data Types
TABLE	VW, IW, QW, MW, SW, SMW, LW, T, C, *VD, *AC, *LD	INT
DATA	VW, IW, QW, MW, SW, SMW, LW, AQW, T, C, AC, *VD, *AC, *LD	WORD

Last-In-First-Out Example

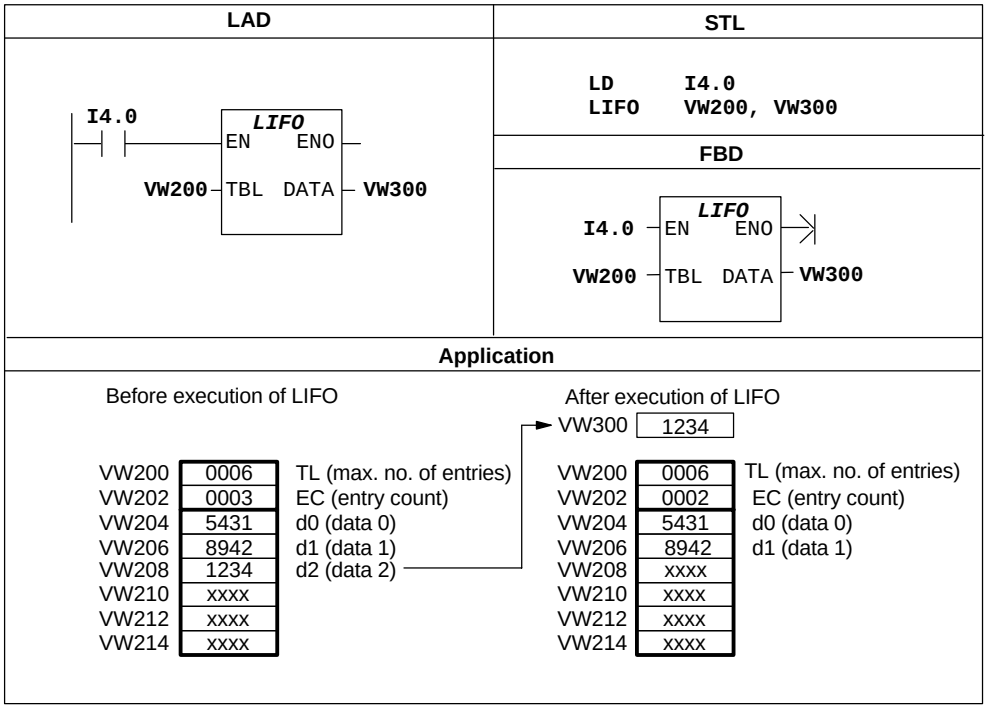
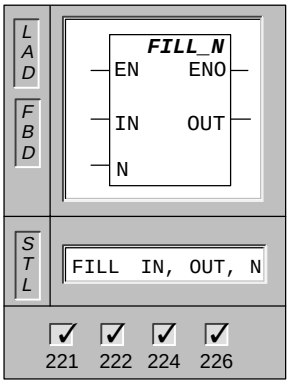


Figure 9-35 Example of Last-In-First-Out Instruction for SIMATIC LAD, STL, and FBD

Memory Fill



The **Memory Fill** instruction fills N number of words at address IN to the address OUT. N has a range of 1 to 255.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, AC, Constant, *VD, *AC, *LD	WORD
N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AQW, *VD, *AC, *LD	WORD

Fill Example

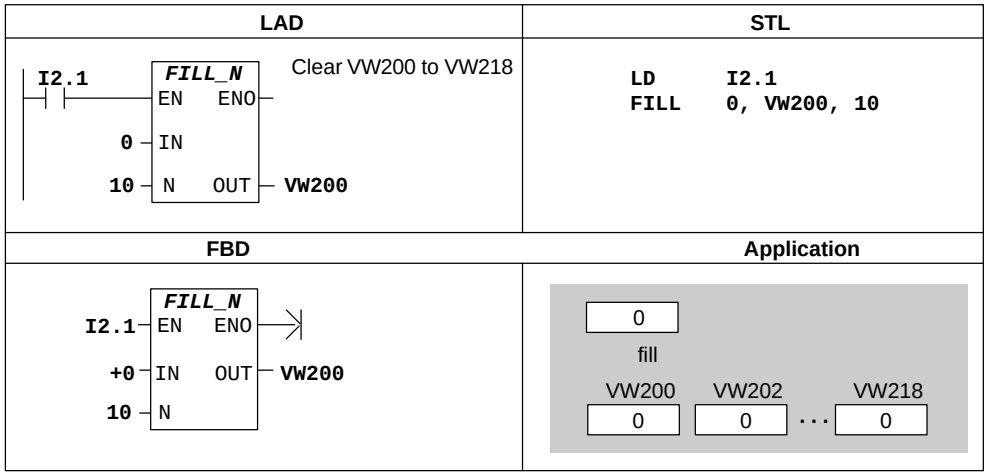
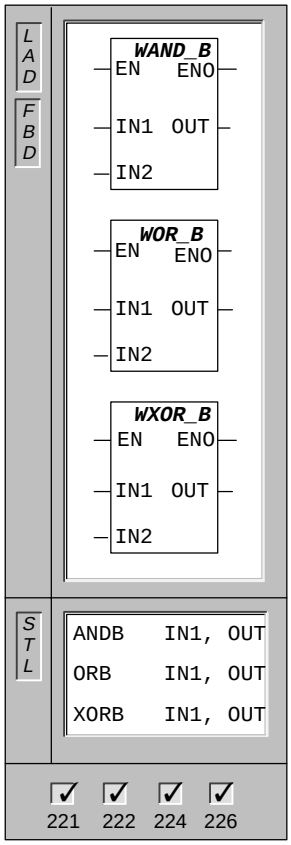


Figure 9-36 Example of Fill Instructions for SIMATIC LAD, STL, and FBD

9.11 SIMATIC Logical Operations Instructions

And Byte, Or Byte, Exclusive Or Byte



The **And Byte** instruction ANDs the corresponding bits of two input bytes and loads the result (OUT) in a byte.

The **Or Byte** instruction ORs the corresponding bits of two input bytes and loads the result (OUT) in a byte.

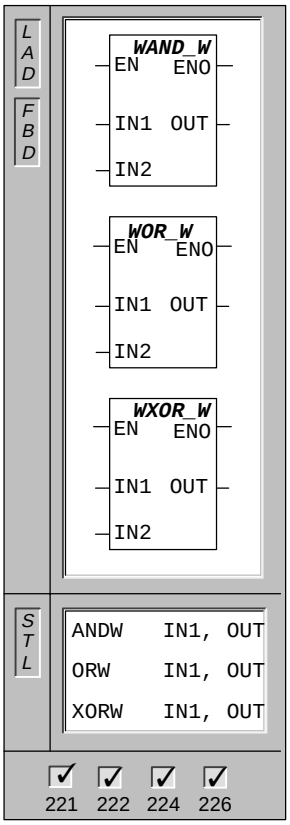
The **Exclusive Or Byte** instruction XORs the corresponding bits of two input bytes and loads the result (OUT) in a byte.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VB, IB, QB, MB,SB, SMB, LB, AC, *VD, *AC, *LD	BYTE

And Word, Or Word, Exclusive Or Word



The **And Word** instruction ANDs the corresponding bits of two input words and loads the result (OUT) in a word.

The **Or Word** instruction ORs the corresponding bits of two input words and loads the result (OUT) in a word.

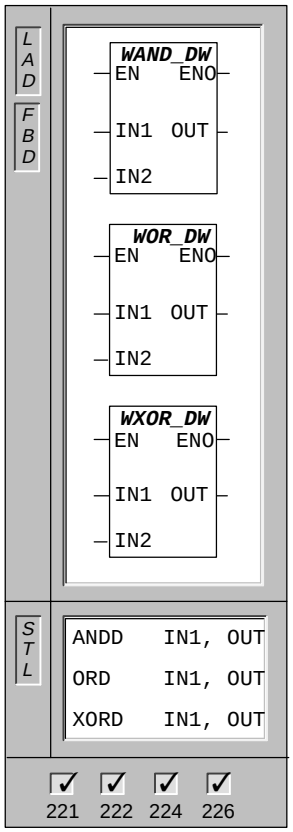
The **Exclusive Or Word** instruction XORs the corresponding bits of two input words and loads the result (OUT) in a word.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, AC, Constant, *VD, *AC, *LD	WORD
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	WORD

And Double Word, Or Double Word, Exclusive Or Double Word



The **And Double Word** instruction ANDs the corresponding bits of two double word inputs and loads the result (OUT) in a double word.

The **Or Double Word** instruction ORs the corresponding bits of two double word inputs and loads the result (OUT) in a double word.

The **Exclusive Or Double Word** instruction XORs the corresponding bits of two double word inputs and loads the result (OUT) in a double word.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VD, ID, QD, MD, SD, SMD, AC, LD, HC, Constant, *VD, *AC, SD, *LD	DWORD
OUT	VD, ID, QD, MD, SMD, LD, AC, *VD, *AC, SD, *LD	DWORD

And, Or, and Exclusive Or Instructions Example

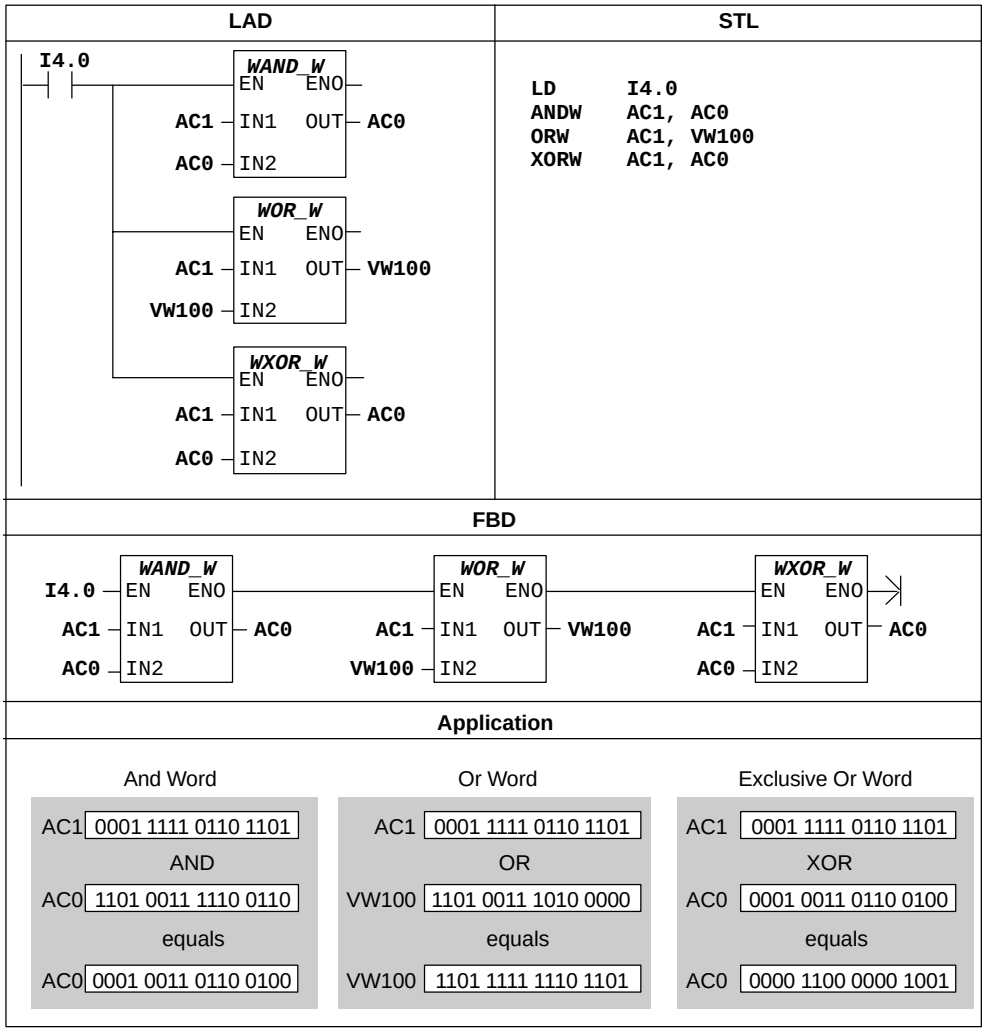
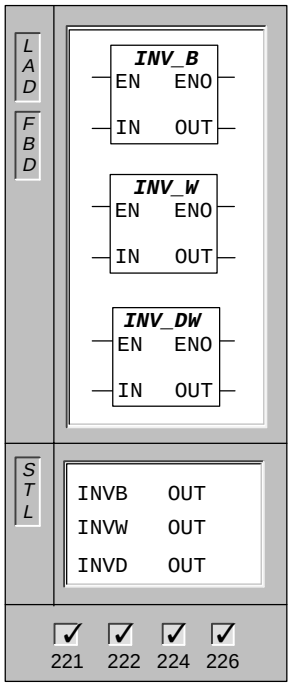


Figure 9-37 Example of the Logical Operation Instructions for SIMATIC LAD, STL, and FBD

Invert Byte, Invert Word, Invert Double Word Instructions



The **Invert Byte** instruction forms the ones complement of the input byte IN, and loads the result into byte value OUT.

The **Invert Word** instruction forms the ones complement of the input word IN, and loads the result in word value OUT.

The **Invert Double Word** instruction forms the ones complement of the input double word IN, and loads the result in double word value OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero)

Invert...	Inputs/Outputs	Operands	Data Types
Byte	IN	VB, IB, QB, MB,SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
	OUT	VB, IB, QB, MB, SB, SMB, LB, AC,*VD, *AC, *LD	BYTE
Word	IN	VW, IW, QW, MW, SW, SMW, T, C, AIW, LW, AC, Constant, *VD, *AC, *LD	WORD
	OUT	VW, IW, QW, MW, SW, SMW, T, C, LW, AC, *VD, *AC, *LD	WORD
Double Word	IN	VD, ID, QD, MD, SD, SMD, LD, HC, AC, Constant, *VD, *AC, *LD	DWORD
	OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	DWORD

Invert Example

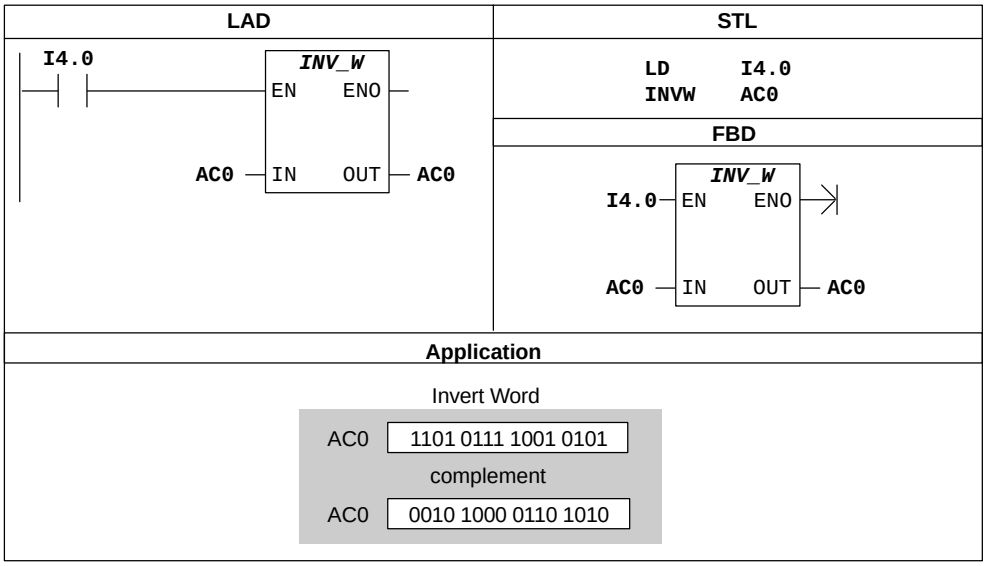
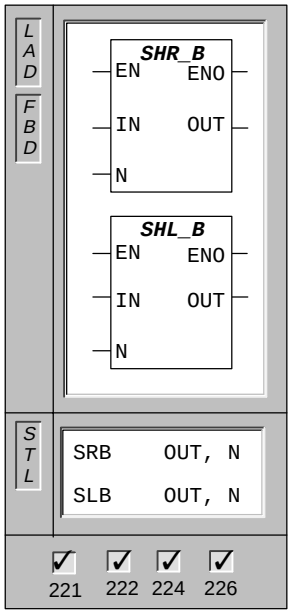


Figure 9-38 Example of Invert Instruction for SIMATIC LAD, STL, and FBD

9.12 SIMATIC Shift and Rotate Instructions

Shift Right Byte, Shift Left Byte



The **Shift Right Byte** and **Shift Left Byte** instructions shift the input byte (IN) value right or left by the shift count (N), and load the result in the output byte (OUT).

The **Shift** instructions fill with zeros as each bit is shifted out. If the shift count (N) is greater than or equal to 8, the value is shifted a maximum of 8 times.

If the shift count is greater than 0, the overflow memory bit (SM1.1) takes on the value of the last bit shifted out. The zero memory bit (SM1.0) is set if the result of the shift operation is zero.

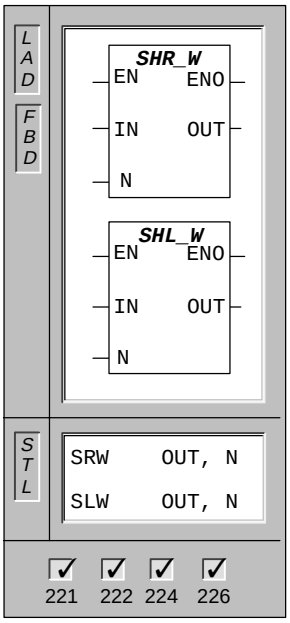
Shift right and shift left byte operations are unsigned.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD	BYTE
N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE

Shift Right Word, Shift Left Word



The **Shift Right Word** and **Shift Left Word** instructions shift the input word (IN) value right or left by the shift count (N), and load the result in the output word (OUT).

The **Shift** instructions fill with zeros as each bit is shifted out. If the shift count (N) is greater than or equal to 16, the value is shifted a maximum of 16 times. If the shift count is greater than 0, the overflow memory bit (SM1.1) takes on the value of the last bit shifted out. The zero memory bit (SM1.0) is set if the result of the shift operation is zero.

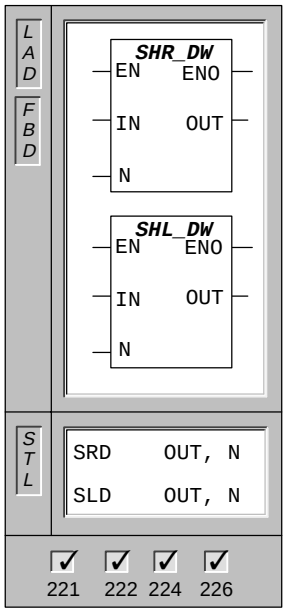
Note that the sign bit is shifted when you are using signed data types.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, AC, Constant, *VD, *AC, *LD	WORD
N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	WORD

Shift Right Double Word, Shift Left Double Word



The **Shift Right Double Word** and **Shift Left Double Word** instructions shift the input double word value (IN) right or left by the shift count (N), and load the result in the output double word (OUT).

The **Shift** instructions fill with zeros as each bit is shifted out. If the shift count (N) is greater than or equal to 32, the value is shifted a maximum of 32 times. If the shift count is greater than 0, the overflow memory bit (SM1.1) takes on the value of the last bit shifted out. The zero memory bit (SM1.0) is set if the result of the shift operation is zero.

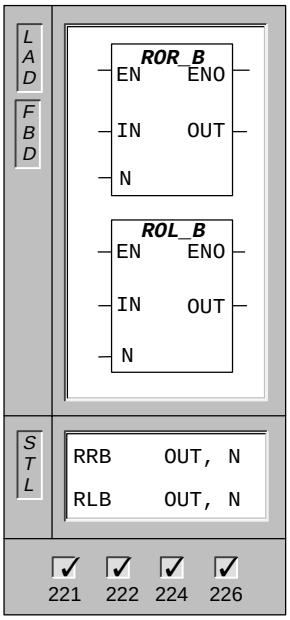
Note that the sign bit is shifted when you are using signed data types.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SD, SMD, LD, AC, HC, Constant, *VD, *AC, *LD	DWORD
N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	DWORD

Logical Rotate Right Byte, Rotate Left Byte



The **Rotate Right Byte** and **Rotate Left Byte** instructions rotate the input byte value (IN) right or left by the shift count (N), and load the result in the output byte (OUT). The rotate is circular.

If the shift count (N) is greater than or equal to 8, a modulo-8 operation is performed on the shift count (N) before the rotation is executed. This results in a shift count of 0 to 7. If the shift count is 0, a rotate is not performed. If the rotate is performed, the value of the last bit rotated is copied to the overflow bit (SM1.1).

If the shift count is not an integer multiple of 8, the last bit rotated out is copied to the overflow memory bit (SM1.1). The zero memory bit (SM1.0) is set when the value to be rotated is zero.

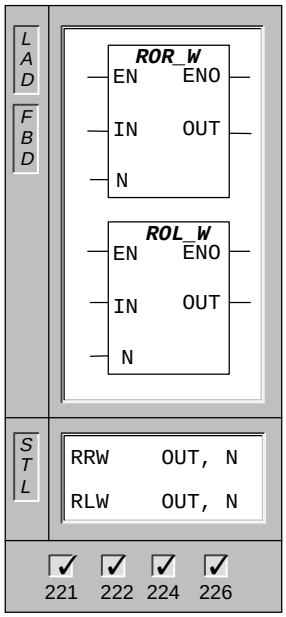
Rotate right byte and rotate left byte operations are unsigned.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SMB, SB, LB, AC, *VD, *AC, *LD	BYTE
N	VB, IB, QB, MB, SMB, SB, LB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VB, IB, QB, MB, SMB, SB, LB, AC, *VD, *AC, *LD	BYTE

Logical Rotate Right Word, Rotate Left Word



The **Rotate Right Word** and **Rotate Left Word** instructions rotate the input word value (IN) right or left by the shift count (N), and load the result in the output word (OUT). The rotate is circular.

If the shift count (N) is greater than or equal to 16, a modulo-16 operation is performed on the shift count (N) before the rotation is executed. This results in a shift count of 0 to 15. If the shift count is 0, a rotation is not performed. If the rotation is performed, the value of the last bit rotated is copied to the overflow bit (SM1.1).

If the shift count is not an integer multiple of 16, the last bit rotated out is copied to the overflow memory bit (SM1.1). The zero memory bit (SM1.0) is set when the value to be rotated is zero.

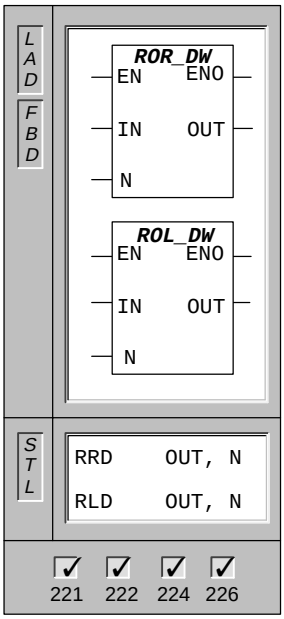
Note that the sign bit is shifted when you are using signed data types.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VW, T, C, IW, MW, SW, SMW, AC, QW, LW, AIW, Constant, *VD, *AC, *LD	WORD
N	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE
OUT	VW, T, C, IW, QW, MW, SW, SMW, LW, AC, *VD, *AC, *LD	WORD

Logical Rotate Right Double Word, Rotate Left Double Word



The **Rotate Right Double Word** and **Rotate Left Double Word** instructions rotate the input double word value (IN) right or left by the shift count (N), and load the result in the output double word (OUT).The rotate is circular.

If the shift count (N) is greater than or equal to 32, a modulo-32 operation is performed on the shift count (N) before the rotation is executed. This results in a shift count of 0 to 31. If the shift count is 0, a rotation is not performed. If the rotation is performed, the value of the last bit rotated is copied to the overflow bit (SM1.1).

If the shift count is not an integer multiple of 32, the last bit rotated out is copied to the overflow memory bit (SM1.1). The zero memory bit (SM1.0) is set when the value to be rotated is zero.

Note that the sign bit is shifted when you are using signed data types.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, LD, AC, HC, Constant, *VD, *AC, SD, *LD	DWORD
N	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE
OUT	VD, ID, QD, MD, SMD, LD, AC, *VD, *AC, SD, *LD	DWORD

Shift and Rotate Examples

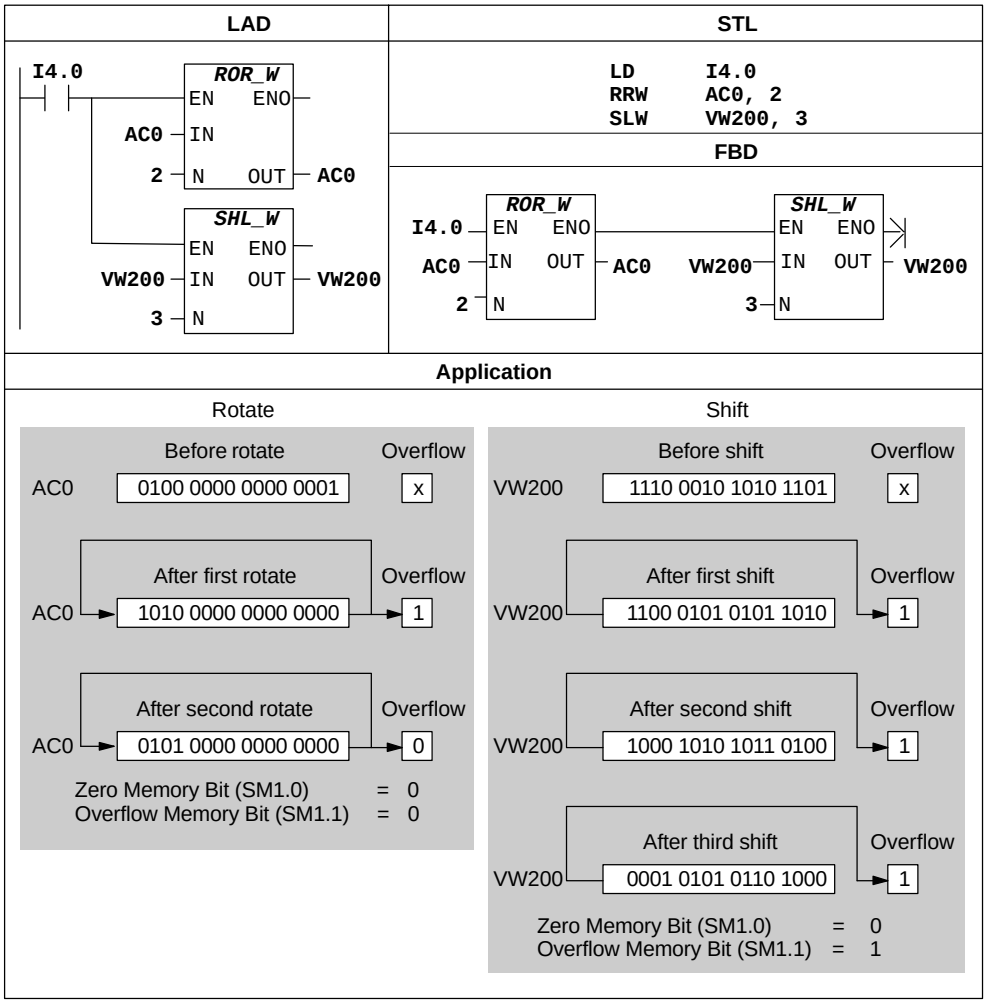
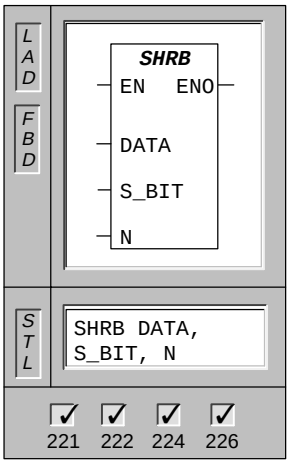


Figure 9-39 Example of Shift and Rotate Instructions for SIMATIC LAD, STL, and FBD

Shift Register Bit



The **Shift Register Bit** (SHRB) instruction shifts the value of DATA into the Shift Register. S_BIT specifies the least significant bit of the Shift Register. N specifies the length of the Shift Register and the direction of the shift (Shift Plus = N, Shift Minus = -N).

Each bit shifted out by the SHRB instruction is placed in the overflow memory bit (SM1.1).

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range), 0092 (error in count field)

This instruction affects the following Special Memory bit: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
DATA, S_BIT	I, Q, M, SM, T, C, V, S, L	BOOL
N	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE

Understanding the Shift Register Bit Instruction

The Shift Register Bit instruction provides an easy method for sequencing and controlling product flow or data. Use the Shift Register Bit instruction to shift the entire register one bit, once per scan. The Shift Register Bit instruction is defined by both the least significant bit (S_BIT) and the number of bits specified by the length (N). Figure 9-41 shows an example of the Shift Register Bit instruction.

The address of the most significant bit of the Shift Register (MSB.b) can be computed by the following equation:

MSB.b = [(Byte of S_BIT) + ([N] - 1 + (bit of S_BIT)) / 8] [remainder of the division by 8]

You must subtract 1 bit because S_BIT is one of the bits of the Shift Register.

For example, if S_BIT is V33.4, and N is 14, then the MSB.b is V35.1, or:

MSB.b = V33 + ([14] - 1 +4)/8
= V33 + 17/8
= V33 + 2 with a remainder of 1
= V35.1

On a Shift Minus, indicated by a negative value of length (N), the input data shifts into the most significant bit of the Shift Register, and shifts out of the least significant bit (S_BIT).

On a Shift Plus, indicated by a positive value of length (N), the input data (DATA) shifts into the least significant bit of the Shift Register, specified by the S_BIT, and out of the most significant bit of the Shift Register.

The data shifted out is then placed in the overflow memory bit (SM1.1). The maximum length of the shift register is 64 bits, positive or negative. Figure 9-40 shows bit shifting for negative and positive values of N.

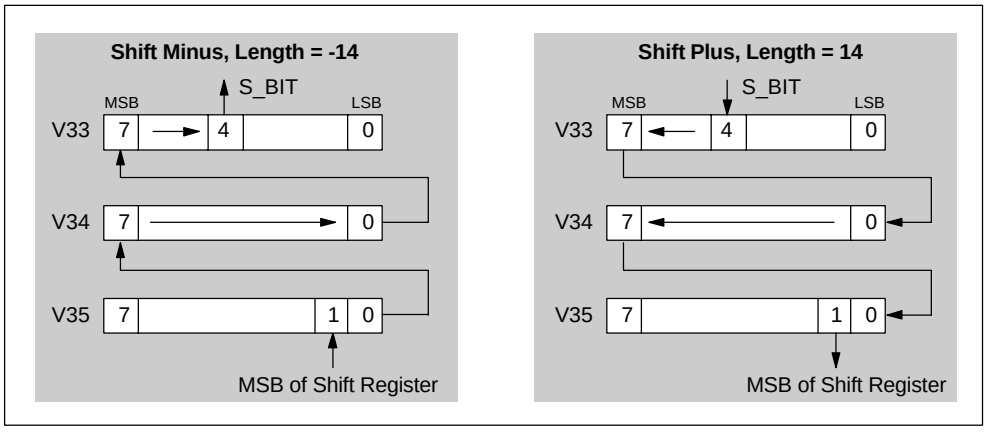


Figure 9-40 Shift Register Entry and Exit for Plus and Minus Shifts

Shift Register Bit Example

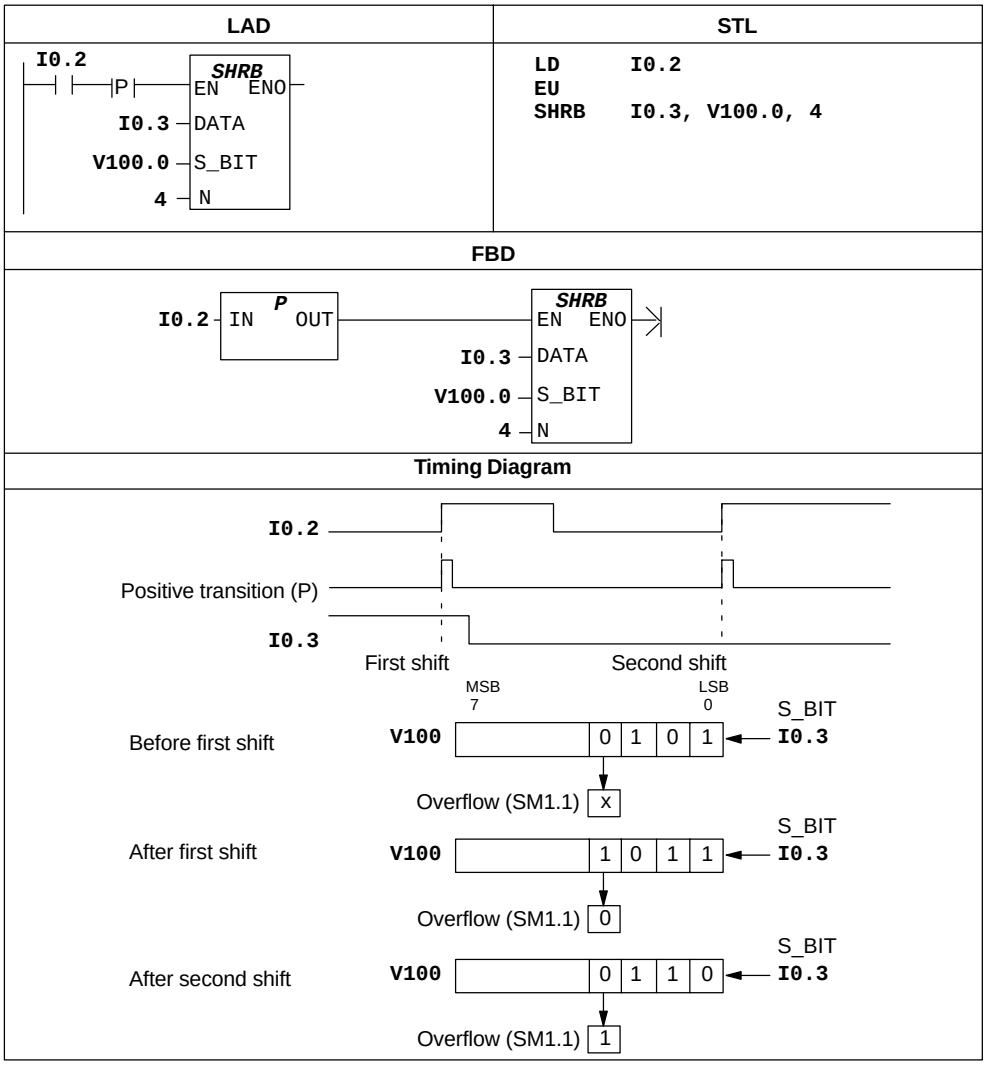
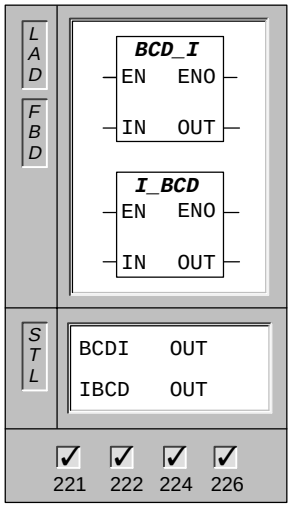


Figure 9-41 Example of Bit Shift Register Instruction for SIMATIC LAD, STL, and FBD

9.13 SIMATIC Conversion Instructions

BCD to Integer, Integer to BCD



The **BCD to Integer** instruction converts the input Binary-Coded Decimal (IN) to an integer value and loads the result into the variable specified by OUT. The valid range for IN is 0 to 9999 BCD.

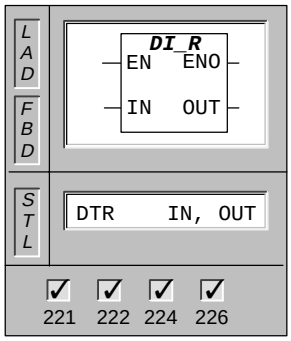
The **Integer to BCD** instruction converts the input integer value (IN) to a Binary-Coded Decimal and loads the result into the variable specified by OUT. The valid range for IN is 0 to 9999 integer.

Error conditions that set ENO = 0: SM1.6 (BCD error), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.6 (invalid BCD)

Inputs/Outputs	Operands	Data Types
IN	VW, T, C, IW, QW, MW, SMW, LW, AC, AIW, Constant, *VD, *AC, SW, *LD	WORD
OUT	VW, T, C, IW, QW, MW, SMW, LW, AC, *VD, *AC, SW, *LD	WORD

Double Integer to Real

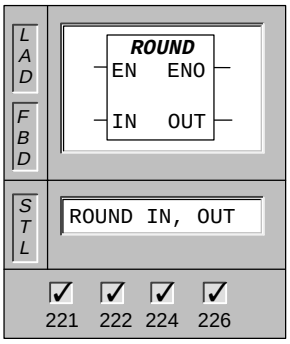


The **Double Integer to Real** instruction converts a 32-bit, signed integer (IN) into a 32-bit real number and places the result into the variable specified by OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, AC, LD, HC, Constant, *VD, *AC, SD, *LD	DINT
OUT	VD, ID, QD, MD, SMD, LD, AC, *VD, *AC, SD, *LD	REAL

Round



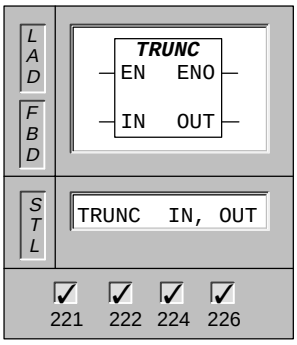
The **Round** instruction converts the real value (IN) to a double integer value and places the result into the variable specified by OUT. If the fraction portion is 0.5 or greater, the number is rounded up.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, AC, LD, Constant, *VD, *AC, SD, *LD	REAL
OUT	VD, ID, QD, MD, SMD, LD, AC, *VD, *AC, SD, *LD	DINT

Truncate



The **Truncate** instruction converts a 32-bit real number (IN) into a 32-bit signed integer and places the result into the variable specified by OUT. Only the whole number portion of the real number is converted, and the fraction is discarded.

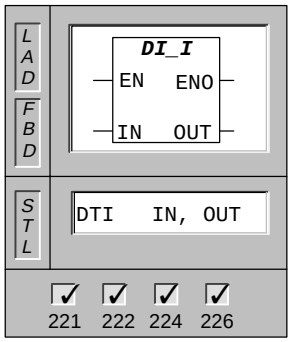
If the value that you are converting is not a valid real number or is too large to be represented in the output, then the overflow bit is set and the output is not affected.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, LD, AC, Constant, *VD, *AC, SD, *LD	REAL
OUT	VD, ID, QD, MD, SMD, LD, AC, *VD, *AC, SD, *LD	DINT

Double Integer to Integer



The **Double Integer to Integer** instruction converts the double integer value (IN) to an integer value and places the result into the variable specified by OUT.

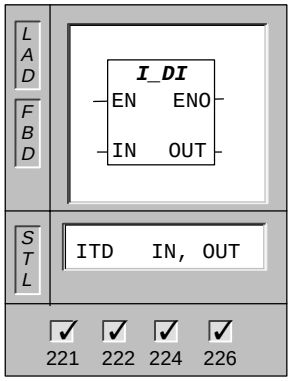
If the value that you are converting is too large to be represented in the output, then the overflow bit is set and the output is not affected.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, AC, LD, HC, Constant, *VD, *AC, SD, *LD	DINT
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *LD, *AC	INT

Integer to Double Integer



The **Integer to Double Integer** instruction converts the integer value (IN) to a double integer value and places the result into the variable specified by OUT. The sign is extended.

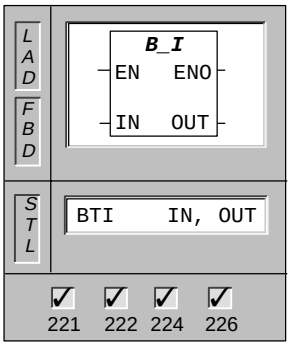
Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, AC, Constant, *AC, *VD, *LD	INT
OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *LD, *AC	DINT

Integer to Real

To change an integer to a real number, use the Integer to Double Integer instruction (page 9-130) and then the Double Integer to Real instruction. Refer to Figure 9-42.

Byte to Integer

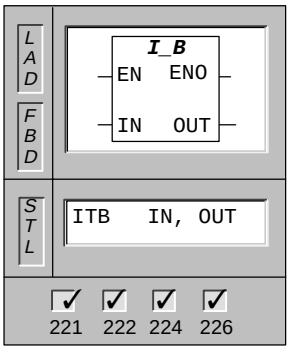


The **Byte to Integer** instruction converts the byte value (IN) to an integer value and places the result into the variable specified by OUT. The byte is unsigned, therefore there is no sign extension.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *AC, *VD, *LD	BYTE
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *LD, *AC	INT

Integer to Byte



The **Integer to Byte** instruction converts the word value (IN) to a byte value and places the result into the variable specified by OUT.

Values 0 to 255 are converted. All other values result in overflow and the output is not affected.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, AC, Constant, *VD, *LD, *AC	INT
OUT	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD	BYTE

Convert Example

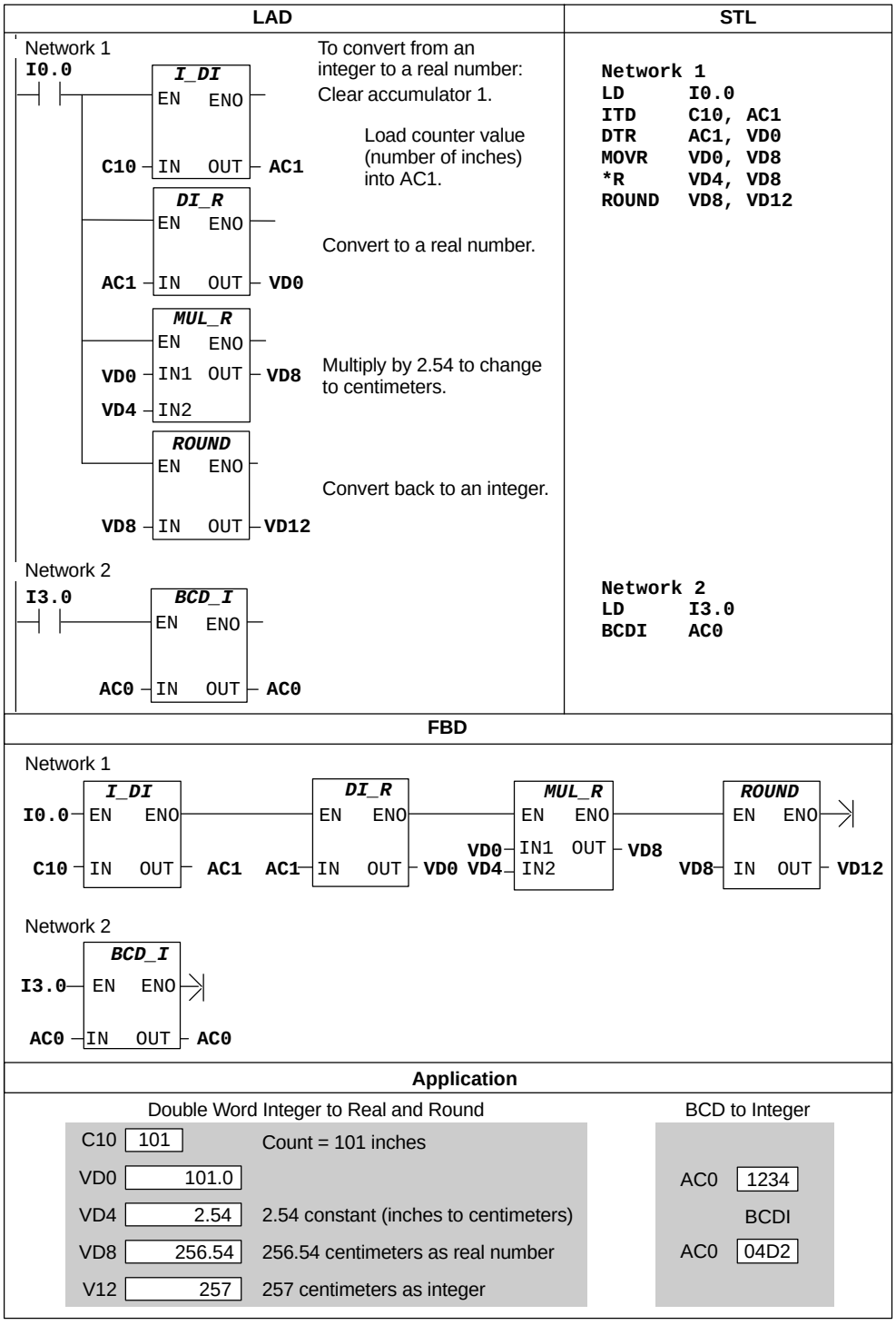
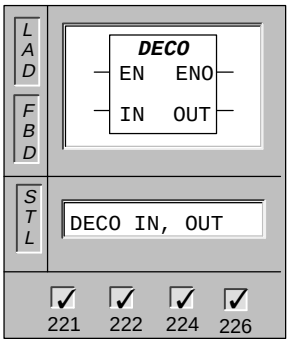


Figure 9-42 Example of Conversion Instructions for SIMATIC LAD, STL, and FBD

Decode

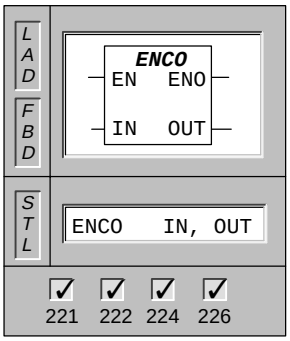


The **Decode** instruction sets the bit in the output word (OUT) that corresponds to the bit number represented by the least significant “nibble” (4 bits) of the input byte (IN). All other bits of the output word are set to 0.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SMB, LB, SB, AC, Constant, *VD, *AC, *LD	BYTE
OUT	VW, IW, QW, MW, SMW, LW, SW, AQW, T, C, AC, *VD, *AC, *LD	WORD

Encode



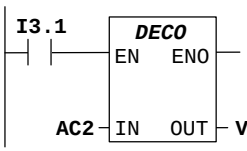
The **Encode** instruction writes the bit number of the least significant bit set of the input word (IN) into the least significant “nibble” (4 bits) of the output byte (OUT).

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VW, T, C, IW, QW, MW, SMW, AC, LW, AIW, Constant, *VD, *AC, SW, *LD	WORD
OUT	VB, IB, QB, MB, SMB, LB, AC, *VD, *AC, SB, *LD	BYTE

Decode, Encode Examples

LAD

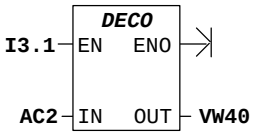


Set the bit that corresponds to the error code in AC2.

STL

```
LD      I3.1
DECO    AC2, VW40
```

FBD



Application

AC2 contains the error code 3. The DECO instruction sets the bit in VW40 that corresponds to this error code.

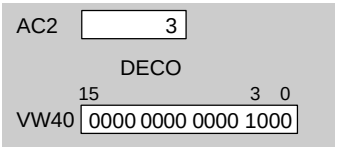
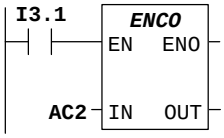


Figure 9-43 Example of Setting an Error Bit Using Decode for LAD, STL, and FBD

LAD

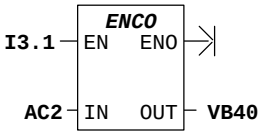


Convert the error bit in AC2 to the error code in VB40.

STL

```
LD      I3.1
ENCO    AC2, VB40
```

FBD



Application

AC2 contains the error bit. The ENCO instruction converts the least significant bit set to an error code that is stored in VB40.

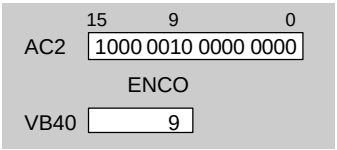
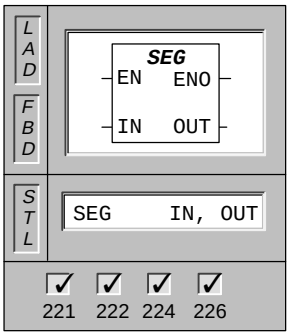


Figure 9-44 Example of Converting the Error Bit into an Error Code Using Encode for LAD, STL, and FBD

Segment



The **Segment** instruction uses the character specified by IN to generate a bit pattern (OUT) that illuminates the segments of a seven-segment display. The illuminated segments represent the character in the least significant digit of the input byte (IN).

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Figure 9-45 shows the seven segment display coding used by the Segment instruction.

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE
OUT	VB, IB, QB, MB, SMB, LB, AC, *VD, *AC, SB, *LD	BYTE

(IN) LSD	Segment Display	(OUT) - g f e d c b a	(IN) LSD	Segment Display	(OUT) - g f e d c b a
0		0 0 1 1 1 1 1 1	8		0 1 1 1 1 1 1 1
1		0 0 0 0 0 1 1 0	9		0 1 1 0 0 1 1 1
2		0 1 0 1 1 0 1 1	A		0 1 1 1 0 1 1 1
3		0 1 0 0 1 1 1 1	B		0 1 1 1 1 1 0 0
4		0 1 1 0 0 1 1 0	C		0 0 1 1 1 0 0 1
5		0 1 1 0 1 1 0 1	D		0 1 0 1 1 1 1 0
6		0 1 1 1 1 1 0 1	E		0 1 1 1 1 0 0 1
7		0 0 0 0 0 1 1 1	F		0 1 1 1 0 0 0 1

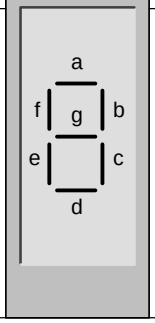


Figure 9-45 Seven Segment Display Coding

Segment Example

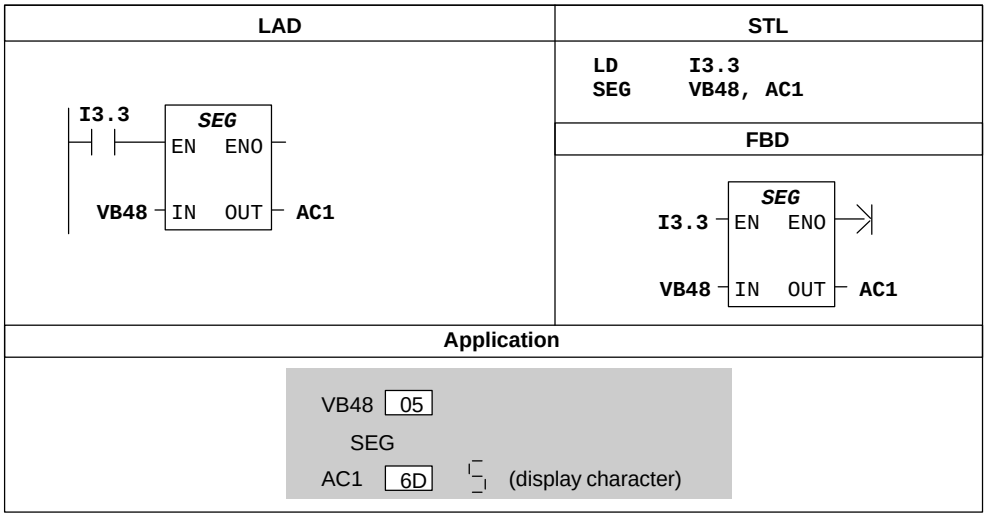
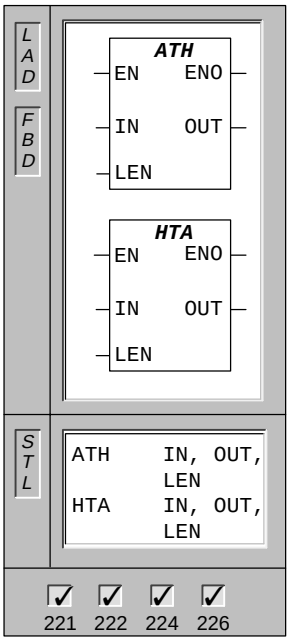


Figure 9-46 Example of Segment Instruction for SIMATIC LAD, STL, and FBD

ASCII to HEX, HEX to ASCII



The **ASCII to HEX** instruction converts the ASCII string of length (LEN), starting at IN, to hexadecimal digits starting at OUT. The maximum length of the ASCII string is 255 characters.

The **HEX to ASCII** instruction converts the hexadecimal digits, starting with the input byte (IN), to an ASCII string starting at OUT. The number of hexadecimal digits to be converted is specified by length (LEN). The maximum number of the hexadecimal digits that can be converted is 255.

Legal ASCII characters are the hexadecimal values 30 to 39, and 41 to 46.

ASCII to Hex: Error conditions that set ENO = 0:
SM1.7 (illegal ASCII), SM4.3 (run-time),
0006 (indirect address), 0091 (operand out of range)

Hex to ASCII: Error conditions that set ENO = 0:
SM4.3 (run-time), 0006 (indirect address),
0091 (operand out of range)

These instructions affect the following Special Memory bits: SM1.7 (illegal ASCII)

Inputs/Outputs	Operands	Data Types
IN, OUT	VB, IB, QB, MB, SMB, LB, *VD, *AC, SB, *LD	BYTE
LEN	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE

ASCII to HEX Example

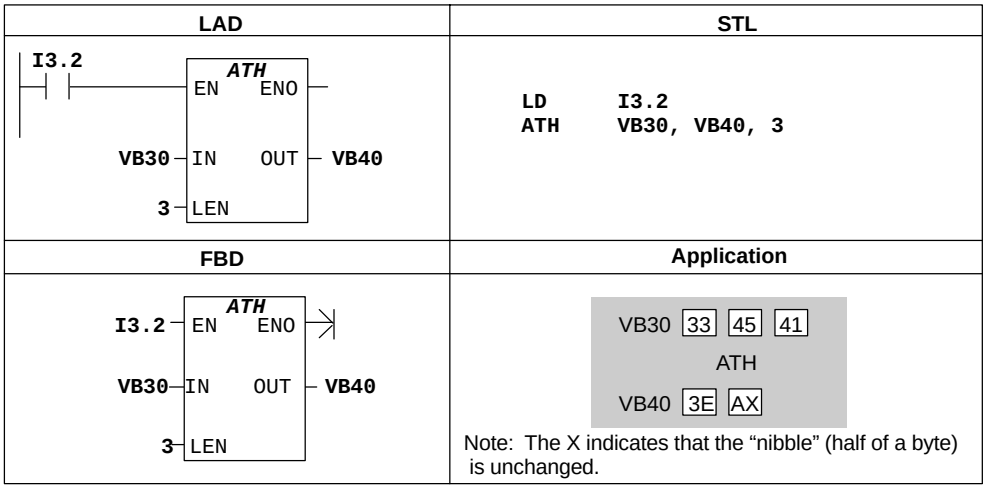
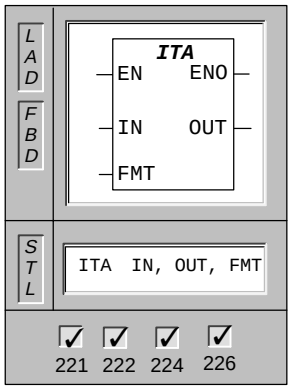


Figure 9-47 Example of SIMATIC ASCII to HEX Instruction for SIMATIC LAD, STL, and FBD

Integer to ASCII



The **Integer to ASCII** instruction converts an integer word (IN) to an ASCII string. The format (FMT) specifies the conversion precision to the right of the decimal, and whether the decimal point is to be shown as a comma or a period. The resulting conversion is placed in 8 consecutive bytes beginning with OUT. The ASCII string is always 8 characters.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), no output (illegal format)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, AC, Constant, *VD, *AC, *LD	INT
FMT	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE
OUT	VB, IB, QB, MB, SMB, LB, *VD, *AC, SB, *LD	BYTE

The format operand (FMT) for the ITA (Integer to ASCII) instruction is defined in Figure 9-48. The size of the output buffer is always 8 bytes. The number of digits to the right of the decimal point in the output buffer is specified by the nnn field. The valid range of the nnn field is 0 to 5. Specifying 0 digits to the right of the decimal point causes the value to be displayed without a decimal point. For values of nnn bigger than 5, the output buffer is filled with ASCII spaces. The c bit specifies the use of either a comma (c=1) or a decimal point (c=0) as the separator between the whole number and the fraction. The upper 4 bits must be zero.

The output buffer is formatted in accord with the following rules:

1. Positive values are written to the output buffer without a sign.
2. Negative values are written to the output buffer with a leading minus sign (-).
3. Leading zeros to the left of the decimal point (except the digit adjacent to the decimal point) are suppressed.
4. Values are right-justified in the output buffer.

Figure 9-48 gives examples of values that are formatted using a decimal point (c = 0) with three digits to the right of the decimal point (nnn = 011).

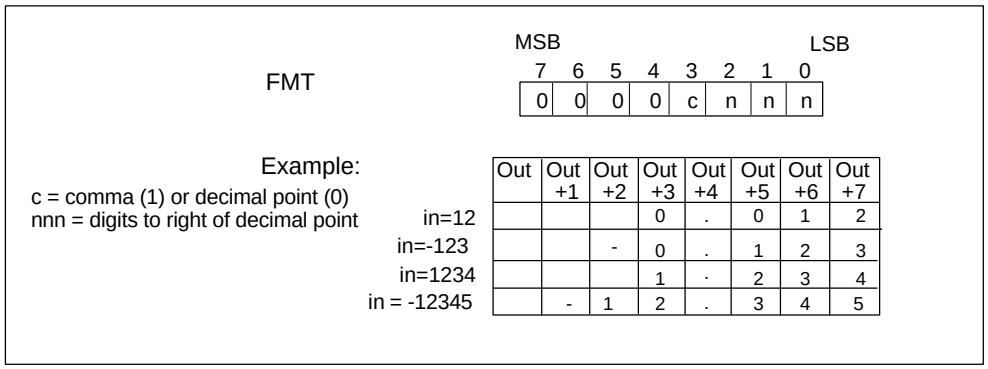
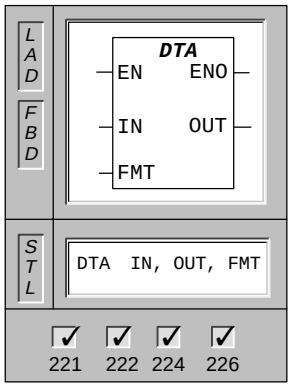


Figure 9-48 FMT Operand for the ITA Instruction

Double Integer to ASCII



The **Double Integer to ASCII** instruction converts a double word (IN) to an ASCII string. The format (FMT) specifies the conversion precision to the right of the decimal. The resulting conversion is placed in 12 consecutive bytes beginning with OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), no output (illegal format)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SD, SMD, LD, HC, Constant, AC, *VD, *AC, *LD	DINT
FMT	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE
OUT	VB, IB, QB, MB, SMB, LB, *VD, *AC, SB, *LD	BYTE

The format operand (FMT) for the DTA instruction is defined in Figure 9-49. The size of the output buffer is always 12 bytes. The number of digits to the right of the decimal point in the output buffer is specified by the nnn field. The valid range of the nnn field is 0 to 5. Specifying 0 digits to the right of the decimal point causes the value to be displayed without a decimal point. For values of nnn bigger than 5, the output buffer is filled with ASCII spaces. The c bit specifies the use of either a comma (c=1) or a decimal point (c=0) as the separator between the whole number and the fraction. The upper 4 bits must be zero. The output buffer is formatted in accord with the following rules:

1. Positive values are written to the output buffer without a sign.
2. Negative values are written to the output buffer with a leading minus sign (-).
3. Leading zeros to the left of the decimal point (except the digit adjacent to the decimal point) are suppressed.
4. Values are right-justified in the output buffer.

Figure 9-49 gives examples of values that are formatted using a decimal point (c = 0) with four digits to the right of the decimal point (nnn = 100).

FMT

MSB							LSB
7	6	5	4	3	2	1	0
0	0	0	0	c	n	n	n

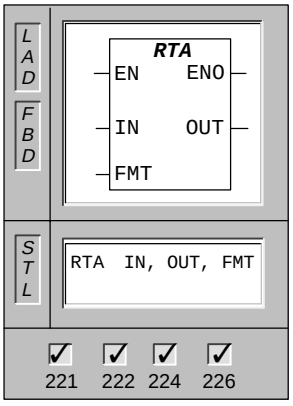
Example:

c = comma (1) or decimal point (0)
nnn = digits to right of decimal point

	Out	Out +1	Out +2	Out +3	Out +4	Out +5	Out +6	Out +7	Out +8	Out +9	Out +10	Out +11
in=-12						-	0	.	0	0	1	2
in=1234567					1	2	3	.	4	5	6	7

Figure 9-49 FMT Operand for DTA Instruction

Real to ASCII



The **Real to ASCII** instruction converts a floating point value (IN) to an ASCII string. The format (FMT) specifies the conversion precision to the right of the decimal, and whether the decimal point is shown as a decimal point or a period, and the output buffer size. The resulting conversion is placed in an output buffer beginning with OUT. The length of the resulting ASCII string is the size of the output buffer, and can be specified to a size ranging from 3 to 15.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), no output (illegal format or buffer too small)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	REAL
FMT	VB, IB, QB, MB, SMB, LB, AC, Constant, *VD, *AC, SB, *LD	BYTE
OUT	VB, IB, QB, MB, SMB, LB, *VD, *AC, SB, *LD	BYTE

The format operand (FMT) for the RTA instruction is defined in Figure 9-50. The size of the output buffer is specified by the ssss field. A size of 0, 1, or 2 bytes is not valid. The number of digits to the right of the decimal point in the output buffer is specified by the nnn field. The valid range of the nnn field is 0 to 5. Specifying 0 digits to the right of the decimal point causes the value to be displayed without a decimal point. The output buffer is filled with ASCII spaces for values of nnn bigger than 5 or when the specified output buffer is too small to store the converted value. The c bit specifies the use of either a comma (c=1) or a decimal point (c=0) as the separator between the whole number and the fraction. The output buffer is formatted in accord with the following rules:

1. Positive values are written to the output buffer without a sign.
2. Negative values are written to the output buffer with a leading minus sign (-).
3. Leading zeros to the left of the decimal point (except the digit adjacent to the decimal point) are suppressed.
4. Values to the right of the decimal point are rounded to fit in the specified number of digits to the right of the decimal point.
5. The size of the output buffer must be a minimum of three bytes more than the number of digits to the right of the decimal point.
6. Values are right-justified in the output buffer.

Figure 9-50 gives examples of values that are formatted using a decimal point (c=0) with one digit to the right of the decimal point (nnn=001) and a buffer size of six bytes (ssss=0110).

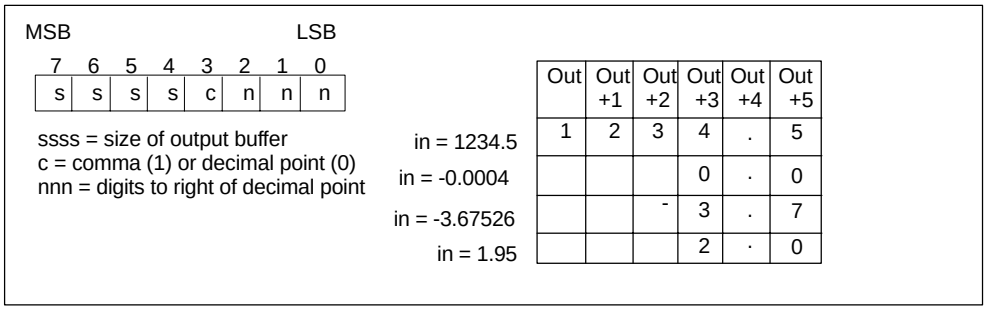


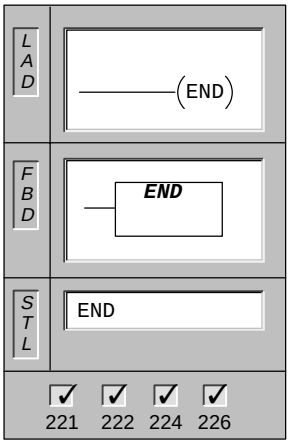
Figure 9-50 FMT Operand for RTA Instruction

Note

The floating point format used by the S7-200 CPU supports a maximum of 7 significant digits. Attempting to display more than the 7 significant digits produces a rounding error.

9.14 SIMATIC Program Control Instructions

Conditional End



The **Conditional END** instruction terminates the main user program based upon the condition of the preceding logic.

Operands: None

Data Types: None

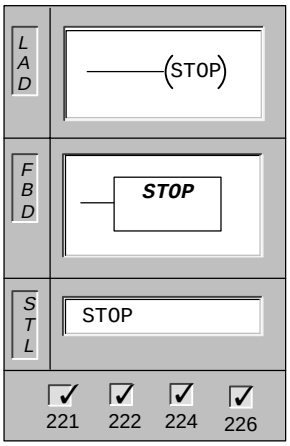
Note

You can use the Conditional END instruction in the main program, but you cannot use it in either subroutines or interrupt routines.

Note

STEP 7-Micro/WIN 32 automatically adds an unconditional end to the main user program.

Stop

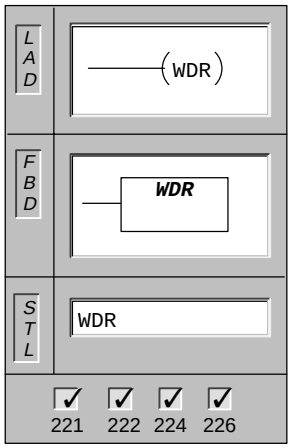


The **STOP** instruction terminates the execution of your program by causing a transition of the CPU from RUN to STOP mode.

Operands: None

If the STOP instruction is executed in an interrupt routine, the interrupt routine is terminated immediately, and all pending interrupts are ignored. Remaining actions in the current scan cycle are completed, including execution of the main user program, and the transition from RUN to STOP mode is made at the end of the current scan.

Watchdog Reset



The **Watchdog Reset** instruction allows the CPU system watchdog timer to be retriggered. This extends the time that the scan is allowed to take without getting a watchdog error.

Operands: None

Considerations for Using the WDR Instruction to Reset the Watchdog Timer

You should use the Watchdog Reset instruction carefully. If you use looping instructions either to prevent scan completion, or to delay excessively the completion of the scan, the following processes are inhibited until the scan cycle is completed.

- Communication (except Freeport Mode)
- I/O updating (except Immediate I/O)
- Force updating
- SM bit updating (SM0, SM5 to SM29 are not updated)
- Run-time diagnostics
- 10-ms and 100-ms timers will not properly accumulate time for scans exceeding 25 seconds
- STOP instruction, when used in an interrupt routine

Note

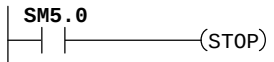
If you expect your scan time to exceed 300 ms, or if you expect a burst of interrupt activity that may prevent returning to the main scan for more than 300 ms, you should use the WDR instruction to re-trigger the watchdog timer.

Changing the switch to the STOP position causes the CPU to transition to STOP mode within 1.4 seconds.

Stop, End, and WDR Example

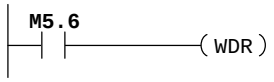
LAD

Network 1



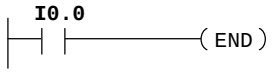
When an I/O error is detected, force the transition to STOP mode.

Network 15



When M5.6 is on, retrigger the Watchdog Reset (WDR) to allow the scan time to be extended.

Network 78



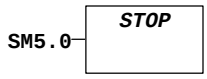
When I0.0 is on, terminate the main program.

STL

```
Network 1
LD      SM5.0
STOP
.
.
.
Network 15
LD      M5.6
WDR
.
.
.
Network 78
LD      I0.0
END
```

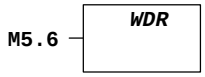
FBD

Network 1



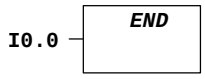
When an I/O error is detected, force the transition to STOP mode.

Network 15



When M5.6 is on, retrigger the Watchdog Reset (WDR) to allow the scan time to be extended.

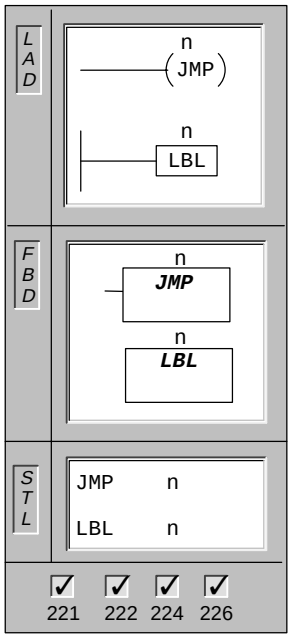
Network 78



When I0.0 is on, terminate the main program.

Figure 9-51 Example of Stop, End, and WDR Instructions for SIMATIC LAD, STL, and FBD

Jump to Label, Label



The **Jump to Label** instruction performs a branch to the specified label (n) within the program. When a jump is taken, the top of stack value is always a logical 1.

The **Label** instruction marks the location of the jump destination (n) .

Operands: n: Constant (0 to 255)

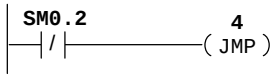
Data Types: WORD

Both the Jump and corresponding Label must be in the main program, a subroutine, or an interrupt routine. You cannot jump from the main program to a label in either a subroutine or an interrupt routine. Likewise, you cannot jump from a subroutine or interrupt routine to a label outside that subroutine or interrupt routine.

Jump to Label Example

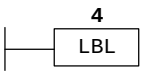
LAD

Network 14



. . .

Network 33



If the retentive data has not been lost, jump to LBL 4.

You can use the JMP to LBL instruction in the main program, in subroutines, or in interrupt routines.The JMP and its corresponding LBL must always be located within the same segment of code (either the main program, a subroutine, or an interrupt routine).

STL

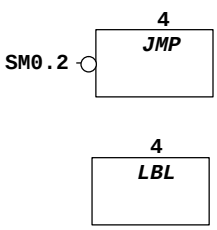
```
Network
LDN     SM0.2
JMP     4
.
.
.

Network
LBL     4
```

FBD

Network 14

. . .

Network 33

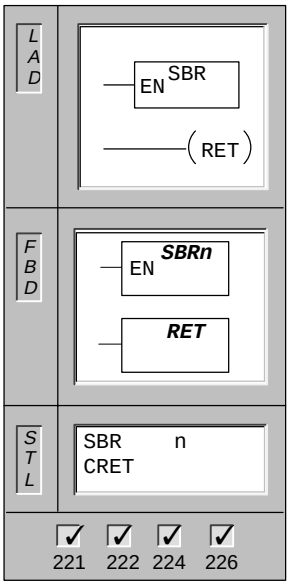


If the retentive data has not been lost, jump to LBL 4.

You can use the JMP to LBL instruction in the main program, in subroutines, or in interrupt routines.The JMP and its corresponding LBL must always be located within the same segment of code (either the main program, a subroutine, or an interrupt routine).

Figure 9-52 Example of Jump to Label and Label Instructions for SIMATIC LAD, STL, and FBD

Subroutine, Return from Subroutine



The Call **Subroutine** instruction transfers control to the subroutine (n). You can use a Call Subroutine instruction with or without parameters. To add a subroutine, select **Edit > Insert > Subroutine** from the menu.

The **Conditional Return from Subroutine** instruction is used to terminate a subroutine based upon the preceding logic.

Operands: None

Data Types: None

Once the subroutine completes its execution, control returns to the instruction that follows the Call Subroutine.

Figure 9-55 shows an example of the Call Subroutine, and Return from Subroutine instructions.

Error conditions that set ENO for Call Subroutine with parameters = 0:

SM4.3 (run-time), 0008 (maximum subroutine nesting exceeded)

Note

STEP 7-Micro/WIN 32 automatically adds a return from each subroutine.

From the main program, you can nest subroutines (place a subroutine call within a subroutine), to a depth of eight. From an interrupt routine, you cannot nest subroutines. A subroutine call cannot be placed in any subroutine called from an interrupt routine. Recursion (a subroutine that calls itself) is not prohibited, but you should use caution when using recursion with subroutines.

When a subroutine is called, the entire logic stack is saved, the top of stack is set to one, all other stack locations are set to zero, and control is transferred to the called subroutine. When this subroutine is completed, the stack is restored with the values saved at the point of call, and control is returned to the calling routine.

Accumulators are common to subroutines and the calling routine. No save or restore operation is performed on accumulators due to subroutine use.

Calling a Subroutine With Parameters

Subroutines may contain passed parameters. The parameters are defined in the local variable table of the subroutine (Figure 9-53). The parameters must have a symbol name (maximum of 8 characters), a variable type, and a data type. Sixteen parameters can be passed to or from a subroutine.

The variable type field in the local variable table defines whether the variable is passed into the subroutine (IN), passed into and out of the subroutine (IN_OUT), or passed out of the subroutine (OUT). The characteristics of the parameter types are as follows:

- IN: parameters are passed into the subroutine. If the parameter is a direct address (such as VB10), the value at the specified location is passed into the subroutine. If the parameter is an indirect address (such as *AC1), the value at the location pointed to is passed into the subroutine. If the parameter is a data constant (16#1234), or an address (VB100), the constant or address value is passed into the subroutine.
- IN_OUT: the value at the specified parameter location is passed into the subroutine and the result value from the subroutine is returned to the same location. Constants (such as 16#1234) and addresses (such as &VB100) are not allowed for input/output parameters.
- OUT: The result value from the subroutine is returned to the specified parameter location. Constants (such as 16#1234) and addresses (such as &VB100) are not allowed as output.
- TEMP:
  Any local memory that is not used for passed parameters may be used for temporary storage within the subroutine.

To add a parameter entry, place the cursor on the variable type field of the type (IN, IN_OUT<OUT) that you want to add. Click the right mouse button to get a menu of options. Select the Insert option and then the Row Below option. Another parameter entry of the selected type appears below the current entry.

	Name	Var. Type	Data Type	Comment
	EN	IN	BOOL	
L0.0	IN1	IN	BOOL	
LB1	IN2	IN	BYTE	
LB2.0	IN3	IN	BOOL	
LD3	IN4	IN	DWORD	
LW7	IN/OUT1	IN_OUT	WORD	
LD9	OUT1	OUT	DWORD	
		TEMP		

Figure 9-53 STEP 7-Micro/WIN 32 Local Variable Table

The data type field in the local variable table defines the size and format of the parameter. The parameter types are:

- Power Flow: Boolean power flow is allowed only for bit (Boolean) inputs. This declaration tells STEP 7-Micro/WIN 32 that this input parameter is the result of power flow based on a combination of bit logic instructions. Boolean power flow inputs must appear first in the local variable table before any other type input. Only input parameters are allowed to be used this way. The enable input (EN) and the IN1 inputs in Figure 9-54 use Boolean logic.
- Boolean - This data type is used for single bit inputs and outputs. IN2 in Figure 9-54 is a Boolean input.
- Byte, Word, Dword - These data types identify an unsigned input or output parameter of 1, 2, or 4 bytes respectively.
- INT, DINT - These data types identify signed input or output parameters of 2 or 4 bytes respectively.
- Real - This data type identifies a single precision (4 byte) IEEE floating point value.

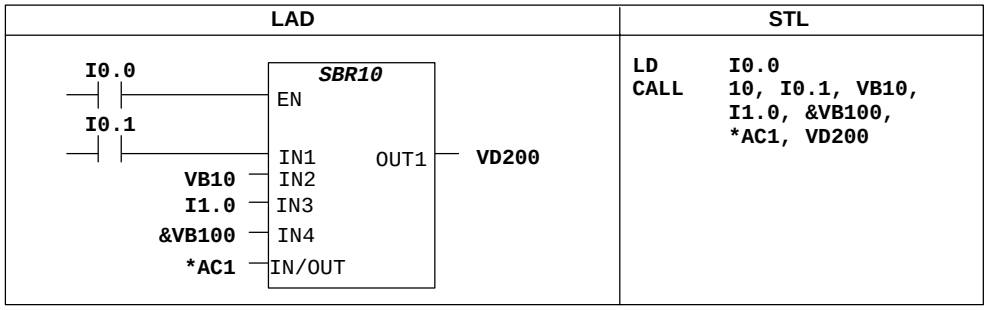


Figure 9-54 Subroutine Call in LAD and STL

Address parameters such as IN4 in Figure 9-54 (&VB100) are passed into a subroutine as a Dword (unsigned double word) value. The type of a constant parameter must be specified for the parameter in the calling routine with a constant describer in front of the constant value. For example, to pass an unsigned double word constant with a value of 12,345 as a parameter, the constant parameter must be specified as DW#12345. If the constant describer is omitted from parameter, the constant may be assumed to be a different type.

There are no automatic data type conversions performed on the input or output parameters. For example, if the local variable table specifies that a parameter has the data type Real, and in the calling routine a double word (Dword) is specified for that parameter, the value in the subroutine will be a double word.

When values are passed to a subroutine, they are placed into the local memory of the subroutine. The left-most column of the local variable table (see Figure 9-53) shows the local memory address for each passed parameter. Input parameter values are copied to the subroutine's local memory when the subroutine is called. Output parameter values are copied from the subroutine's local memory to the specified output parameter addresses when the subroutine execution is complete.

The data element size and type are represented in the coding of the parameters. Assignment of parameter values to local memory in the subroutine is as follows:

- Parameter values are assigned to local memory in the order specified by the call subroutine instruction with parameters starting at L.0.
- One to eight consecutive bit parameter values are assigned to a single byte starting with Lx.0 and continuing to Lx.7.
- Byte, word, and double word values are assigned to local memory on byte boundaries (LBx, LWx, or LDx).

In the Call Subroutine instruction with parameters, parameters must be arranged in order with input parameters first, followed by input/output parameters, and then followed by output parameters.

If you are programming in STL, the format of the CALL instruction is:

```
CALL    subroutine number, parameter 1, parameter 2, ... , parameter
```

Error conditions that set ENO for Call Subroutine with parameters = 0:
SM4.3 (run-time), 0008 (maximum subroutine nesting exceeded)

Subroutine, and Return from Subroutine Example

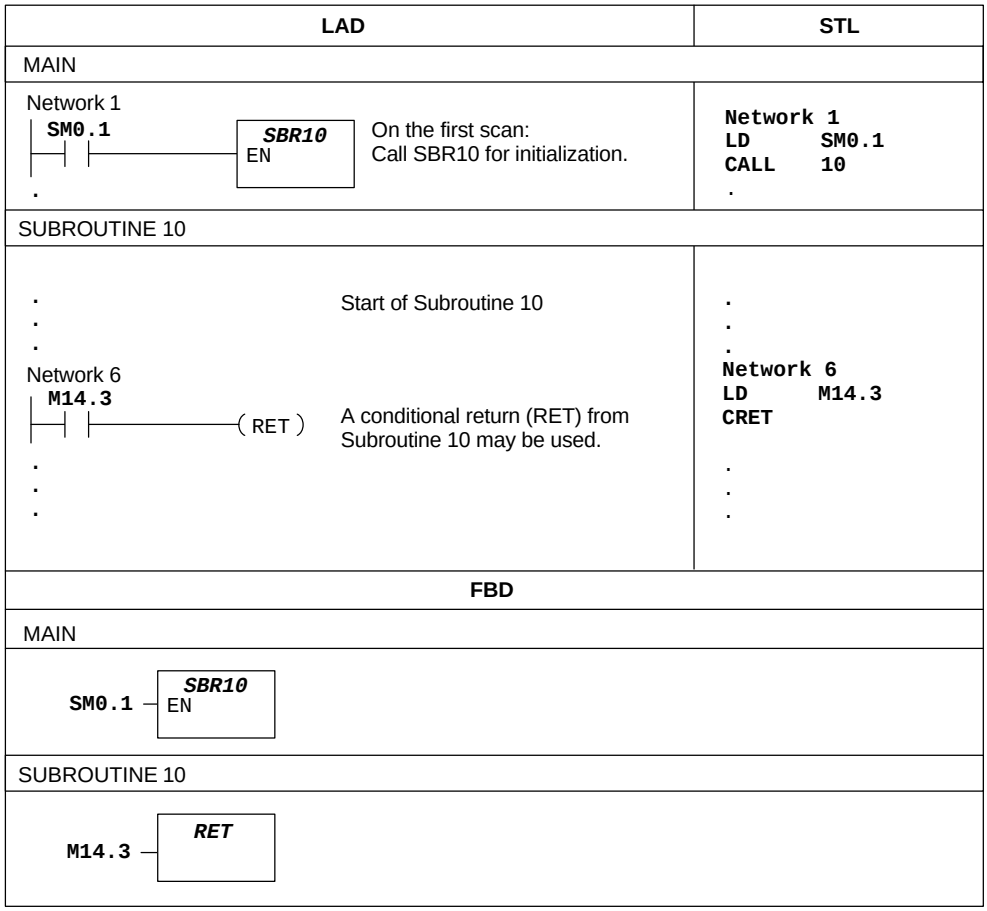
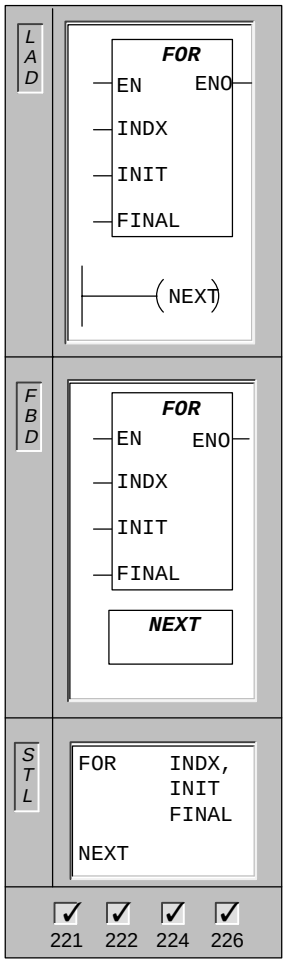


Figure 9-55 Example of Subroutine Instructions for SIMATIC LAD, STL, and FBD

For, Next



The **FOR** instruction executes the instructions between the FOR and the NEXT. You must specify the index value or current loop count (INDX), the starting value (INIT), and the ending value (FINAL).

The **NEXT** instruction marks the end of the FOR loop, and sets the top of the stack to 1.

For example, given an INIT value of 1 and a FINAL value of 10, the instructions between the FOR and the NEXT are executed 10 times with the INDX value being incremented: 1, 2, 3, ...10.

If the starting value is greater than the final value, the loop is not executed. After each execution of the instructions between the FOR and the NEXT instruction, the INDX value is incremented and the result is compared to the final value. If the INDX is greater than the final value, the loop is terminated.

For: Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
INDX	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	INT
INIT	VW, IW, QW, MW, SW, SMW, T, C, AC, LW, AIW, Constant, *VD, *AC, *LD	INT
FINAL	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, AIW, Constant, *VD, *AC, *LD	INT

Here are some guidelines for using the FOR/NEXT loop:

- If you enable the FOR/NEXT loop, it continues the looping process until it finishes the iterations, unless you change the final value from within the loop itself. You can change the values while the FOR/NEXT is in the looping process.
- When the loop is enabled again, it copies the initial value into the index value (current loop number). The FOR/NEXT instruction resets itself the next time it is enabled.

Use the FOR/NEXT instructions to delineate a loop that is repeated for the specified count. Each FOR instruction requires a NEXT instruction. You can nest FOR/NEXT loops (place a FOR/NEXT loop within a FOR/NEXT loop) to a depth of eight.

For/Next Example

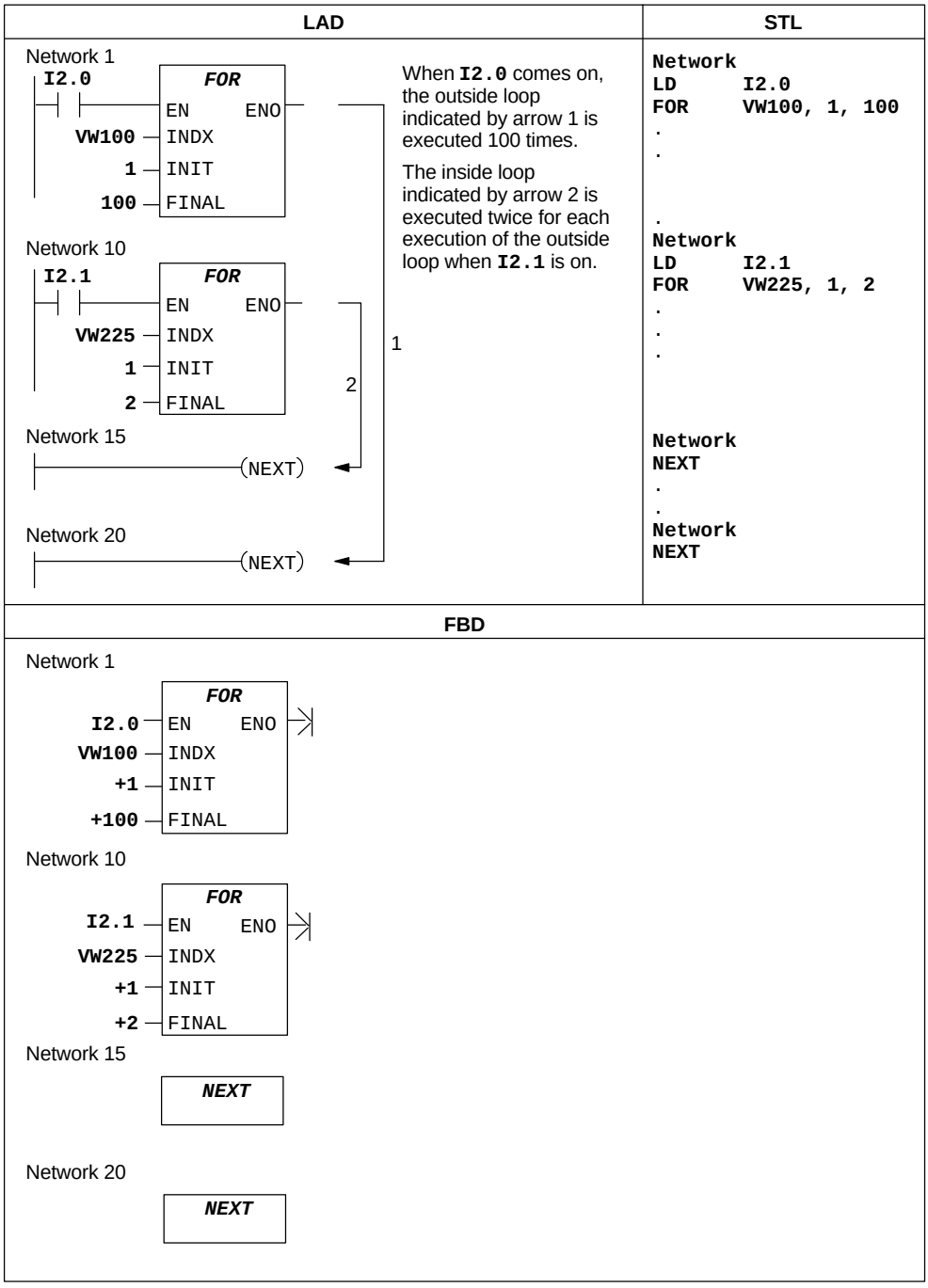
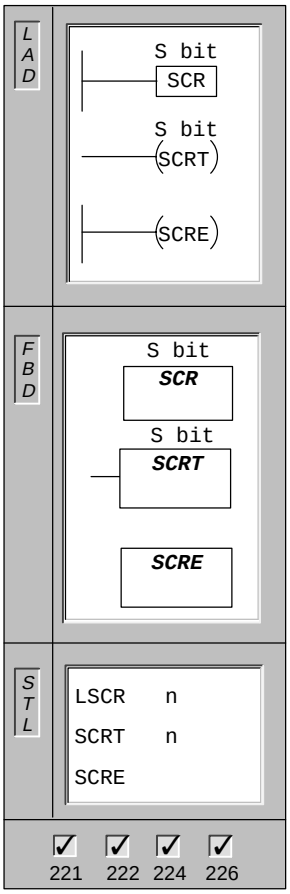


Figure 9-56 Example of For/Next Instructions for SIMATIC LAD, STL, and FBD

Sequence Control Relay



The **Load Sequence Control Relay** instruction marks the beginning of an SCR segment. When n equals 1, power flow is enabled to the SCR segment. The SCR segment must be terminated with an SCRE instruction.

The **Sequence Control Relay Transition** instruction identifies the SCR bit to be enabled (the next S bit to be set). When power flows to the coil or FBD box, the referenced S bit is turned on and the S bit of the LSCR instruction (that enabled this SCR segment) is turned off.

The **Sequence Control Relay End** instruction marks the end of an SCR segment.

Inputs/Outputs	Operands	Data Types
n	S	BOOL

Understanding SCR Instructions

In LAD, FBD, and STL, Sequence Control Relays (SCRs) are used to organize machine operations or steps into equivalent program segments. SCRs allow logical segmentation of the control program.

The LSCR instruction loads the SCR and logic stacks with the value of the S bit referenced by the instruction. The SCR segment is energized or de-energized by the resulting value of the SCR stack. The top of the logic stack is loaded to the value of the referenced S bit so that boxes or output coils can be tied directly to the left power rail without an intervening contact. Figure 9-57 shows the S stack and the logic stack and the effect of executing the LSCR instruction.

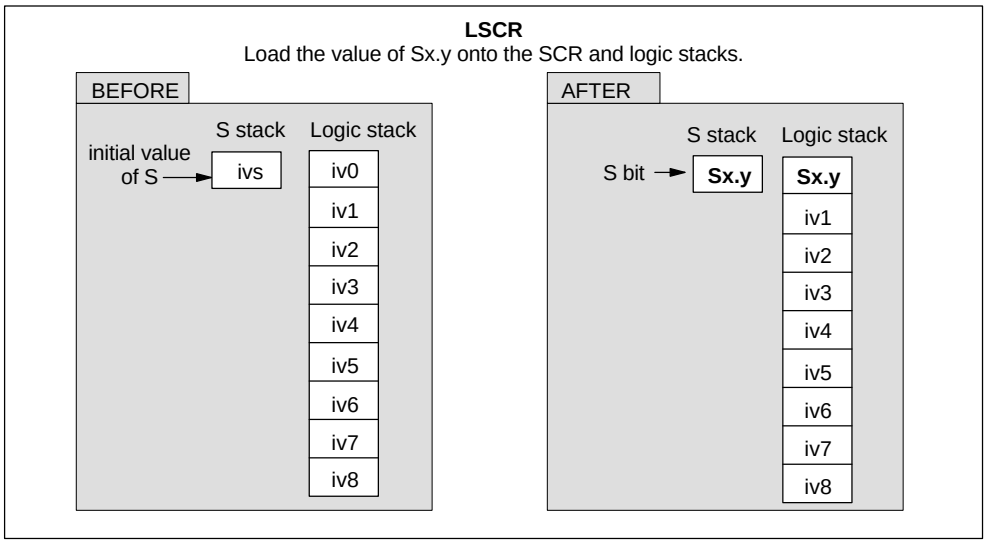


Figure 9-57 Effect of LSCR on the Logic Stack

The following is true of Sequence Control Relay instructions:

- All logic between the LSCR and the SCRE instructions make up the SCR segment and are dependent upon the value of the S stack for its execution. Logic between the SCRE and the next LSCR instruction have no dependency upon the value of the S stack.
- The SCRT instruction sets an S bit to enable the next SCR and also resets the S bit that was loaded to enable this section of the SCR segment.

Restrictions

Restrictions for using SCRs follow:

- You cannot use the same S bit in more than one routine. For example, if you use S0.1 in the main program, do not use it in the subroutine.
- You cannot use the JMP and LBL instructions in an SCR segment. This means that jumps into, within, or out of an SCR segment are not allowed. You can use jump and label instructions to jump around SCR segments.
- You cannot use the FOR, NEXT, and END instructions in an SCR segment.

SCR Example

Figure 9-58 shows an example of the operation of SCRs.

- In this example, the first scan bit SM0.1 is used to set S0.1, which will be the active State 1 on the first scan.
- After a 2-second delay, T37 causes a transition to State 2. This transition deactivates the State 1 SCR (S0.1) segment and activates the State 2 SCR (S0.2) segment.

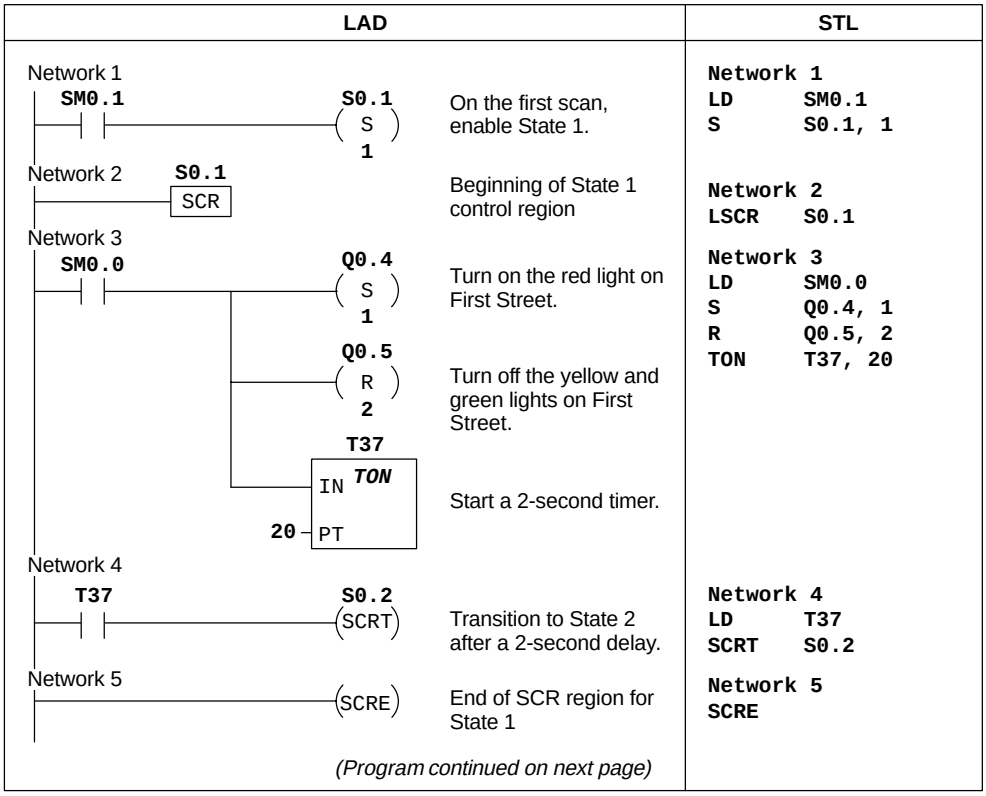


Figure 9-58 Example of Sequence Control Relays (SCRs) for SIMATIC LAD, STL, and FBD

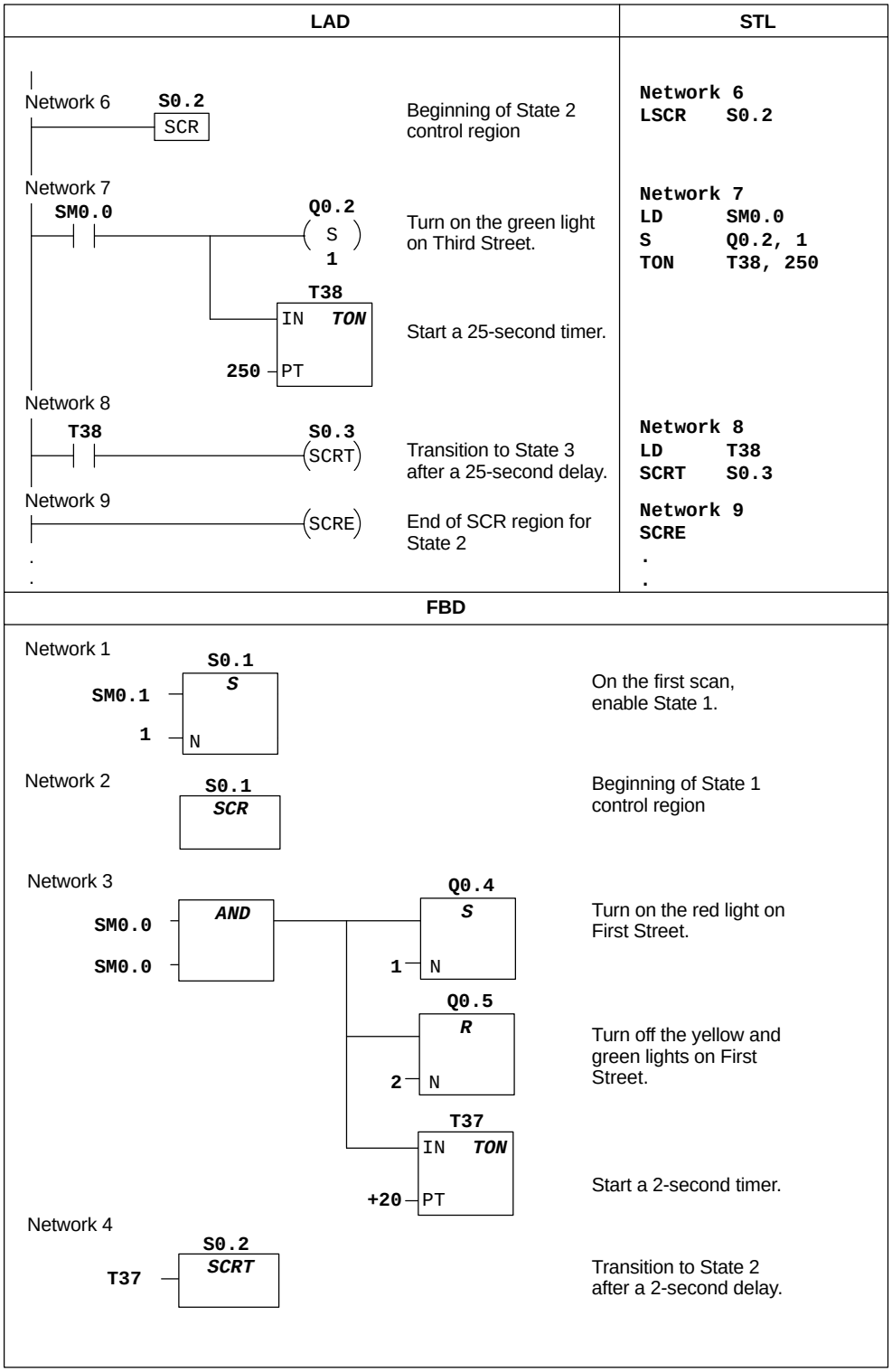


Figure 9-58 Example of Sequence Control Relays (SCRs) for SIMATIC LAD, STL, and FBD (continued)

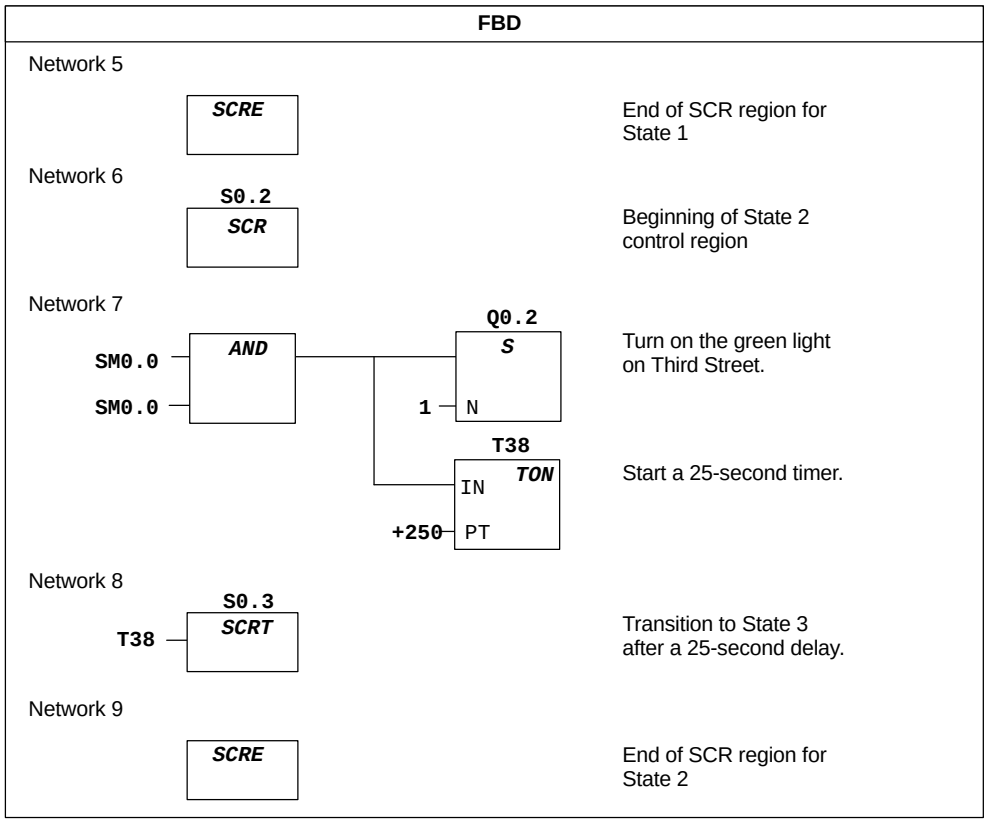


Figure 9-58 Example of Sequence Control Relays (SCRs) for SIMATIC LAD, STL, and FBD (continued)

Divergence Control

In many applications, a single stream of sequential states must be split into two or more different streams. When a stream of control diverges into multiple streams, all outgoing streams must be activated simultaneously. This is shown in Figure 9-59.

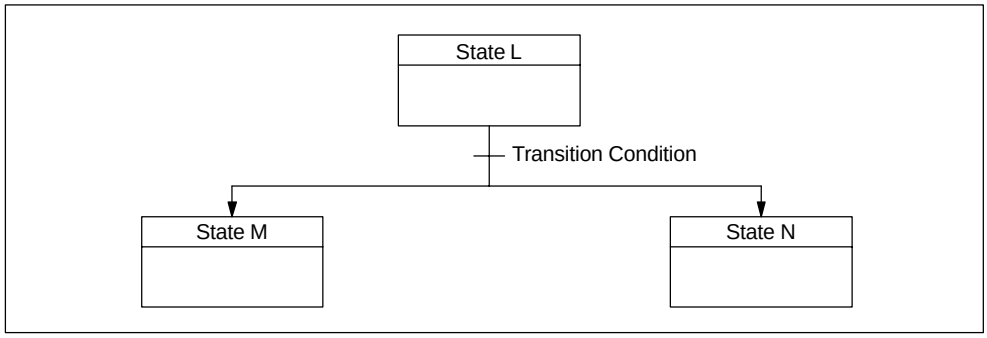


Figure 9-59 Divergence of Control Stream

The divergence of control streams can be implemented in an SCR program by using multiple SCRT instructions enabled by the same transition condition, as shown in Figure 9-60.

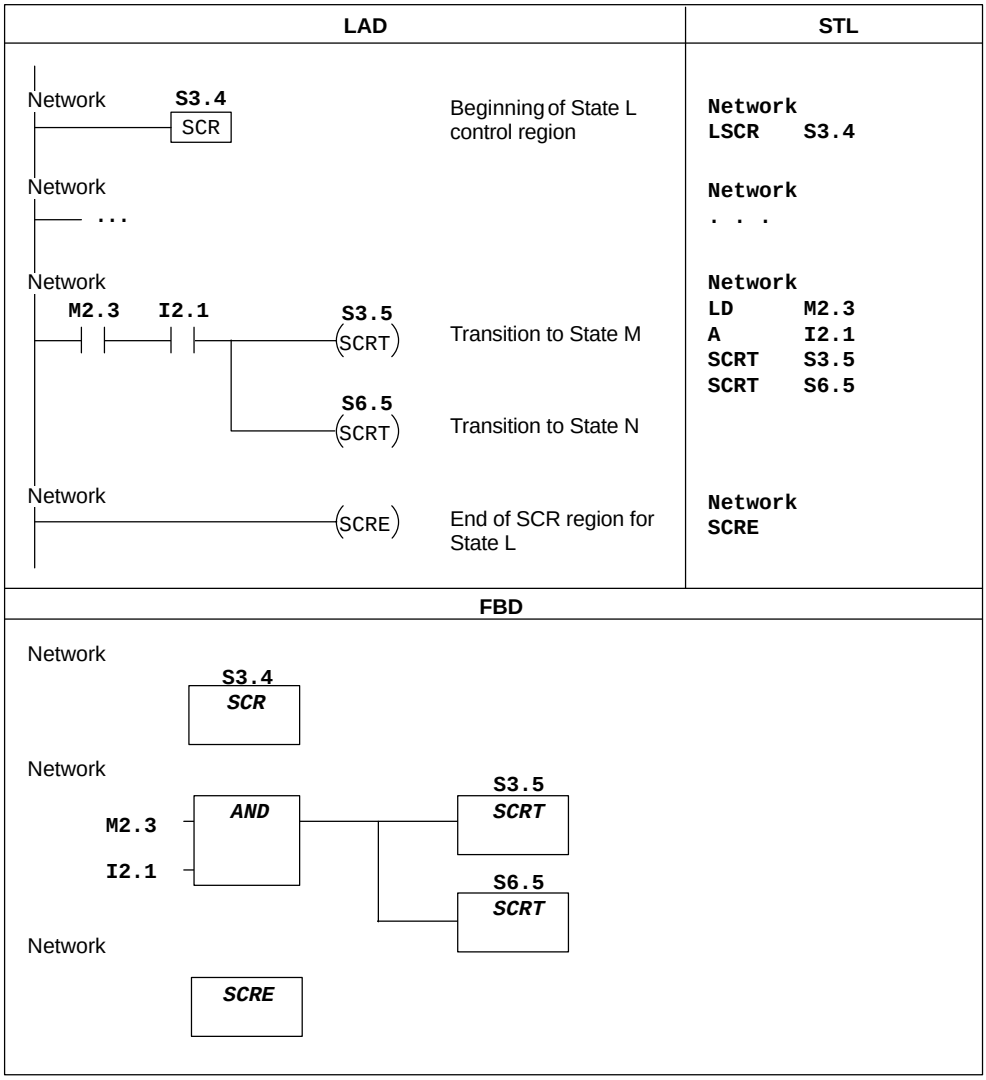


Figure 9-60 Example of Divergence of Control Streams for LAD, STL, and FBD

Convergence Control

A similar situation arises when two or more streams of sequential states must be merged into a single stream. When multiple streams merge into a single stream, they are said to converge. When streams converge, all incoming streams must be complete before the next state is executed. Figure 9-61 depicts the convergence of two control streams.

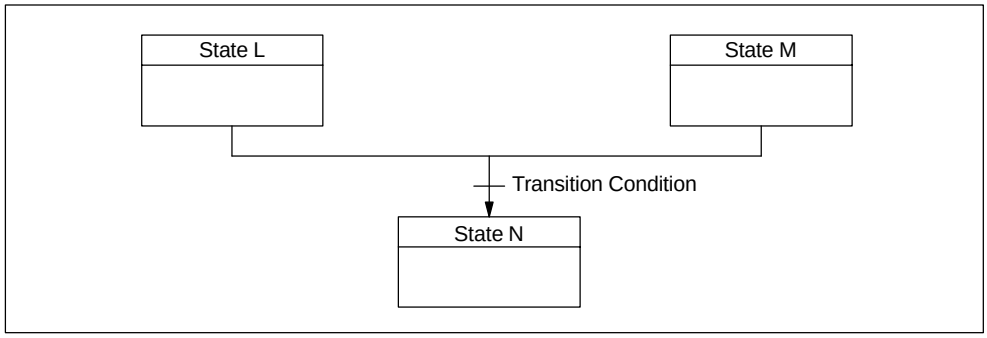


Figure 9-61 Convergence of Control Streams

The convergence of control streams can be implemented in an SCR program by making the transition from state L to state L' and by making the transition from state M to state M'. When both SCR bits representing L' and M' are true, state N can the enabled as shown in Figure 9-62.

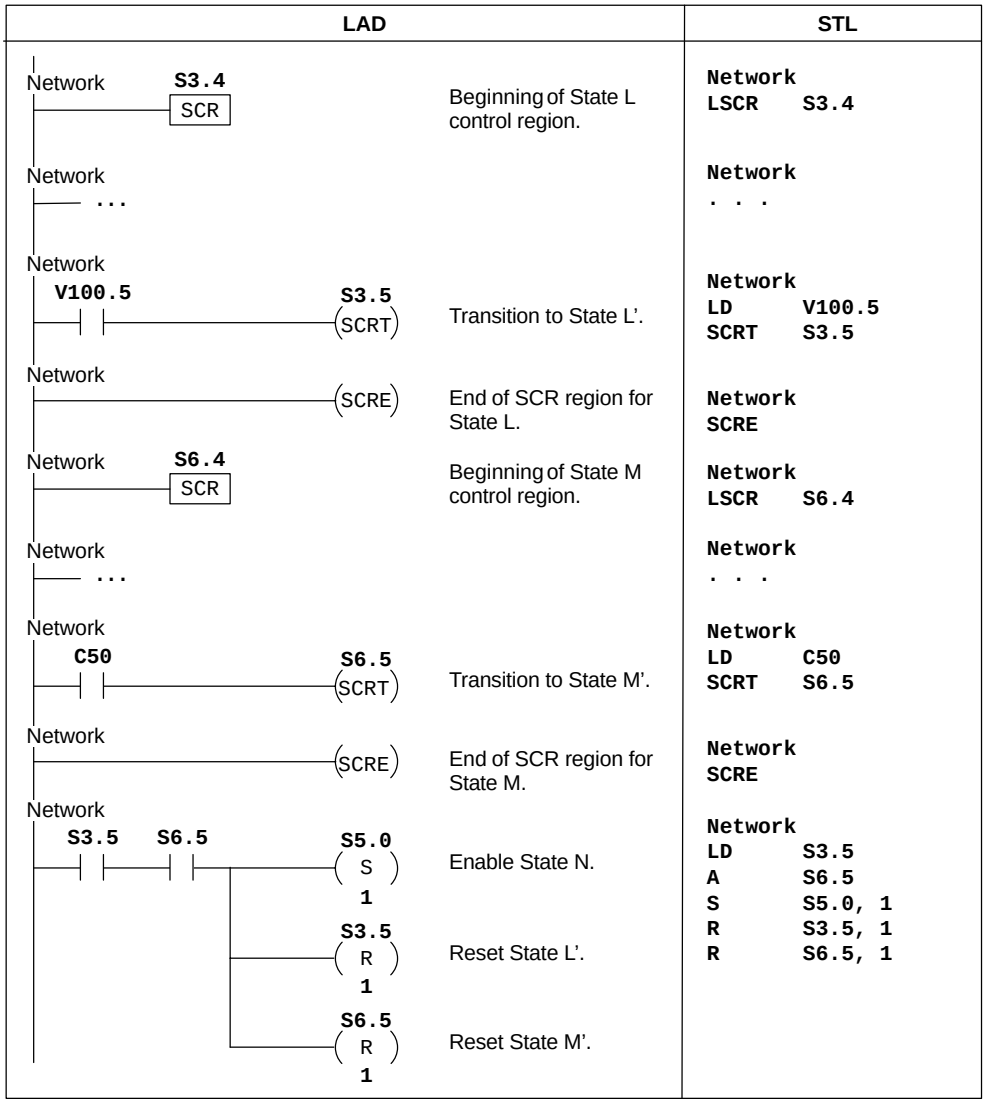


Figure 9-62 Example of Convergence of Control Streams for LAD, STL, and FBD

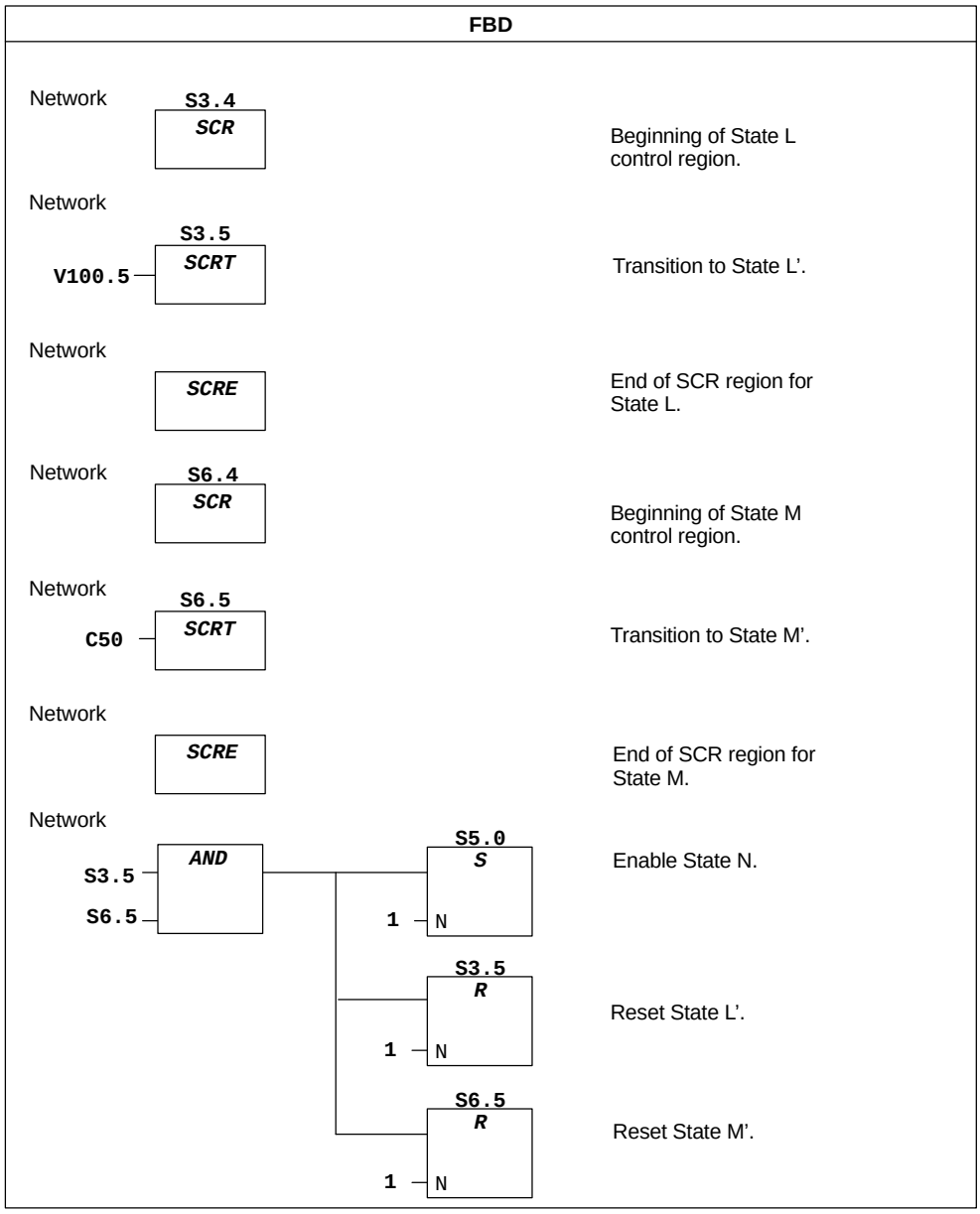


Figure 9-62 Example of Convergence of Control Streams for LAD, STL, and FBD (continued)

In other situations, a control stream may be directed into one of several possible control streams, depending upon which transition condition comes true first. Such a situation is depicted in Figure 9-63.

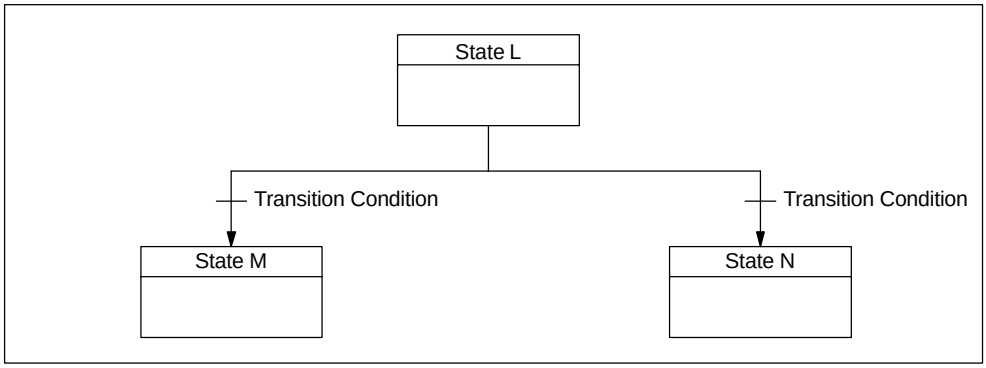


Figure 9-63 Divergence of Control Stream, Depending on Transition Condition

An equivalent SCR program is shown in Figure 9-64.

LAD		STL
Network S3.4 SCR	Beginning of State L control region.	**Network** **LSCR S3.4**
Network ...		**Network** **. . .**
Network M2.3 — S3.5 (SCRT)	Transition to State M.	**Network** **LD M2.3** **SCRT S3.5**
Network I3.3 — S6.5 (SCRT)	Transition to State N.	**Network** **LD I3.3** **SCRT S6.5**
Network (SCRE)	End of SCR region for State L.	**Network** **SCRE**

Figure 9-64 Example of Conditional Transitions for LAD, STL, and FBD

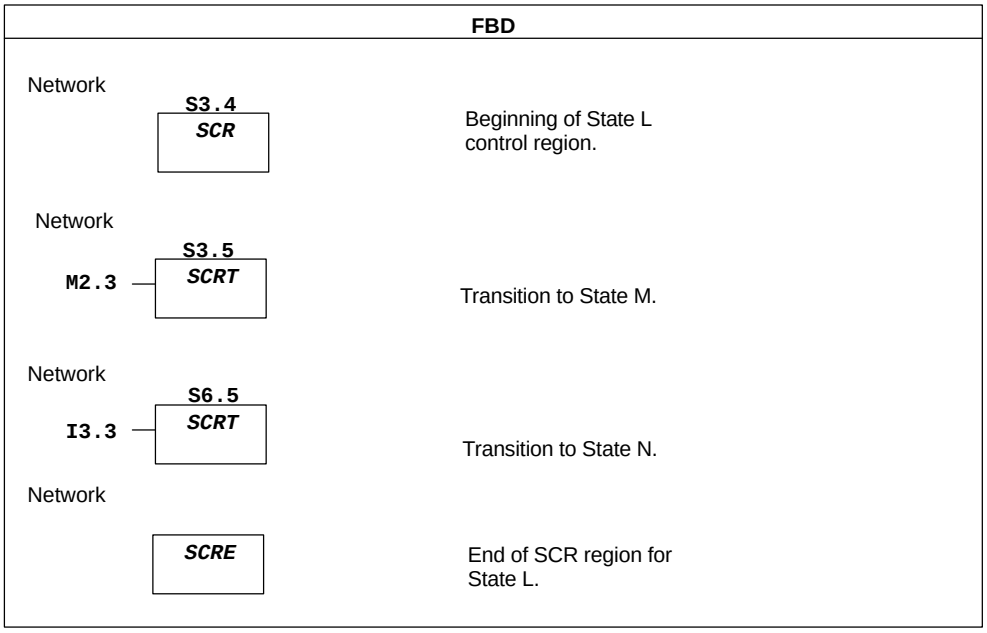
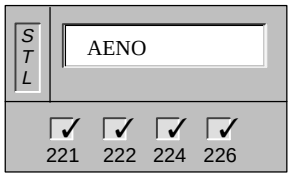


Figure 9-64 Example of Conditional Transitions for LAD, STL, and FBD (continued)

ENO



ENO is a Boolean output for boxes in LAD and FBD. If a box has power flow at the EN input and is executed without error, the ENO output passes power flow to the next element. ENO can be used as an enable bit that indicates the successful completion of an instruction.

The ENO bit is used with the top of stack to affect power flow for execution of subsequent instructions.

STL instructions do not have an EN input; the top of the stack must be a logic 1 for the instruction to be executed.

In STL there is no ENO output, but the STL instructions that correspond to LAD and FBD instructions with ENO outputs do set a special ENO bit. This bit is accessible with the **And ENO** (AENO) instruction. AENO can be used to generate the same effect as the ENO bit of a box. The AENO instruction is only available in STL.

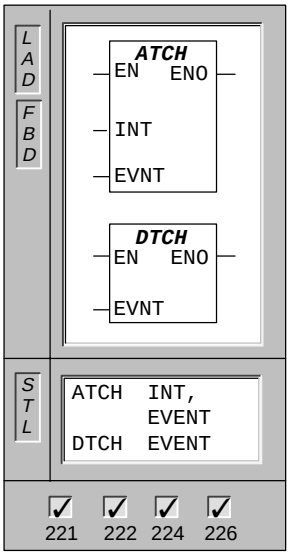
AENO will perform a logical AND of the ENO bit and the top of stack. The result of the AND operation is the new top of stack.

Operands: None

Data Types: None

9.15 SIMATIC Interrupt and Communications Instructions

Attach Interrupt, Detach Interrupt



The **Attach Interrupt** instruction associates an interrupt event (EVNT) with an interrupt routine number (INT), and enables the interrupt event.

The **Detach Interrupt** instruction disassociates an interrupt event (EVNT) from all interrupt routines, and disables the interrupt event.

Attach Interrupt: Error conditions that set ENO = 0: SM4.3 (run-time), 0002 (conflicting assignment of inputs to an HSC).

Inputs/Outputs	Operands	Data Types
INT	Constant	BYTE
EVNT	Constant (CPU 221/222: 0-12, 19-23, 27-33; CPU 224: 0-23, 27-33; CPU 226: 0 - 33)	BYTE

Understanding Attach and Detach Interrupt Instructions

Before an interrupt routine can be invoked, an association must be established between the interrupt event and the program segment that you want to execute when the event occurs. Use the Attach Interrupt instruction (ATCH) to associate an interrupt event (specified by the interrupt event number) and the program segment (specified by an interrupt routine number). You can attach multiple interrupt events to one interrupt routine, but one event cannot be concurrently attached to multiple interrupt routines. When an event occurs with interrupts enabled, only the last interrupt routine attached to this event is executed.

When you attach an interrupt event to an interrupt routine, that interrupt is automatically enabled. If you disable all interrupts using the global disable interrupt instruction, each occurrence of the interrupt event is queued until interrupts are re-enabled, using the global enable interrupt instruction.

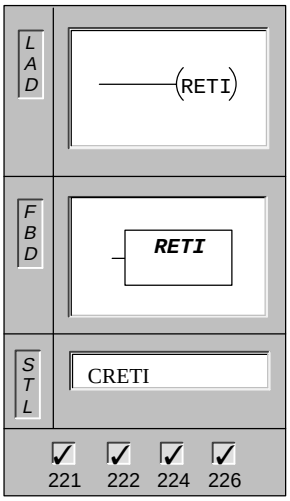
You can disable individual interrupt events by breaking the association between the interrupt event and the interrupt routine with the Detach Interrupt instruction (DTCH). The Detach instruction returns the interrupt to an inactive or ignored state.

Table 9-20 lists the different types of interrupt events.

Table 9-20 Interrupt Events

Event Number	Interrupt Description	CPU 221	CPU 222	CPU 224	CPU 226
0	Rising edge, I0.0	Y	Y	Y	Y
1	Falling edge, I0.0	Y	Y	Y	Y
2	Rising edge, I0.1	Y	Y	Y	Y
3	Falling edge, I0.1	Y	Y	Y	Y
4	Rising edge, I0.2	Y	Y	Y	Y
5	Falling edge, I0.2	Y	Y	Y	Y
6	Rising edge, I0.3	Y	Y	Y	Y
7	Falling edge, I0.3	Y	Y	Y	Y
8	Port 0: Receive character	Y	Y	Y	Y
9	Port 0: Transmit complete	Y	Y	Y	Y
10	Timed interrupt 0, SMB34	Y	Y	Y	Y
11	Timed interrupt 1, SMB35	Y	Y	Y	Y
12	HSC0 CV=PV (current value = preset value)	Y	Y	Y	Y
13	HSC1 CV=PV (current value = preset value)			Y	Y
14	HSC1 direction changed			Y	Y
15	HSC1 external reset			Y	Y
16	HSC2 CV=PV (current value = preset value)			Y	Y
17	HSC2 direction changed			Y	Y
18	HSC2 external reset			Y	Y
19	PLS0 pulse count complete interrupt	Y	Y	Y	Y
20	PLS1 pulse count complete interrupt	Y	Y	Y	Y
21	Timer T32 CT=PT interrupt	Y	Y	Y	Y
22	Timer T96 CT=PT interrupt	Y	Y	Y	Y
23	Port 0: Receive message complete	Y	Y	Y	Y
24	Port 1: Receive message complete				Y
25	Port 1: Receive character				Y
26	Port 1: Transmit complete				Y
27	HSC0 direction changed	Y	Y	Y	Y
28	HSC0 external reset	Y	Y	Y	Y
29	HSC4 CV=PV (current value = preset value)	Y	Y	Y	Y
30	HSC4 direction changed	Y	Y	Y	Y
31	HSC4 external reset	Y	Y	Y	Y
32	HSC3 CV=PV (current value = preset value)	Y	Y	Y	Y
33	HSC5 CV=PV (current value = preset value)	Y	Y	Y	Y

Conditional Return from Interrupt



The **Conditional Return from Interrupt** instruction may be used to return from an interrupt, based upon the condition of the preceding logic. To add an interrupt, select **Edit > Insert > Interrupt** from the menu.

Operands: None

Data Types: None

The Return from Interrupt routines are identified by separate program tabs in the STEP 7-Micro/WIN 32 screen.

Interrupt Routines

The interrupt routine is executed in response to an associated internal or external event. Once the last instruction of the interrupt routine has been executed, control is returned to the main program. You can exit the routine by executing a conditional return from interrupt instruction (CRETI).

Interrupt Use Guidelines

Interrupt processing provides quick reaction to special internal or external events. You should optimize interrupt routines to perform a specific task, and then return control to the main routine. By keeping the interrupt routines short and to the point, execution is quick and other processes are not deferred for long periods of time. If this is not done, unexpected conditions can cause abnormal operation of equipment controlled by the main program. For interrupts, the axiom, “the shorter, the better,’’ is definitely true.

Restrictions

You cannot use the DISI, ENI, HDEF, LSCR, and END instructions in an interrupt routine.

System Support for Interrupt

Because contact, coil, and accumulator logic may be affected by interrupts, the system saves and reloads the logic stack, accumulator registers, and the special memory bits (SM) that indicate the status of accumulator and instruction operations. This avoids disruption to the main user program caused by branching to and from an interrupt routine.

Calling Subroutine From Interrupt Routines

You can call one nesting level of subroutines from an interrupt routine. The accumulators and the logic stack are shared between an interrupt routine and a subroutine that is called.

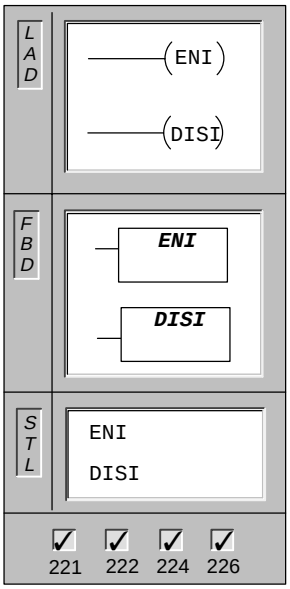
Sharing Data Between the Main Program and Interrupt Routines

You can share data between the main program and one or more interrupt routines. For example, a part of your main program may provide data to be used by an interrupt routine, or vice versa. If your program is sharing data, you must also consider the effect of the asynchronous nature of interrupt events, which can occur at any point during the execution of your main program. Problems with the consistency of shared data can result due to the actions of interrupt routines when the execution of instructions in your main program is interrupted by interrupt events.

There are a number of programming techniques you can use to ensure that data is correctly shared between your main program and interrupt routines. These techniques either restrict the way access is made to shared memory locations, or prevent interruption of instruction sequences using shared memory locations.

- For an STL program that is sharing a single variable: If the shared data is a single byte, word, or double-word variable and your program is written in STL, then correct shared access can be ensured by storing the intermediate values from operations on shared data only in non-shared memory locations or accumulators.
- For a LAD program that is sharing a single variable: If the shared data is a single byte, word, or double-word variable and your program is written in LAD, then correct shared access can be ensured by establishing the convention that access to shared memory locations be made using only Move instructions (MOVB, MOVW, MOVD, MOVR). While many LAD instructions are composed of interruptible sequences of STL instructions, these Move instructions are composed of a single STL instruction whose execution cannot be affected by interrupt events.
- For an STL or LAD program that is sharing multiple variables: If the shared data is composed of a number of related bytes, words, or double-words, then the interrupt disable/enable instructions (DISI and ENI) can be used to control interrupt routine execution. At the point in your main program where operations on shared memory locations are to begin, disable the interrupts. Once all actions affecting the shared locations are complete, re-enable the interrupts. During the time that interrupts are disabled, interrupt routines cannot be executed and therefore cannot access shared memory locations; however, this approach can result in delayed response to interrupt events.

Enable Interrupt, Disable Interrupt



The **Enable Interrupt** instruction globally enables processing of all attached interrupt events.

The **Disable Interrupt** instruction globally disables processing of all interrupt events.

Operands: None

Data Types: None

When you make the transition to the RUN mode, interrupts are initially disabled. Once in RUN mode, you can enable all interrupts by executing the global Enable Interrupt instruction. The global Disable Interrupt instruction allows interrupts to be queued, but does not allow the interrupt routines to be invoked.

Error conditions that set ENO = 0: SM4.3 (run-time), 0004 (attempted execution of ENI, DISI, or HDEF instructions in an interrupt routine).

Communication Port Interrupts

The serial communications port of the programmable logic controller can be controlled by the LAD or STL program. This mode of operating the communications port is called Freeport mode. In Freeport mode, your program defines the baud rate, bits per character, parity, and protocol. The receive and transmit interrupts are available to facilitate your program-controlled communications. Refer to the transmit/receive instructions for more information.

I/O Interrupts

I/O interrupts include rising/falling edge interrupts, high-speed counter interrupts, and pulse train output interrupts. The CPU can generate an interrupt on rising and/or falling edges of an input. See Table 9-21 for the inputs available for the interrupts. The rising edge and the falling edge events can be captured for each of these input points. These rising/falling edge events can be used to signify a condition that must receive immediate attention when the event happens.

Table 9-21 Rising/Falling Edge Interrupts Supported

I/O Interrupts	S7-200 CPU
I/O Points	I0.0 to I0.3

The high-speed counter interrupts allow you to respond to conditions such as the current value reaching the preset value, a change in counting direction that might correspond to a reversal in the direction in which a shaft is turning, or an external reset of the counter. Each of these high-speed counter events allows action to be taken in real time in response to high-speed events that cannot be controlled at programmable logic controller scan speeds.

The pulse train output interrupts provide immediate notification of completion of outputting the prescribed number of pulses. A typical use of pulse train outputs is stepper motor control.

You can enable each of the above interrupts by attaching an interrupt routine to the related I/O event.

Time-Based Interrupts

Time-based interrupts include timed interrupts and the Timer T32/T96 interrupts. The CPU can support timed interrupts. You can specify actions to be taken on a cyclic basis using a timed interrupt. The cycle time is set in 1-ms increments from 1 ms to 255 ms. You must write the cycle time in SMB34 for timed interrupt 0, and in SMB35 for timed interrupt 1.

The timed interrupt event transfers control to the appropriate interrupt routine each time the timer expires. Typically, you use timed interrupts to control the sampling of analog inputs at regular intervals or to execute a PID loop at a timed interrupt.

A timed interrupt is enabled and timing begins when you attach an interrupt routine to a timed interrupt event. During the attachment, the system captures the cycle time value, so subsequent changes do not affect the cycle time. To change the cycle time, you must modify the cycle time value, and then re-attach the interrupt routine to the timed interrupt event. When the re-attachment occurs, the timed interrupt function clears any accumulated time from the previous attachment, and begins timing with the new value.

Once enabled, the timed interrupt runs continuously, executing the attached interrupt routine on each expiration of the specified time interval. If you exit the RUN mode or detach the timed interrupt, the timed interrupt is disabled. If the global disable interrupt instruction is executed, timed interrupts continue to occur. Each occurrence of the timed interrupt is queued (until either interrupts are enabled, or the queue is full). See Figure 9-66 for an example of using a timed interrupt.

The timer T32/T96 interrupts allow timely response to the completion of a specified time interval. These interrupts are only supported for the 1-ms resolution on-delay (TON) and off-delay (TOF) timers T32 and T96. The T32 and T96 timers otherwise behave normally. Once the interrupt is enabled, the attached interrupt routine is executed when the active timer’s current value becomes equal to the preset time value during the normal 1-ms timer update performed in the CPU. You enable these interrupts by attaching an interrupt routine to the T32/T96 interrupt events.

Understanding the Interrupt Priority and Queuing

Interrupts are prioritized according to the fixed priority scheme shown below:

- Communication (highest priority)
- I/O interrupts
- Time-based interrupts (lowest priority)

Interrupts are serviced by the CPU on a first-come-first-served basis within their respective priority assignments. Only one user-interrupt routine is ever being executed at any point in time. Once the execution of an interrupt routine begins, the routine is executed to completion. It cannot be pre-empted by another interrupt routine, even by a higher priority routine. Interrupts that occur while another interrupt is being processed are queued for later processing.

The three interrupt queues and the maximum number of interrupts they can store are shown in Table 9-22.

Table 9-22 Interrupt Queues and Maximum Number of Entries per Queue

Queue	CPU 221	CPU 222	CPU 224	CPU 226
Communications queue	4	4	4	8
I/O Interrupt queue	16	16	16	16
Timed Interrupt queue	8	8	8	8

Potentially, more interrupts can occur than the queue can hold. Therefore, queue overflow memory bits (identifying the type of interrupt events that have been lost) are maintained by the system. The interrupt queue overflow bits are shown in Table 9-23. You should use these bits only in an interrupt routine because they are reset when the queue is emptied, and control is returned to the main program.

Table 9-23 Special Memory Bit Definitions for Interrupt Queue Overflow Bits

Description (0 = no overflow, 1 = overflow)	SM Bit
Communication interrupt queue overflow	SM4.0
I/O interrupt queue overflow	SM4.1
Timed interrupt queue overflow	SM4.2

Table 9-24 shows the interrupt event, priority, and assigned event number.

Table 9-24 Interrupt Events in Priority Order

Event Number	Interrupt Description	Priority Group	Priority in Group
8	Port 0: Receive character	Communications (highest)	0
9	Port 0: Transmit complete		0
23	Port 0: Receive message complete		0
24	Port 1: Receive message complete		1
25	Port 1: Receive character		1
26	Port 1: Transmit complete		1
19	PTO 0 complete interrupt	Discrete (middle)	0
20	PTO 1 complete interrupt		1
0	Rising edge, I0.0		2
2	Rising edge, I0.1		3
4	Rising edge, I0.2		4
6	Rising edge, I0.3		5
1	Falling edge, I0.0		6
3	Falling edge, I0.1		7
5	Falling edge, I0.2		8
7	Falling edge, I0.3		9
12	HSC0 CV=PV (current value = preset value)		10
27	HSC0 direction changed		11
28	HSC0 external reset		12
13	HSC1 CV=PV (current value = preset value)		13
14	HSC1 direction input changed		14
15	HSC1 external reset		15
16	HSC2 CV=PV		16
17	HSC2 direction changed		17
18	HSC2 external reset		18
32	HSC3 CV=PV (current value = preset value)		19
29	HSC4 CV=PV (current value = preset value)		20
30	HSC4 direction changed		21
31	HSC4 external reset		22
33	HSC5 CV=PV (current value = preset value)		23
10	Timed interrupt 0	Timed (lowest)	0
11	Timed interrupt 1		1
21	Timer T32 CT=PT interrupt		2
22	Timer T96 CT=PT interrupt		3

Interrupt Examples

Figure 9-65 shows an example of the Interrupt Routine instructions.

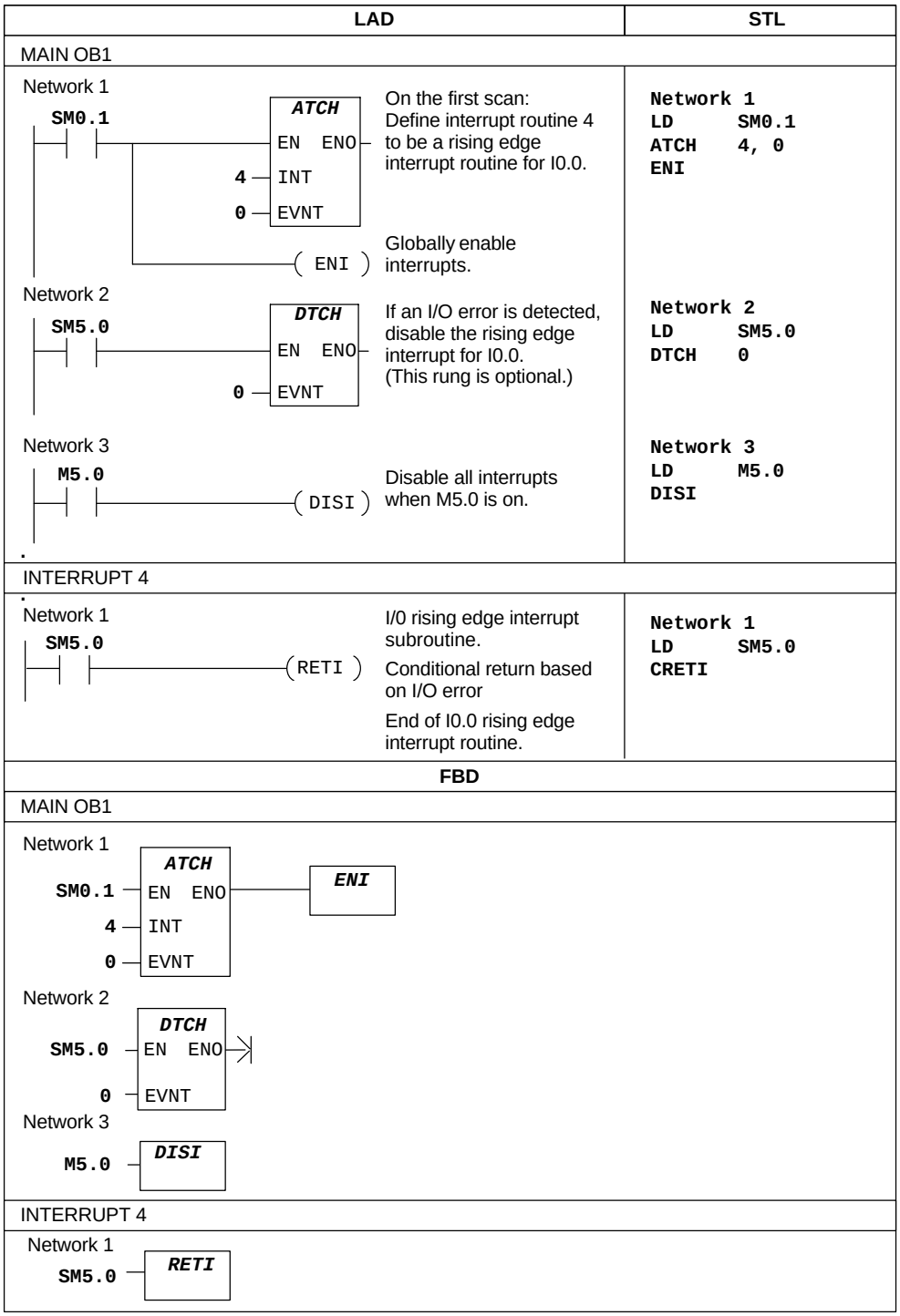


Figure 9-65 Example of Interrupt Instructions for SIMATIC LAD, STL, and FBD

Figure 9-66 shows how to set up a timed interrupt to read the value of an analog input.

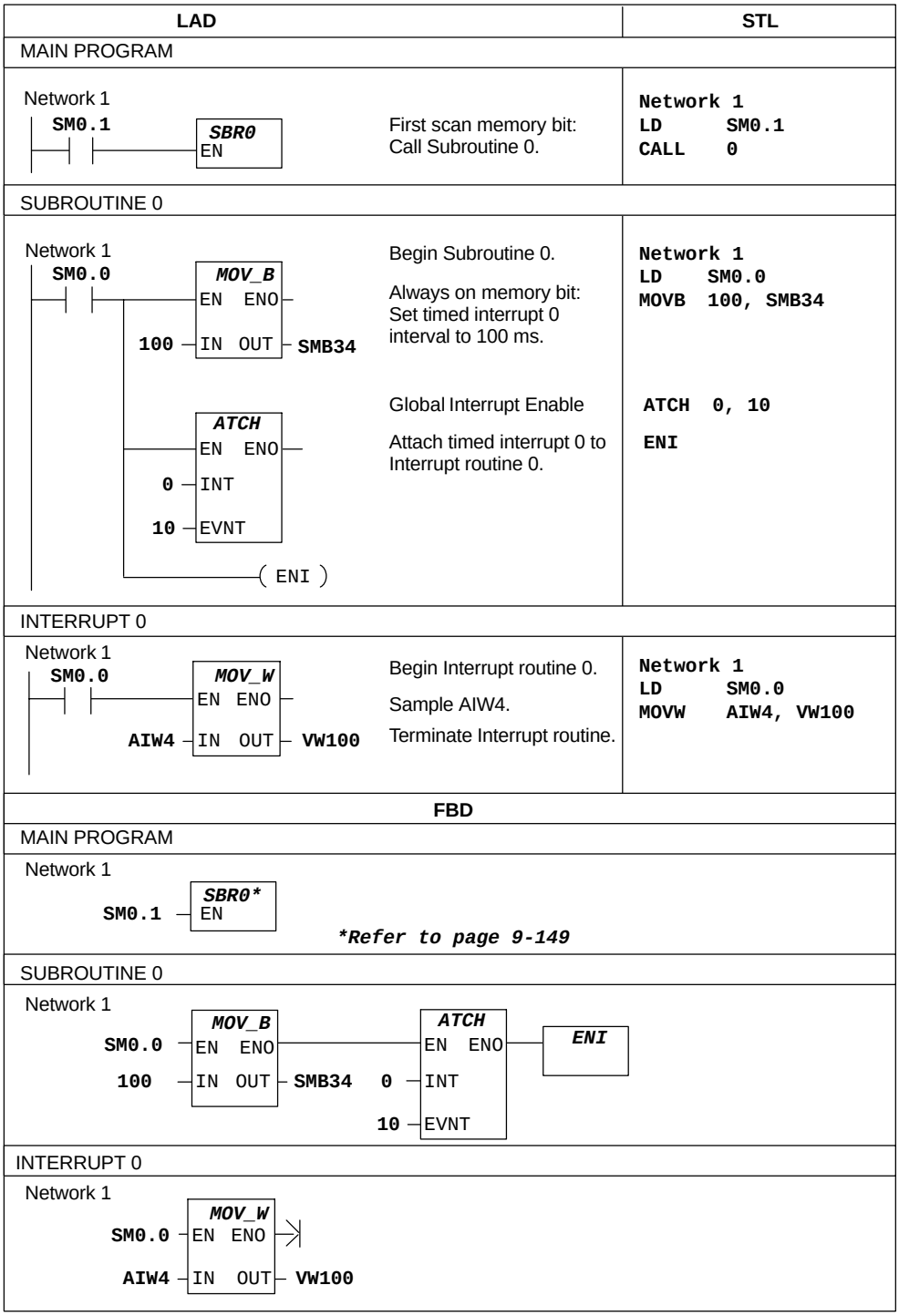
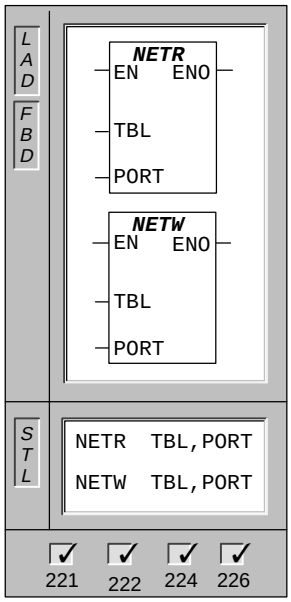


Figure 9-66 Example of How to Set Up a Timed Interrupt to Read the Value of an Analog Input

Network Read, Network Write



The **Network Read** instruction initiates a communication operation to gather data from a remote device through the specified port (PORT), as defined by the table (TBL).

The **Network Write** instruction initiates a communication operation to write data to a remote device through the specified port (PORT), as defined by the table (TBL).

The NETR instruction can read up to 16 bytes of information from a remote station, and the NETW instruction can write up to 16 bytes of information to a remote station. You may have any number of NETR/NETW instructions in the program, but only a maximum of eight NETR and NETW instructions may be activated at any one time. For example, you can have four NETRs and four NETWs, or two NETRs and six NETWs active at the same time in a given S7-200.

Figure 9-67 defines the table that is referenced by the TBL parameter in the NETR and NETW instructions.

NETR: Error conditions that set ENO = 0:
SM4.3 (run-time), 0006 (indirect address)

NETW: Error conditions that set ENO = 0:
SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
TBL	VB, MB, *VD, *AC, *LD	BYTE
PORT	Constant	BYTE

D Done (function has been completed): 0 = not done 1 = done
A Active (function has been queued): 0 = not active 1 = active
E Error (function returned an error): 0 = no error 1 = error

Byte Offset	7				0
0	D	A	E	0	Error code
1	Remote station address				
2	Pointer to the data				
3	area in the				
4	remote station				
5	(I, Q, M, or V)				
6	Data length				
7	Data byte 0				
8	Data byte 1				
	⋮				
22	Data byte 15				

Remote station address: the address of the PLC whose data is to be accessed.

Pointer to the data area in the remote station: an indirect pointer to the data that is to be accessed.

Data length: the number of bytes of data that is to be accessed in the remote station (1 to 16 bytes).

Receive or transmit data area: 1 to 16 bytes reserved for the data, as described below:

For NETR, this data area is where the values that are read from the remote station are stored after execution of the NETR.

For NETW, this data area is where the values to be sent to the remote station are stored before execution of the NETW.

Error Code	Definition
0	No error
1	Time-out error; remote station not responding
2	Receive error; parity, framing or checksum error in the response
3	Offline error; collisions caused by duplicate station addresses or failed hardware
4	Queue overflow error; more than eight NETR/NETW boxes have been activated
5	Protocol violation; attempt execute NETR/NETW without enabling PPI+ in SMB30
6	Illegal parameter; the NETR/NETW table contains an illegal or invalid value
7	No resource; remote station is busy (upload or download sequence in process)
8	Layer 7 error; application protocol violation
9	Message error; wrong data address or incorrect data length
A-F	Not used; (reserved for future use)

Figure 9-67 Definition of TABLE for NETR and NETW

Example of Network Read and Network Write

Figure 9-68 shows an example to illustrate the utility of the NETR and NETW instructions. For this example, consider a production line where tubs of butter are being filled and sent to one of four boxing machines (case packers). The case packer packs eight tubs of butter into a single cardboard box. A diverter machine controls the flow of butter tubs to each of the case packers. Four CPU 221 modules are used to control the case packers and a CPU 222 module equipped with a TD 200 operator interface is used to control the diverter. Figure 9-68 shows the network setup.

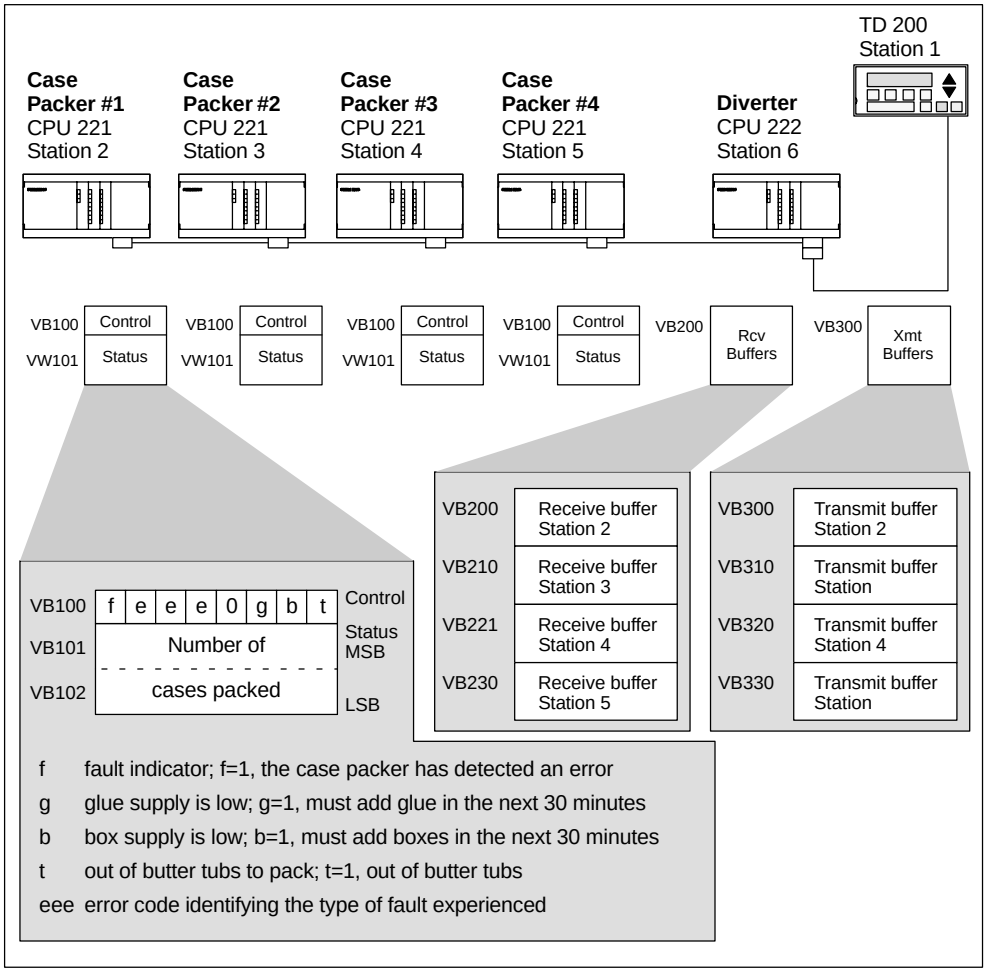


Figure 9-68 Example of NETR and NETW Instructions

The receive and transmit buffers for accessing the data in station 2 (located at VB200 and VB300, respectively) are shown in detail in Figure 9-69.

The CPU 224 uses a NETR instruction to read the control and status information on a continuous basis from each of the case packers. Each time a case packer has packed 100 cases, the diverter notes this and sends a message to clear the status word using a NETW instruction.

The program required to read the control byte, the number of cases packed and to reset the number of cases packed for a single case packer (case packer #1) is shown in Figure 9-70.

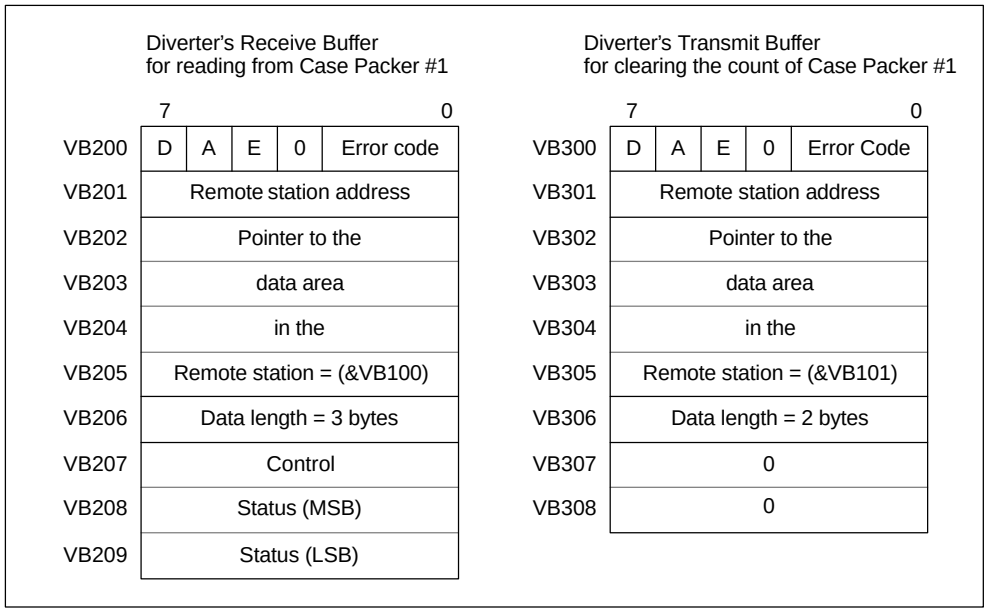


Figure 9-69 Sample TABLE Data for NETR and NETW Example

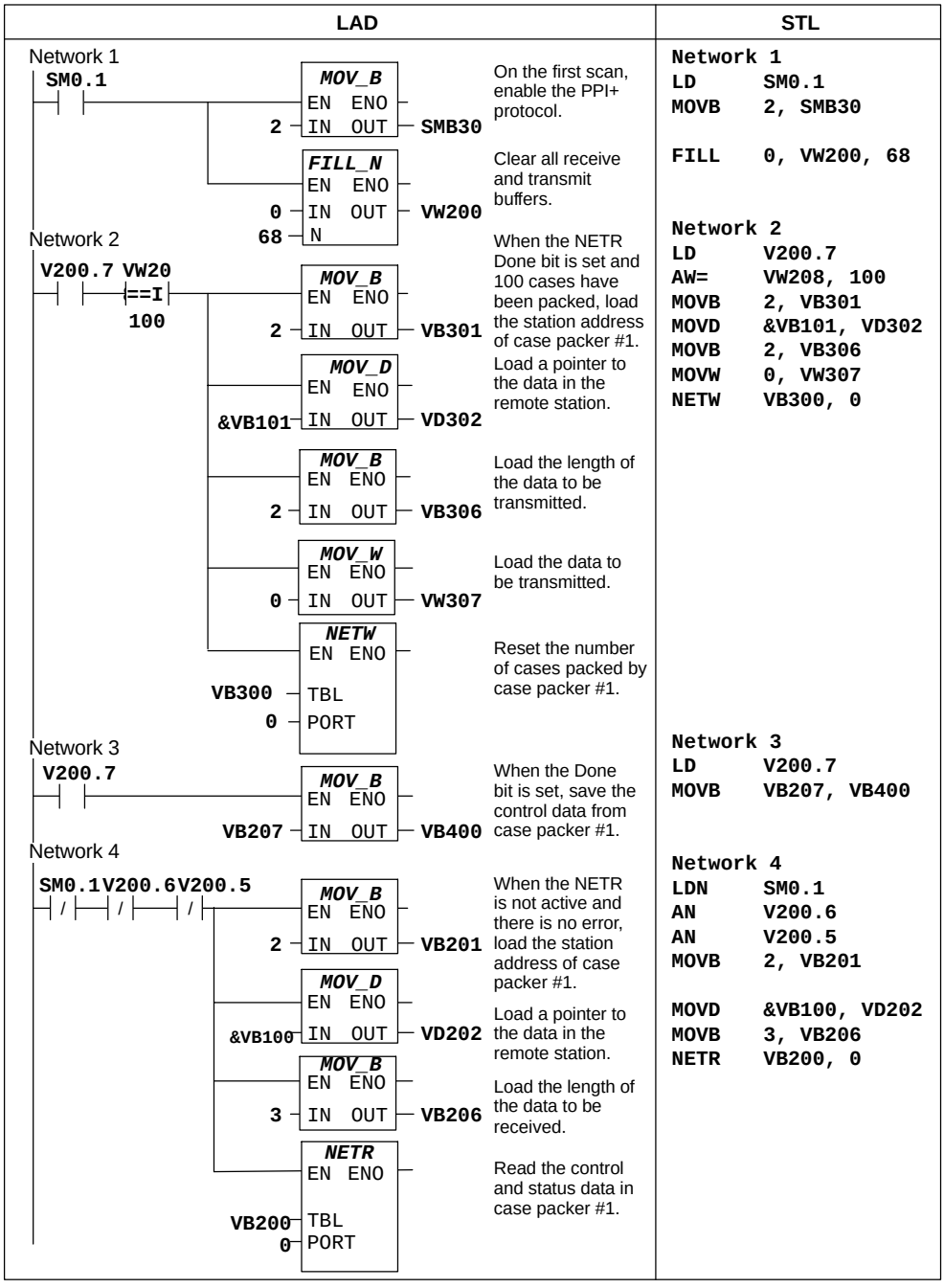


Figure 9-70 Example of NETR and NETW Instructions for SIMATIC LAD and STL

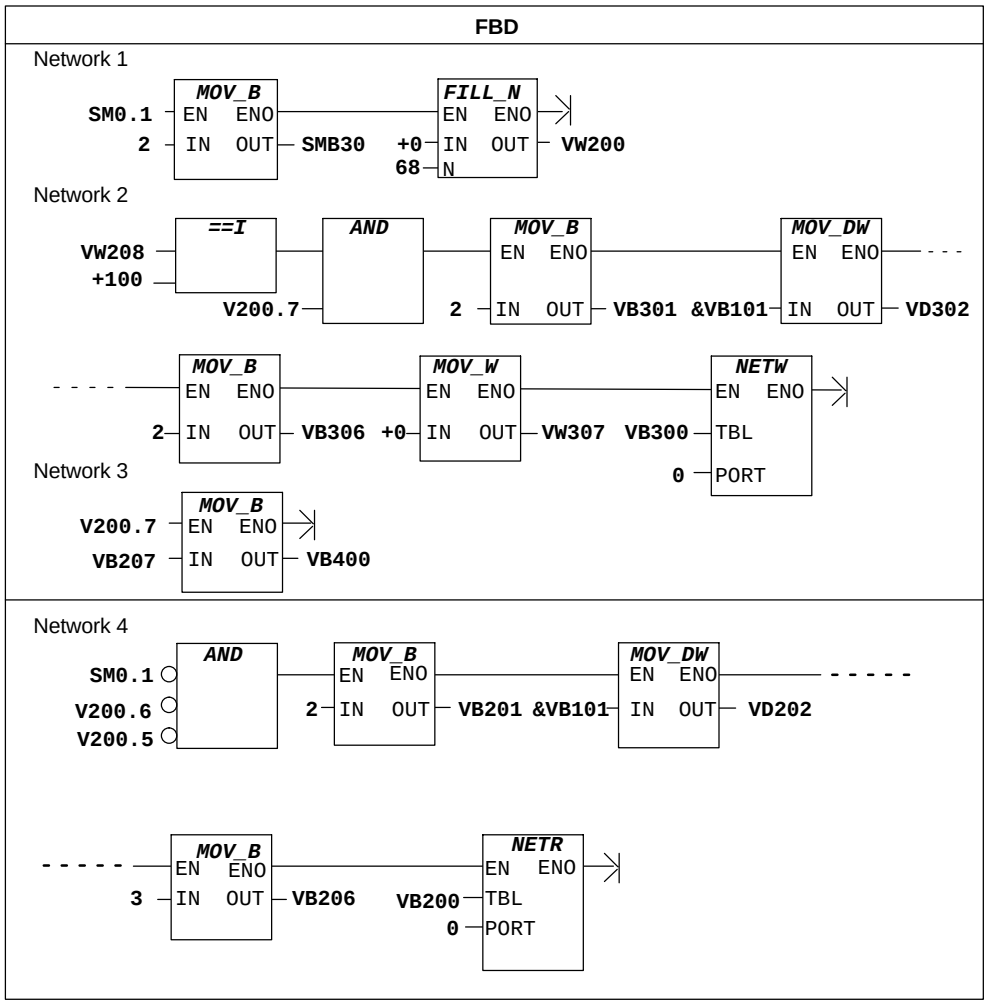
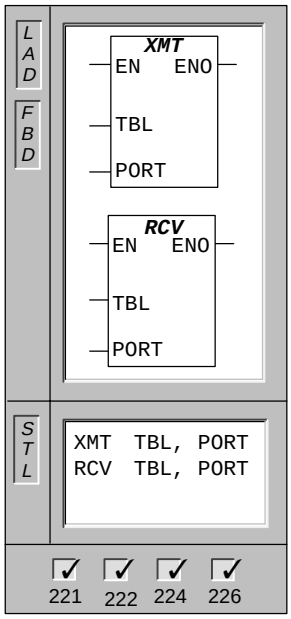


Figure 9-71 Example of NETR and NETW instructions for SIMATIC FBD

Transmit, Receive



The **Transmit** instruction invokes the transmission of the data buffer (TBL). The first entry in the data buffer specifies the number of bytes to be transmitted. PORT specifies the communication port to be used for transmission.

The XMT instruction is used in Freeport mode to transmit data by means of the communication port(s).

The format of the XMT buffer is:

The **Receive** instruction initiates or terminates the Receive Message service. You must specify a start and an end condition for the Receive box to operate. Messages received through the specified port (PORT) are stored in the data buffer (TBL). The first entry in the data buffer specifies the number of bytes received.

Transmit: Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0009 (simultaneous XMT/RCV on port 0), 000B (simultaneous XMT/RCV on port 1), CPU not in Freeport mode.

Receive: Error conditions that set ENO = 0: SM86.6 and SM186.6 (RCV parameter error), SM4.3 (run-time), 0006 (indirect address), 0009 (simultaneous XMT/RCV on port 0), 000B (simultaneous XMT/RCV on port 1), CPU not in Freeport mode.

Inputs/Outputs	Operands	Data Types
TABLE	VB, IB, QB, MB, SB, SMB, *VD, *AC, *LD	BYTE
PORT	Constant (0 for CPU 221, CPU 222, CPU 224; 0 or 1 for CPU 226)	BYTE

Understanding Freeport Mode

You can select the Freeport mode to control the serial communication port of the CPU by means of the user program. When you select Freeport mode, the LAD program controls the operation of the communication port through the use of the receive interrupts, the transmit interrupts, the transmit instruction (XMT), and the receive instruction (RCV). The communication protocol is entirely controlled by the ladder program while in Freeport mode. SMB30 (for port 0) and SMB130 (for port 1 if your CPU has two ports) are used to select the baud rate and parity.

The Freeport mode is disabled and normal communication is re-established (for example, programming device access) when the CPU is in the STOP mode.

In the simplest case, you can send a message to a printer or a display using only the Transmit (XMT) instruction. Other examples include a connection to a bar code reader, a weighing scale, and a welder. In each case, you must write your program to support the protocol that is used by the device with which the CPU communicates while in Freeport mode.

Freeport communication is possible only when the CPU is in the RUN mode. Enable the Freeport mode by setting a value of 01 in the protocol select field of SMB30 (Port 0) or SMB130 (Port 1). While in Freeport mode, communication with the programming device is not possible.

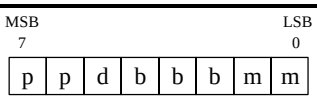
Note

Entering Freeport mode can be controlled using special memory bit SM0.7, which reflects the current position of the operating mode switch. When SM0.7 is equal to 0, the switch is in TERM position; when SM0.7 = 1, the operating mode switch is in RUN position. If you enable Freeport mode only when the switch is in RUN position, you can use the programming device to monitor or control the CPU operation by changing the switch to any other position.

Freeport Initialization

SMB30 and SMB130 configure the communication ports, 0 and 1, respectively, for Freeport operation and provide selection of baud rate, parity, and number of data bits. The Freeport control byte(s) description is shown in Table 9-25.

Table 9-25 Special Memory Bytes SMB30 and SMB130

Port 0	Port 1	Description
Format of SMB30	Format of SMB130	 Freeport mode control byte
SM30.6 and SM30.7	SM130.6 and SM130.7	pp: Parity select 00 = no parity 01 = even parity 10 = no parity 11 = odd parity
SM30.5	SM130.5	d: Data bits per character 0 = 8 bits per character 1 = 7 bits per character
SM30.2 to SM30.4	SM130.2 to SM130.4	bbb: Freeport Baud rate 000 = 38,400 baud 001 = 19,200 baud 010 = 9,600 baud 011 = 4,800 baud 100 = 2,400 baud 101 = 1,200 baud 110 = 600 baud 111 = 300 baud
SM30.0 and SM30.1	SM130.0 and SM130.1	mm: Protocol selection 00 = Point-to-Point Interface protocol (PPI/slave mode) 01 = Freeport protocol 10 = PPI/master mode 11 = Reserved (defaults to PPI/slave mode)
Note: One stop bit is generated for all configurations.		

Using the XMT Instruction to Transmit Data

The XMT instruction lets you send a buffer of one or more characters, up to a maximum of 255. An interrupt is generated (interrupt event 9 for port 0 and interrupt event 26 for port 1) after the last character of the buffer is sent, if an interrupt routine is attached to the transmit complete event. You can make transmissions without using interrupts (for example, sending a message to a printer) by monitoring SM4.5 or SM4.6 to signal when transmission is complete.

The XMT instruction can be used to generate a BREAK condition by setting the number of characters to zero and then executing the XMT instruction. This generates a BREAK condition on the line for 16-bit times at the current baud rate. Transmitting a BREAK is handled in the same manner as transmitting any other message, in that a XMT interrupt is generated when the BREAK is complete and SM4.5 or SM4.6 signal the current status of the XMT.

The format of the XMT buffer is shown in Figure 9-72.

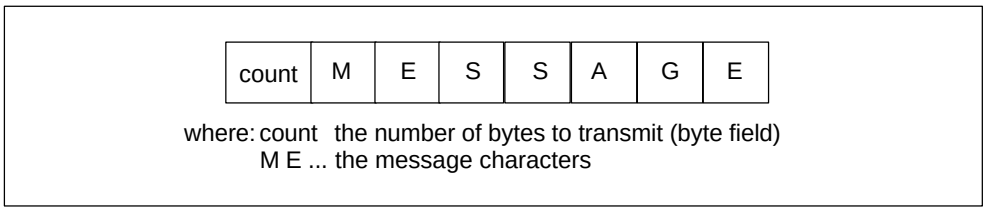


Figure 9-72 XMT Buffer Format

Using the RCV Instruction to Receive Data

The RCV instruction lets you receive a buffer of one or more characters, up to a maximum of 255. An interrupt is generated (interrupt event 23 for port 0 and interrupt event 24 for port 1) after the last character of the buffer is received, if an interrupt routine is attached to the receive message complete event.

You can receive messages without using interrupts by monitoring SMB86. SMB86 (or SMB186) will be non-zero when the RCV box is inactive or has been terminated. It will be zero when a receive is in progress.

The RCV instruction allows you to select the message start and message end conditions. See Table 9-26 (SM86 through SM94 for port 0, and SM186 through SM194 for port 1) for descriptions of the start and end message conditions. The format of the RCV buffer is shown in Figure 9-73.

Note

The Receive Message function is automatically terminated by an overrun or a parity error. You must define a start condition (x or z), and an end condition (y, t, or maximum character count) for the Receive Message function to operate.

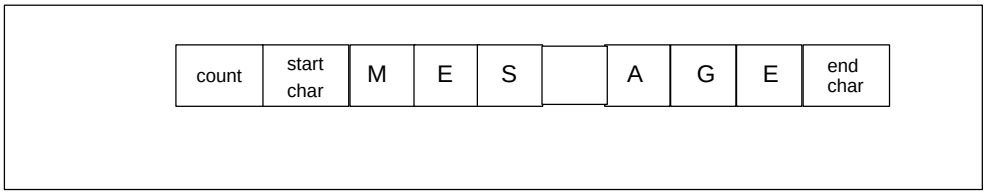


Figure 9-73 RCV Buffer Format

Table 9-26 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194

Port 0	Port 1	Description
SMB86	SMB186	MSB 7 … LSB 0 n r e 0 0 t c p — Receive message status byte n: 1 = Receive message terminated by user disable command r: 1 = Receive message terminated: error in input parameters or missing start or end condition e: 1 = End character received t: 1 = Receive message terminated: timer expired c: 1 = Receive message terminated: maximum character count achieved p 1 = Receive message terminated because of a parity error

Table 9-26 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194 (continued)

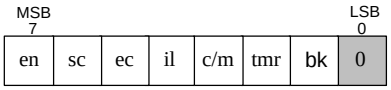
Port 0	Port 1	Description
SMB87	SMB187	 Receive message control byte en: 0 =Receive Message function is disabled. 1 =Receive Message function is enabled. The enable/disable receive message bit is checked each time the RCV instruction is executed. sc: 0 =Ignore SMB88 or SMB188. 1 =Use the value of SMB88 or SMB188 to detect start of message. ec: 0 =Ignore SMB89 or SMB189. 1 =Use the value of SMB89 or SMB189 to detect end of message. il: 0 =Ignore SMW90 or SMB190. 1 =Use the value of SMW90 to detect an idle line condition. c/m: 0 =Timer is an inter-character timer. 1 =Timer is a message timer. tmr: 0 =Ignore SMW92 or SMW192. 1 =Terminate receive if the time period in SMW92 or SMW192 is exceeded. bk: 0 =ignore break conditions, 1 =Use break condition as start of message detection. The bits of the message interrupt control byte are used to define the criteria by which the message is identified. Both start of message and end of message criteria are defined. To determine the start of a message, either of two sets of logically ANDed start of message criteria must be true and must occur in sequence (idle line followed by start character, or break followed by start character). To determine the end of a message, the enabled end of the message criteria is logically ORed. The equations for start and stop criteria are given below: Start of Message = il * sc + bk * sc End of Message = ec + tmr + maximum character count reached Programming the start of message criteria for: 1. Idle line detection: il=1, sc=0, bk=0, SMW90>0 2. Start character detection: il=0, sc=1, bk=0, SMW90 is a don't care 3. Break Detection: il=0, sc=0, bk=1, SMW90 is a don't care 4. Any response to a request: il=1, sc=0, bk=0, SMW90=0 (Message timer can be used to terminate receive if there is no response.) 5. Break and a start character: il=0, sc=1, bk=1, SMW90 is a don't care 6. Idle line and a start character: il=1, sc=1, bk=0, SMW90 >0 7. Idle line and start character (Illegal): il=1, sc=1, bk=0, SMW90=0 Note: Receive will automatically be terminated by an overrun or a parity error (if enabled).
SMB88	SMB188	Start of message character

Table 9-26 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194 (continued)

Port 0	Port 1	Description
SMB89	SMB189	End of message character
SMB90 SMB91	SMB190 SMB191	Idle line time period given in milliseconds. The first character received after idle line time has expired is the start of a new message. SM90 (or SM190) is the most significant byte and SM91 (or SM191) is the least significant byte.
SMB92 SMB93	SMB192 SMB193	Inter-character/message timer time-out value given in milliseconds. If the time period is exceeded, the receive message is terminated. SM92 (or SM192) is the most significant byte, and SM93 (or SM193) is the least significant byte.
SMB94	SMB194	Maximum number of characters to be received (1 to 255 bytes). Note: This range must be set to the expected maximum buffer size, even if the character count message termination is not used.

Using Character Interrupt Control to Receive Data

To allow complete flexibility in protocol support, you can also receive data using character interrupt control. Each character received generates an interrupt. The received character is placed in SMB2, and the parity status (if enabled) is placed in SM3.0 just prior to execution of the interrupt routine attached to the receive character event.

- SMB2 is the Freeport receive character buffer. Each character received while in Freeport mode is placed in this location for easy access from the user program.
- SMB3 is used for Freeport mode and contains a parity error bit that is turned on when a parity error is detected on a received character. All other bits of the byte are reserved. Use this bit either to discard the message or to generate a negative acknowledge to the message.

Note

SMB2 and SMB3 are shared between Port 0 and Port 1. When the reception of a character on Port 0 results in the execution of the interrupt routine attached to that event (interrupt event 8), SMB2 contains the character received on Port 0, and SMB3 contains the parity status of that character. When the reception of a character on Port 1 results in the execution of the interrupt routine attached to that event (interrupt event 25), SMB2 contains the character received on Port 1 and SMB3 contains the parity status of that character.

Receive and Transmit Example

This sample program (Figure 9-74) shows the use of Receive and Transmit. This program will receive a string of characters until a line feed character is received. The message is then transmitted back to the sender.

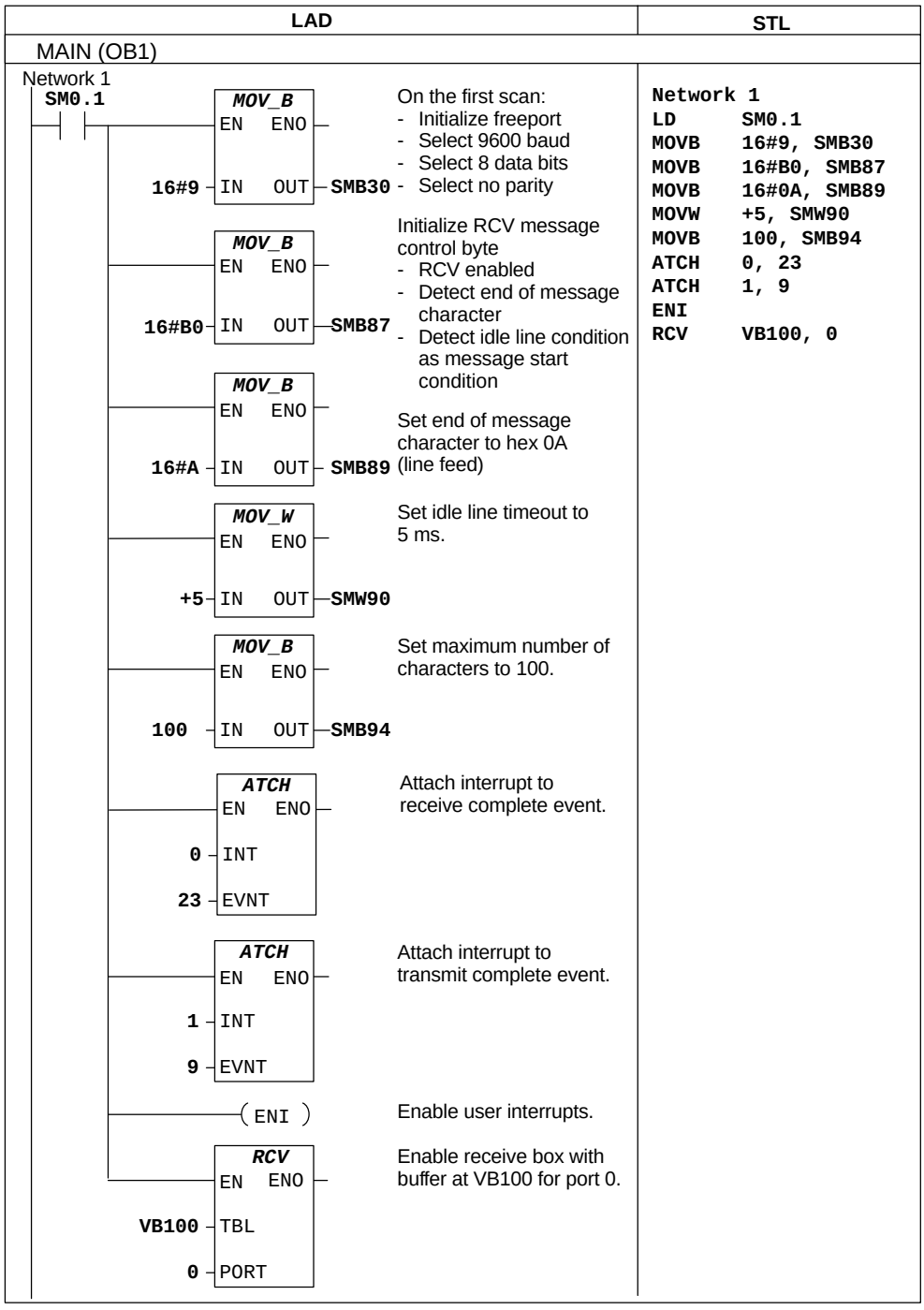


Figure 9-74 Example of Transmit Instruction for SIMATIC LAD, STL, and FBD

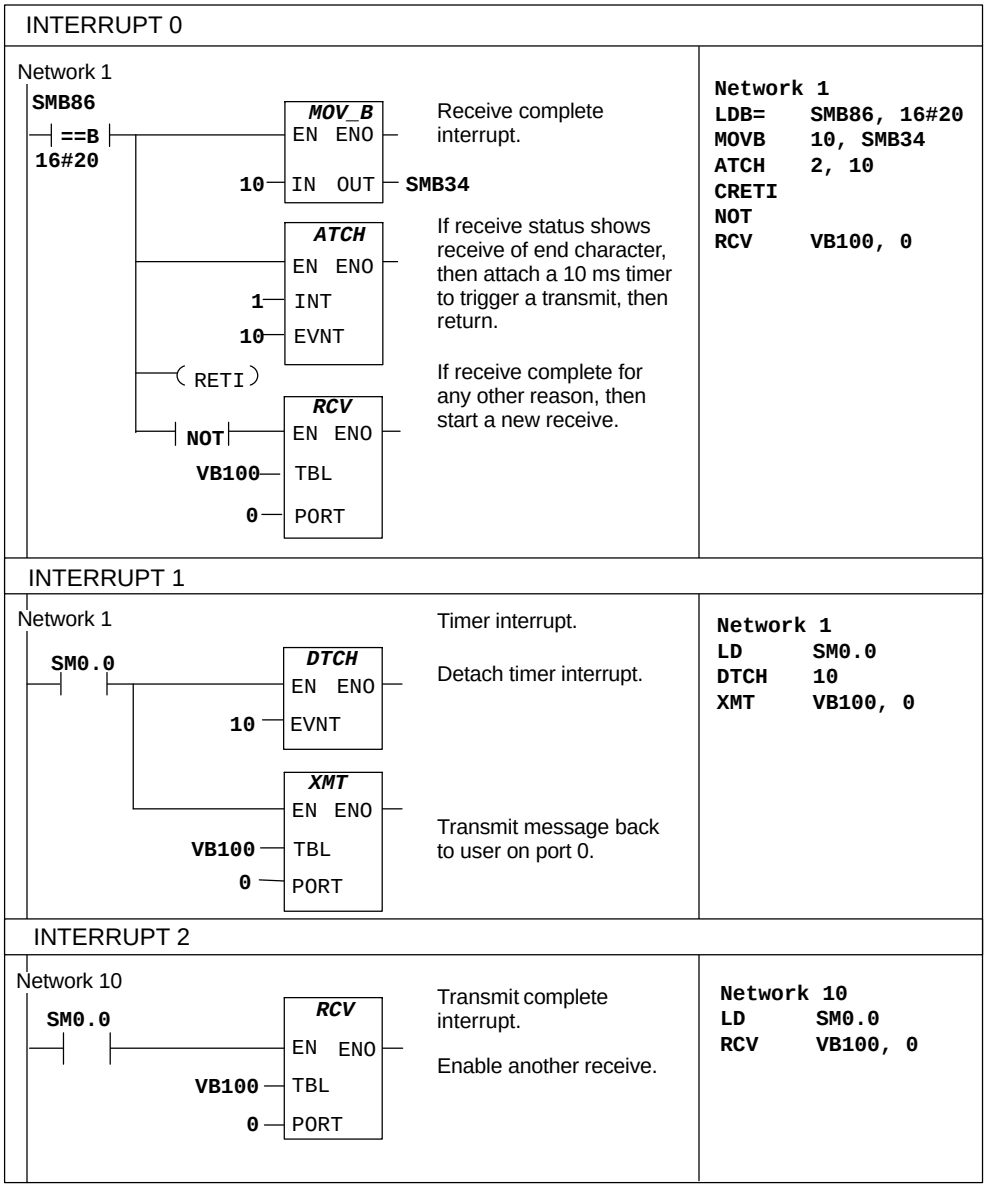


Figure 9-23 Example of Transmit Instruction for SIMATIC LAD, STL, and FBD (continued)

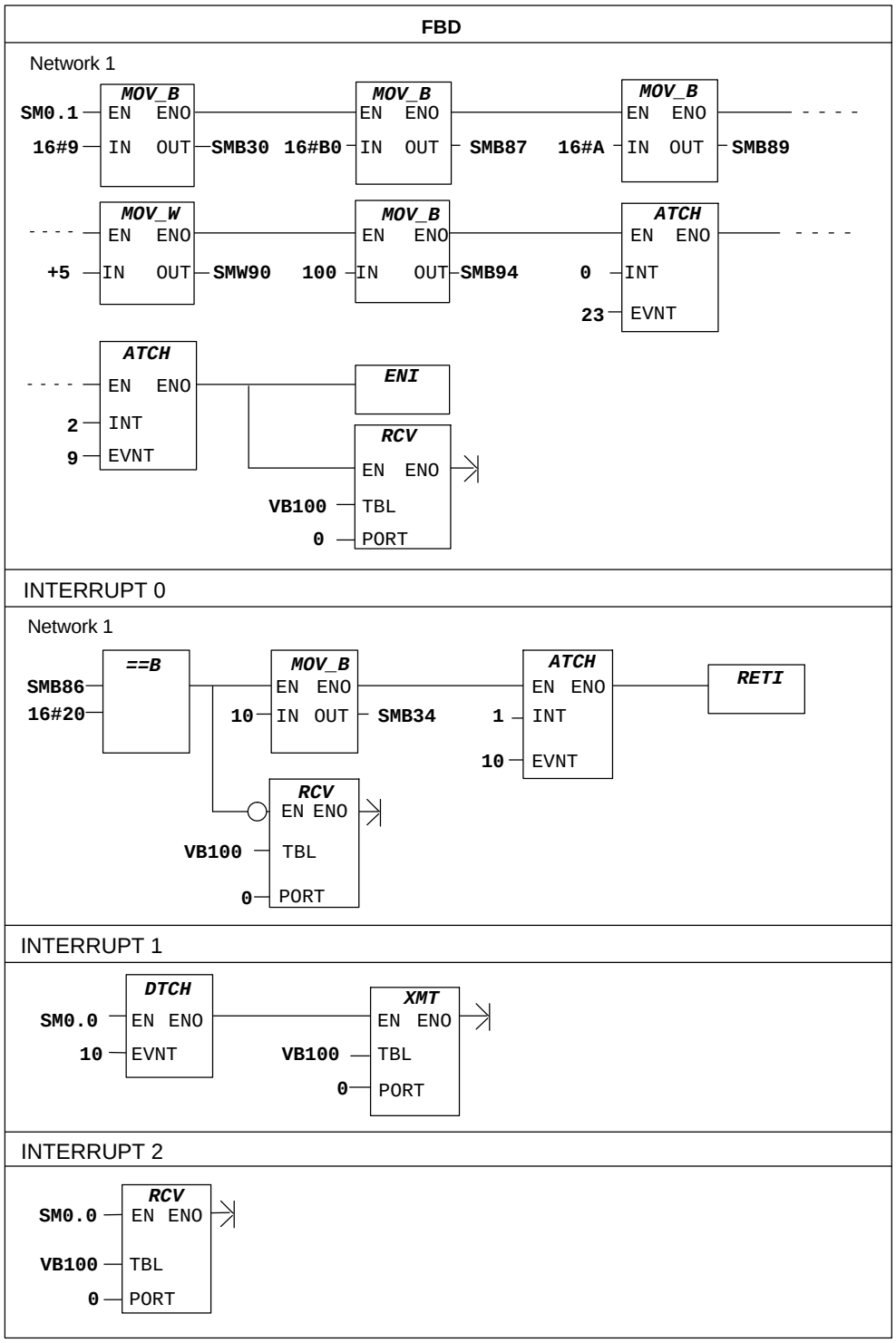
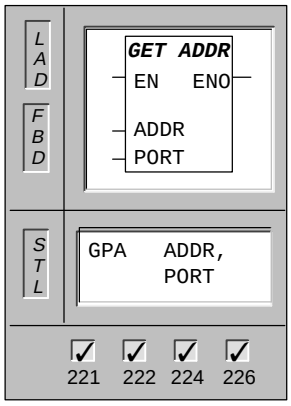


Figure 9-23 Example of Transmit Instruction for SIMATIC LAD, STL, and FBD (continued)

Get Port Address

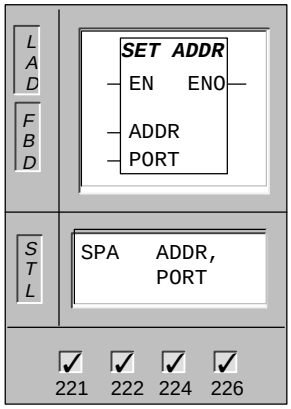


The **Get Port Address** instruction reads the station address of the CPU port specified in PORT and places the value in the address specified in ADDR.

Get Port Address: Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
ADDR	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD	BYTE
PORT	Constant	BYTE

Set Port Address



The **Set Port Address** instruction sets the port station address (PORT) to the value specified in ADDR.

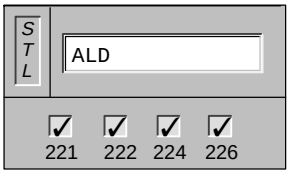
Set Port Address: Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

The new address is not saved permanently. After a power cycle, the affected port will return to the last address (the one that was downloaded with the system block).

Inputs/Outputs	Operands	Data Types
ADDR	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
PORT	Constant	BYTE

9.16 SIMATIC Logic Stack Instructions

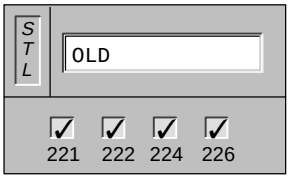
And Load



The **And Load** instruction combines the values in the first and second levels of the stack using a logical And operation. The result is loaded in the top of stack. After the ALD is executed, the stack depth is decreased by one.

Operands: none

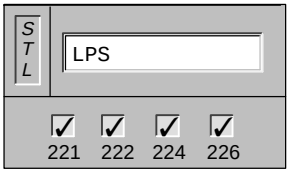
Or Load



The **Or Load** instruction combines the values in the first and second levels of the stack, using a logical Or operation. The result is loaded in the top of stack. After the OLD is executed, the stack depth is decreased by one.

Operands: none

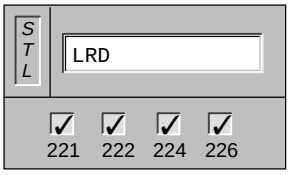
Logic Push



The **Logic Push** instruction duplicates the top value on the stack and pushes this value onto the stack. The bottom of the stack is pushed off and lost.

Operands: none

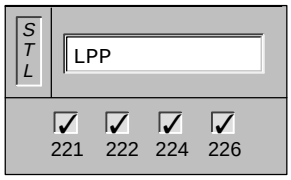
Logic Read



The **Logic Read** instruction copies the second stack value to the top of stack. The stack is not pushed or popped, but the old top of stack value is destroyed by the copy.

Operands: none

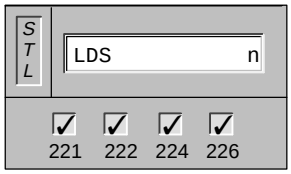
Logic Pop



The **Logic Pop** instruction pops one value off of the stack. The second stack value becomes the new top of stack value.

Operands: none

Load Stack



The **Load Stack** instruction duplicates the stack bit n on the stack and places this value on top of the stack. The bottom of the stack is pushed off and lost.

Operands: n (1 to 8)

Logic Stack Operations

Figure 9-75 illustrates the operation of the And Load and Or Load instructions.

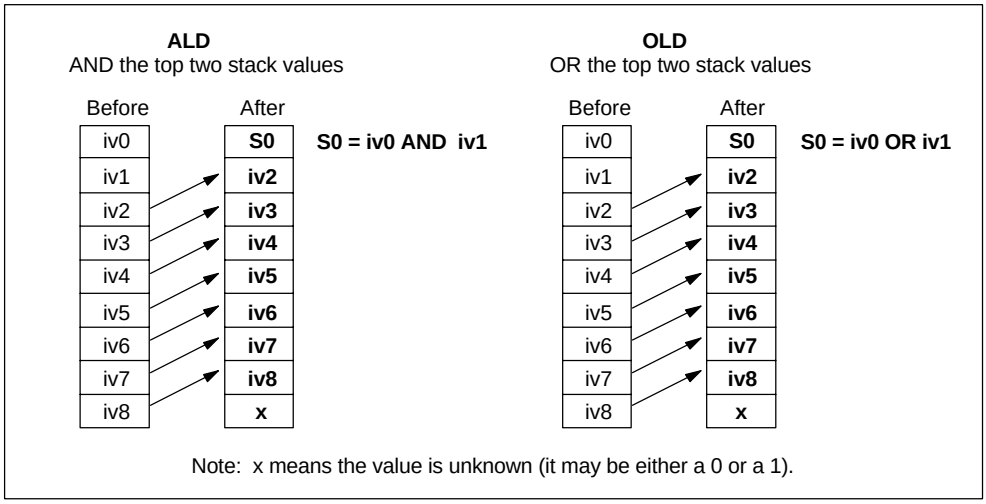


Figure 9-75 And Load and Or Load Instructions

Figure 9-76 illustrates the operation of the Logic Push, Logic Read, and Logic Pop instructions.

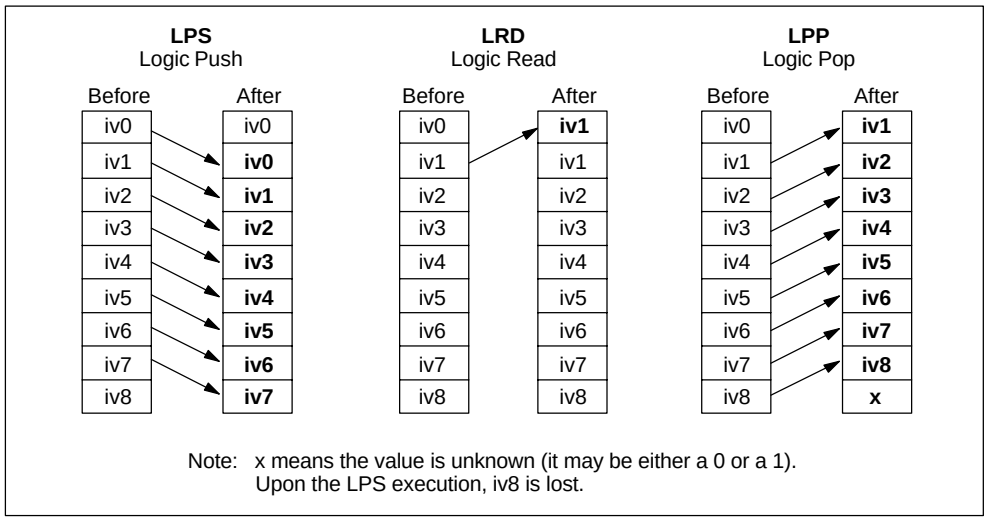


Figure 9-76 Logic Push, Logic Read, and Logic Pop Instructions

Figure 9-77 illustrates the operation of the Load Stack instructions.

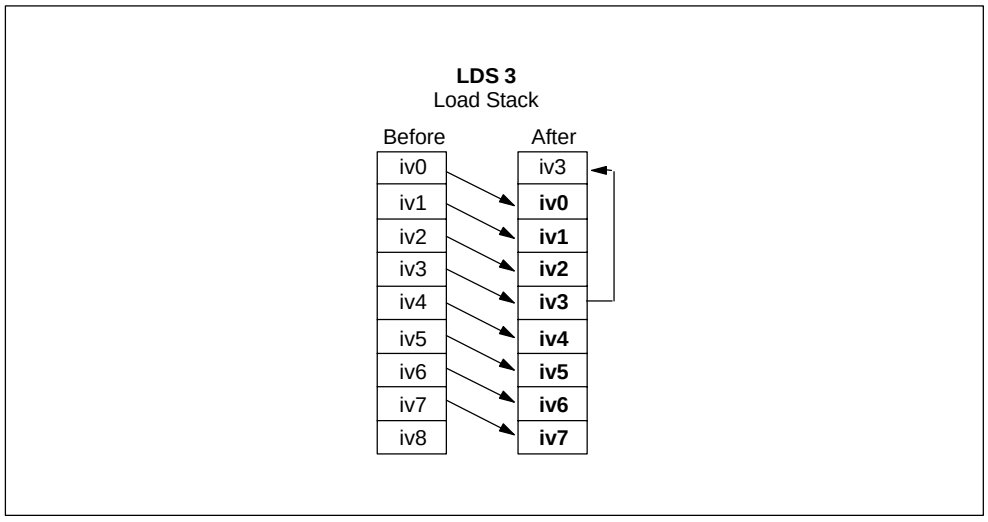


Figure 9-77 Load Stack Instructions

Logic Stack Example

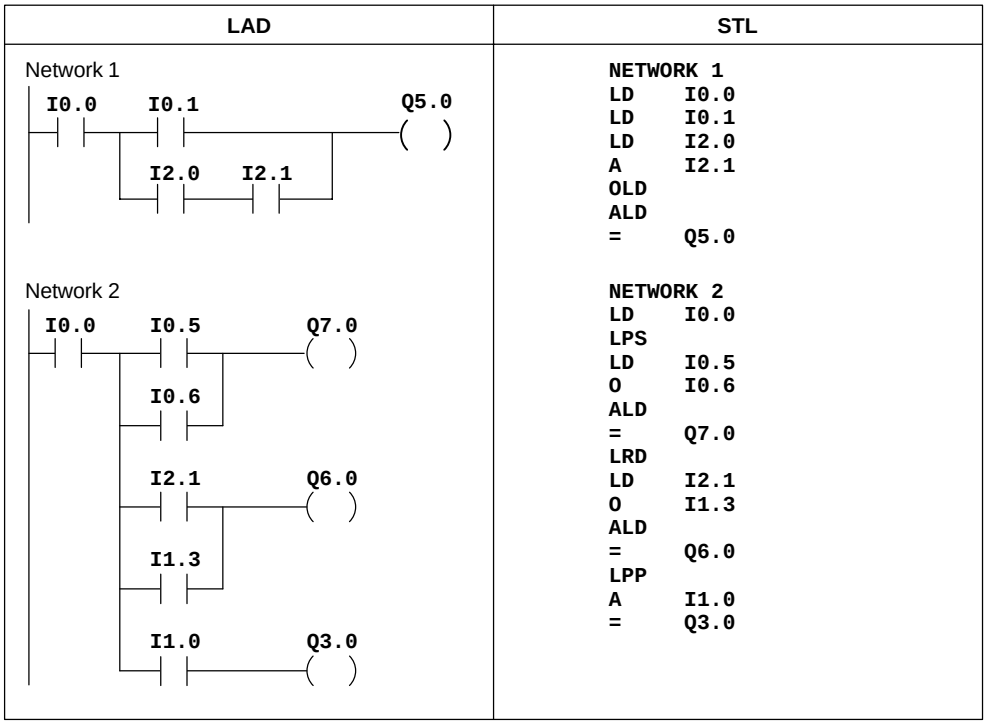


Figure 9-78 Example of Logic Stack Instructions for SIMATIC LAD and STL

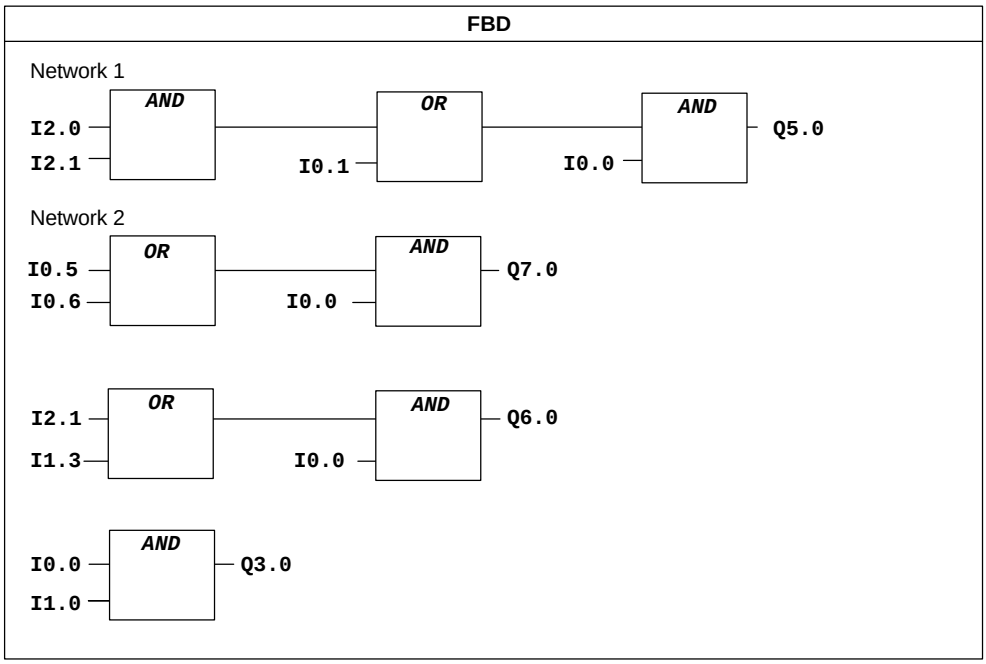


Figure 9-79 Example of Logic Stack Instructions for SIMATIC FBD

IEC 1131-3 Instructions

10

This chapter describes the standard IEC 1131-3 instructions. There are some SIMATIC instructions that can be used in an IEC program. These instructions are called non-standard IEC instructions, and are shown at the beginning of each section.

Chapter Overview

Section	Description	Page
10.1	IEC Bit Logic Instructions	10-2
10.2	IEC Compare Instructions	10-8
10.3	IEC Timer Instructions	10-11
10.4	IEC Counter Instructions	10-15
10.5	IEC Math Instructions	10-18
10.6	IEC Numerical Functions Instructions	10-21
10.7	IEC Move Instructions	10-23
10.8	IEC Logic Instructions	10-25
10.9	IEC Shift and Rotate Instructions	10-27
10.10	IEC Conversion Instructions	10-30

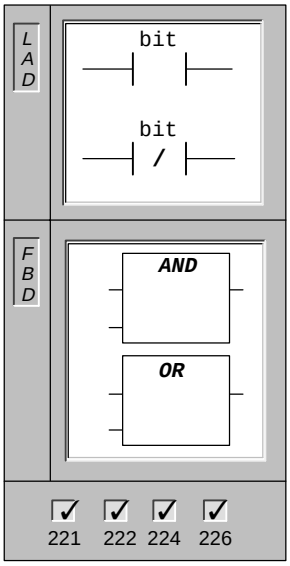
10.1 IEC Bit Logic Instructions

Table 10-1 gives page references for the non-standard IEC Bit Logic instructions.

Table 10-1 Non-Standard IEC Bit Logic Instructions

Description	Page
Standard Contacts	9-2
Immediate Contacts	9-3
Not Contact	9-4
Positive and Negative Transition	9-4
Output Contact	9-6
Output Immediate	9-6
Set and Reset (N Bits)	9-7

Standard Contacts (non-standard IEC 1131-3)



The **Normally Open** contact is closed (on) when the bit is equal to 1.

The **Normally Closed** contact is closed (on) when the bit is equal to 0.

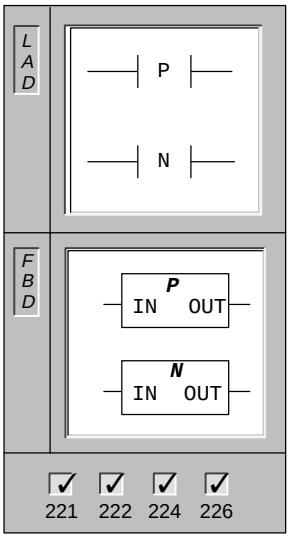
These instructions obtain the referenced value from memory or from the process image register if the memory type is I or Q.

In LAD, normally open and normally closed instructions are represented by contacts.

In FBD, normally open instructions are represented by AND/OR boxes. These instructions can be used to manipulate Boolean signals in the same manner as ladder contacts. Normally closed instructions are also represented by boxes. A normally closed instruction is constructed by placing the negation symbol on the stem of the input signal. Inputs to both the AND and OR boxes can be expanded to a maximum of seven inputs.

Inputs/Outputs	Operands	Data Types
bit (LAD, STL)	I, Q, M, SM, T, C, V, S, L	BOOL
Input (LAD)	Power Flow	BOOL
Inputs (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
Output (LAD, FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Positive, Negative Transition



The **Positive Transition** contact allows power to flow for one scan for each off-to-on transition.

The **Negative Transition** contact allows power to flow for one scan, for each on-to-off transition.

In LAD, the Positive and Negative Transition instructions are represented by contacts.

In FBD, the instructions are represented by the P and N boxes.

Inputs/Outputs	Operands	Data Types
IN (LAD)	Power Flow	BOOL
IN (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
OUT (LAD)	Power Flow	BOOL
OUT (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Contact Examples

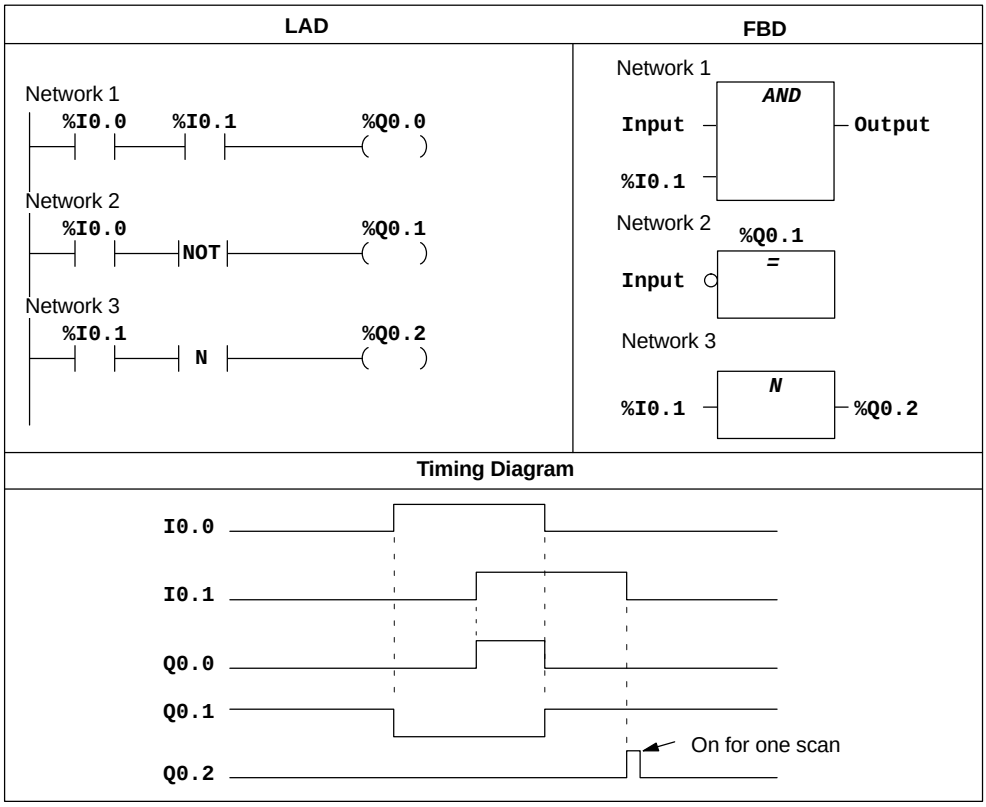
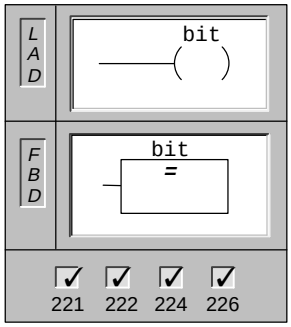


Figure 10-1 Examples of Boolean Contact Instructions for LAD and FBD

Output



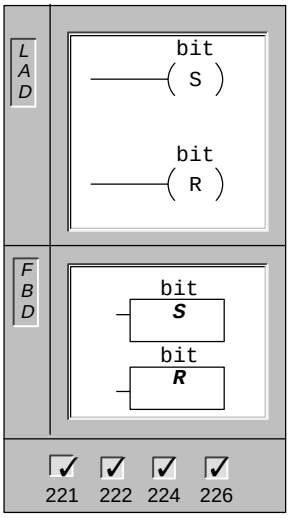
When the **Output** is executed, the output is turned on.

In LAD, the Output instruction is represented by a coil.

In FBD, the instruction is represented by the = box.

Inputs/Outputs	Operands	Data Types
bit (LAD/FBD)	I, Q, M, SM, T, C, V, S, L	BOOL
Input (LAD)	Power flow	BOOL
Input (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Set, Reset



When **Set** and **Reset** are executed, the value specified by the bit or OUT parameter is set or reset.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

Inputs/Outputs	Operands	Data Types
bit (LAD, FBD)	I, Q, M, SM, T, C, V, S, L	BOOL
Input (LAD)	Power Flow	BOOL
Input (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Output Examples

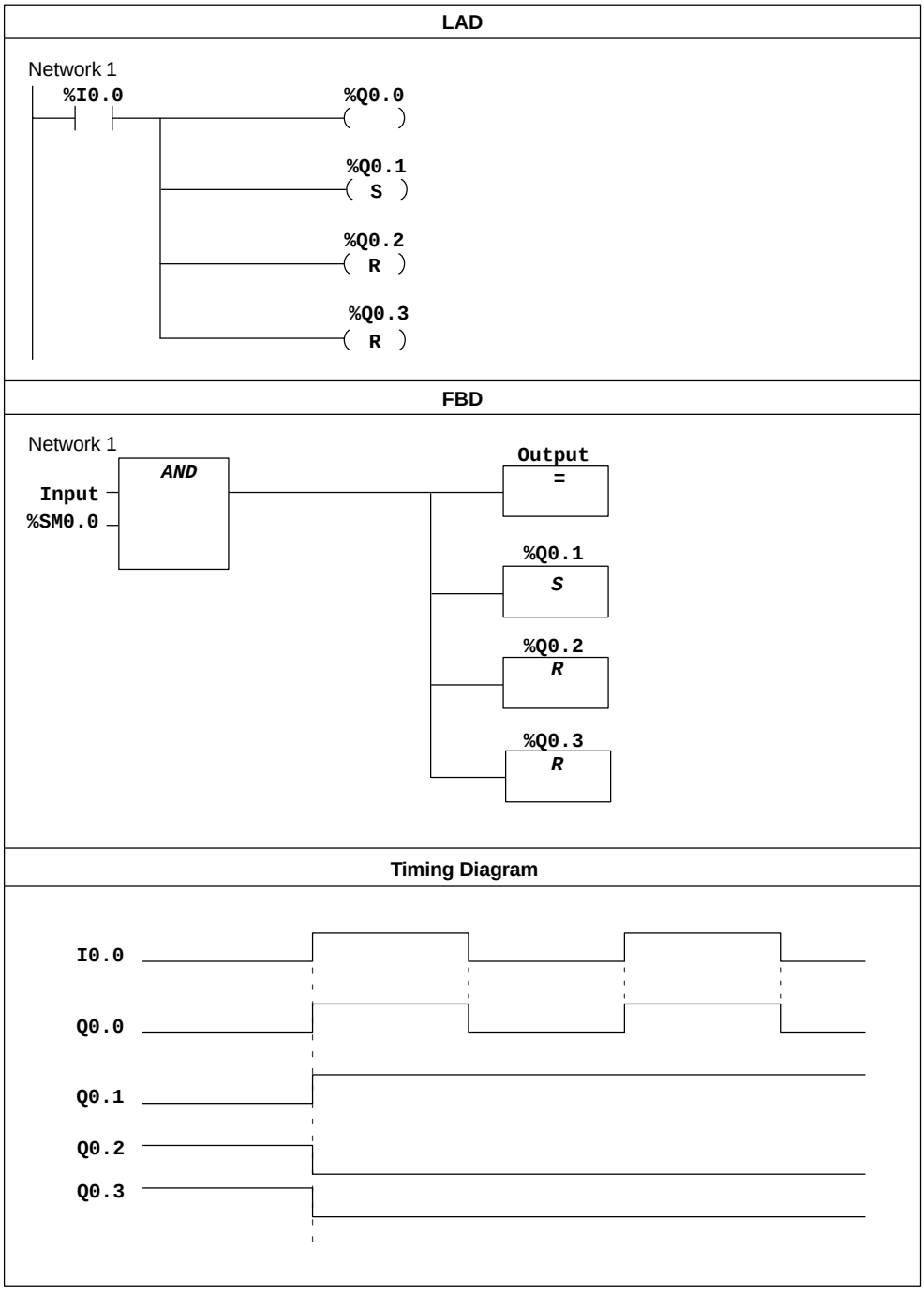
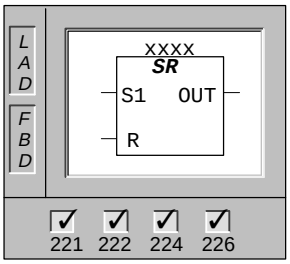


Figure 10-2 Examples of Output Instructions for LAD and FBD

Set Dominant Bistable

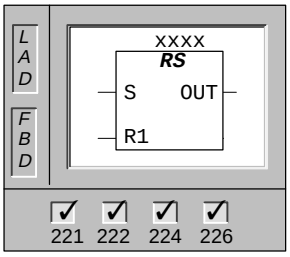


The **Set Dominant Bistable** is a latch where the set dominates. If the set (S1) and reset (R) signals are both true, the output (OUT) will be true.

The xxxx function block parameter specifies the Boolean parameter that is set or reset. The optional output reflects the signal state of the xxxx parameter.

Inputs/Outputs	Operands	Data Types
S1, R (LAD)	Power Flow	BOOL
S1, R (FBD)	I, Q, M, SM, T, C,V, S, Power Flow	BOOL
OUT (LAD)	Power Flow	BOOL
OUT (FBD)	I, Q, M, SM,T, C, V, S, L, Power Flow	BOOL
xxxx	I, Q, M, V, S	BOOL

Reset Dominant Bistable



The **Reset Dominant Bistable** is a latch where the reset dominates. If the set (S) and reset (R1) signals are both true, the output (OUT) will be false.

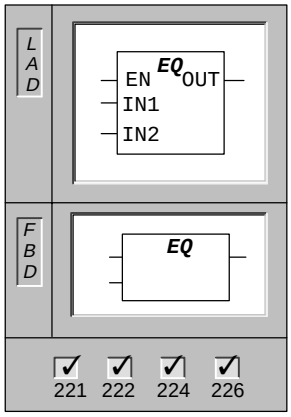
The xxxx function block parameter specifies the Boolean parameter that is set or reset. The optional output reflects the signal state of the xxxx parameter.

Inputs/Outputs	Operands	Data Types
S, R1 (LAD)	Power Flow	BOOL
S, R1 (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
OUT (LAD)	Power Flow	BOOL
OUT (FBD)	I, Q, M, SM, T, C,V, S, L, Power Flow	BOOL
xxxx	I, Q, M, V, S	BOOL

10.2 IEC Compare Instructions

There are no non-standard IEC Compare instructions.

Compare Equal

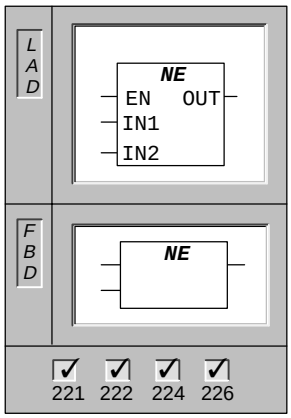


The **Compare Equal** function compares IN1 and IN2 with the Boolean result placed in OUT. The input and output data types can vary but must be of the same type.

Byte comparisons are unsigned. Integer, double integer, and real comparisons are signed. Time operations are signed integers.

Inputs/Outputs	Operands	Data Types
Inputs (LAD & FBD)	IB, QB, MB, SB, SMB, VB, LB, IW, QW, MW, SW, SMW, VW, LW, T, C, AIW, ID, QD, MD, SD, SMD, VD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, INT, DINT REAL
OUT (LAD only)	Power Flow	BOOL
OUT (FBD only)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Compare Not Equal

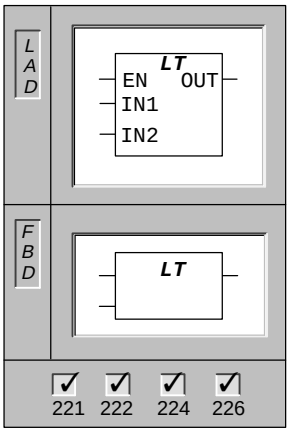


The **Compare Not Equal** function compares IN1 and IN2 with the Boolean result placed in OUT. The input and output data types can vary, but must be of the same type.

Byte comparisons are unsigned. Integer, double integer, and real comparisons are signed. Time operations are signed integers.

Inputs/Outputs	Operands	Data Types
Inputs (LAD & FBD)	IB, QB, MB, SB, SMB, VB, LB, IW, QW, MW, SW, SMW, VW, LW, T, C, AIW, ID, QD, MD, SD, SMD, VD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, INT, DINT, REAL
OUT (LAD only)	Power Flow	BOOL
OUT(FBD only)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL

Compare Less Than

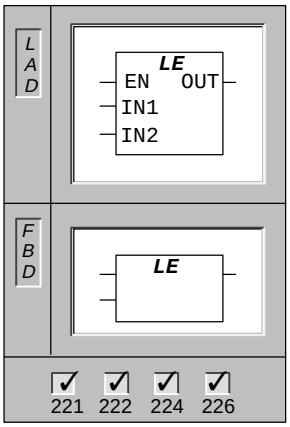


The **Compare Less Than** function compares IN1 less than IN2 with the Boolean result placed in OUT. The input and output data types can vary, but they must be of the same type.

Byte comparisons are unsigned. Integer, double integer, and real comparisons are signed. Time operations are signed integers.

Inputs/Outputs	Operands	Data Types
Inputs (LAD & FBD)	IB, QB, MB, SB, SMB, VB, LB, IW, QW, MW, SW, SMW, VW, LW, T, C, AIW, ID, QD, MD, SD, SMD, VD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, INT, DINT, REAL
OUT (LAD only)	Power Flow	BOOL
OUT (FBD only)	I, Q, M, SM, V, S, L, Power Flow	BOOL

Compare Less Than or Equal

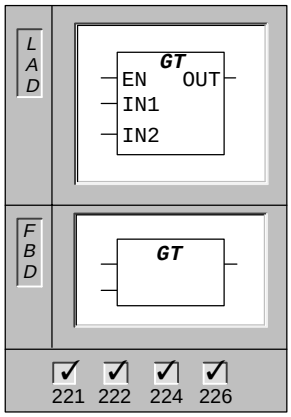


The **Compare Less Than or Equal** function compares IN1 less than or equal to IN2 with the Boolean result placed in OUT. The input and output data types can vary, but they must be of the same type.

Byte comparisons are unsigned. Integer, double integer, and real comparisons are signed. Time operations are signed integers.

Inputs/Outputs	Operands	Data Types
Inputs (LAD & FBD)	IB, QB, MB, SB, SMB, VB, LB, IW, QW, MW, SW, SMW, VW, LW, T, C, AIW, ID, QD, MD, SD, SMD, VD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, INT, DINT, REAL
OUT (LAD only)	Power Flow	BOOL
OUT (FBD only)	I, Q, M, SM, V, S, L, Power Flow	BOOL

Compare Greater Than

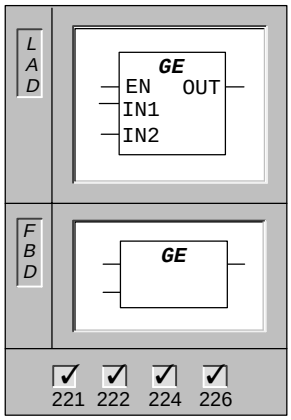


The **Compare Greater Than** function compares IN1 greater than IN2 with the Boolean result placed in OUT. The input and output data types can vary, but they must be of the same type.

Byte comparisons are unsigned. Integer, double integer, and real comparisons are signed. Time operations are signed integers.

Inputs/Outputs	Operands	Data Types
Inputs (LAD & FBD)	IB, QB, MB, SB, SMB, VB, LB, IW, QW, MW, SW, SMW, VW, LW, T, C, AIW, ID, QD, MD, SD, SMD, VD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, INT, DINT, REAL
OUT (LAD only)	Power Flow	BOOL
OUT (FBD only)	I, Q, M, SM, V, S, L, Power Flow	BOOL

Compare Greater Than or Equal



The **Compare Greater Than or Equal** function compares IN1 greater than or equal to IN2 with the Boolean result placed in OUT. The input and output data types can vary, but they must be of the same type.

Byte comparisons are unsigned. Integer, double integer, and real comparisons are signed.

Inputs/Outputs	Operands	Data Types
Inputs (LAD & FBD)	IB, QB, MB, SB, SMB, VB, LB, IW, QW, MW, SW, SMW, VW, LW, T, C, AIW, ID, QD, MD, SD, SMD, VD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, INT, DINT, REAL
OUT (LAD only)	Power Flow	BOOL
OUT (FBD only)	I, Q, M, SM, V, S, L, Power Flow	BOOL

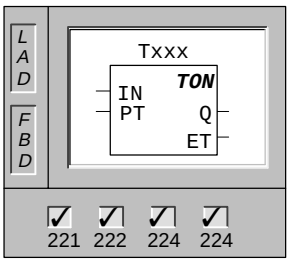
10.3 IEC Timer Instructions

Table 10-2 gives page references for the non-standard IEC Timer instructions.

Table 10-2 Non-Standard IEC Timer Instructions

Description	Page
On-Delay Retentive Timer Instruction	9-15
On-Delay Retentive Timer Function Block	9-15

On-Delay Timer Function Block

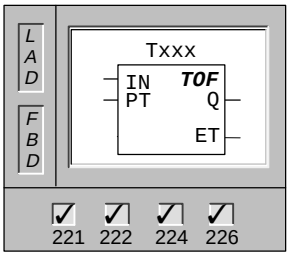


The **On-Delay Timer** function block times up to the preset value when the enabling input (IN) becomes true. When the elapsed time (ET) is greater than or equal to the Preset Time (PT), the timer output bit (Q) turns on.

The output bit resets when the enabling input goes false. When the preset time (PT) is reached, timing stops and the timer is disabled.

Inputs/Outputs	Operands	Data Types
IN (LAD)	Power Flow	BOOL
IN (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
PT (LAD & FBD)	VW, IW, QW, MW, SMW, LW, SW, AIW, AC, Constant, *VD, *AC, *LD	INT
Q (LAD & FBD)	I, Q, M, SM, V, S, L	BOOL
ET (LAD & FBD)	VW, IW, QW, MW, SMW, LW, SW, AQW, AC, *VD, *AC, *LD	INT
Txxx	Constant, refer to Table 10-3, page 10-12.	TON

Off-Delay Timer



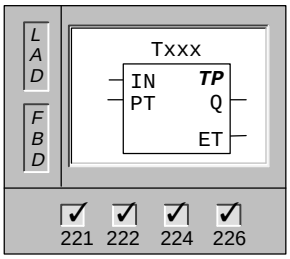
The **Off-Delay Timer** function block is used to delay the setting of an output false for a fixed period of time after the input goes false. It times up to the preset value when the enabling input (IN) goes false. When the elapsed time (ET) is greater than or equal to the preset time (PT), the timer output bit (Q) turns on.

Once the preset is reached, the timer output bit turns false and the elapsed time is maintained until the enabling input (IN) makes the transition to true. If the enabling input (IN) makes the transition to false for a period of time shorter than the preset time (PT), the output bit remains true.

For information about timer numbers and resolutions, refer to Table 10-3.

Inputs/Outputs	Operands	Data Types
IN (LAD)	Power Flow	BOOL
IN (FBD)	I, Q, M, SM,T, C, V, S, L, Power Flow	BOOL
PT (LAD & FBD)	VW, IW, QW, MW, SMW, LW, SW, AIW, AC, Constant, *VD, *AC, *LD	INT
Q (LAD & FBD)	I, Q, M, SM, V, S, L	BOOL
ET (LAD & FBD)	VW, IW, QW, MW, SMW, LW, SW, AQW, AC,*VD, *AC, *LD	INT
Txxx	Constant, refer to Table 10-3, page 10-12.	TOF

Pulse Timer



The **Pulse Timer** function block is used to generate pulses for a specific duration. As the enabling input (IN) becomes true, the output bit (Q) turns on. The output bit remains true for the pulse specified within the preset time (PT). Once the elapsed time (ET) reaches preset (PT), the output bit (Q) becomes false. The elapsed time (ET) is maintained until the enabling input becomes false. Once the output bit (Q) becomes true, it remains true until the pulse time (PT) has elapsed.

For information about timer numbers and resolutions, refer to Table 10-3.

Inputs/Outputs	Operands	Data Types
IN LAD)	Power Flow	BOOL
IN (FBD)	I, Q, M, SM, T, C, V, S, L, Power Flow	BOOL
PT (LAD & FBD)	VW, IW, QW, MW, SMW, LW, SW, AIW, AC, Constant, *VD, *AC, *LD	INT
Q (LAD & FBD)	I, Q, M, SM, S, V, L	BOOL
ET (LAD & FBD)	VW, IW, QW, MW, SW, SMW, LW, AQW, AC, *VD, *AC, *LD	INT
Txxx	Constant, refer to Table 10-3	TP

Understanding the IEC 1131-3 Timer Instructions

TON, TOF and TP timers are available in three resolutions. The resolution is determined by the timer number and is shown in Table 10-3. Each count of the current value is a multiple of the time base. For example, a count of 50 on a 10-ms timer represents 500 ms.

Table 10-3 Timer Numbers and Resolutions

Timer Type	Resolution in milliseconds (ms)	Maximum Value in seconds (s)	Timer Number
TON, TOF, TP	1 ms	32.767 s	T32, T96
	10 ms	327.67 s	T33 to T36, T97 to T100
	100 ms	3276.7 s	T37 to T63, T101 to T255

Note

You cannot share the same timer numbers for TOF, TP, and TON. For example, you cannot have both a TON T32 and a TOF T32.

On-Delay Timer Example

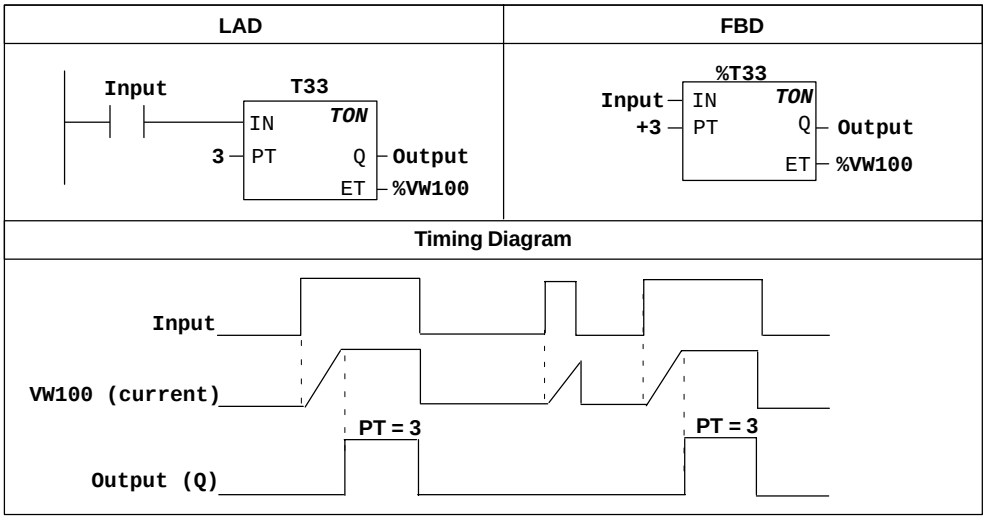


Figure 10-3 Example of On-Delay Timer for LAD and FBD

Off-Delay Timer Example

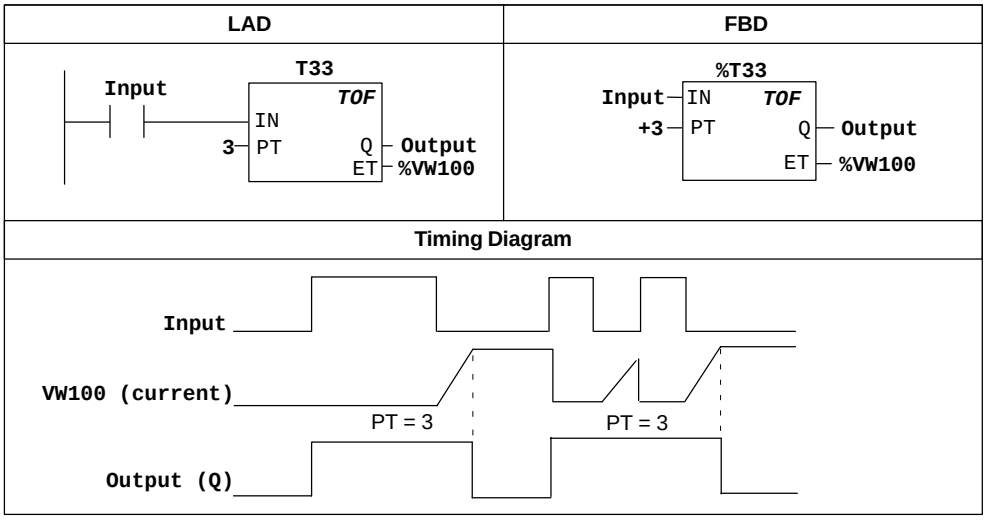


Figure 10-4 Example of Off-Delay Timer for LAD and FBD

Pulse Timer Example

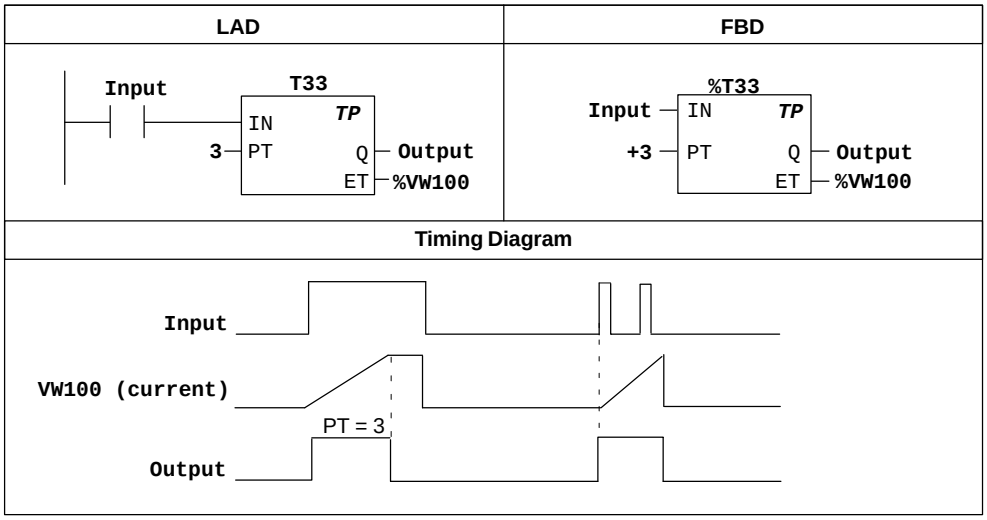


Figure 10-5 Example of Pulse Timer Instruction for LAD and FBD

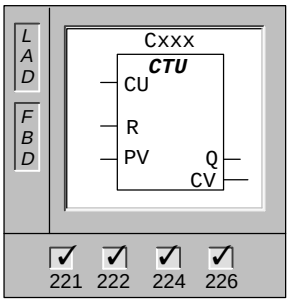
10.4 IEC Counter Instructions

Table 10-4 gives page references for the non-standard IEC Counter instructions.

Table 10-4 Non-Standard IEC Counter Instructions

Description	Page
High-Speed Counter Instruction	9-27
High-Speed Counter Definition Instruction	9-27
Pulse Output Instruction	9-49

Up Counter



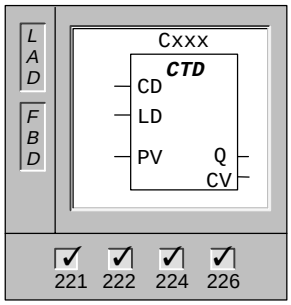
The **Up Counter** function block counts up from the current value to the preset value on the rising edges of the Count Up (CU) input. When the current value (CV) is greater than or equal to the preset value (PV), the counter output bit (Q) turns on. The counter resets when the reset input (R) is enabled. The Up Counter stops counting when it reaches the preset value (PV).

Note

Since there is one current value for each counter, do not assign the same number to more than one counter. (Up Counters, Down Counters, and Up/Down Counters access the same current value.)

Inputs/Outputs	Operands	Data Types
CU, R (LAD only)	Power Flow	BOOL
CU, R (FBD only)	I, Q, M, SM, V, S, L, T, C, Power Flow	BOOL
PV (LAD & FBD)	VW, IW, QW, MW, SMW, LW, SW, AIW, AC, Constant, *VD, *AC, *LD	INT
Q (LAD & FBD)	I, Q, M, SM, V, S, L	BOOL
CV (LAD & FBD)	VW, IW, QW, MW, SW, LW, AC, *VD, *AC, *LD	INT
Cxxx (LAD & FBD)	Constant	CTU

Down Counter



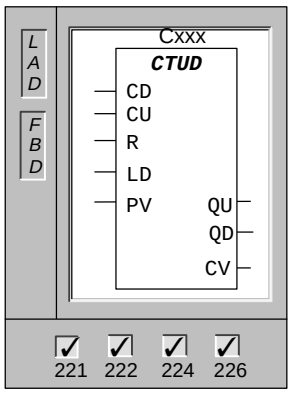
The **Down Counter** function block counts down from the preset value (PV) on the rising edges of the Count Down (CD) input. When the current value (CV) is equal to zero, the counter output bit (Q) turns on. The counter resets and loads the current value (CV) with the preset value (PV) when the load input (LD) is enabled. The Down Counter stops counting when it reaches zero.

Note

Since there is one current value for each counter, do not assign the same number to more than one counter. (Up Counters, Down Counters, and Up/Down Counters access the same current value.)

Inputs/Outputs	Operands	Data Types
CD, LD (LAD)	Power Flow	BOOL
CD, LD (FBD)	I, Q, M, SM, V, S, L, T, C, Power Flow	BOOL
PV (LAD, FBD)	VW, IW, QW, MW, SMW, LW, SW, AIW, AC, Constant, *VD, *AC, *LD	INT
Q (LAD & FBD)	I, Q, M, SM, V, S, L	BOOL
CV (LAD & FBD)	VW, IW, QW, MW, SW, LW, AC, *VD, *AC, *LD	INT
Cxxx	Constant	CTD

Up/Down Counter



The **Up/Down Counter** function block counts up or down from the preset value on the rising edges of the Count Up (CU) or Count Down (CD) input. When the current value (CV) is equal to preset, the output (QU) turns on. When the current value (CV) is equal to zero, the output (QD) turns on. The counter loads the current value (CV) with the preset value (PV) when the load (LD) input is enabled. Similarly, the counter resets and loads the current value (CV) with zero when the reset (R) is enabled. The counter stops counting when it reaches preset or zero.

Note

Since there is one current value for each counter, do not assign the same number to more than one counter. (Up Counters, Down Counters, and Up/Down Counters access the same current value.)

Inputs/Outputs	Operands	Data Types
CU, CD, R, LD (LAD only)	Power Flow	BOOL
CU, CD, R, LD (FBD only)	I, Q, M, SM, V, S, L, T, C, Power Flow	BOOL
PV (LAD & FBD)	VW, IW, QW, MW, SMW, LW, SW, AIW, AC, Constant, *VD, *AC, *LD	INT
QU (LAD & FBD)	I, Q, M, SM, V, S, L	BOOL
QD (LAD & FBD)	I, Q, M, SM, V, S, L	BOOL
CV (LAD & FBD)	VW, IW, QW, MW, SW, LW, AC, *VD, *AC, *LD	INT
Cxxx	Constant	CTUD

Counter Example

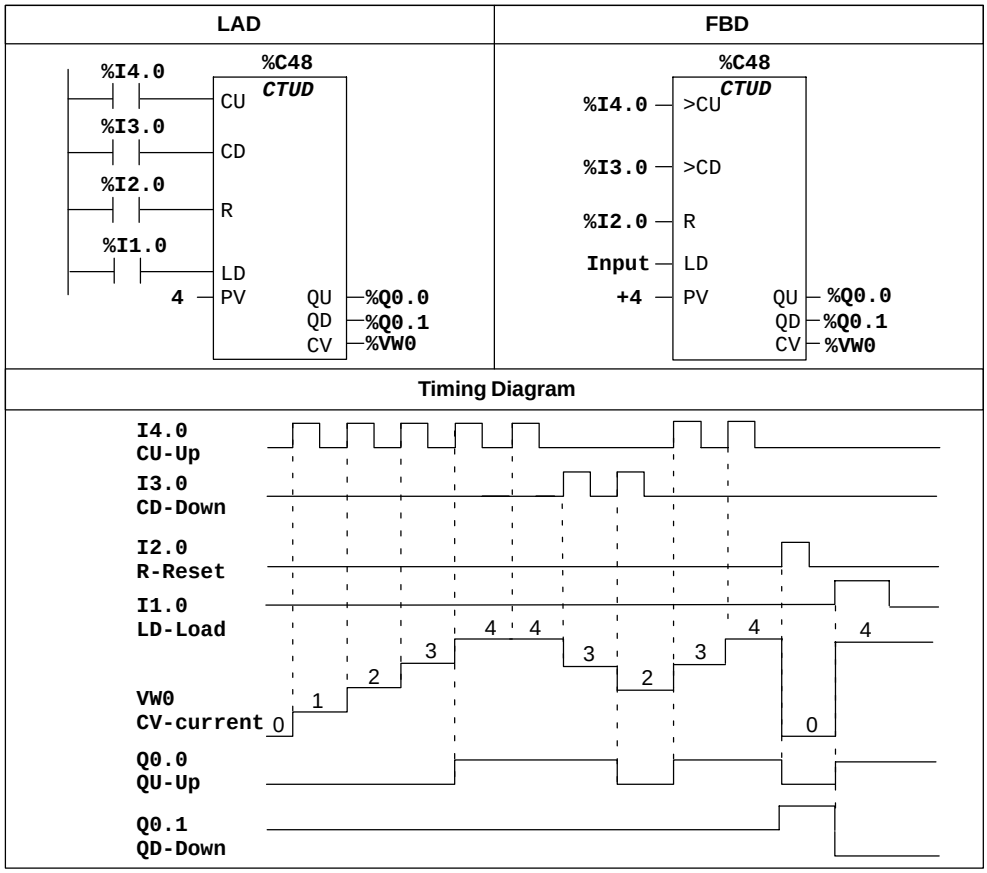
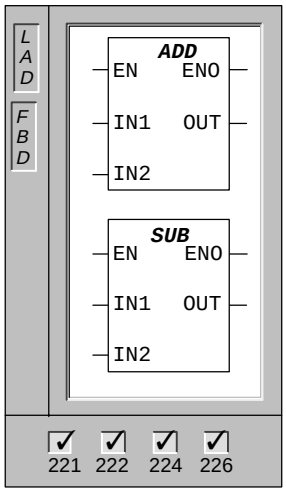


Figure 10-6 Example of Counter Instruction for LAD and FBD

10.5 IEC Math Instructions

Add, Subtract



The **Add** and **Subtract** functions add or subtract IN1 and IN2 and place the result in OUT. The input and output data types can vary, but must be of the same type. For example, two 16-bit variables can be added or subtracted, but the result must be placed in a 16-bit variable; the result of adding or subtracting two 32-bit variables must be placed in a 32-bit variable.

In LAD: IN1 + IN2 = OUT
IN1 - IN2 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

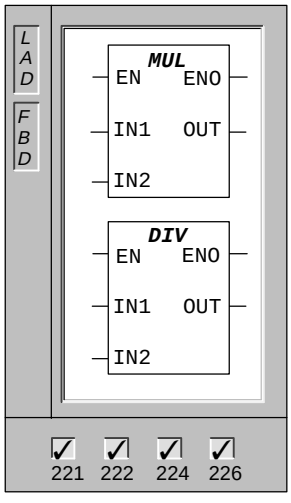
These functions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, VD, ID, QD, MD, SMD, SD, LD, HC, AC, Constant, *VD, *AC, *LD	INT, DINT, REAL
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	INT, DINT, REAL

Note

Real or floating-point numbers are represented in the format described in the ANSI/IEEE 754-1985 standard (single-precision). Refer to the standard for more information.

Multiply, Divide



The **Multiply** function multiplies IN1 and IN2 and places the result in the variable specified by OUT.

The **Divide** function divides IN1 by IN2 and places the result in the variable specified by OUT.

The input and output data types can vary, but must be of the same type. For example, the product of multiplying two 16-bit variables must be placed in a 16-bit variable, the product of multiplying two 32-bit variables must be placed in a 32-bit variable.

In LAD: IN1 * IN2 = OUT
IN1 / IN2 = OUT

Error conditions that set ENO = 0: SM1.1 (overflow), SM1.3 (divide-by-zero), SM4.3 (run-time), 0006 (indirect address)

These functions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative); SM1.3 (divide-by-zero)

If SM1.1 (overflow bit) is set, then the other math status bits are cleared and the output operand is not altered. For integer operations, if SM1.3 is set during a divide operation, the other math status bits are left unchanged and the original input operands are not altered. Otherwise, all supported math status bits contain valid status upon completion of the math operation.

Inputs/Outputs	Operands	Data Types
IN1, IN2	VW, IW, QW, MW, SW, SMW, LW, AIW, T, C, VD, ID, QD, MD, SMD, SD, LD, HC, AC, Constant, *VD, *AC, *LD	INT, DINT, REAL
OUT	VW, IW, QW, MW, SW, SMW, T, C, LW, VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	INT, DINT, REAL

Note

Real or floating-point numbers are represented in the format described in the ANSI/IEEE 754-1985 standard (single-precision). Refer to the standard for more information.

Math Examples

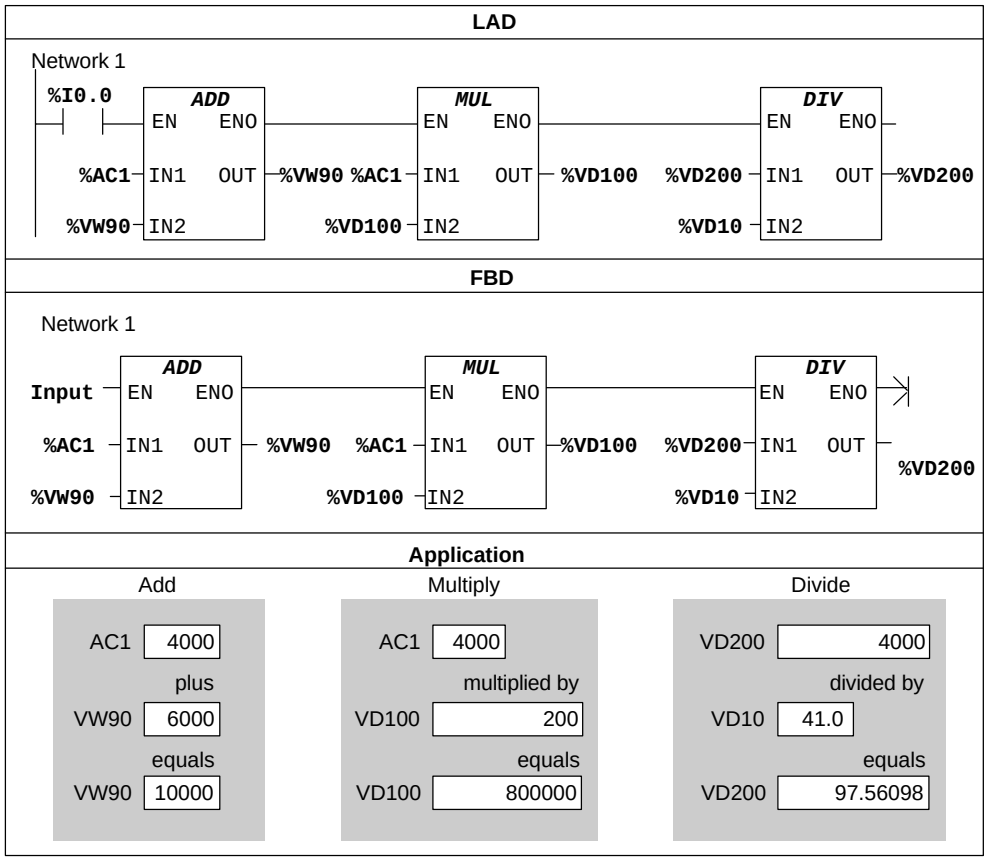
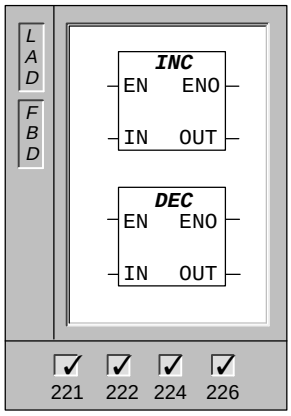


Figure 10-7 Examples of Math Functions for LAD and FBD

Increment, Decrement



The **Increment** and **Decrement** functions add or subtract 1 to or from IN and place the result into OUT.

Increment and decrement byte operations are unsigned.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

These functions affect the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow), SM1.2 (negative)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, VD, ID, QD, MD, SD, SMD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, INT, DINT
OUT	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, T, C, LW, VD, ID, QD, MD, SMD, SD, LD, AC,*VD, *AC, *LD	BYTE, INT, DINT

Increment, Decrement Example

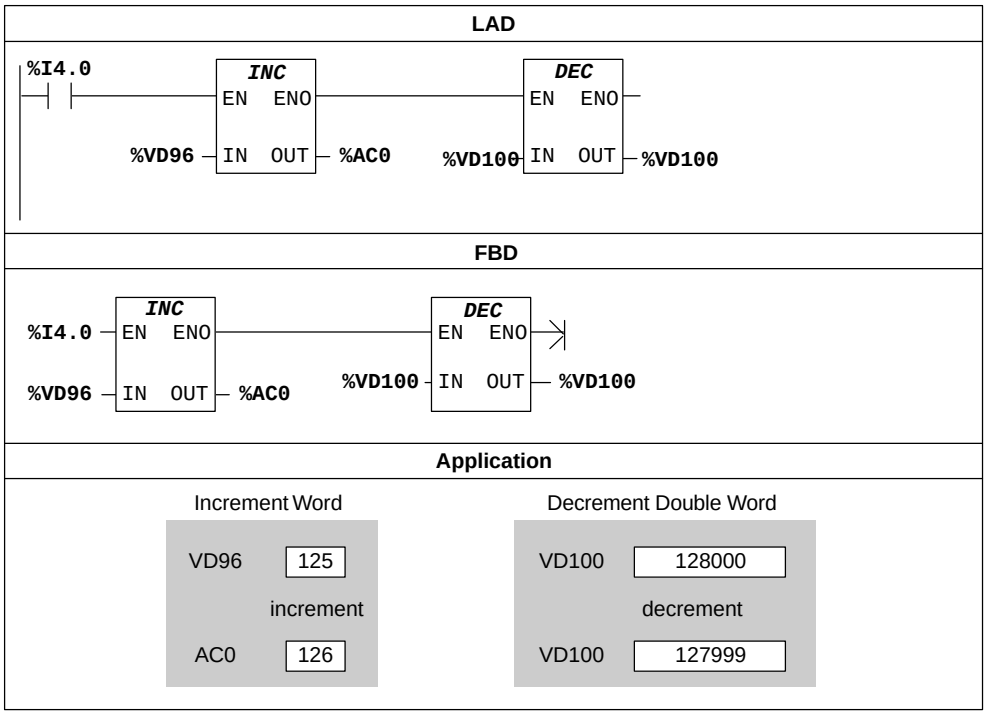


Figure 10-8 Example of Increment/Decrement Functions for LAD and FBD

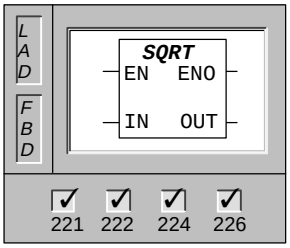
10.6 IEC Numerical Functions Instructions

Table 10-5 gives page references for the non-standard IEC Numerical Functions instructions.

Table 10-5 Non-Standard IEC Numerical Functions Instructions

Description	Page
PID Instruction	9-87

Square Root



The **Square Root** instruction takes the square root of a value provided by IN and places the result in OUT.

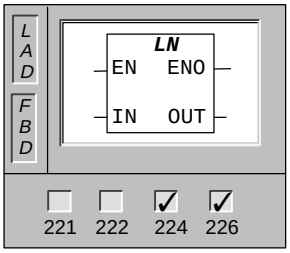
Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

This function affects the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative)

If SM1.1 (overflow bit) is set, then the other math status bits are cleared and the output operand is not altered.

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

Natural Logarithm



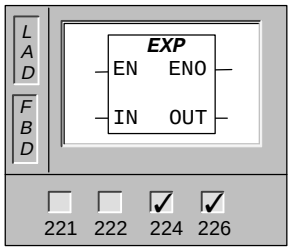
The **Natural Logarithm** instruction performs the natural logarithm of the value in IN and places the result in OUT.

Error conditions that set ENO = 0: SM1.1 (overflow), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative).

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

Natural Exponential



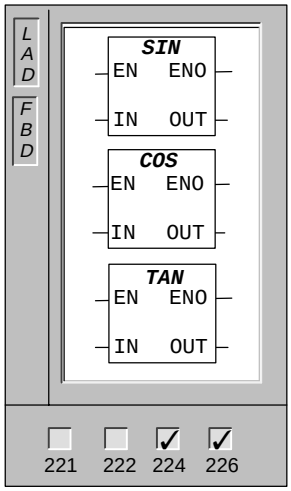
The **Natural Exponential** instruction performs the exponential operation of e raised to the power of the value in IN and places the result in OUT.

Error conditions that set ENO = 0: SM1.1 (overflow), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative).

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

Sine, Cosine, Tangent



The **Sine** instruction calculates the sine of the angle value IN and places the result in OUT. The input angle is in radians. If the angle is in degrees, it must be multiplied by π /180 to convert it to radians.

The **Cosine** instruction calculates the cosine of the angle value IN and places the result in OUT. The input angle is in radians. If the angle is in degrees, it must be multiplied by π /180 to convert it to radians.

The **Tangent** instruction calculates the tangent of the angle value IN and places the result in OUT. The input angle is in radians. If the angle is in degrees, it must be multiplied by π /180 to convert it to radians.

Error conditions that set ENO = 0: SM1.1 (overflow), 0006 (indirect address)

These instructions affect the following Special Memory bits:
SM1.0 (zero); SM1.1 (overflow); SM1.2 (negative).

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SMD, SD, LD, AC, Constant, *VD, *AC, *LD	REAL
OUT	VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	REAL

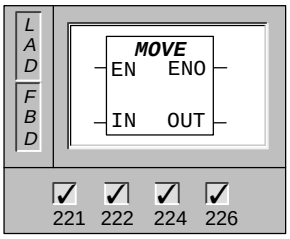
10.7 IEC Move Instructions

Table 10-6 gives page references for the non-standard IEC Move instructions.

Table 10-6 Non-Standard IEC Move Instructions

Description	Page
Swap Instructions	9-105
Move Byte Immediate Read	9-106
Move Byte Immediate Write	9-106

Move



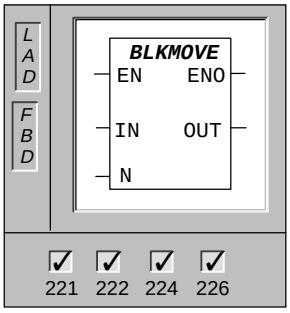
The **Move and Assign Values** function moves the value IN to the address OUT. This instruction performs an assignment operation. The input parameter is not modified during execution.

The input and output data types can vary, but must be of the same type.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SM, SMW, LW, T, C, AIW, VD, ID, QD, MD, SMD, SD, LD, HC, &VB, &IB, &QB, &MB, &SB, AC, Constant, *VD, *AC, *LD	BYTE, WORD, INT, DWORD, DINT, REAL
OUT	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, LW, T, C, AQW, VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	BYTE, WORD, INT, DWORD, DINT, REAL

Block Move



The **Block Move** function moves the N number of words specified by the address IN to the address OUT. N has a range of 1 to 255.

The input and output data types can vary, but must be of the same type.

Block Move is a non-standard IEC-only function.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address), 0091 (operand out of range)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SM, SMW, LW, T, C, AIW, VD, ID, QD, MD, SMD, SD, LD, *VD, *AC, *LD	BYTE, WORD, DWORD, INT, DINT
OUT	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, LW, T, C, AQW, VD, ID, QD, MD, SMD, SD, LD, AC, *VD, *AC, *LD	BYTE, WORD, DWORD, INT, DINT
N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE

Move Examples

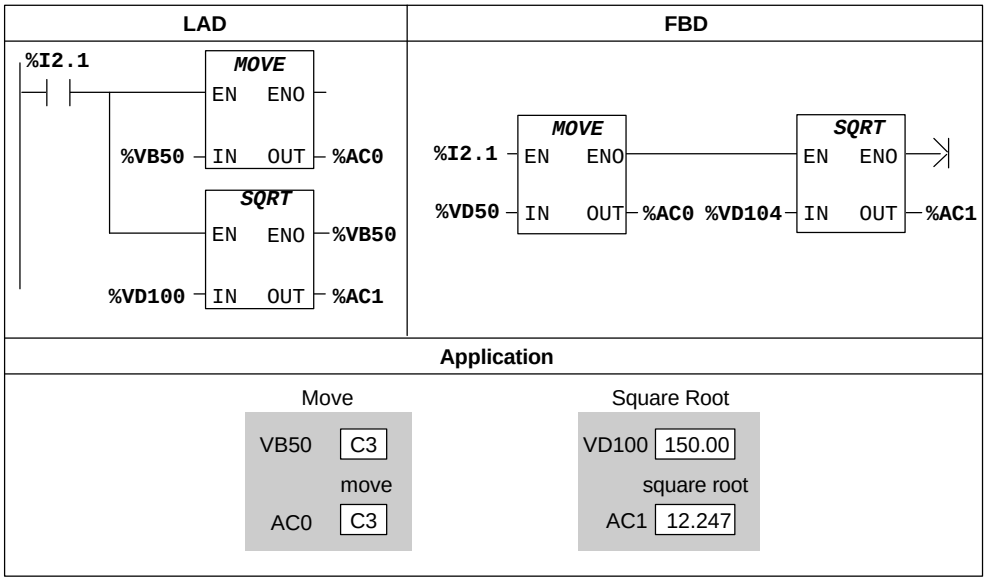
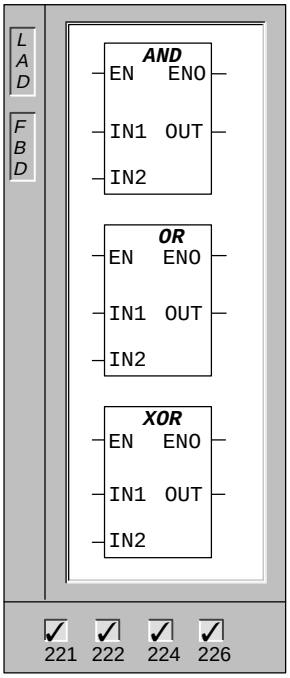


Figure 10-9 Example of Move Function for LAD and FBD

10.8 IEC Logic Instructions

There are no non-standard IEC Logic instructions.

And, Or, Exclusive Or



The **And** function ANDs the corresponding bits of IN1 and IN2 and loads the result into OUT.

The **Or** function ORs the corresponding bits of IN1 with IN2 and loads the result into OUT.

The **Exclusive Or** (XOR) function XORs the corresponding bits of IN1 with IN2 and loads the result into OUT.

The input and output data types can vary, but must be of the same type.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

These instructions affect the following Special Memory bits: SM1.0 (zero)

Inputs/Outputs	Operands	Data Types
IN1, IN2	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, AIW, T, C, LW, VD, ID, QD, MD, SD, SMD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, WORD DWORD
OUT	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, T, C, LW, VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	BYTE, WORD DWORD

And, Or, and Exclusive Or Example

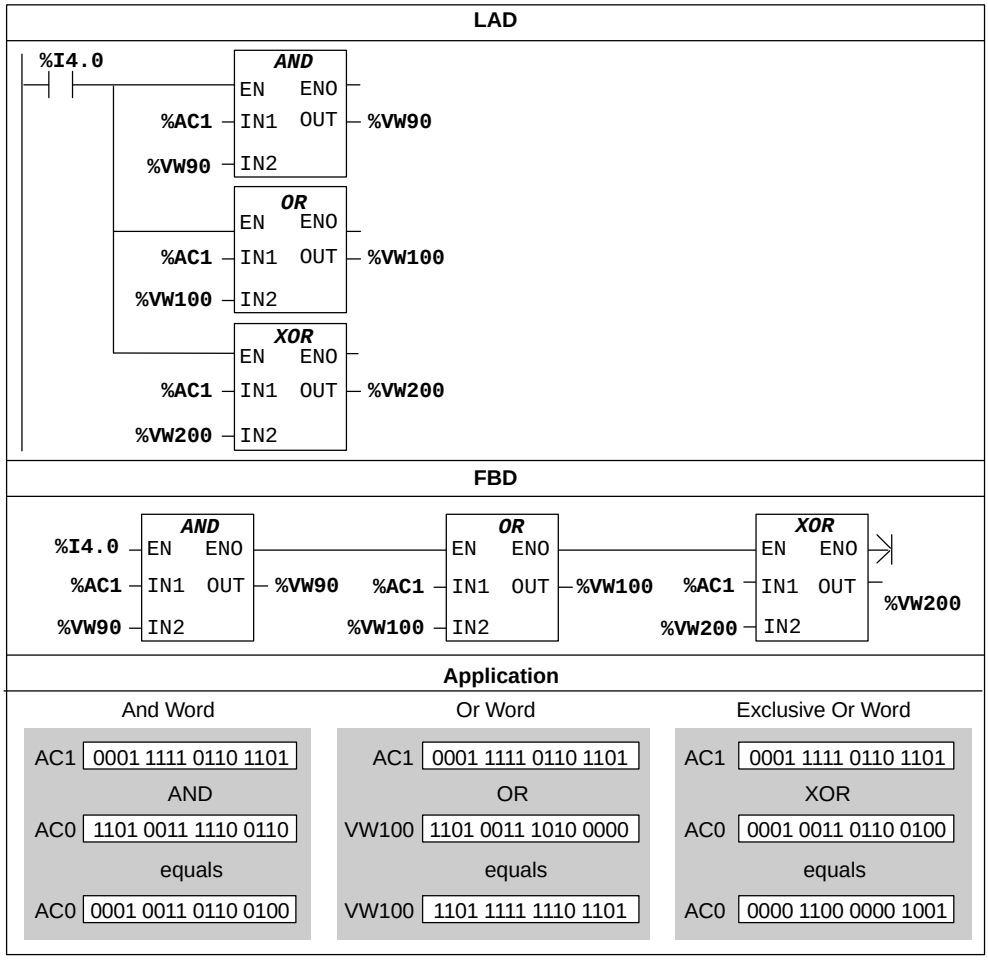
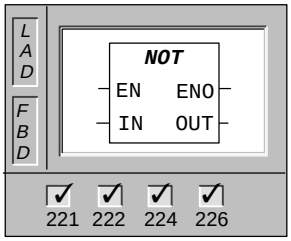


Figure 10-10 Example of And, Or, Exclusive Or Functions

Not



The **Not** function inverts the corresponding bits of IN and loads the result into OUT.

The input and output data types can vary, but must be of the same type.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

This instruction affects the following Special Memory bits: SM1.0 (zero)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, AIW, T, C, LW, VD, ID, QD, MD, SD, SMD, LD, HC, AC, Constant, *VD, *AC, *LD	BYTE, WORD DWORD
OUT	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, T, C, LW, VD, ID, QD, MD, SD, SMD, LD, AC,*VD, *AC, *LD	BYTE, WORD DWORD

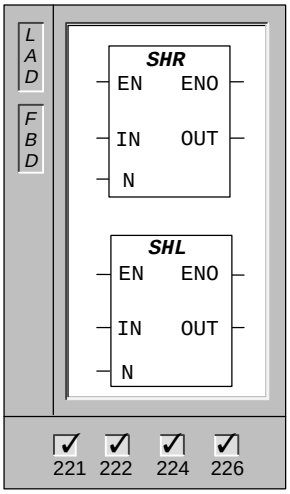
10.9 IEC Shift and Rotate Instructions

Table 10-7 gives page references for the non-standard IEC Shift instructions.

Table 10-7 Non-Standard IEC Instructions

Description	Page
Shift Register Bit Instruction	9-127

Logical Shift Right, Logical Shift Left



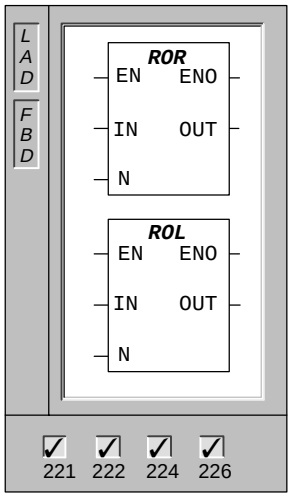
The **Shift Right** function shifts the value specified by the variable IN to the right for the number of locations specified by N. The result is placed into the variable specified by OUT. Each bit is filled with a zero when it is shifted right. Note that the sign bit is shifted when you are using signed data types.

The **Shift Left** function shifts the value specified by the variable IN to the left for the number of locations specified by N. The result is placed into the variable specified by OUT. Each bit is filled with a zero when it is shifted left. Note that the sign bit is shifted when you are using signed data types.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, VD, ID, QD, MD, SD, SMD, LD, HC, AC, Constant, *VD, *LD, *AC	BYTE, WORD DWORD
N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *LD, *AC	BYTE
OUT	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, LW,T, C, VD, ID, QD, MD, SD, SMD, LD, AC *VD, *LD, *AC	BYTE, WORD DWORD

Logical Rotate Right, Logical Rotate Left



The **Rotate Right** and **Rotate Left** functions rotate the input value (IN) right or left by the shift count (N), and load the result in the output (OUT).

The rotate is circular. In ROR, bit zero is rotated to the most significant bit. In ROL, the most significant bit is rotated to bit zero. Note that the sign bit is shifted when you are using signed data types.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, VD, ID, QD, MD, SD, SMD, LD, HC, AC, Constant, *VD, *LD, *AC	BYTE, WORD DWORD
N	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *LD, *AC	BYTE
OUT	VB, IB, QB, MB, SB, SMB, LB, VW, IW, QW, MW, SW, SMW, LW, T, C, VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *LD, *AC	BYTE, WORD DWORD

Shift and Rotate Examples

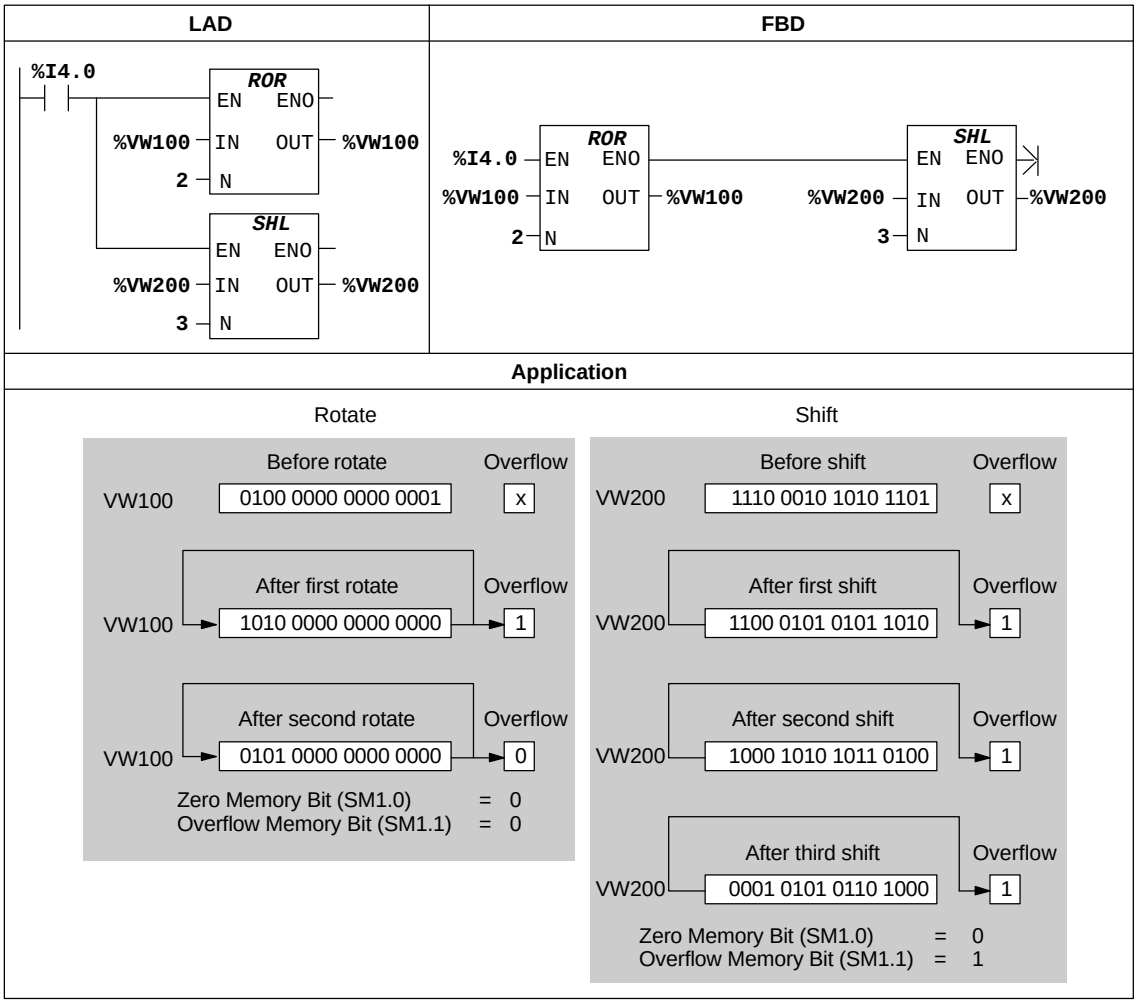


Figure 10-11 Example of Shift and Rotate Functions for LAD and FBD

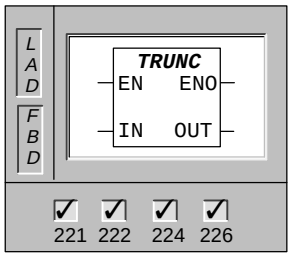
10.10 IEC Conversion Instructions

Table 10-8 gives page references for the non-standard IEC Conversion instructions.

Table 10-8 Non-Standard IEC Conversion Instructions

Description	Page
Decode Instruction	9-135
Encode Instruction	9-135
Segment Instruction	9-137
ASCII to Hex, Hex to ASCII Instruction	9-139
Integer to ASCII Instruction	9-140
Double Integer to ASCII Instruction	9-142
Real to ASCII Instruction	9-143

Truncate



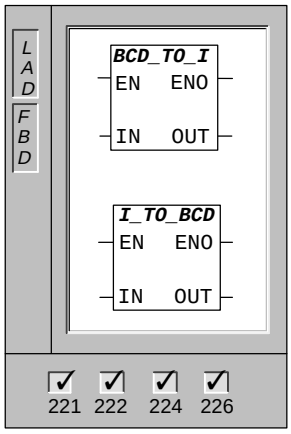
The **Truncate** function converts a real number (IN) into a double integer value and places the result in OUT. No rounding is performed.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

This function affects the following Special Memory bits: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SD, SMD, LD, AC, Constant, *VD, *AC,* LD	REAL
OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	DINT

Binary Coded Decimal to Integer, Integer to BCD



The **BCD to Integer** function converts the input Binary-Coded Decimal value (IN) to an integer value and loads the result into the variable specified by OUT.

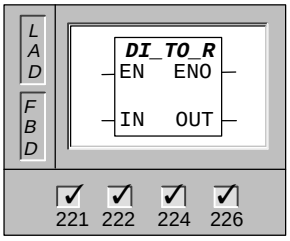
The **Integer to BCD** function converts the input integer value to a Binary-Coded Decimal value and loads the result in OUT.

Error conditions that set ENO = 0: SM1.6 (BCD), SM4.3 (run-time), 0006 (indirect address)

These functions affect the following Special Memory bits: SM1.6 (invalid BCD)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, AC, Constant, *VD, *LD, *AC	WORD
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *AC, *LD	WORD

Double Integer to Real

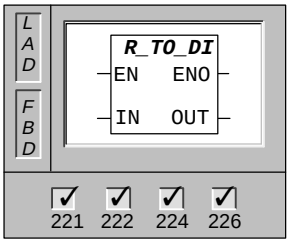


The **Double Integer to Real** function converts a 32-bit, signed integer (IN) into a 32-bit real number loads the result into the variable specified by OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD,SD, SMD, LD, HC, AC, Constant,*VD,*LD, *AC	DINT
OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *LD, *AC	REAL

Real To Double Integer

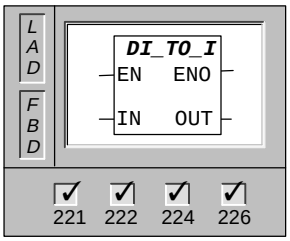


The **Real To Double Integer** function converts a real value (N) to a double Integer value and loads the result into the variable specified by OUT.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SD, SMD, LD, AC, Constant,*VD,*LD, *AC	REAL
OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *LD, *AC	DINT

Double Integer To Integer



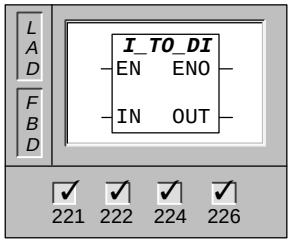
The **Double Integer to Integer** function converts the double integer (IN) to an integer value and loads the result into the variable specified by OUT.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

This function affects the following Special Memory bits: SM1.1 (overflow)

Inputs/Outputs	Operands	Data Types
IN	VD, ID, QD, MD, SD, SMD, LD, HC, AC, Constant,*VD,*LD, *AC	DINT
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *LD, *AC	INT

Integer to Double Integer

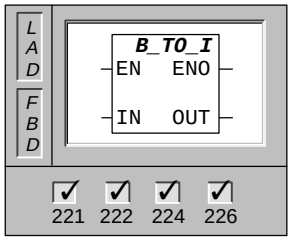


The **Integer to Double Integer** function converts the integer value specified by IN to a double integer value and loads the result into the variable specified by OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, Constant, AC, *VD,*LD, *AC	INT
OUT	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *LD, *AC	DINT

Byte To Integer

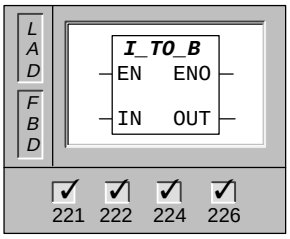


The **Byte to Integer** function converts the byte value (IN) to an integer value and loads the result into the variable specified by OUT.

Error conditions that set ENO = 0: SM4.3 (run-time), 0006 (indirect address)

Inputs/Outputs	Operands	Data Types
IN	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *LD, *AC	BYTE
OUT	VW, IW, QW, MW, SW, SMW, LW, T, C, AC, *VD, *LD, *AC	INT

Integer to Byte



The **Integer to Byte** function converts the integer value (IN) to a byte value and loads the result into the variable specified by OUT.

Error conditions that set ENO = 0: SM1.1 (overflow), SM4.3 (run-time), 0006 (indirect address)

This function affects the following Special Memory bits: SM1.1 (overflow).

Inputs/Outputs	Operands	Data Types
IN	VW, IW, QW, MW, SW, SMW, LW, T ,C, AIW, AC, Constant, *VD, *LD, *AC	INT
OUT	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *LD, *AC	BYTE

Conversion Example

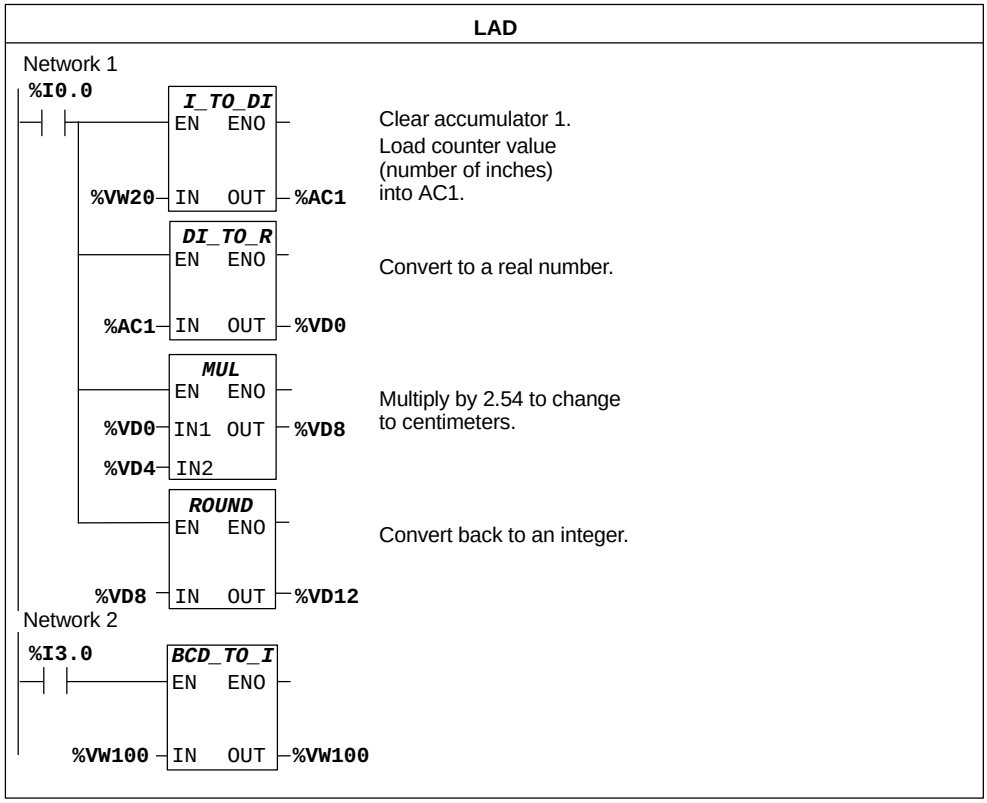


Figure 10-12 Example of Real Number Conversion Instruction for LAD

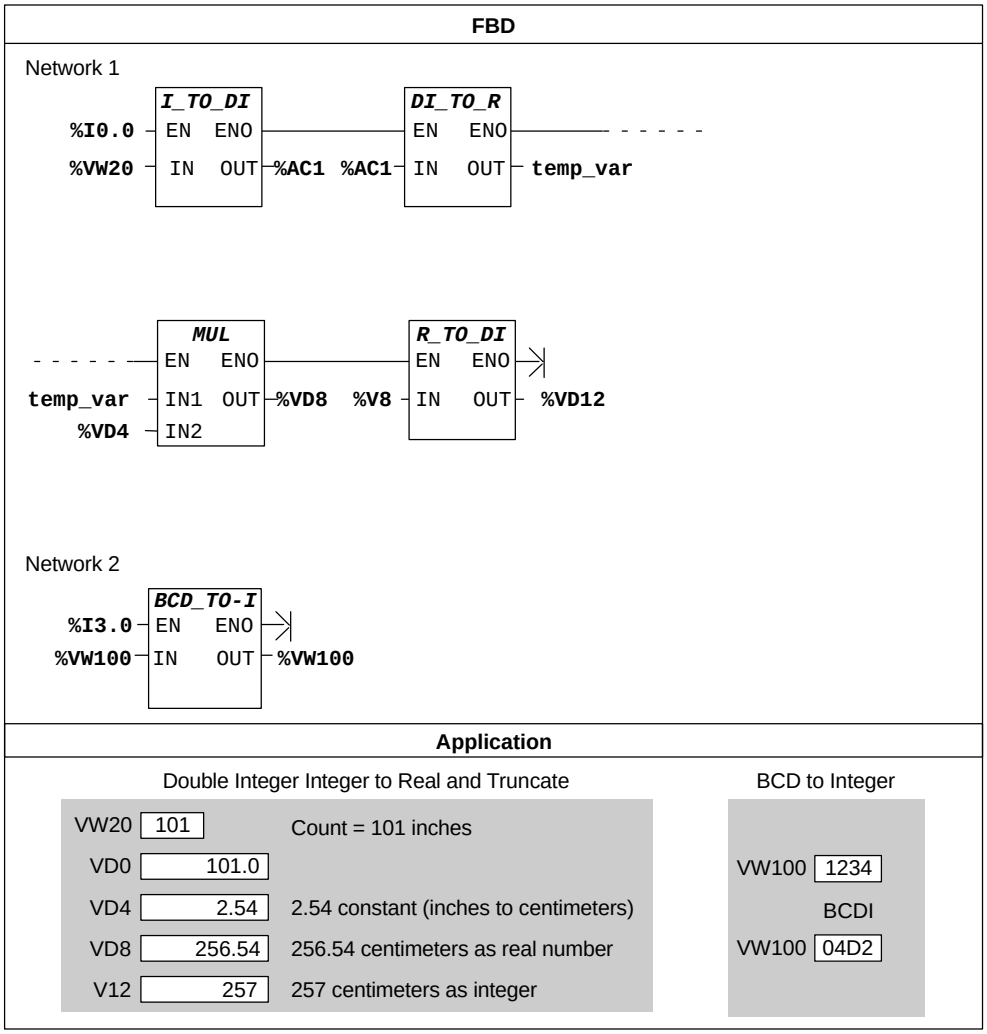


Figure 10-13 Example of Real Number Conversion Instruction for FBD

Using USS Protocol Instructions to Communicate with Drives

11

This chapter describes the standard USS Protocol instructions that allow the S7-200 to control a MicroMaster drive. USS Protocol instructions are a feature of STEP 7-Micro/WIN 32 Toolbox.

STEP 7-Micro/WIN 32 Toolbox makes controlling MicroMaster drives easier by including preconfigured subroutines and interrupt routines that are specifically designed for USS Protocol communication. These routines appear as instructions in the Libraries folder of the STEP 7-Micro/WIN instruction tree. With these new instructions, you can control the physical drive and the read/write drive parameters

When you select a USS Protocol instruction, one or more associated subroutines (USS1 through USS7) are added automatically. You do not need to pay attention to these subroutines.

Chapter Overview

Section	Description	Page
11.1	USS Protocol Instruction Requirements	11-2
11.2	Programming Sequence	11-4
11.3	USS Protocol Instructions	11-5
11.4	Connecting the Drives	11-17
11.5	Drive Setup	11-18

11.1 USS Protocol Instruction Requirements

The USS Protocol instructions require the following resources from your CPU:

- Size 1250 bytes to 1750 bytes (depending on the instructions used)
- Port 0 (only)
- 8 subroutines and 3 interrupts
- V memory size 400 bytes and a16-byte buffer for some instructions

Resource Usage

USS Protocol Instruction uses resources as shown below:

- Port 0: When Port 0 is being used for USS Protocol communications, it cannot be used for any other purpose, including communicating with STEP 7-Micro/WIN. The USS_INIT instruction controls assignment of Port 0 to USS Protocol or PPI. Once Port 0 has been assigned to USS usage, Port 0 can only be used again for STEP 7-Micro/WIN communication by a programmed reassignment via another USS_INIT instruction, or by setting the MODE switch to STOP. Stopping communication to the drives will cause the drives to stop. It is recommended that during program development of USS Protocol applications, the developer should use a CPU 226, or EM 277 PROFIBUS-DP in conjunction with a PROFIBUS CP card in the PC. This allows a second communications port to be used for STEP 7-Micro/WIN monitoring of the application while USS Protocol is running.
- All SM locations associated with Freeport communication on Port 0 will be affected by USS protocol instructions.
- User program space: In addition to the space occupied by each instruction, there is a user program space overhead of up to 1750 bytes occupied by USS protocol support routines
- V memory: A 400 byte block of V memory, starting at a user assigned location, is reserved for USS variables. A 16-byte communications buffer, starting at a user assigned location, is required for some instructions. It is recommended that a unique buffer be assigned for each instance of USS protocol instructions.
- 9 subroutines and 3 interrupts are taken by USS protocol.

Global Symbol Table Configuration

After you enter an address for the first symbol, the table automatically calculates and assigns the remainder of the symbols in the table. Figure 11-1 shows the USS tab of the Symbol Table. You should assign a starting V location for the table, which will occupy 400 bytes.

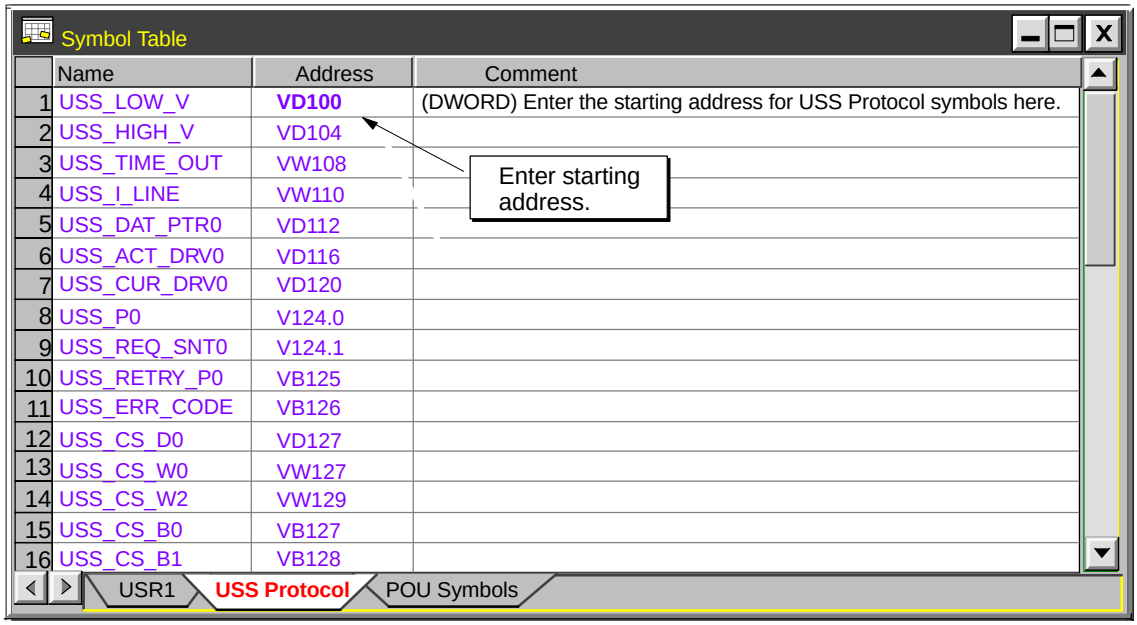


Figure 11-1 Symbol Table Configuration

Drive Communications Time

Communication with the drive is asynchronous to the CPU scan. Several CPU scans will usually complete while one drive communication transaction completes. This depends on the number of drives present, the baud rate, and the scan time of the CPU. Table 11-1 shows communications transaction times. Once a USS_INIT instruction assigns Port 0 to USS Protocol, the CPU regularly polls all active drives at the intervals shown in Table 11-1. The timeout parameter of each drive must be set to allow for this poll time.

Table 11-1 Drive Communications Times

Baud Rate	Time Between Polls to the Active Drives (ms)
1200	(460 maximum/230 typical) * number of drives
2400	(240 maximum/120 typical) * number of drives
4800	(130 maximum/65 typical) * number of drives
9600	(80 maximum/40 typical) * number of drives
19200	(50 maximum/25 typical) * number of drives

Restriction

Only one READ_PM or WRITE_PM instruction can be active at a time. The Done output of each instruction should signal completion before user logic initiates a new instruction. Use only one DRV_CTRL instruction for each drive.

11.2 Programming Sequence

The programming sequence for using USS Protocol instructions is shown below.

1. Place the USS_INIT instruction in the user program. This automatically adds several hidden subroutines and interrupt routines to the program. The USS_INIT should only be called for one scan to initiate or change the USS communication parameters. See page 11-5 for more information about the USS_INIT instruction.
2. Assign a V memory address to the first location in the USS global symbol table. All the other addresses are automatically assigned. A total of 400 consecutive bytes are required. See Figure 11-1 for the USS tab of the Symbol Table.
3. Place only one DRV_CTRL instruction per active drive in your program. You may add as many READ_PM and WRITE_PM instructions as you wish, but only one of these may be active at a time.
4. Configure the drive parameters to match the baud rate and address used in the program. Refer to the Drive Setup in Section 11.5.
5. Connect the communications cable between the CPU and the drives. It is very important that any control equipment that is connected to the drive (such as a PLC) is connected to the same ground or star point as the drive by using a short, thick cable.

Caution

Interconnecting equipment with different reference potentials can cause unwanted currents to flow through the interconnecting cable.

These unwanted currents can cause communication errors or damage equipment.

Be sure all equipment that you are about to connect with a communication cable either shares a common circuit reference or is isolated to prevent unwanted current flows. See “Grounding and Circuit Reference Point for Using Isolated Circuits” in Section 2.3.

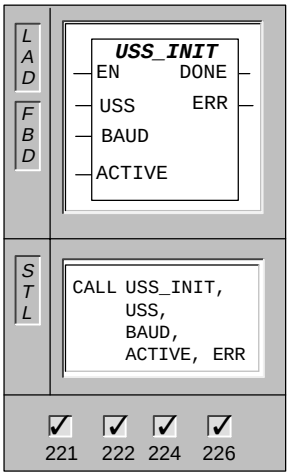
The shield must be tied to chassis ground or terminal 1 on the 9-pin connector. It is recommended that you tie terminal 2-0V on the MicroMaster drive to chassis ground.

Note

If you cannot read all the variables on the USS instruction blocks, select **View ▸Zoom** from the menu and then increase the grid width.

11.3 USS Protocol Instructions

USS_INIT



The **USS_INIT** instruction is used to enable and initialize, or to disable MicroMaster Drive communication. Before any other USS Protocol instruction can be used, the USS_INIT instruction must be executed without errors being returned. The instruction completes and the Done bit is set immediately, before continuing to the next instruction.

The instruction is executed on each scan when the EN input is on. The USS_INIT instruction should be executed exactly once for each change in communication state. Therefore, the EN input should be pulsed on through an edge detection element. Once USS Protocol has been initiated, it must be disabled by execution of a new USS_INIT instruction before a change in initialization parameters can be made.

The value for the USS input selects the communication protocol. 1 assigns port 0 to USS protocol and enables the protocol. 0 assigns port 0 to PPI and disables the USS protocol.

BAUD sets the baud rate at 1200, 2400, 4800, 9600, or 19,200.

ACTIVE indicates which drives are active. Some drives only support addresses 0 through 30. Figure 11-2 shows the description and format of the active drive input**.** Any drive that is marked as ACTIVE is automatically polled in the background to control the drive, collect status, and prevent serial link timeouts in the drive. Refer to Table 11-1 on page 11-3 to compute the time between status polls. Refer to Section 11.5 for information about how to configure the serial link timeout parameter (P093).

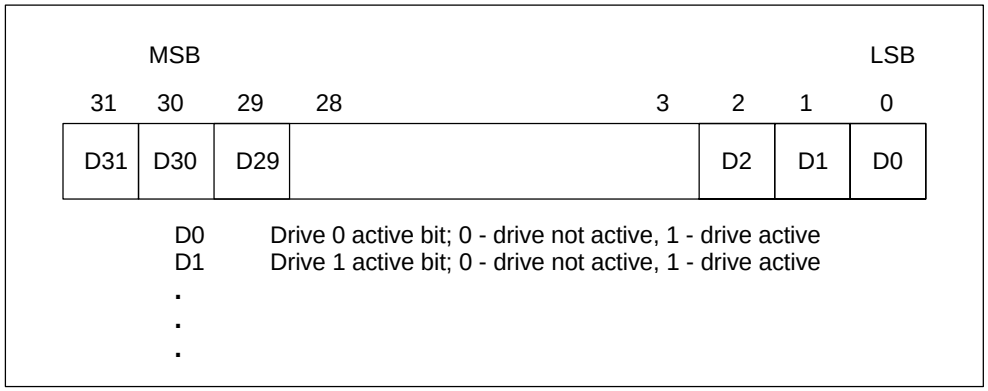


Figure 11-2 Active Drive Description and Format

When the USS_INIT instruction completes, the DONE output is turned on. The ERR output byte contains the result of executing the instruction. Table 11-6 on page 11-16 defines the possible error conditions that may result from executing the instruction.

Table 11-2 shows the operands and data types of the USS subroutines.

Table 11-2 Operands and Data Types for the USS_INIT Subroutine

Inputs/Outputs	Operands	Data Types
USS	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
BAUD	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, Constant, AC *VD, *AC, *LD	WORD
ACTIVE	VD, ID, QD, MD, SD, SMD, LD, AC, Constant, *VD, *AC, *LD	DWORD
DONE	I, Q, M, S, SM, T, C, V, L	BOOL
ERR	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD	BYTE

Figure 11-3 shows how the USS_INIT subroutine is used in LAD, FBD, and STL.

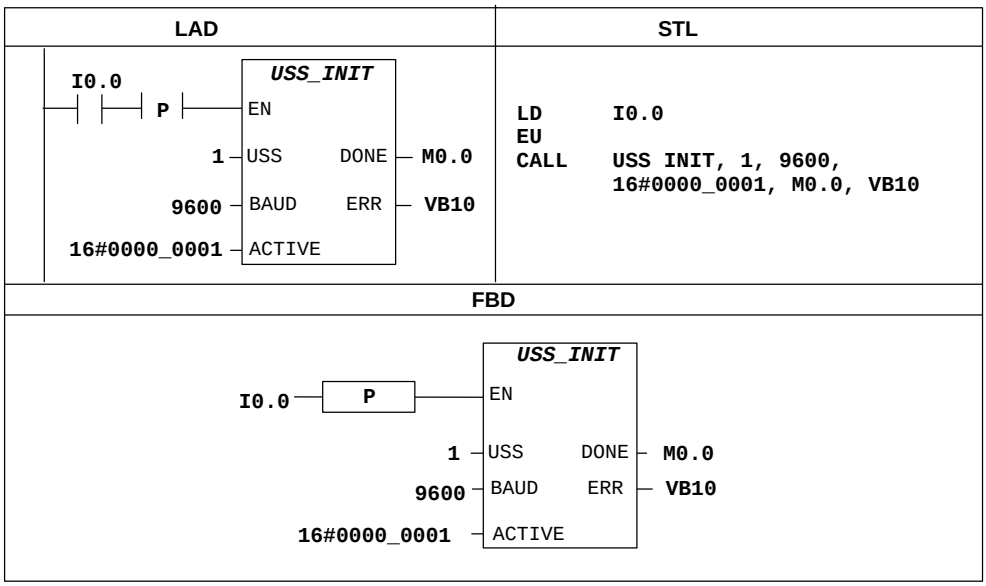
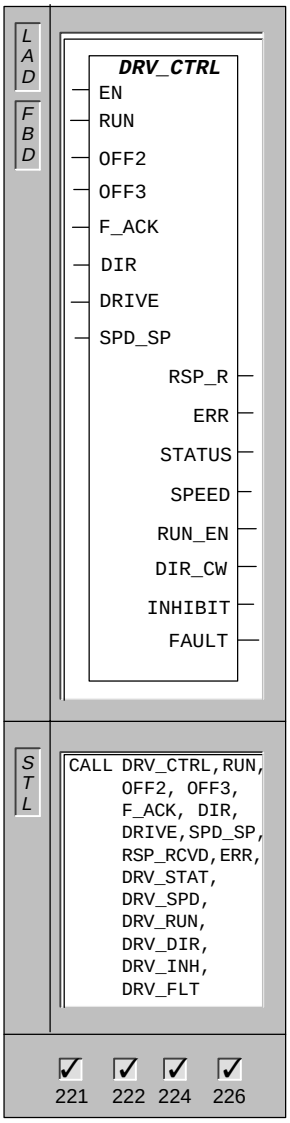


Figure 11-3 Using the USS_INIT Subroutine in LAD, FBD, and STL

DRV_CTRL



The **DRV_CTRL** instruction is used to control an ACTIVE MicroMaster Drive. The DRV_CTRL instruction places the selected commands in a communication buffer. Commands in the buffer are sent to the addressed drive (DRIVE parameter), if that drive has been selected in the ACTIVE parameter of the USS_INIT instruction. Each drive should have only one DRV_CTRL instruction.

The EN bit must be on to enable the DRV_CTRL instruction. Typically, this instruction is always enabled.

RUN (RUN/STOP) indicates whether the drive is on (1) or off (0). When the RUN bit is on, the MicroMaster Drive receives a command to start running at the specified speed and direction. In order for the drive to run, the following must be true:

- DRIVE must be selected as ACTIVE in USS_INIT.
- OFF1 and OFF2 must be set to 0.
- FAULT and INHIBIT must be 0.

When RUN is off, a command is sent to the MicroMaster Drive to ramp the speed down until the motor comes to a stop.

The OFF2 bit is used to allow the MicroMaster Drive to coast to a stop. The OFF3 bit is used to command the MicroMaster drive to stop quickly.

The F_ACK (Fault Acknowledge) bit is used to acknowledge a fault in the drive. The drive clears the fault (FAULT) when F_ACK goes from low to high.

The DIR (direction) bit indicates in which direction the drive should move (0 - counterclockwise, 1 - clockwise).

The DRIVE (drive address) input is the address of the MicroMaster Drive to which the DRV_CTRL command is to be sent. Valid addresses are 0 to 31.

SPD_SP (speed setpoint) is drive speed as a percentage of full speed (-200.0% to 200.0%). Negative values of SPD_SP cause the drive to reverse its direction of rotation.

Note

Only one DRV_CTRL instruction should be assigned to each drive.

The RSP_R (Response Received) bit acknowledges a response from the drive. All the ACTIVE drives are polled for the latest drive status information. Each time the CPU receives a response from the drive, the RSP_R bit is turned on for one scan and all the following values are updated.

ERR is an error byte that contains the result of the latest communication request to the drive. Table 11-6 on page 11-16 defines the possible error conditions that may result from executing the instruction.

STATUS is the raw value of the status word returned by the drive. Figure 11-4 shows the status bits for Standard Status Word and Main Feedback.

SPEED is drive speed as a percentage of full speed (-200.0% to 200.0%).

Note

Some drives only report speed as a positive value. If the speed is negative, the drive reports the speed as positive but reverses the DIR_CW (direction) bit.

RUN_EN (RUN Enable) indicates whether the drive is running (1) or stopped (0).

DIR_CW indicates the drive's direction of rotation (0 - counterclockwise, 1 - clockwise).

INHIBIT indicates the state of the inhibit bit on the drive (0 - not inhibited, 1 - inhibited). To clear the inhibit bit, the FAULT bit must be off, and the RUN, OFF2, and OFF3 inputs must also be off.

FAULT indicates the state of the fault bit (0 - no fault, 1 - fault). The drive displays the fault code. (Refer to the manual for your drive). To clear the FAULT bit, correct the cause of the fault and turn on the F_ACK bit.

Table 11-3 shows the operands and data types of the DRV_CTRL subroutine.

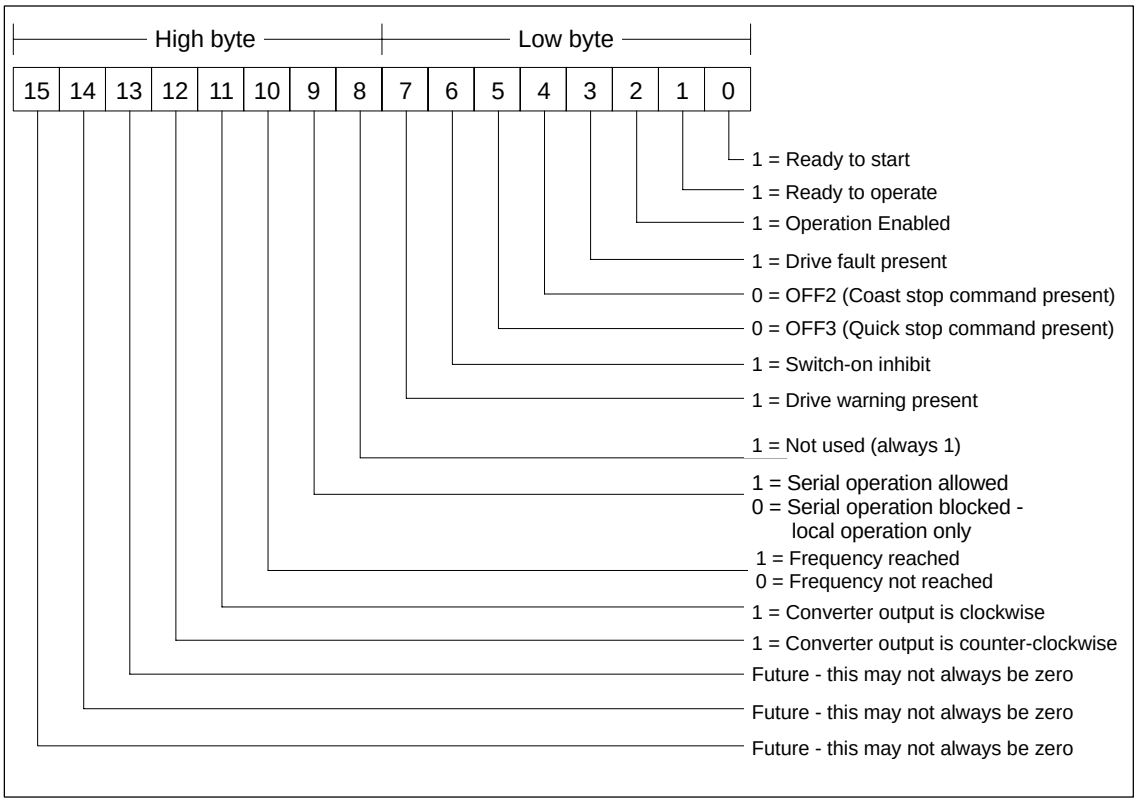


Figure 11-4 Status Bits for Standard Status Word and Main Feedback

Table 11-3 Operands and Data Types for the DRV_CTRL Subroutine

Inputs/Outputs	Operands	Data Types
RUN	I, Q, M, S, SM, T, C, V, L, Power Flow	BOOL
OFF2	I, Q, M, S, SM, T, C, V, L, Power Flow	BOOL
OFF3	I, Q, M, S, SM, T, C, V, L, Power Flow	BOOL
F_ACK	I, Q, M, S, SM, T, C, V, L, Power Flow	BOOL
DIR	I, Q, M, S, SM, T, C, V, L, Power Flow	BOOL
DRIVE	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
SPD_SP	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD, Constant	REAL
RSP_R	I, Q, M, S, SM, T, C, V, L	BOOL
ERR	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD	BYTE
STATUS	VW, T, C, IW, QW, SW, MW, SMW, LW, AC, AQW, *VD, *AC, *LD	WORD
SPEED	VD, ID, QD, MD, SD, SMD, LD, AC, *VD, *AC, *LD	REAL
RUN_EN	I, Q, M, S, SM, T, C, V, L	BOOL
DIR_CW	I, Q, M, S, SM, T, C, V, L	BOOL

Table 11-3 Operands and Data Types for the DRV_CTRL Subroutine

Inputs/Outputs	Operands	Data Types
INHIBIT	I, Q, M, S, SM, T, C, V, L	BOOL
FAULT	I, Q, M, S, SM, T, C, V, L	BOOL

Figure 11-5 shows how the DRV_CTRL subroutine should be used in LAD, FBD, and STL.

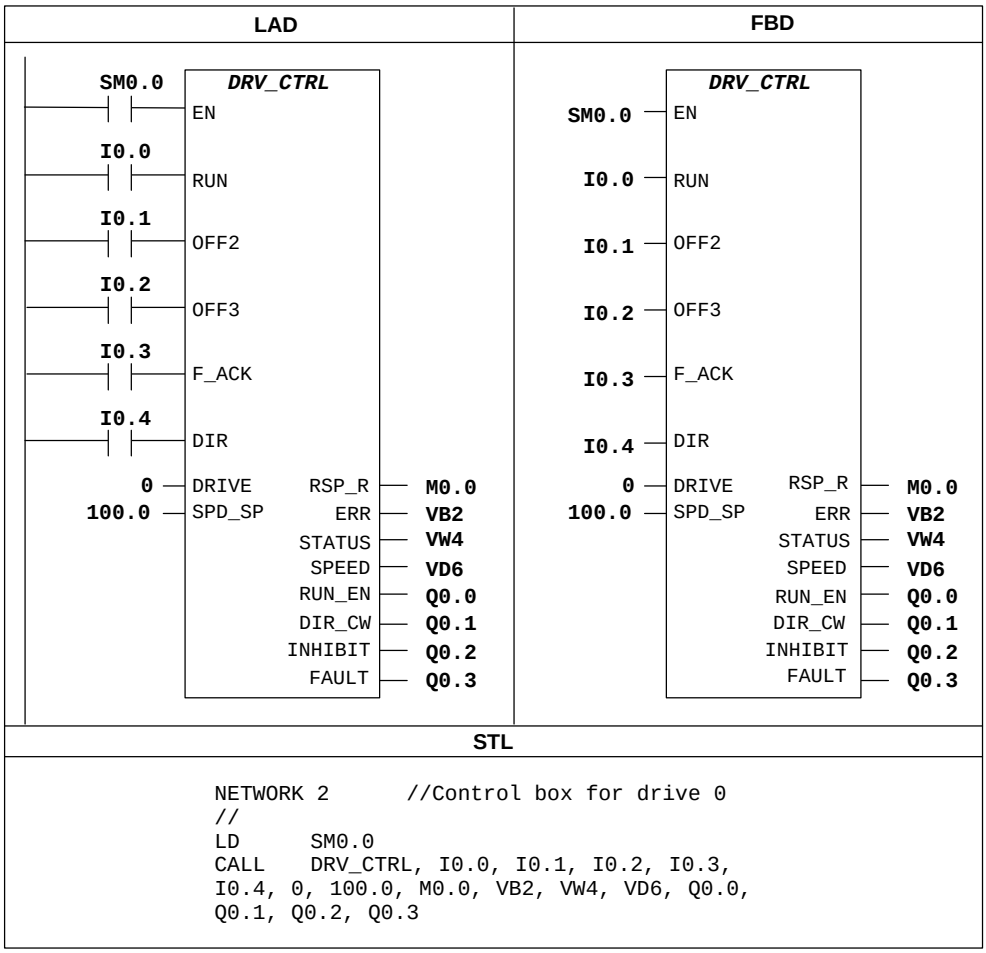
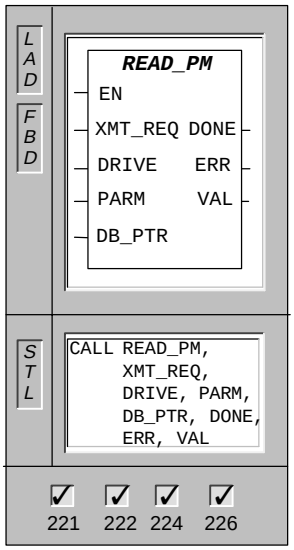


Figure 11-5 Using the DRV_CTRL Subroutine in LAD, FBD, and STL

READ_PM



The **READ_PM** instruction reads a drive parameter. The READ_PM transaction completes when the MicroMaster Drive acknowledges receipt of the command, or when an error condition is posted. The logic scan continues to execute while this process awaits a response.

The EN bit must be on to enable transmission of a request, and should remain on until the DONE bit is set signaling completion of the process. A READ_PM request is transmitted to the MicroMaster drive on each scan when XMT_REQ input is on. Therefore, the XMT_REQ input should be pulsed on through an edge detection element which causes one request to be transmitted for each positive transition of the EN input.

The DRIVE input is the address of the MicroMaster Drive to which the READ_PM command is to be sent. Valid addresses of individual drives are 0 to 31.

PARM is the parameter number.

The address of a 16-byte buffer must be supplied to the DB_PTR input. This buffer is used by the READ_PM instruction to store the results of the command issued to the MicroMaster Drive.

When the READ_PM instruction completes, the DONE output is turned on and the ERR output byte contains the result of executing the instruction. Table 11-6 on page 11-16 defines the possible error conditions that may result from executing the instruction.

VAL is the parameter value returned.

Note

Only one READ_PM or WRITE_PM instruction can be active at a time.

Table 11-4 the operands and data types of the READ_PM subroutine.

Table 11-4 Operands and Data Types for the READ_PM Subroutine

Inputs/Outputs	Operands	Data Types
XMT_REQ	I, Q, M, S, SM, T, C, V, L, Power Flow conditioned by a rising edge detection element.	BOOL
DRIVE	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
PARM	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, Constant, AC *VD, *AC, *LD	WORD
DB_PTR	&VB	DWORD
DONE	I, Q, M, S, SM, T, C, V, L	BOOL

Table 11-4 Operands and Data Types for the READ_PM Subroutine

Inputs/Outputs	Operands	Data Types
ERR	VB, IB, QB, MB, SB, SMB, LB, AC. *VD, *AC, *LD	BYTE
VAL	VW, T, C, IW, QW, SW, MW, SMW, LW, AC, AQW, *VD, *AC, *LD	WORD

Figure 11-6 shows how the READ_PM subroutine is used in LAD, FBD, and STL.

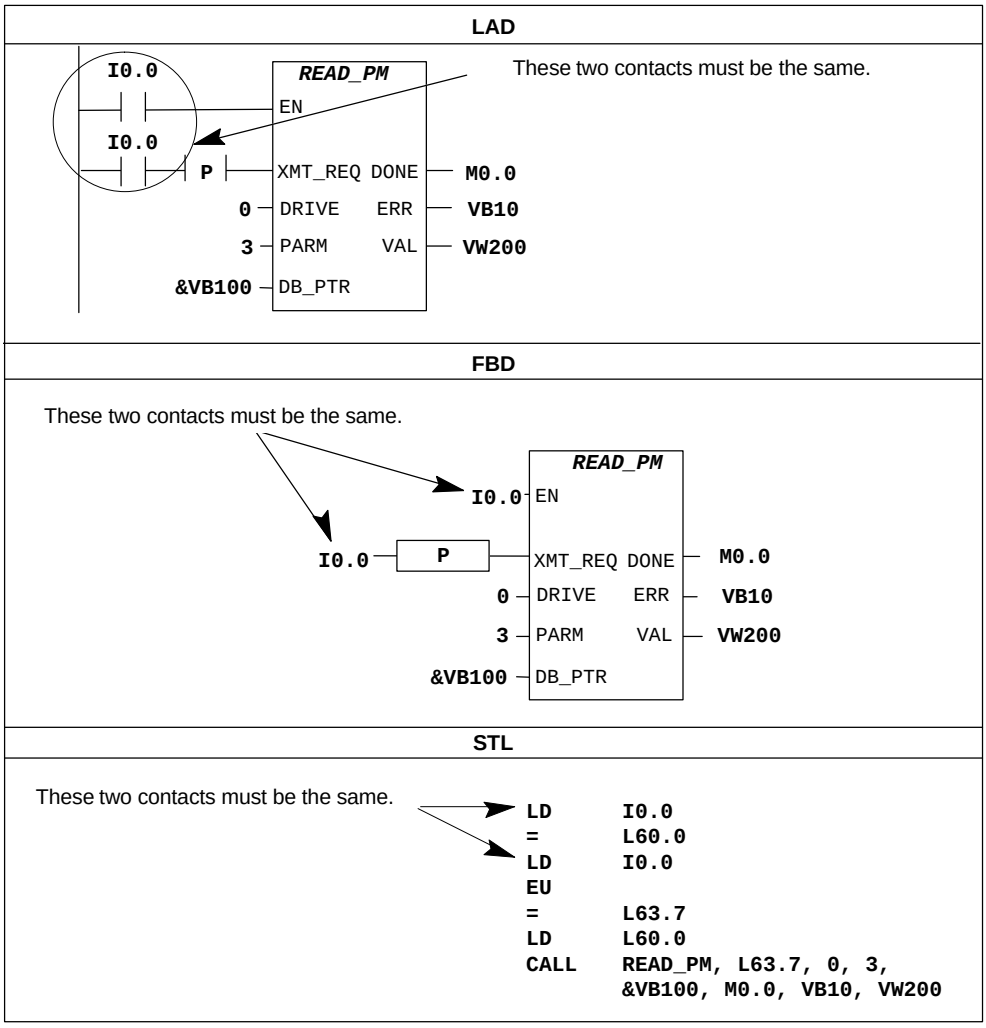
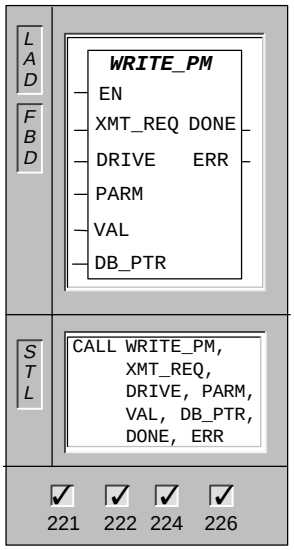


Figure 11-6 Using the READ_PM Subroutine in LAD, FBD, and STL

WRITE_PM



The **WRITE_PM** instruction writes a drive parameter to a specified location. The WRITE_PM transaction completes when the MicroMaster Drive acknowledges receipt of the command, or when an error condition is posted. The logic scan continues to execute while this process awaits a response.

The EN bit must be on to enable transmission of a request, and should remain on until the DONE bit is set signaling completion of the process. A WRITE_PM request is transmitted to the MicroMaster drive on each scan when XMT_REQ input is on. Therefore the XMT_REQ input should be pulsed on through an edge detection element which causes one request to be transmitted for each positive transition of the EN input.

The DRIVE input is the address of the MicroMaster Drive to which the WRITE_PM command is to be sent. Valid addresses of individual drives are 0 to 31.

PARM is the parameter number. VAL is the parameter value to be written.

The address of a 16-byte buffer must be supplied to the DB_PTR input. This buffer is used by the WRITE_PM instruction to store the results of the command issued to the MicroMaster Drive.

When the WRITE_PM instruction completes, the DONE output is turned on and the ERR output byte contains the result of executing the instruction. Table 11-6 on page 11-16 defines the possible error conditions that may result from executing the instruction.

Note

Only one READ_PM or WRITE_PM instruction can be active at a time.

CAUTION

When you use the WRITE_PM instruction to update the parameter set held in drive EEPROM, you must ensure that the maximum number of write cycles (approximately 50,000) to the EEPROM is not exceeded.

Exceeding the maximum number of write cycles will result in corruption of the stored data and subsequent data loss. The number of read cycles are unlimited.

If frequent writes to the drive parameters are required, then you should first set P971 (EEPROM storage control) to zero.

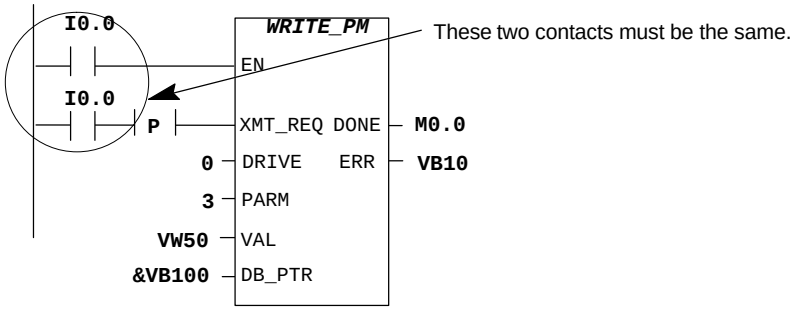
Table 11-5 shows the operands and data types of the WRITE_PM subroutine.

Table 11-5 Operands and Data Types for the WRITE_PM Subroutine

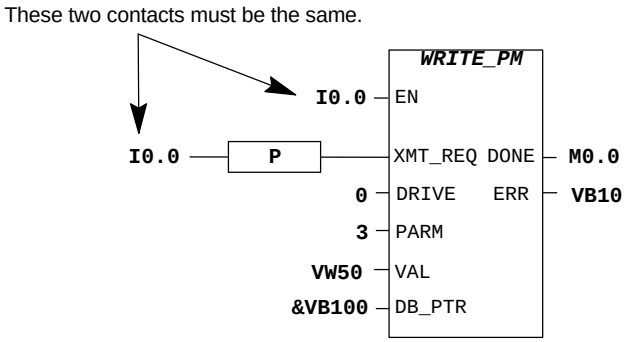
Inputs/Outputs	Operands	Data Types
XMT_REQ	I, Q, M, S, SM, T, C, V, L, Power Flow conditioned by a rising edge detection element.	BOOL
DRIVE	VB, IB, QB, MB, SB, SMB, LB, AC, Constant, *VD, *AC, *LD	BYTE
PARM	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, Constant, AC *VD, *AC, *LD	WORD
VAL	VW, IW, QW, MW, SW, SMW, LW, T, C, AIW, Constant, AC *VD, *AC, *LD	WORD
DB_PTR	&VB	DWORD
DONE	I, Q, M, S, SM, T, C, V, L	BOOL
ERR	VB, IB, QB, MB, SB, SMB, LB, AC, *VD, *AC, *LD	BYTE

Figure 11-7 shows how the WRITE_PM subroutine is used in LAD, FBD, and STL.

LAD



FBD



STL

These two contacts must be the same.

```
LD      I0.0
=       L60.0
LD      I0.0
EU
=       L63.7
LD      L60.0
CALL    WRITE_PM, L63.7, 0, 3,
        VW50, &VB100, M0.0, VB10
```

Figure 11-7 Using the WRITE_PM Subroutine in LAD, FBD, and STL

Table 11-6 Execution Errors for the USS Instructions

Error Number	Explanation
0	No error.
1	Drive did not respond.
2	A checksum error in the response from the drive was detected.
3	A parity error in the response from the drive was detected.
4	An error was caused by interference from the user program.
5	An illegal command was attempted.
6	An illegal drive address was supplied.
7	The communication port was not set up for USS protocol.
8	The communication port is busy processing an instruction.
9	The drive speed input is out of range.
10	The length of the drive response is incorrect.
11	The first character of the drive response is incorrect.
12	The length character in the drive response is incorrect.
13	The wrong drive responded.
14	The DB_PTR address supplied is incorrect.
15	The parameter number supplied is incorrect.
16	Invalid protocol selected.
17	USS active; change not allowed.
18	Illegal baud rate specified.
19	No communication: drive is not ACTIVE.
20	The parameter or value in the drive response is incorrect.

11.4 Connecting the Drives

The standard PROFIBUS cable and connectors can be used to connect the CPU to the MicroMaster drive. See Network Connectors in Chapter 7 for more information. See Figure 11-8 for the proper cable bias and termination of the interconnecting cable.

Caution

Interconnecting equipment with different reference potentials can cause unwanted currents to flow through the interconnecting cable.

These unwanted currents can cause communication errors or can damage equipment.

Be sure all equipment that you are about to connect with a communication cable either shares a common circuit reference or is isolated to prevent unwanted current flows. See “Grounding and Circuit Reference Point for Using Isolated Circuits” in Section 2.3.

The shield must be tied to chassis ground or terminal 1 on the 9-pin connector. It is recommended that you tie terminal 2-0V on the MicroMaster drive to chassis ground.

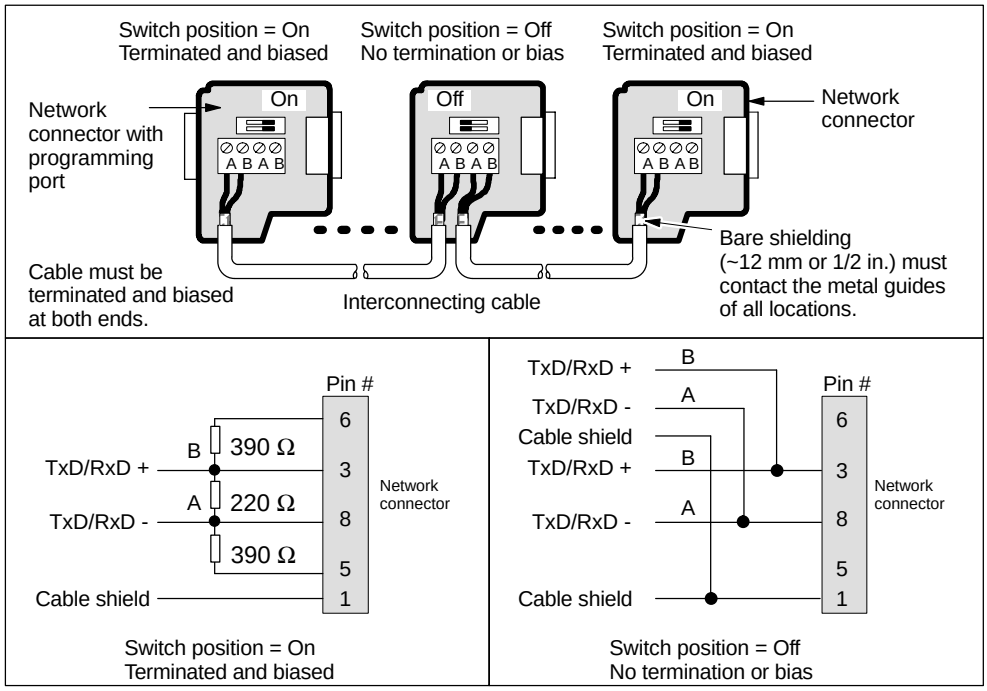


Figure 11-8 Bias and Termination of Interconnecting Cable

11.5 Drive Setup

Before you connect a drive to the PLC, you must ensure that the drive has the following system parameters. You set the parameters by using the drive keypad.

Follow the steps below to set the parameters on your drive:

1. Reset the drive to factory settings (optional). Press the P key: P000 is displayed. Press the up or down arrow key until the display shows the P944. Press P to enter the parameter.

   P944=1

2. Enable the read/write access to all parameters. Press the P key. Press the up or down arrow key until the display shows P009. Press P to enter the parameter.

   P009=3

3. Check motor settings for your drive. The settings will vary according to the motor(s) being used. Press the P key. Press the up or down arrow key until the display shows the motor setting for your drive. Press P to enter the parameter.

   P081=Nominal frequency of motor (Hz)
   P082=Nominal speed of motor (RPM)
   P083=Nominal current of motor (A)
   P084=Nominal voltage of motor (V)
   P085=Nominal power of motor (kW/HP)

4. Set the Local/Remote control mode. Press the P key. Press the up or down arrow key until the display shows P910. Press P to enter the parameter.

   P910=1 Remote control mode

5. Set the Baud Rate of the RS-485 serial interface. Press the P key. Press the up or down arrow key until P092 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the number that corresponds to the baud rate of your RS-485 serial interface. Press P to enter.

P092	3	(1200 baud)
	4	(2400 baud)
	5	(4800 baud)
	6	(9600 baud - default)
	7	(19200 baud)

6. Enter the Slave address. Each drive (a maximum of 31) can be operated over the bus). Press the P key. Press the up or down arrow key until P091 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the slave address you want. Press P to enter.

   P091=0 through 31.

7. Ramp up time(s) (optional). This is the time in seconds that it takes the motor to accelerate to maximum frequency. Press the P key. Press the up or down arrow key until P002 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the ramp up time you want. Press P to enter.

   P002=0-650.00

8. Ramp down time(s) (optional). This is the time in seconds that it takes the motor to decelerate to a complete stop. Press the P key. Press the up or down arrow key until P003 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the ramp down time you want. Press P to enter.

   P003=0-650.00

9. Serial Link Timeout. This is the maximum permissible period between two incoming data telegrams. This feature is used to turn off the inverter in the event of a communications failure.

   Timing starts after a valid data telegram has been received. If a further data telegram is not received within the specified time period, the inverter will trip and display fault code F008. Setting the value to zero switches off the control. The time between the status polls to the drive can be calculated using Table 11-1.

   Press the P key. Press the up or down arrow key until P093 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the serial link timeout you want. Press P to enter.

   P093=0-240 (0 is default; time is in seconds)

10. Serial Link Nominal System Setpoint. This value can vary, but will typically correspond to 50 Hz or 60 Hz, which defines the corresponding 100% value for PVs or SPs. Press the P key. Press the up or down arrow key until P094 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the serial link nominal system setpoint you want. Press P to enter.

    P094=0-400.00

11. USS Compatibility (optional). Press the P key. Press the up or down arrow key until P095 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the number that corresponds to the USS compatibility you want. Press P to enter.

    P095 = 0 0.1 Hz resolution (default)
    1 0.01 Hz resolution

12. EEPROM storage control (optional). Press the P key. Press the up or down arrow key until P971 appears. Press P to enter the parameter. Press the up or down arrow key until the display shows the number that corresponds to the EEPROM storage control you want. Press P to enter.

    P971 = 0 Changes to parameter settings (including P971) are lost when power is removed.
    1 (default) Changes to parameter settings are retained during periods when power is removed.

13. Operating display, Press P to exit out of parameter mode. P

Example of USS Protocol Program

Figures 11-9 through 11-11 show an example of a USS program in LAD, FBD, and STL.

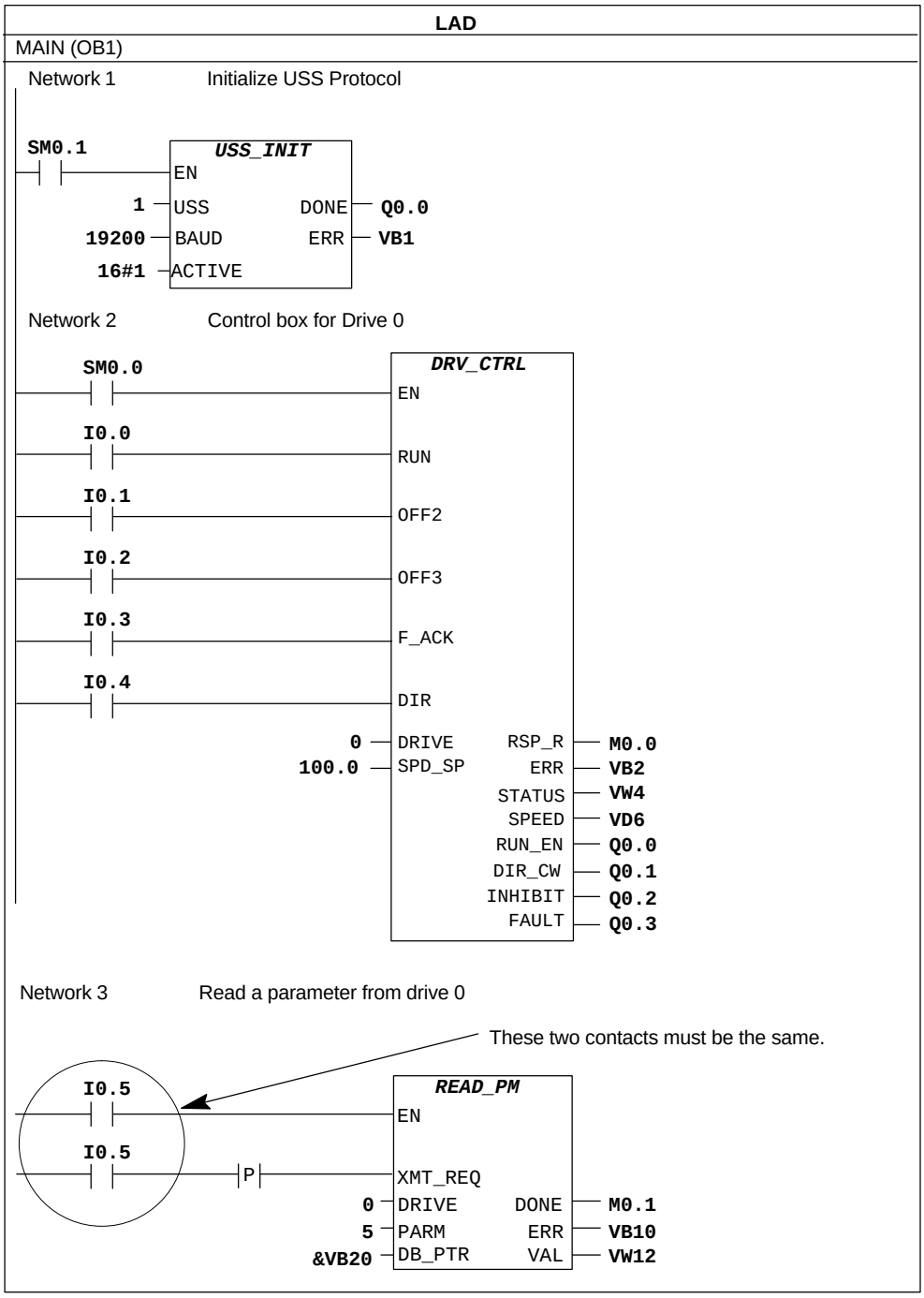


Figure 11-9 Example of USS Instructions for SIMATIC LAD

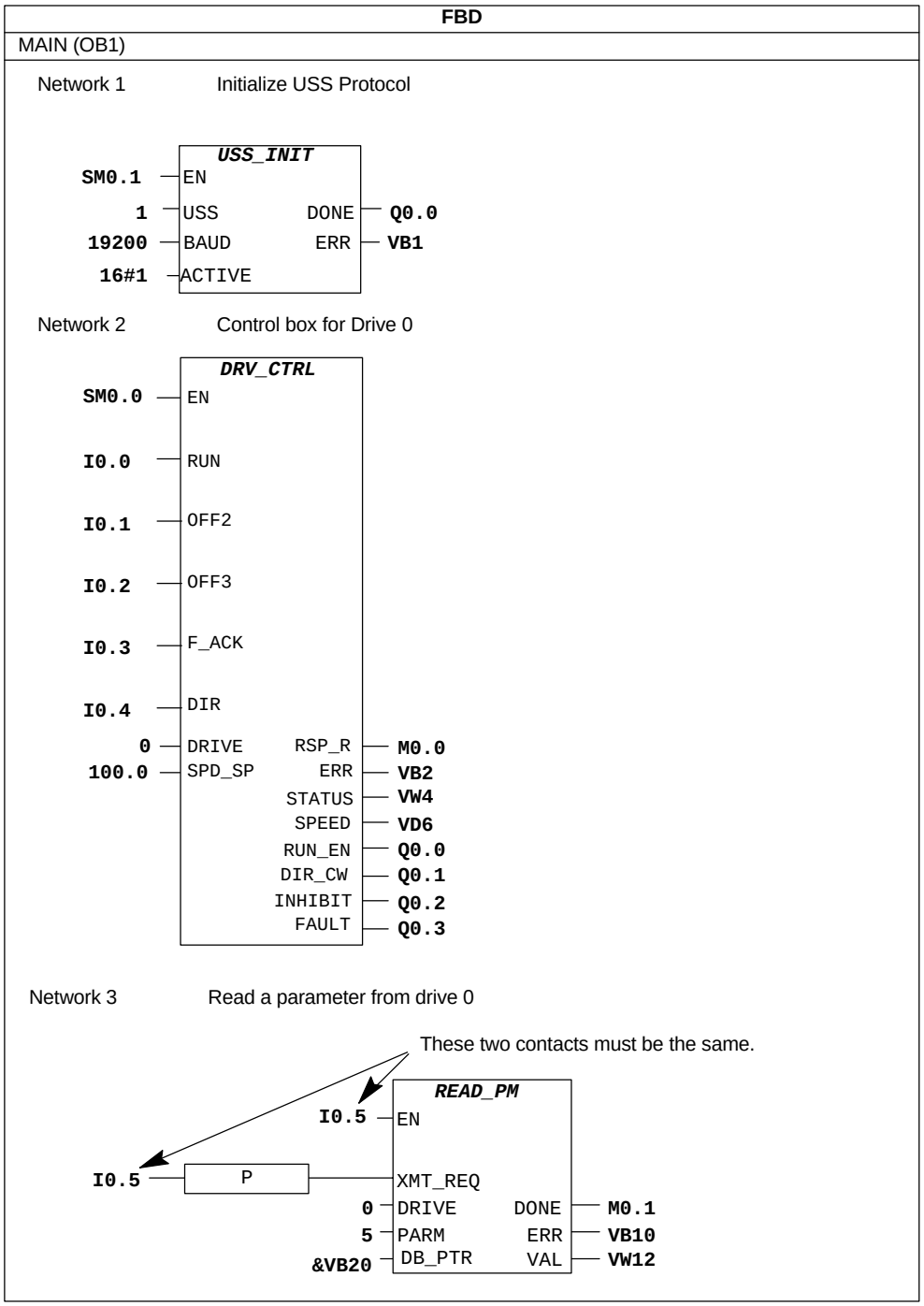


Figure 11-10 Example of USS Instructions for SIMATIC FBD

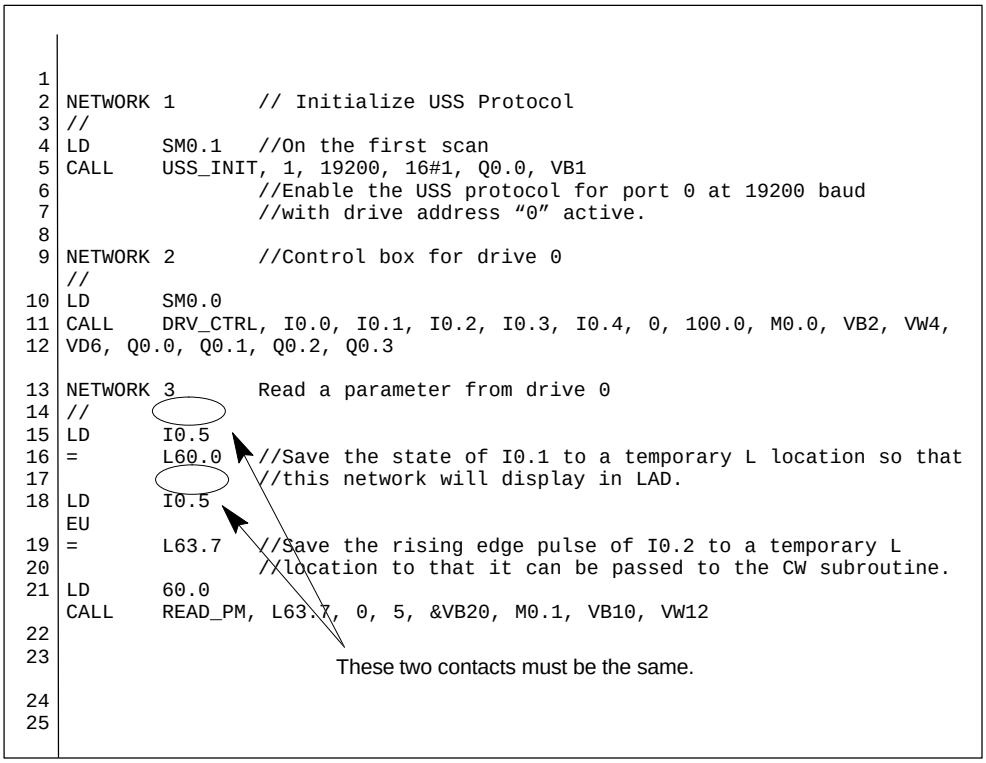


Figure 11-11 Example of USS Instructions for SIMATIC STL

S7-200 Specifications

A

Chapter Overview

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A.1 General Technical Specifications

National and International Standards

The national and international standards listed below were used to determine appropriate performance specifications and testing for the S7-200 family of products. Table A-1 defines the specific adherence to these standards.

- Underwriters Laboratories, Inc.: UL 508 Listed (Industrial Control Equipment)
- Canadian Standards Association: CSA C22.2 Number 142 Certified (Process Control Equipment)
- Factory Mutual Research: FM Class I, Division 2, Groups A, B, C, & D Hazardous Locations, T4A. Class I, Zone 2, IIC, T4. Group and Temperature ratings are referenced to a 40C ambient operating environment.
- VDE 0160: Electronic equipment for use in electrical power installations
- European Community (CE) Low Voltage Directive 73/23/EEC
  EN 61131-2: Programmable controllers - Equipment requirements
- European Community (CE) EMC Directive 89/336/EEC

  Electromagnetic emission standards:
  EN 50081-1: residential, commercial, and light industry
  EN 50081-2: industrial environment

  Electromagnetic immunity standards:
  EN 50082-2: industrial environment

Technical Specifications

The S7-200 CPUs and all S7-200 expansion modules conform to the technical specifications listed in Table A-1.

Table A-1 Technical Specifications for the S7-200 Family

Environmental Conditions — Transport and Storage	
IEC 68-2-2, Test Bb, Dry heat and IEC 68-2-1, Test Ab, Cold	-40° C to +70° C
IEC 68-2-30, Test Db, Damp heat	25° C to 55° C, 95% humidity
IEC 68-2-31, Toppling	100 mm, 4 drops, unpacked
IEC 68-2-32, Free fall	1 m, 5 times, packed for shipment
Environmental Conditions — Operating	
Ambient Temperature Range (Inlet Air 25 mm below unit)	0° C to 55° C horizontal mounting 0° C to 45° C vertical mounting 95% non-condensing humidity
IEC 68-2-14, Test Nb	5° C to 55° C, 3° C/minute
IEC 68-2-27 Mechanical shock	15 G, 11 ms pulse, 6 shocks in each of 3 axis
IEC 68-2-6 Sinusoidal vibration	0.30 mm peak-to-peak 10 to 57 Hz; 2 G panel mount, 1 G DIN rail mount, 57 Hz to 150 Hz; 10 sweeps each axis, 1 octave/minute
EN 60529, IP20 Mechanical protection	Protects against finger contact with high voltage as tested by standard probes. External protection is required for dust, dirt, water, and foreign objects of less than 12.5 mm in diameter.
Electromagnetic Compatibility — Immunity[1] per EN50082-2[1]	
EN 61000-4-2 (IEC 801-2) Electrostatic discharge	8 kV air discharge to all surfaces and communication port
EN 50140 (IEC 801-3) Radiated electromagnetic field	80 MHz to 1 GHz 10 V/m, 80% modulation with 1 kHz signal
EN 50141 Conducted disturbances	0.15 to 80 MHz 10 V RMS 80% amplitude modulation at 1kHz
EN 50204 Digital telephone immunity	900 MHz ± 5 MHz, 10 V/m, 50% duty cycle, 200 Hz repetition frequency
EN 61000-4-4 (IEC 801-4) Fast transient bursts	2 kV, 5 kHz with coupling network to AC and DC system power 2 kV, 5 kHz with coupling clamp to digital I/O and communications
EN 61000-4-5 (IEC 801-5) Surge immunity	2 kV asymmetrical, 1 kV symmetrical 5 positive/5 negative pulses 0°, +90°, -90° phase angle (24 VDC circuits require external surge protection)
VDE 0160 Non-periodic overvoltage	at 85 VAC line, 90° phase angle, apply 390 V peak, 1.3 ms pulse at 180 VAC line, 90° phase angle, apply 750 V peak, 1.3 ms pulse

Table A-1 Technical Specifications for the S7-200 Family (continued)

Electromagnetic Compatibility — Conducted and Radiated Emissions per EN50081 -1[2] and -2	
EN 55011, Class A, Group 1, conducted[1]	
0.15 MHz to 0.5 MHz	< 79 dB (µV) Quasi-peak; < 66 dB (µV) Average
0.5 MHz to 5 MHz	< 73 dB (µV) Quasi-peak; < 60 dB (µV) Average
5 MHz to 30 MHz	< 73 dB (µV) Quasi-peak; < 60 dB (µV) Average
EN 55011, Class A, Group 1, radiated[1]	
30 MHz to 230 MHz	30 dB (µV/m) Quasi-peak; measured at 30 m
230 MHz to 1 GHz	37 dB (µV/m) Quasi-peak; measured at 30 m
EN 55011, Class B, Group 1, conducted[2]	
0.15 to 0.5 MHz	<66 dB (µV) Quasi-peak decreasing with log frequency to 56 dB (µV); < 56 dB (µV) Average decreasing with log frequency to 46 dB (µV)
0.5 MHz to 5 MHz	< 56 dB (µV) Quasi-peak; < 46 dB (µV) Average
5 MHz to 30 MHz	< 60 dB (µV) Quasi-peak; < 50 dB (µV) Average
EN 55011, Class B, Group 1, radiated[2]	
30 MHz to 230 kHz	30 dB (µV/m) Quasi-peak; measured at 10 m
230 MHz to 1 GHz	37 dB (µV/m) Quasi-peak; measured at 10 m
	High Potential Isolation Test
24 V/5 V nominal circuits	500 VAC (optical isolation boundaries)
115/230 V circuits to ground	1,500 VAC
115/230 V circuits to 115/230 V circuits	1,500 VAC
230 V circuits to 24 V/5 V circuits	1,500 VAC
115 V circuits to 24 V/5 V circuits	1,500 VAC

1 Unit must be mounted on a grounded metallic frame with the S7-200 ground connection made directly to the mounting metal. Cables are routed along metallic supports.

2 Unit must be mounted in a grounded metal enclosure. AC input power line must be equipped with a SIEMENS B84115-E-A30 filter or equivalent, 25 cm max. wire length from filters to the S7-200. The 24 VDC supply and sensor supply wiring must be shielded.

Relay Electrical Service Life

Figure A-1 shows typical performance data supplied by relay vendors. Actual performance may vary depending upon your specific application.

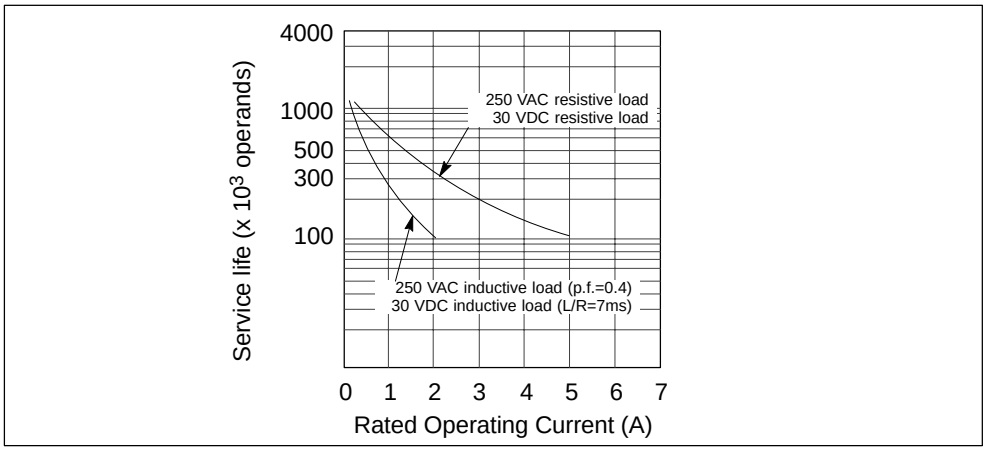


Figure A-1 Electrical Service Life

A.2 Specifications for the CPU 221, Firmware Release 1.1

Table A-2 Specifications for CPU 221 DC/DC/DC and CPU 221 AC/DC/Relay

Description Order Number	CPU 221 DC/DC/DC 6ES7 211-0AA21-0XBO	CPU 221 AC/DC/Relay 6ES7 211-0BA21-0XB0
Physical Size		
Dimensions (W x H x D)	90 mm x 80 mm x 62 mm	90 mm x 80 mm x 62 mm
Weight	270 g	310 g
Power loss (dissipation)	3 W	6 W
CPU Features		
On-board digital inputs	6 inputs	6 inputs
On-board digital output	4 outputs	4 outputs
High-speed counters (32-bit value)		
Total No. of single phase counters No. of two phase counters	4 High-speed counters 4, each at 20 kHz clock rate 2, each at 20 kHz clock rate	4 High-speed counters 4, each at 20 kHz clock rate 2, each at 20 kHz clock rate
Pulse outputs	2 at 20 kHz pulse rate	2 at 20 kHz pulse rate
Analog adjustments	1 with 8 bit resolution	1 with 8 bit resolution
Timed interrupts	2 with 1 ms resolution	2 with 1 ms resolution
Edge interrupts	4 edge up and/or 4 edge down	4 edge up and/or 4 edge down
Selectable input filter times	7 ranges from 0.2 ms to 12.8 ms	7 ranges from 0.2 ms to 12.8 ms
Pulse catch	6 pulse catch inputs	6 pulse catch inputs
Program size (stored permanently)	2048 words	2048 words
Data block size: Stored permanently Backed by super capacitor or battery	1024 words 1024 words 1024 words	1024 words 1024 words 1024 words
Maximum digital I/O	10 points	10 points
Internal memory bits Stored permanently on power down Backed by super capacitor or battery	256 bits 112 bits 256 bits	256 bits 112 bits 256 bits
Timers total Backed by super capacitor or battery 1 ms 10 ms 100 ms	256 timers 64 timers 4 timers 16 timers 236 timers	256 timers 64 timers 4 timers 16 timers 236 timers
Counters total Backed by super capacitor or battery	256 counters 256 counters	256 counters 256 counters
Boolean execution speed	0.37 µs per instruction	0.37 µs per instruction
Move Word execution speed	34 µs per instruction	34 µs per instruction
Timer/Counter execution speed	50 µs to 64 µs per instruction	50 µs to 64 µs per instruction
Single precision math execution speed	46 µs per instruction	46 µs per instruction
Real math execution speed	100 µs to 400 µs per instruction	100 µs to 400 µs per instruction
Super capacitor data retention time	50 hours, typical, 8 hours min. at 40° C	50 hours, typical, 8 hours min. at 40° C

Table A-2 Specifications for CPU 221 DC/DC/DC and CPU 221 AC/DC/Relay (continued)

Description Order Number	CPU 221 DC/DC/DC 6ES7 211-0AA21-0XBO	CPU 221 AC/DC/Relay 6ES7 211-0BA21-0XB0
On-board Communication		
Number of ports	1 port	1 port
Electrical interface	RS-485	RS-485
Isolation (external signal to logic circuit)	Not isolated	Not isolated
PPI/MPI baud rates	9.6, 19.2, and 187.5 kbaud	9.6, 19.2, and 187.5 kbaud
Freeport baud rates	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud
Maximum cable length per segment up to 38.4 kbaud 187.5 kbaud	 1200 m 1000 m	 1200 m 1000 m
Maximum number of stations Per segment Per network	 32 stations 126 stations	 32 stations 126 stations
Maximum number of masters	32 masters	32 masters
PPI master mode (NETR/NETW)	Yes	Yes
MPI connections	4 total; 2 reserved: 1 for PG and 1 OP	4 total; 2 reserved: 1 for PG and 1 OP
Cartridge Options		
Memory cartridge (permanent storage)	Program, data, and configuration	Program, data, and configuration
Battery cartridge (data retention time)	200 days, typical	200 days, typical
Clock cartridge (clock accuracy)	2 minutes per month at 25° C 7 minutes per month 0° C to 55° C	2 minutes per month at 25° C 7 minutes per month 0° C to 55° C
Power Supply		
Line voltage-permissible range	20.4 to 28.8 VDC	85 to 264 VAC 47 to 63 Hz
Input current CPU only/max load	80/900 mA at 24 VDC	15/60 mA at 240 VAC 30/120 mA at 120 VAC
In rush current (max)	10 A at 28.8 VDC	20 A at 264 VAC
Isolation (input power to logic)	Not isolated	1500 VAC
Hold up time (from loss of input power)	10 ms at 24 VDC	80 ms at 240 VAC, 20 ms at 120 VAC
Internal fuse, not user-replaceable	2 A, 250 V, Slow Blow	2 A, 250 V, Slow Blow
24 VDC Sensor Power Output		
Voltage range	15.4 to 28.8 VDC	20.4 to 28.8 VDC
Maximum current	180 mA	180 mA
Ripple noise	Same as input line	Less than 1 V peak-to-peak (maximum)
Current limit	600 mA	600 mA
Isolation (sensor power to logic circuit)	Not isolated	Not isolated

Table A-2 Specifications for CPU 221 DC/DC/DC and CPU 221 AC/DC/Relay (continued)

Description Order Number	CPU 221 DC/DC/DC 6ES7 211-0AA21-0XBO	CPU 221 AC/DC/Relay 6ES7 211-0BA21-0XB0
Input Features		
Number of integrated inputs	6 inputs	6 inputs
Input type	Sink/Source (IEC Type 1 sink)	Sink/Source (IEC Type 1 sink)
Input Voltage		
Maximum continuous permissible	30 VDC	30 VDC
Surge	35 VDC for 0.5 s	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum	5 VDC at 1 mA, maximum
Isolation (Field Side to Logic Circuit)		
Optical isolation (galvanic)	500 VAC for 1 minute	500 VAC for 1 minute
Isolation groups of	4 points/2 points	4 points/2 points
Input Delay Times		
Filtered Inputs and Interrupt Inputs	0.2 to 12.8 ms, user-selectable	0.2 to 12.8 ms, user-selectable
HSC Clock Input Rate		
Single Phase		
Logic 1 Level = 15 to 30 VDC	20 kHz	20 kHz
Logic 1 Level = 15 to 26 VDC	30 kHz	30 kHz
Quadrature		
Logic 1 Level = 15 to 30 VDC	10 kHz	10 kHz
Logic 1 Level = 15 to 26 VDC	20 kHz	20 kHz
Connection of 2-Wire Proximity Sensor (Bero)		
Permissible leakage current	1 mA, maximum	1 mA, maximum
Cable Length		
Unshielded (not HSC)	300 m	300 m
Shielded	500 m	500 m
HSC inputs, shielded	50 m	50 m
Number of Inputs ON Simultaneously		
40 ° C	6	6
55 ° C	6	6
Output Features		
Number of integrated outputs	4 outputs	4 outputs
Output type	Solid State-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10 K Ω load	0.1 VDC, maximum	-
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of output groups	1	2
Number of outputs ON (maximum)	4	4
Per group - horizontal mounting (maximum)	4	3 and 1
Per group - vertical mounting (maximum)	4	3 and 1
Maximum current per common/group	3.0 A	6.0 A
Lamp load	5.0 W	30 W DC/200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2 Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No

Table A-2 Specifications for CPU 221 DC/DC/DC and CPU 221 AC/DC/Relay (continued)

Description Order Number	CPU 221 DC/DC/DC 6ES7 211-0AA21-0XBO	CPU 221 AC/DC/Relay 6ES7 211-0BA21-0XB0
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	4 points	3 points and 1 point
Inductive Load Clamping		
Repetitive Energy dissipation < 0.5 LI^2 x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48 V	-
Output Delay		
Off to On (Q0.0 and Q0.1)	2 µs, maximum	-
On to Off (Q0.0 and Q0.1)	10 µs, maximum	-
Off to On (Q0.2 and Q0.3)	15 µs, maximum	-
On to Off (Q0.2 and Q0.3)	100 µs, maximum	-
Switching Frequency (Pulse Train Outputs)		
Q0.0 and Q0.1	20 kHz, maximum	1 Hz, maximum
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	10,000,000 open/close cycles
Lifetime contacts at rated Load	-	100,000 open/close cycles
Cable Length		
Unshielded	150 m	150 m
Shielded	500 m	500 m

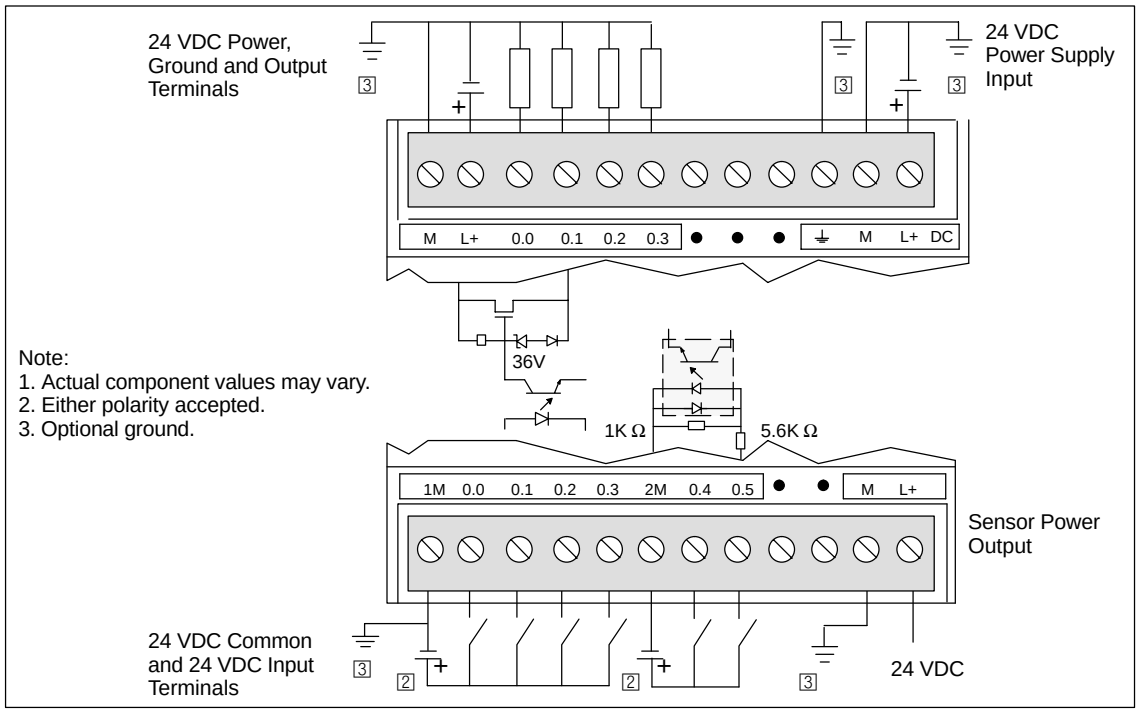


Figure A-2 Connector Terminal Identification for CPU 221 DC/DC/DC

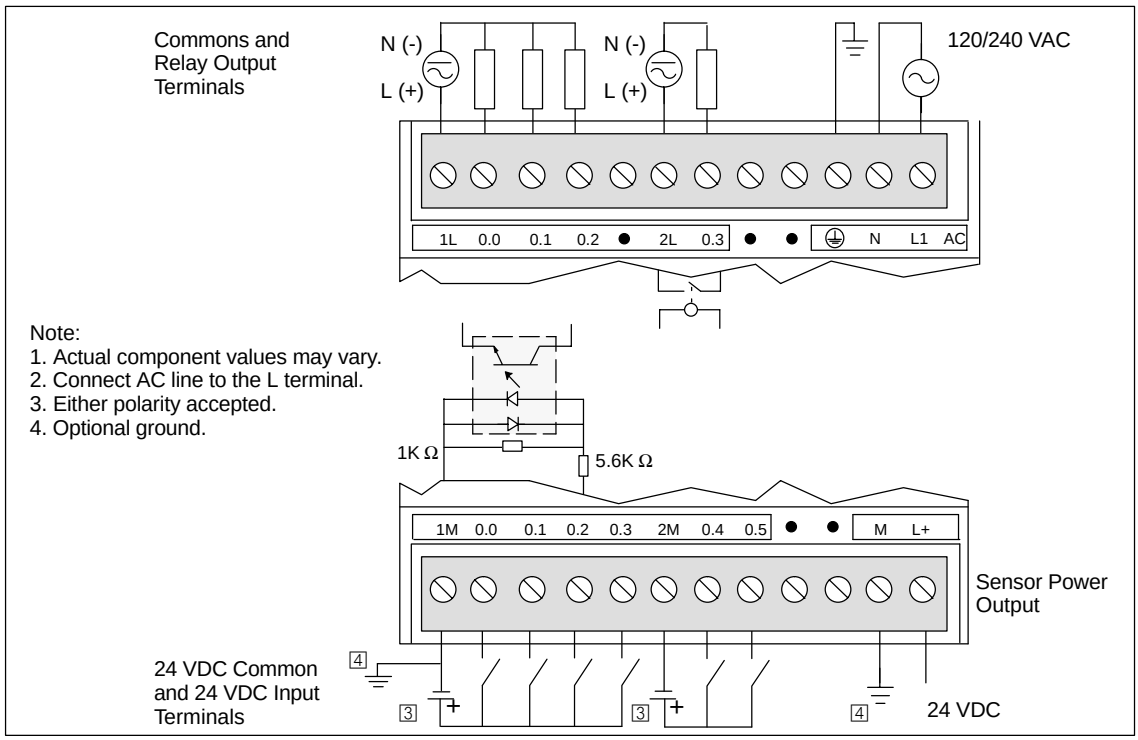


Figure A-3 Connector Terminal Identification for CPU 221 AC/DC/Relay

A.3 Specifications for the CPU 222, Firmware Release 1.1

Table A-3 Specifications for CPU 222 DC/DC/DC and CPU 222 AC/DC/Relay

Description Order Number	CPU 222 DC/DC/DC 6ES7 212-1AB21-0XB0	CPU 222 AC/DC/Relay 6ES7 212-1BB21-0XB0
Physical Size		
Dimensions (W x H x D)	90 mm x 80 mm x 62 mm	90 mm x 80 mm x 62 mm
Weight	270 g	310 g
Power loss (dissipation)	5 W	7 W
CPU Features		
On-board digital inputs	8 inputs	8 inputs
On-board digital outputs	6 outputs	6 outputs
High-speed counters (32 bit value) Total Single phase counters Two phase counters	 4 High-speed counters 4, each at 20 kHz clock rate 2, each at 20 kHz clock rate	 4 High-speed counters 4, each at 20 kHz clock rate 2, each at 20 kHz clock rate
Pulse outputs	2 at 20 kHz pulse rate	2 at 20 kHz pulse rate
Analog adjustments	1 with 8 bit resolution	1 with 8 bit resolution
Timed interrupts	2 with 1 ms resolution	2 with 1 ms resolution
Edge interrupts	4 edge up and/or 4 edge down	4 edge up and/or 4 edge down
Selectable input filter times	7 ranges from 0.2 ms to 12.8 ms	7 ranges from 0.2 ms to 12.8 ms
Pulse catch	8 pulse catch inputs	8 pulse catch inputs
Program size (stored permanently)	2048 words	2048 words
Data block size Stored permanently Backed by super capacitor or battery	1024 words 1024 words 1024 words	1024 words 1024 words 1024 words
Number of expansion I/O modules	2 modules	2 modules
Maximum digital I/O	256 points	256 points
Maximum analog I/O	16 inputs and 16 outputs	16 inputs and 16 outputs
Internal memory bits Stored permanently on power down Backed by super capacitor or battery	256 bits 112 bits 256 bits	256 bits 112 bits 256 bits
Timers Total Backed by super capacitor or battery 1 ms 10 ms 100 ms	256 timers 64 timers 4 timers 16 timers 236 timers	256 timers 64 timers 4 timers 16 timers 236 timers
Counters total Backed by super capacitor or battery	256 counters 256 counters	256 counters 256 counters
Boolean execution speed	0.37 µs per instruction	0.37 µs per instruction
Move word execution speed	34 µs per instruction	34 µs per instruction
Timer/Counter execution speed	50 µs to 64 µs per instruction	50 µs to 64 µs per instruction
Single precision math execution speed	46 µs per instruction	46 µs per instruction
Real math execution speed	100 µs to 400 µs per instruction	100 µs to 400 µs per instruction
Super capacitor data retention time	50 hours, typical, 8 hours minimum at 40° C	50 hours, typical, 8 hours minimum at 40° C

Table A-3 Specifications for CPU 222 DC/DC/DC and CPU 222 AC/DC/Relay (continued)

Description Order Number	CPU 222 DC/DC/DC 6ES7 212-1AB21-0XB0	CPU 222 AC/DC/Relay 6ES7 212-1BB21-0XB0
On-board Communication		
Number of ports	1 port	1 port
Electrical interface	RS-485	RS-485
Isolation (external signal to logic circuit)	Not isolated	Not isolated
PPI/MPI baud rates	9.6, 19.2, and 187.5 kbaud	9.6, 19.2, and 187.5 kbaud
Freeport baud rates	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud
Maximum cable length per segment		
up to 38.4 kbaud	1200 m	1200 m
187.5 kbaud	1000 m	1000 m
Maximum number of stations		
Per segment	32 stations	32 stations
Per network	126 stations	126 stations
Maximum number of masters	32 masters	32 masters
PPI master mode (NETR/NETW)	Yes	Yes
MPI connections	4 total, 2 reserved: 1 for PG and 1 OP	4 total, 2 reserved: 1 for PG and 1 OP
Cartridge Options		
Memory cartridge (permanent storage)	Program, Data, and Configuration	Program, Data, and Configuration
Battery cartridge (data retention time)	200 days, typical	200 days, typical
Clock cartridge (clock accuracy)	2 minutes per month at 25° C 7 minutes per month at 0° C to 55° C	2 minutes per month at 25° C 7 minutes per month at 0° C to 55° C
Power Supply		
Line voltage-permissible range	20.4 to 28.8 VDC	85 to 264 VAC, 47 to 63 Hz
Input current CPU only/max load	85/500 mA at 24 VDC	20/70 mA at 240 VAC 40/140 mA at 120 VAC
In rush current (maximum)	10 A at 28.8 VDC	20 A at 264 VAC
Isolation (input power to logic)	Not isolated	1500 VAC
Hold up time (from loss of input power)	10 ms at 24 VDC	80 ms at 240 VAC, 20 ms at 120 VAC
Internal Fuse, not user-replaceable	2 A, 250 V, Slow Blow	2 A, 250 V, Slow Blow
+5 Power for Expansion I/O (max)	340 mA	340 mA
24 VDC Sensor Power Output		
Voltage range	15.4 to 28.8 VDC	20.4 to 28.8 VDC
Maximum current	180 mA	180 mA
Ripple noise	Same as input line	Less than 1 V peak to peak (maximum)
Current limit	600 mA	600 mA
Isolation (sensor power to logic circuit)	Not isolated	Not isolated

Table A-3 Specifications for CPU 222 DC/DC/DC and CPU 222 AC/DC/Relay (continued)

Description Order Number	CPU 222 DC/DC/DC 6ES7 212-1AB21-0XB0	CPU 222 AC/DC/Relay 6ES7 212-1BB21-0XB0
Input Features		
Number of integrated inputs	8 inputs	8 inputs
Input type	Sink/Source (IEC Type 1 sink)	Sink/Source (IEC Type 1 sink)
Input Voltage		
Maximum continuous permissible	30 VDC	30 VDC
Surge	35 VDC for 0.5 s	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum	5 VDC at 1 mA, maximum
Isolation (Field Side to Logic Circuit)		
Optical isolation (Galvanic)	500 VAC for 1 minute	500 VAC for 1 minute
Isolation groups of	4 points	4 points
I**nput Delay Times**		
Filtered inputs and interrupt inputs	0.2 to 12.8 ms, user-selectable	0.2 to 12.8 ms, user-selectable
HSC Clock Input Rate		
Single Phase		
Logic 1 level = 15 to 30 VDC	20 kHz, maximum	20 kHz, maximum
Logic 1 level = 15 to 26 VDC	30 kHz, maximum	30 kHz, maximum
Quadrature		
Logic 1 level = 15 to 30 VDC	10 kHz, maximum	10 kHz, maximum
Logic 1 level = 15 to 26 VDC	20 kHz, maximum	20 kHz, maximum
Connection of 2 Wire Proximity Sensor (Bero)		
Permissible leakage current	1 mA, maximum	1 mA, maximum
Cable Length		
Unshielded (not HSC)	300 m	300 m
Shielded	500 m	500 m
HSC inputs, shielded	50 m	50 m
Number of Inputs ON Simultaneously		
40 ° C	8	8
55 ° C	8	8
Output Features		
Number of integrated outputs	6 outputs	6 outputs
Output type	Solid State-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10 K Ω load	0.1 VDC, maximum	-
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of output groups	1	2
Number of outputs ON (maximum)	6	6
Per group - horizontal mounting (maximum)	6	3
Per group - vertical mounting (maximum)	6	3
Maximum current per common/group	4.5 A	6 A
Lamp load	5 W	30 W DC/ 200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2 Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No

Table A-3 Specifications for CPU 222 DC/DC/DC and CPU 222 AC/DC/Relay (continued)

Description Order Number	CPU 222 DC/DC/DC 6ES7 212-1AB21-0XB0	CPU 222 AC/DC/Relay 6ES7 212-1BB21-0XB0
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	6 points	3 points
Inductive Load Clamping		
Repetitive energy dissipation < 0.5 LI^2 x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48V	-
Output Delay		
Off to On (Q0.0 and Q0.1)	2 µs, maximum	-
On to Off (Q0.0 and Q0.1)	10 µs, maximum	-
Off to On (Q0.2 through Q0.5)	15 µs, maximum	-
On to Off (Q0.2 through Q0.5)	100 µs, maximum	-
Switching Frequency (Pulse Train Outputs)		
Q0.0 and I0.1	20 kHz, maximum	1 Hz, maximum
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	10,000,000 open/close cycles
Lifetime contacts at rated load	-	100,000 open/close cycles
Cable Length		
Shielded	150 m	150 m
Unshielded	500 m	500 m

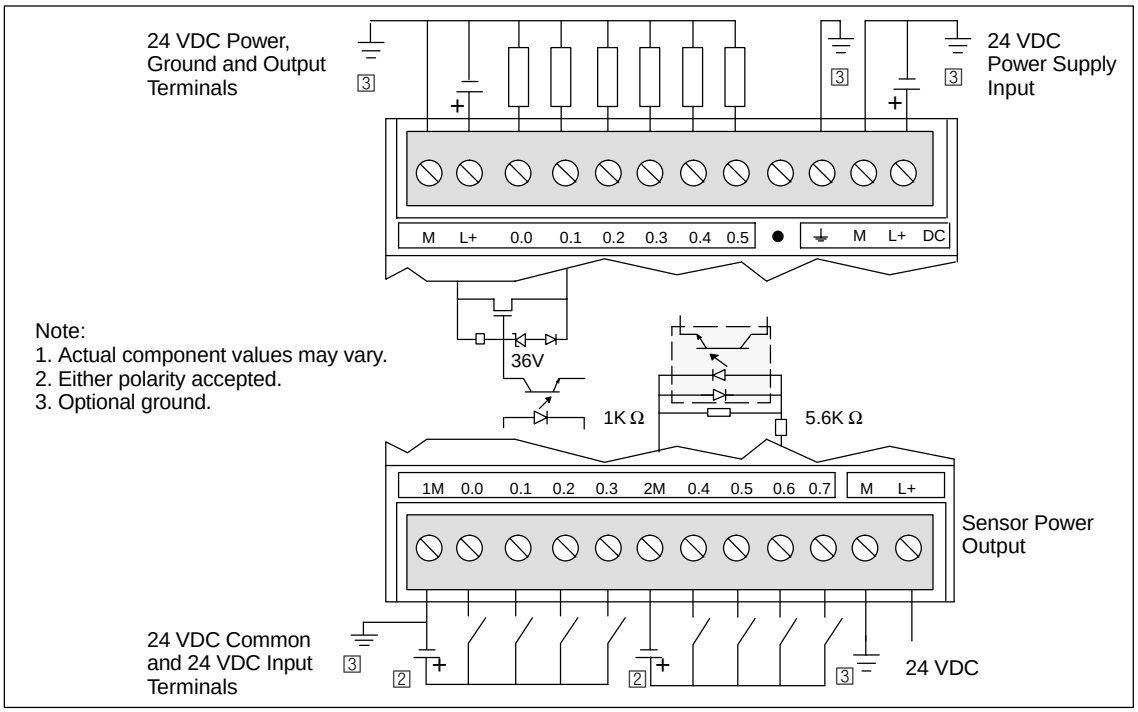


Figure A-4 Connector Terminal Identification for CPU 222 DC/DC/DC

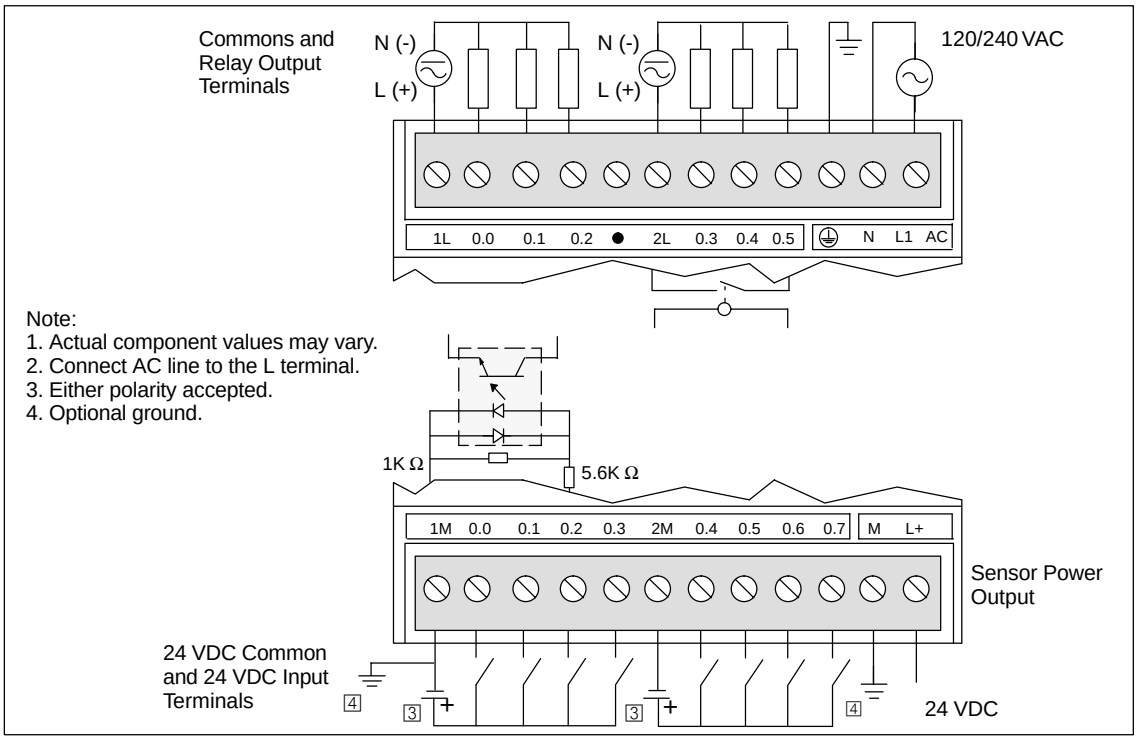


Figure A-5 Connector Terminal Identification for CPU 222 AC/DC/Relay

A.4 Specifications for the CPU 224, Firmware Release 1.1

Table A-4 Specifications for CPU 224 DC/DC/DC and CPU 224 AC/DC/Relay

Description Order Number	CPU 224 DC/DC/DC 6ES7 214-1AD21-0XB0	CPU 224 AC/DC/Relay 6ES7 214-1BD21-0XB0
Physical Size		
Dimensions (W x H x D)	120.5 mm x 80 mm x 62 mm	120.5 mm x 80 mm x 62 mm
Weight	360 g	410 g
Power loss (dissipation)	7 W	10 W
CPU Features		
On-board digital inputs	14 inputs	14 inputs
On-board digital outputs	10 outputs	10 outputs
High speed counters (32 bit value) Total Single phase counters Two phase counters	 6 High-speed counters 6, each at 20 kHz clock rate 4, each at 20 kHz clock rate	 6 High-speed counters 6, each at 20 kHz clock rate 4, each at 20 kHz clock rate
Pulse outputs	2 at 20 kHz pulse rate	2 at 20 kHz pulse rate
Analog adjustments	2 with 8 bit resolution	2 with 8 bit resolution
Timed interrupts	2 with 1 ms resolution	2 with 1 ms resolution
Edge interrupts	4 edge up and/or 4 edge down	4 edge up and/or 4 edge down
Selectable input filter times	7 ranges from 0.2 ms to 12.8 ms	7 ranges from 0.2 ms to 12.8 ms
Pulse Catch	14 pulse catch inputs	14 pulse catch inputs
Time of Day Clock (clock accuracy)	2 minutes per month at 25° C 7 minutes per month 0° C to 55° C	2 minutes per month at 25° C 7 minutes per month at 0° C to 55° C
Program size (stored permanently)	4096 words	4096 words
Data block size (stored permanently): Stored permanently Backed by super capacitor or battery	2560 words 2560 words 2560 words	2560 words 2560 words 2560 words
Number of expansion I/O modules	7 modules	7 modules
Maximum digital I/O	256 points	256 points
Maximum analog I/O	32 inputs and 32 outputs	32 inputs and 32 outputs
Internal memory bits Stored permanently on power down Backed by super capacitor or battery	256 bits 112 bits 256 bits	256 bits 112 bits 256 bits
Timers total Backed by super capacitor or battery 1 ms 10 ms 100 ms	256 timers 64 timers 4 timers 16 timers 236 timers	256 timers 64 timers 4 timers 16 timers 236 timers
Counters total Backed by super capacitor or battery	256 counters 256 counters	256 counters 256 counters
Boolean execution speed	0.37 µs per instruction	0.37 µs per instruction
Move Word execution speed	34 µs per instruction	34 µs per instruction
Timer/Counter execution speed	50 µs to 64 µs per instruction	50 µs to 64 per µs instruction
Single precision math execution speed	46 µs per instruction	46 µs per instruction
Real math execution speed	100 µs to 400 µs per instruction	100 µs to 400 µs per instruction
Super capacitor data retention time	190 hours, typical, 120 hours minimum at 40° C	190 hours, typical, 120 hours minimum at 40° C

Table A-4 Specifications for CPU 224 DC/DC/DC and CPU 224 AC/DC/Relay (continued)

Description Order Number	CPU 224 DC/DC/DC 6ES7 214-1AD21-0XB0	CPU 224 AC/DC/Relay 6ES7 214-1BD21-0XB0
On-board Communication		
Number of ports	1 port	1 port
Electrical interface	RS-485	RS-485
Isolation (external signal to logic circuit)	Not isolated	Not isolated
PPI/MPI baud rates	9.6, 19.2, and 187.5 kbaud	9.6, 19.2, and 187.5 kbaud
Freeport baud rates	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud
Maximum cable length per segment up to 38.4 kbaud 187.5 kbaud	 1200 m 1000 m	 1200 m 1000 m
Maximum number of stations Per segment Per Network	 32 stations 126 stations	 32 stations 126 stations
Maximum number of masters	32 masters	32 masters
PPI master mode (NETR/NETW)	Yes	Yes
MPI connections	4 total, 2 reserved: 1 for PG and 1 OP	4 total, 2 reserved: 1 for PG and 1 OP
Cartridge Options		
Memory cartridge (permanent storage)	Program, Data, and Configuration	Program, Data, and Configuration
Battery cartridge (data retention time)	200 days, typical	200 days, typical
Power Supply		
Line voltage-permissible range	20.4 to 28.8 VDC	85 to 264 VAC 47 to 63 Hz
Input current CPU only/max load	110/700 mA at 24 VDC	30/100 mA at 240 VAC 60/200 mA at 120 VAC
In rush current (maximum)	10 A at 28.8 VDC	20 A at 264 VAC
Isolation (input power to logic)	Not isolated	1500 VAC
Hold up time (from loss of input power)	10 ms at 24 VDC	80 ms at 240 VAC, 20 ms at 120 VAC
Internal fuse, not user-replaceable	2 A, 250 V, Slow Blow	2 A, 250 V, Slow Blow
+5 Power for Expansion I/O (max)	660 mA	660 mA
24 VDC Sensor Power Output		
Voltage range	15.4 to 28.8 VDC	20.4 to 28.8 VDC
Maximum current	280 mA	280 mA
Ripple noise	Same as input line	Less than 1 V peak-to-peak (maximum)
Current limit	600 mA	600 mA
Isolation (sensor power to logic circuit)	Not isolated	Not isolated

Table A-4 Specifications for CPU 224 DC/DC/DC and CPU 224 AC/DC/Relay (continued)

Description Order Number	CPU 224 DC/DC/DC 6ES7 214-1AD21-0XB0	CPU 224 AC/DC/Relay 6ES7 214-1BD21-0XB0
Input Features		
Number of integrated inputs	14 inputs	14 inputs
Input type	Sink/Source (IEC Type 1)	Sink/Source (IEC Type 1)
Input Voltage		
Maximum continuous permissible	30 VDC	30 VDC
Surge	35 VDC for 0.5 s	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum	5 VDC at 1 mA, maximum
Isolation (Field Side to Logic Circuit)		
Optical isolation (galvanic)	500 VAC for 1 minute	500 VAC for 1 minute
Isolation groups of	8 points and 6 points	8 points and 6 points
Input Delay Times		
Filtered inputs and interrupt inputs	0.2 to 12.8 ms, user-selectable	0.2 to 12.8 ms, user-selectable
HSC clock input rate		
Single Phase		
Logic 1 level = 15 to 30 VDC	20 kHz	20 kHz
Logic 1 level = 15 to 26 VDC	30 kHz	30 kHz
Quadrature		
Logic 1 level = 15 to 30 VDC	10 kHz	10 kHz
Logic 1 level = 15 to 26 VDC	20 kHz	20 kHz
Connection of 2 Wire Proximity Sensor (Bero)		
Permissible leakage current	1 mA, maximum	1 mA, maximum
Cable Length		
Unshielded (not HSC)	300 m	300 m
Shielded	500 m	50 m
HSC inputs, shielded	50 m	50 m
Number of Inputs ON Simultaneously		
40 ° C	14	14
55 ° C	14	14
Output Features		
Number of integrated outputs	10 outputs	10 outputs
Output type	Solid state-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10 K Ω load	0.1 VDC, maximum	-
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of output groups	2	3
Number of outputs ON (maximum)	10	10
Per group - horizontal mounting (maximum)	5	4/3/3
Per group - vertical mounting (maximum)	5	4/3/3
Maximum current per common/group	3.75 A	8 A
Lamp load	5 W	30 W DC/200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2 Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No

Table A-4 Specifications for CPU 224 DC/DC/DC and CPU 224 AC/DC/Relay (continued)

Description Order Number	CPU 224 DC/DC/DC 6ES7 214-1AD21-0XB0	CPU 224 AC/DC/Relay 6ES7 214-1BD21-0XB0
Isolation (Field Side to Logic)		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	5 points	4 points/3 points/3 points
Inductive Load Clamping		
Repetitive Energy dissipation < 0.5 LI^2 x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48V	-
Output Delay		
Off to On (Q0.0 and Q0.1)	2 µs, maximum	-
On to Off (Q0.0 and Q0.1)	10 µs, maximum	-
Off to On (Q0.2 through Q1.1)	15 µs, maximum	-
On to Off (Q0.2 through Q1.1)	100 µs, maximum	-
Switching Frequency (Pulse Train Outputs)		
Q0.0 and I0.1	20 kHz, maximum	1 Hz, maximum
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	10,000,000 open/close cycles
Lifetime contacts at rated load	-	100,000 open/close cycles
Cable Length		
Unshielded	150 m	150 m
Shielded	500 m	500 m

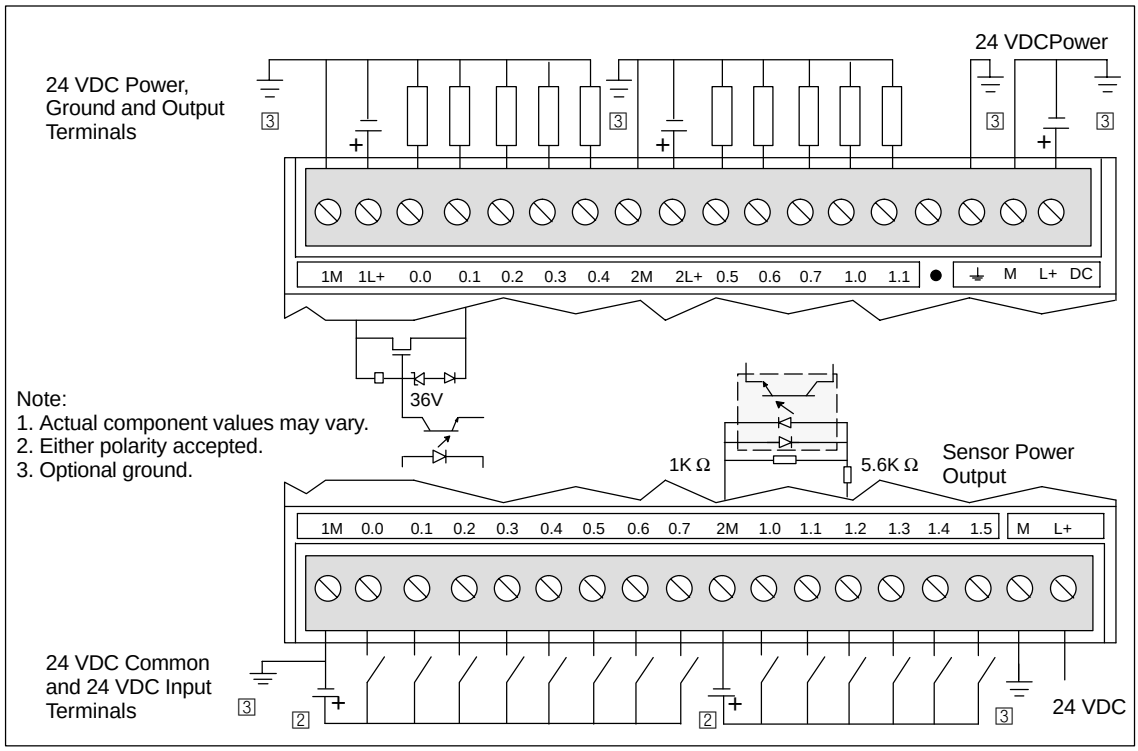


Figure A-6 Connector Terminal Identification for CPU 224 DC/DC/DC

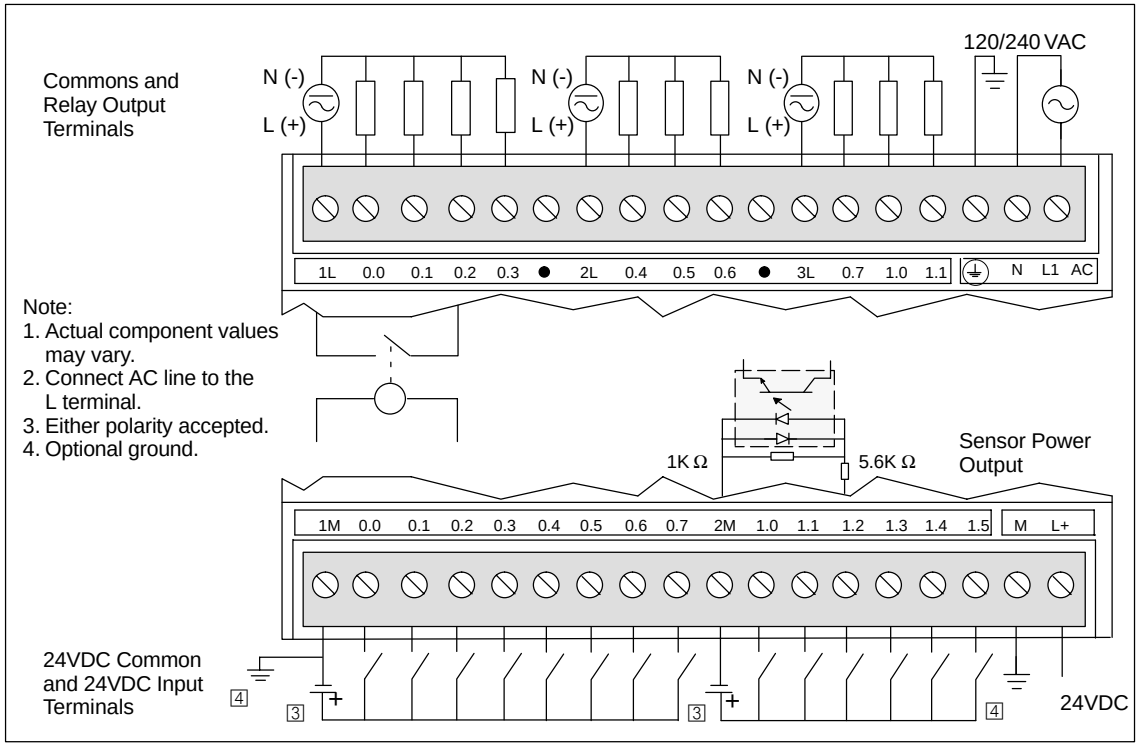


Figure A-7 Connector Terminal Identification for CPU 224 AC/DC/Relay

A.5 Specifications for the CPU 226

Table A-5 Specifications for CPU 226 DC/DC/DC and CPU 226 AC/DC/Relay

Description Order Number	CPU 226 DC/DC/DC 6ES7 216-2AD21-0XB0	CPU 226 AC/DC/Relay 6ES7 216-2BD21-0XB0
Physical Size		
Dimensions (W x H x D)	196 mm x 80 mm x 62 mm	196 mm x 80 mm x 62 mm
Weight	550 g	660 g
Power loss (dissipation)	11 W	17 W
CPU Features		
On-board digital inputs	24 inputs	24 inputs
On-board digital outputs	16 outputs	16 outputs
High speed counters (32 bit value) Total Single phase counters Two phase counters	 6 High-speed counters 6, each at 20 kHz clock rate 4, each at 20 kHz clock rate	 6 High-speed counters 6, each at 20 kHz clock rate 4, each at 20 kHz clock rate
Pulse outputs	2 at 20 kHz pulse rate	2 at 20 kHz pulse rate
Analog adjustments	2 with 8 bit resolution	2 with 8 bit resolution
Timed interrupts	2 with 1 ms resolution	2 with 1 ms resolution
Edge interrupts	4 edge up and/or 4 edge down	4 edge up and/or 4 edge down
Selectable input filter times	7 ranges from 0.2 ms to 12.8 ms	7 ranges from 0.2 ms to 12.8 ms
Pulse Catch	14 pulse catch inputs	14 pulse catch inputs
Time of Day Clock (clock accuracy)	2 minutes per month at 25° C 7 minutes per month 0° C to 55° C	2 minutes per month at 25° C 7 minutes per month at 0° C to 55° C
Program size (stored permanently)	4096 words	4096 words
Data block size (stored permanently): Stored permanently Backed by super capacitor or battery	2560 words 2560 words 2560 words	2560 words 2560 words 2560 words
Number of expansion I/O modules	7 modules	7 modules
Maximum digital I/O	256 points	256 points
Maximum analog I/O	32 inputs and 32 outputs	32 inputs and 32 outputs
Internal memory bits Stored permanently on power down Backed by super capacitor or battery	256 bits 112 bits 256 bits	256 bits 112 bits 256 bits
Timers total Backed by super capacitor or battery 1 ms 10 ms 100 ms	256 timers 64 timers 4 timers 16 timers 236 timers	256 timers 64 timers 4 timers 16 timers 236 timers
Counters total Backed by super capacitor or battery	256 counters 256 counters	256 counters 256 counters
Boolean execution speed	0.37 µs per instruction	0.37 µs per instruction
Move Word execution speed	34 µs per instruction	34 µs per instruction
Timer/Counter execution speed	50 µs to 64 µs per instruction	50 µs to 64 per µs instruction
Single precision math execution speed	46 µs per instruction	46 µs per instruction
Real math execution speed	100 µs to 400 µs per instruction	100 µs to 400 µs per instruction
Super capacitor data retention time	190 hours, typical, 120 hours minimum at 40° C	190 hours, typical, 120 hours minimum at 40° C

Table A-5 Specifications for CPU 226 DC/DC/DC and CPU 226 AC/DC/Relay (continued)

Description Order Number	CPU 226 DC/DC/DC 6ES7 216-2AD21-0XB0	CPU 226 AC/DC/Relay 6ES7 216-2BD21-0XB0
On-board Communication		
Number of ports	2 ports	2 ports
Electrical interface	RS-485	RS-485
Isolation (external signal to logic circuit)	Not isolated	Not isolated
PPI/MPI baud rates	9.6, 19.2, and 187.5 kbaud	9.6, 19.2, and 187.5 kbaud
Freeport baud rates	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud	0.3, 0.6, 1.2, 2.4, 4.8, 9.6, 19.2, and 38.4 kbaud
Maximum cable length per segment		
up to 38.4 kbaud	1200 m	1200 m
187.5 kbaud	1000 m	1000 m
Maximum number of stations		
Per segment	32 stations	32 stations
Per network	126 stations	126 stations
Maximum number of masters	32 masters	32 masters
PPI master mode (NETR/NETW)	Yes	Yes
MPI connections	4 total, 2 reserved: 1 for PG and 1 OP	4 total, 2 reserved: 1 for PG and 1 OP
Cartridge Options		
Memory cartridge (permanent storage)	Program, Data, and Configuration	Program, Data, and Configuration
Battery cartridge (data retention time)	200 days, typical	200 days, typical
Power Supply		
Line voltage-permissible range	20.4 to 28.8 VDC	85 to 264 VAC 47 to 63 Hz
Input current CPU only/max load	150/1050 mA	40/160 mA at 240 VAC 80/320 mA at 120 VAC
In rush current (maximum)	10 A at 28.8 VDC	20 A at 264 VAC
Isolation (input power to logic)	Not isolated	1500 VAC
Hold up time (from loss of input power)	10 ms at 24 VDC	80 ms at 240 VAC, 20 ms at 120 VAC
Internal fuse, not user-replaceable	3 A, 250 V, Slow Blow	2 A, 250 V, Slow Blow
+5 Power for Expansion I/O (max)	1000 mA	1000 mA
24 VDC Sensor Power Output		
Voltage range	15.4 to 28.8 VDC	20.4 to 28.8 VDC
Maximum current	400 mA	400 mA
Ripple noise	Same as input line	Less than 1 V peak-to-peak (maximum)
Current limit	1.5 A Approx.	1.5 A Approx.
Isolation (sensor power to logic circuit)	Not isolated	Not isolated

Table A-5 Specifications for CPU 226 DC/DC/DC and CPU 226 AC/DC/Relay (continued)

Description Order Number	CPU 226 DC/DC/DC 6ES7 216-2AD21-0XB0	CPU 226 AC/DC/Relay 6ES7 216-2BD21-0XB0
Input Features		
Number of integrated inputs	24 inputs	24 inputs
Input type	Sink/Source (IEC Type 1)	Sink/Source (IEC Type 1)
Input Voltage		
Maximum continuous permissible	30 VDC	30 VDC
Surge	35 VDC for 0.5 s	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum	5 VDC at 1 mA, maximum
Isolation (Field Side to Logic Circuit)		
Optical isolation (galvanic)	500 VAC for 1 minute	500 VAC for 1 minute
Isolation groups of	13 points and 11 points	13 points and 11 points
Input Delay Times		
Filtered inputs and interrupt inputs	0.2 to 12.8 ms, user-selectable	0.2 to 12.8 ms, user-selectable
HSC clock input rate		
Single Phase		
Logic 1 level = 15 to 30 VDC	20 kHz	20 kHz
Logic 1 level = 15 to 26 VDC	30 kHz	30 kHz
Quadrature		
Logic 1 level = 15 to 30 VDC	10 kHz	10 kHz
Logic 1 level = 15 to 26 VDC	20 kHz	20 kHz
Connection of 2 Wire Proximity Sensor (Bero) Permissible leakage current	1 mA, maximum	1 mA, maximum
Cable Length		
Unshielded (not HSC)	300 m	300 m
Shielded	500 m	50 m
HSC inputs, shielded	50 m	50 m
Number of Inputs ON Simultaneously		
40 ° C	24	24
55 ° C	24	24

Table A-5 Specifications for CPU 226 DC/DC/DC and CPU 226 AC/DC/Relay (continued)

Description Order Number	CPU 226 DC/DC/DC 6ES7 216-2AD21-0XB0	CPU 226 AC/DC/Relay 6ES7 216-2BD21-0XB0
Output Features		
Number of integrated outputs	16 outputs	16 outputs
Output type	Solid state-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10 K Ω load	0.1 VDC, maximum	-
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of output groups	2	3
Number of outputs ON (maximum)	16	16
Per group - horizontal mounting (maximum)	8	4/5/7
Per group - vertical mounting (maximum)	8	4/5/7
Maximum current per common/group	6 A	10 A
Lamp load	5 W	30 W DC/200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No
Isolation (Field Side to Logic)		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	8 points	4 points/5 points/7 points
Inductive Load Clamping		
Repetitive Energy dissipation < 0.5 LI^2 x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48V	-
Output Delay		
Off to On (Q0.0 and Q0.1)	2 µs, maximum	-
On to Off (Q0.0 and Q0.1)	10 µs, maximum	-
Off to On (Q0.2 through Q1.7)	15 µs, maximum	-
On to Off (Q0.2 through Q1.7)	100 µs, maximum	-
Switching Frequency (Pulse Train Outputs) Q0.0 and Q0.1	20 kHz, maximum	1 Hz, maximum
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	10,000,000 open/close cycles
Lifetime contacts at rated load	-	100,000 open/close cycles
Cable Length		
Unshielded	150 m	150 m
Shielded	500 m	500 m

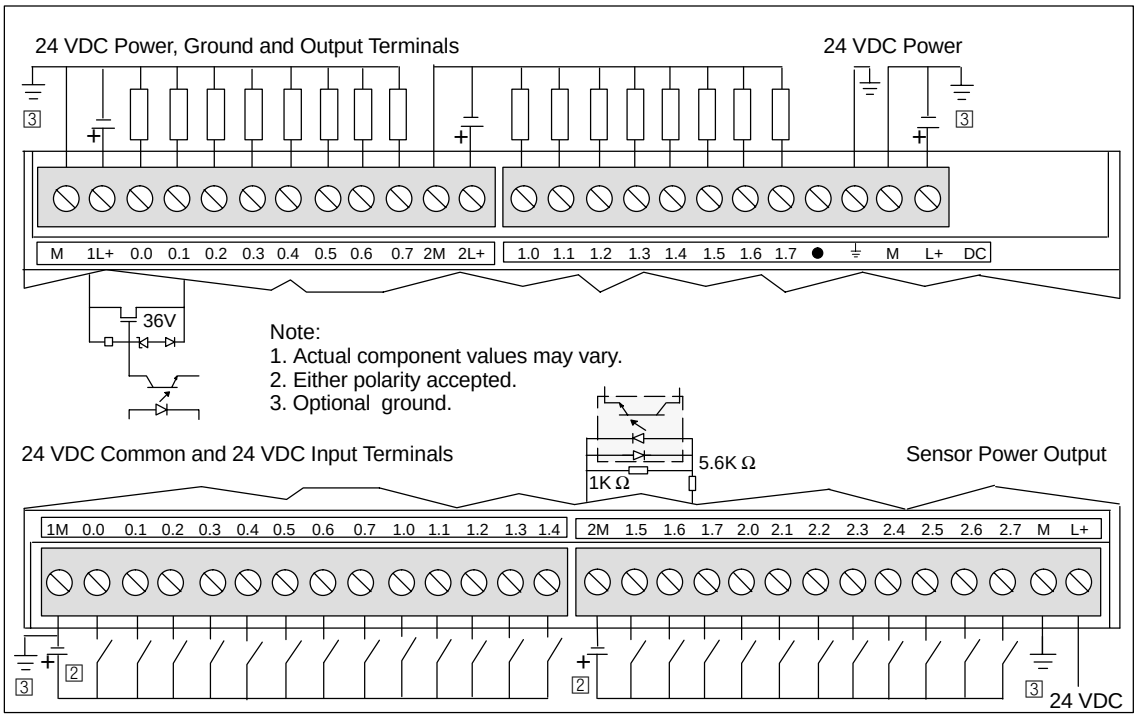


Figure A-8 Connector Terminal Identification for CPU 226 DC/DC/DC

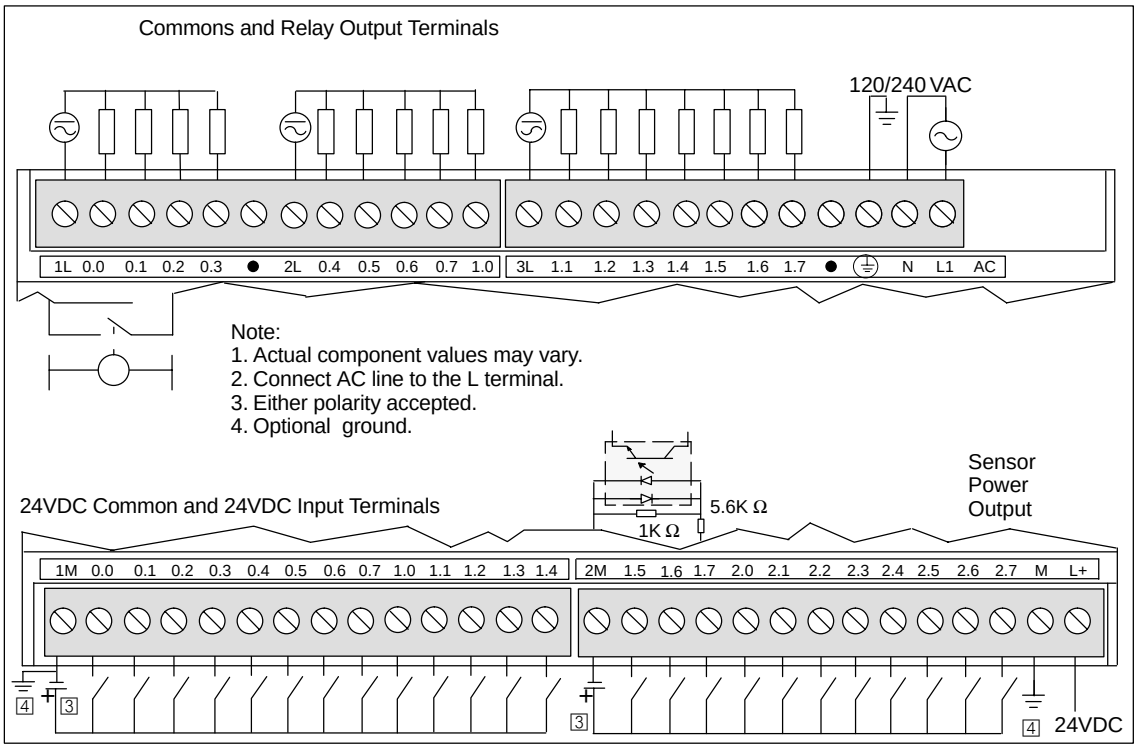


Figure A-9 Connector Terminal Identification for CPU 226 AC/DC/Relay

A.6 Specifications for the EM 221 Digital Input Module

Table A-6 Specifications for EM 221 24 VDC, 8 Digital Input Module

Description Order Number	EM 221 DI8 X DC24V 6ES7 221-1BF20-0XA0
Physical Size	
Dimensions (W x H x D)	46 x 80 x 62 mm
Weight	150 g
Power loss (dissipation)	2 W
Input Features	
Number of integrated inputs	8 inputs
Input type	Sink/Source (IEC Type 1 sink)
Input Voltage	
Maximum continuous permissible	30 VDC
Surge	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum
Isolation	
Optical isolation (galvanic)	500 VAC for 1 minute
Isolation groups of	4 points
Input Delay Times	
Maximum	4.5 ms
Connection of 2-Wire Proximity Sensor (Bero)	
Permissible leakage current	1 mA, maximum
Cable Length	
Unshielded	300 m
Shielded	500 m
Number of Inputs ON Simultaneously	
40 ° C	8
55 ° C	8
Power Consumption	
From +5 VDC (from I/O bus)	30 mA

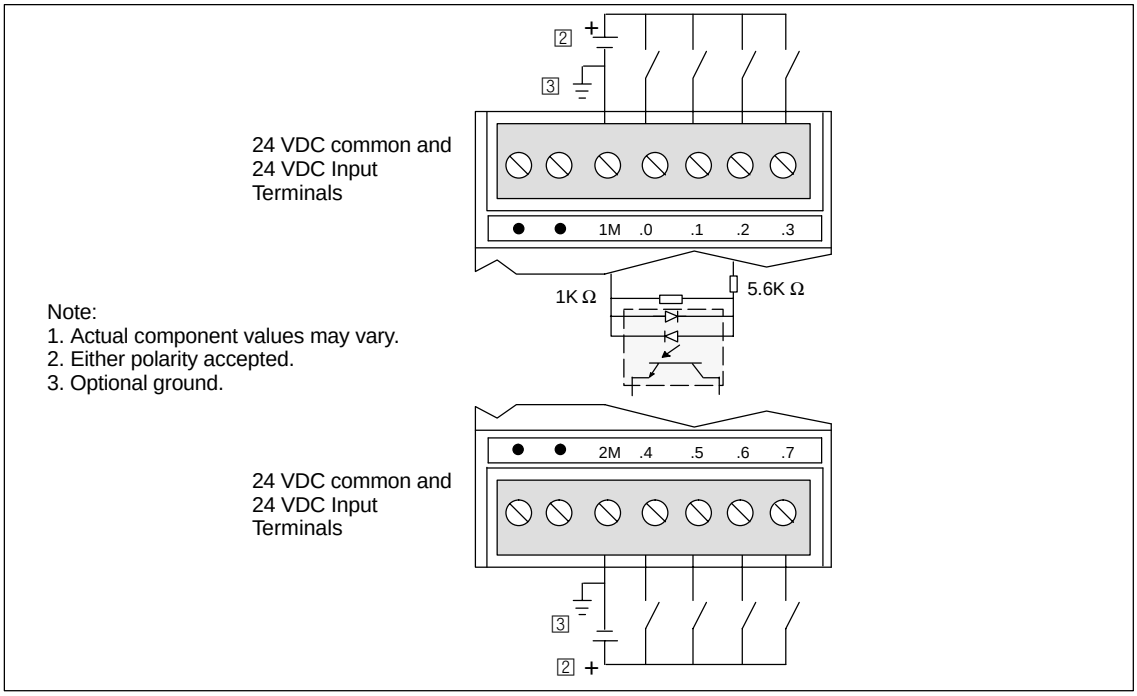


Figure A-10 Connector Terminal Identification for EM 221 Digital Input 8 x 24 VDC

A.7 Specifications for the EM 222 Digital Output Modules

Table A-7 Specifications for EM 222 24 VDC Output and Relay Output Modules

Description Order Number	EM 222 DO8 X DC24V 6ES7 222-1BF20-0XA0	EM 222 DO8 X Rly 6ES7 222-1HF20-0XA0
Physical Size		
Dimensions (W x H x D)	46 x 80 x 62 mm	46 x 80 x 62 mm
Weight	150 g	170 g
Power loss (dissipation)	2 W	2 W
Output Features		
Number of outputs	8 points	8 points
Output type	Solid state-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC, or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10 K Ω load	0.1 VDC, maximum	-
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of outputs groups	2	2
Number of outputs on (maximum)	8	8
Per group - horizontal mounting (maximum)	4	4
Per group - vertical mounting (maximum)	4	4
Maximum current per common/group	3 A	8 A
Lamp load	5 W	30 W DC/200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2 Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	4 points	4 points
Inductive Load Clamping		
Repetitive Energy dissipation $< 0.5\ LI^2$ x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48 V	-
Output Delay		
Off to On	50 µs, maximum	-
On to Off	200 µs, maximum	-
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	10,000,000 open/close cycles
Lifetime contacts at rated load	-	100,000 open/close cycles
Cable Length		
Unshielded	150 m	150 m
Shielded	500 m	500 m
Power Consumption		
From +5 VDC (from I/O bus)	50 mA	40 mA
From L+	-	9 mA per output when ON
L+ coil power voltage range	-	20.4 to 28.8 VDC

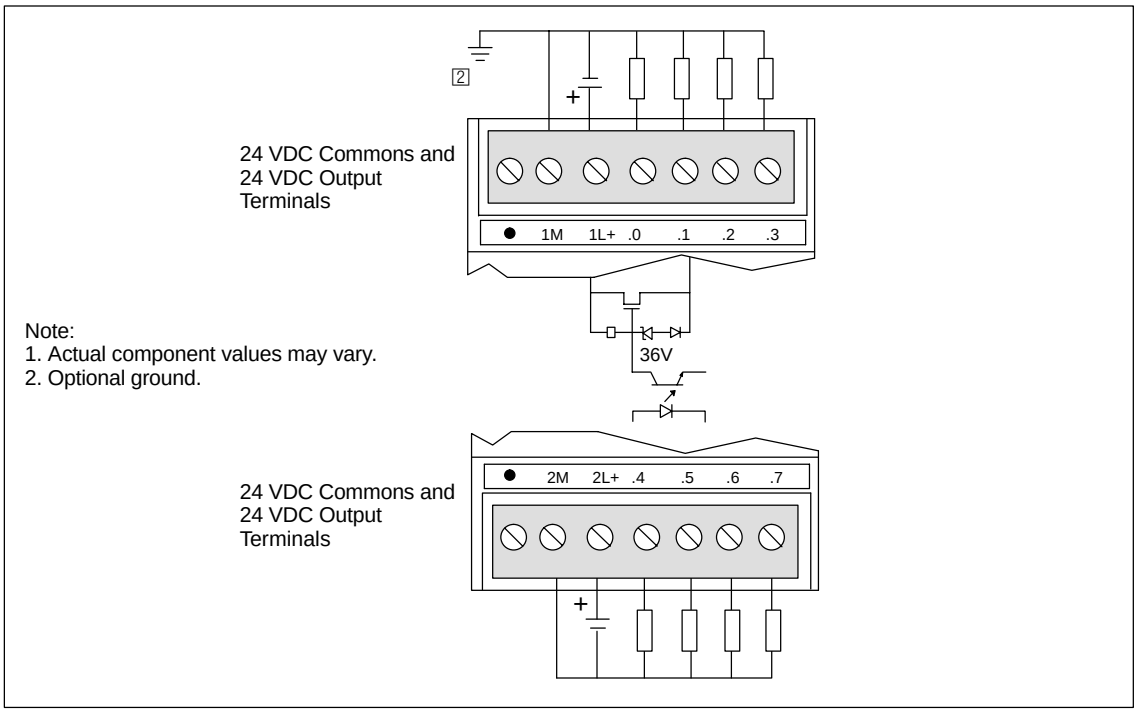


Figure A-11 Connector Terminal Identification for EM 222 Digital Output 8 x 24 VDC

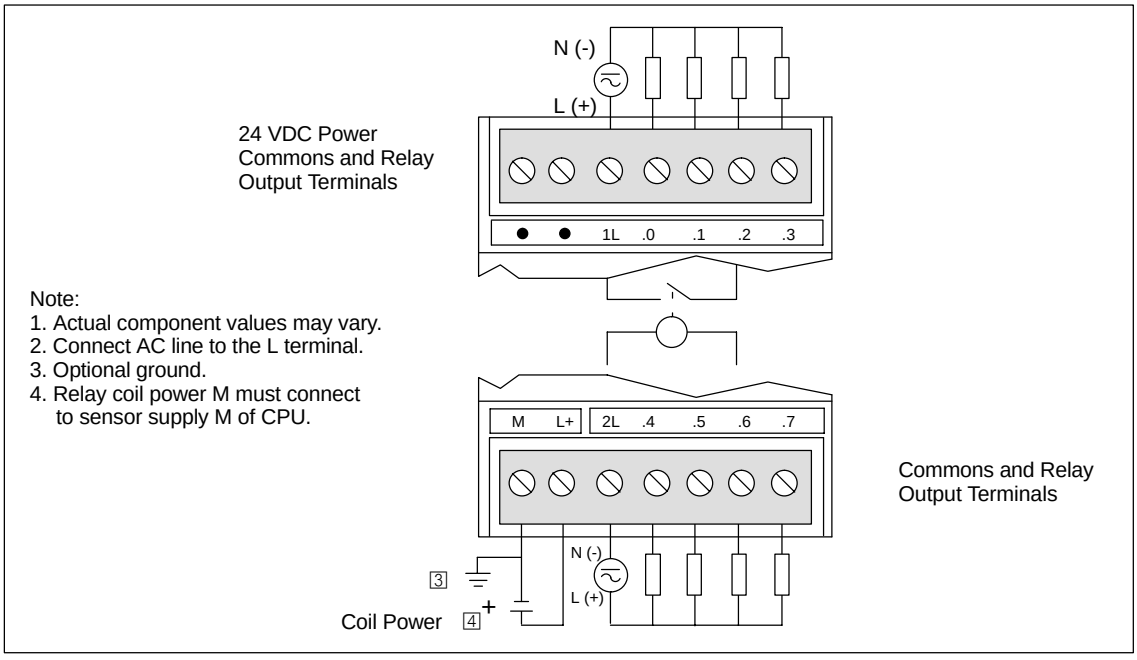


Figure A-12 Connector Terminal Identification for EM 222 Digital Output 8 x Relay

A.8 Specifications for the EM 223 Digital Combination Modules, 4 Inputs/4 Outputs

Table A-8 Specifications for EM 223 24 VDC 4 In/4 Out and EM 223 24 VDC 4 In/4 Relay Out

Description Order Number	EM 223 DI4/DO4 X DC24V 6ES7 223-1BF20-0XA0	EM 223 DI4/DO4 X DC24V/Rly 6ES7 223-1HF20-0XA0
Physical Size		
Dimensions (W x H x D)	46 mm x 80 mm x 62 mm	46 mm x 80 mm x 62 mm
Weight	160 g	170 g
Power loss (dissipation)	2 W	2 W
Input Features		
Number of inputs	4 inputs	4 inputs
Input type	Sink/Source (IEC Type 1 sink)	Sink/Source (IEC Type 1 sink)
Input Voltage		
Maximum continuous permissible	30 VDC	30 VDC
Surge	35 VDC for 0.5 s	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum	5 VDC at 1 mA, maximum
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	500 VAC for 1 minute
Isolation groups of	4 points	4 points
Input Delay Times		
Maximum	4.5 ms	4.5 ms
Connection of 2-Wire Proximity Sensor (Bero)		
Maximum	1 mA	1 mA
Cable Length		
Unshielded	300 m	300 m
Shielded	500 m	500 m
Number of Inputs On Simultaneously		
40 ° C	4	4
55 ° C	4	4

Table A-8 Specifications for EM 223 24 VDC 4 In/4 Out and EM 223 24 VDC 4 In/4 Relay Out

Description Order Number	EM 223 DI4/DO4 X DC24V 6ES7 223-1BF20-0XA0	EM 223 DI4/DO4 X DC24V/Rly 6ES7 223-1HF20-0XA0
Output Features		
Number of integrated outputs	4 points	4 points
Output type	Solid State-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10K Ω load	0.1 VDC, maximum	-
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of output groups	1	1
Number of outputs on (maximum)	4	4
Per group - horizontal mounting (maximum)	4	4
Per group - vertical mounting (maximum)	4	4
Maximum current per common/group	3 A	8 A
Lamp load	5 W	30 W DC/200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2 Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	4 points	4 points
Inductive Load Clamping		
Repetitive Energy dissipation < 0.5 LI^2 x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48V	-
Output Delay		
Off to On	50 µs, maximum	-
On to Off	200 µs, maximum	-
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	10,000,000 open/close cycles
Lifetime contacts at rated load	-	100,000 open/close cycles
Cable Length		
Unshielded	150 m	150 m
Shielded	500 m	500 m
Power Consumption		
From +5 VDC (from I/O bus)	40 mA	40 mA
From L+	-	9 mA per output when On
L+ coil power voltage range	-	20.4 to 28.8 VDC

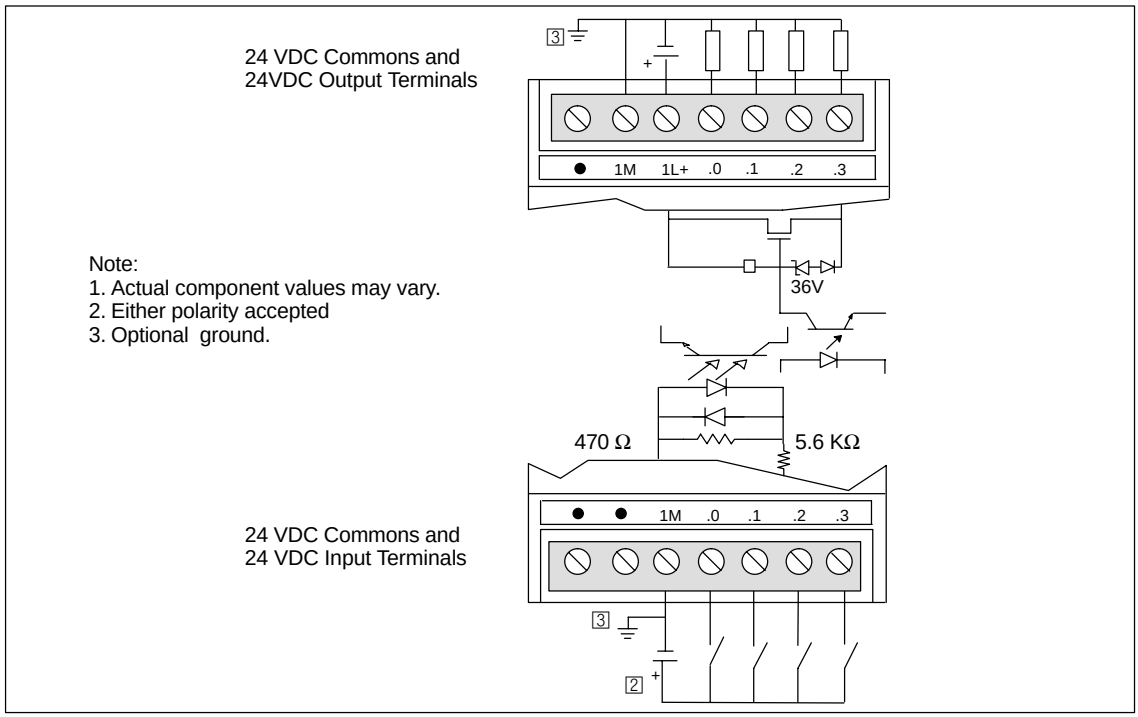


Figure A-13 Connector Terminal Identification for EM 223 4 x 24 VDC In/4 x 24 VDC Out

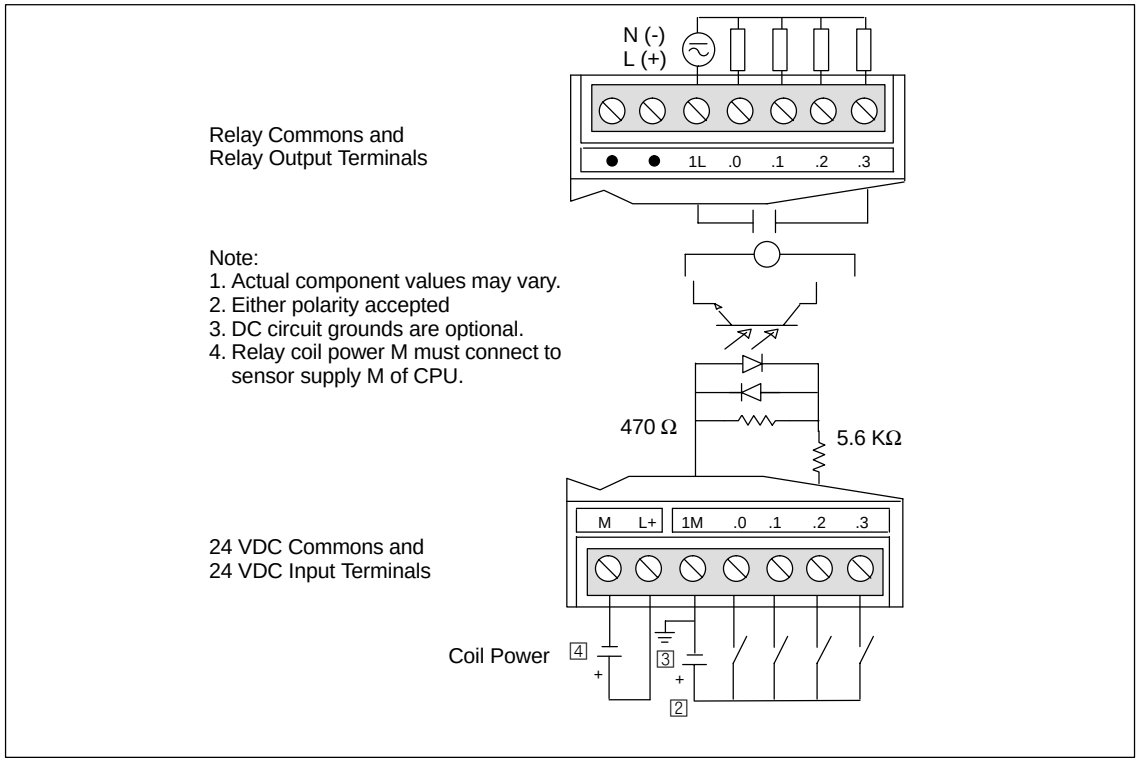


Figure A-14 Connector Terminal Identification for EM 223 4 x 24 VDC In/4 x Relay Out

A.9 Specifications for the EM 223 Digital Combination Modules, 8 Inputs/8 Outputs

Table A-9 Specifications for EM 223 24 VDC 8 In/8 Out, and EM 223 24 VDC 8 In/8 Relay Out

Description Order Number	EM 223 DI8/DO8 X DC24V 6ES7 223-1BH20-0XA0	EM 223 DI8/DO8 X DC24V/Rly 6ES7 223-1PH20-0XA0
Physical Size		
Dimensions (W x H x D)	71.2 mm x 80 mm x 62 mm	71.2 mm x 80 mm x 62 mm
Weight	200 g	300 g
Power loss (dissipation)	3 W	3 W
Input Features		
Number of inputs	8 inputs	8 inputs
Input type	Sink/Source (IEC Type 1 sink)	Sink/Source (IEC Type 1 sink)
Input Voltage		
Maximum continuous permissible	30 VDC	30 VDC
Surge	35 VDC for 0.5 s	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum	5 VDC at 1 mA, maximum
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	500 VAC for 1 minute
Isolation groups of	4 points	4 points
Input Delay Times		
Maximum	4.5 ms	4.5 ms
Connection of 2-Wire Proximity Sensor (Bero)		
Maximum	1 mA	1 mA
Cable Length		
Unshielded	300 m	300 m
Shielded	500 m	500 m
Number of Inputs On Simultaneously		
40 ° C	8	8
55 ° C	8	8
Output Features		
Number of integrated outputs	8 points	8 points
Output type	Solid State-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10K Ω load	0.1 VDC, maximum	-

Table A-9 Specifications for EM 223 24 VDC 8 In/8 Out, and EM 223 24 VDC 8 In/8 Relay Out

Description Order Number	EM 223 DI8/DO8 X DC24V 6ES7 223-1BH20-0XA0	EM 223 DI8/DO8 X DC24V/Rly 6ES7 223-1PH20-0XA0
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of outputs groups	2	2
Number of outputs on (maximum)	8	8
Per group - horizontal mounting (maximum)	4	4
Per group - vertical mounting (maximum)	4	4
Maximum current per common/group	3 A	8 A
Lamp load	5 W	30 W DC/200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2 Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	4 points	4 points
Inductive Load Clamping		
Repetitive Energy dissipation $< 0.5\ LI^2$ x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48V	-
Output Delay		
Off to On	50 µs, maximum	-
On to Off	200 µs, maximum	-
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	100,000,000 open/close cycles
Lifetime contacts at rated load	-	100,000 open/close cycles
Cable Length		
Unshielded	150 m	150 m
Shielded	500 m	500 m
Power Consumption		
From +5 VDC (from I/O bus)	80 mA	80 mA
From L+	-	9 mA per output when On
L+ coil power voltage range	-	20.4 to 28.8 VDC

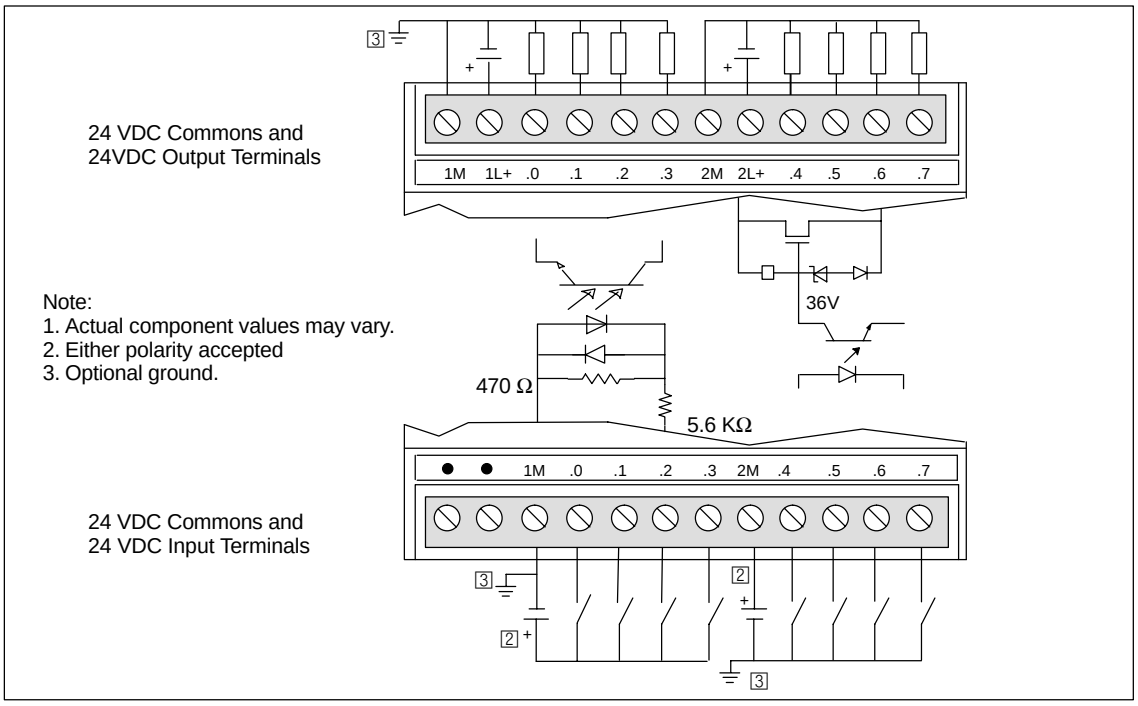


Figure A-15 Connector Terminal Identification for EM 223 Digital Combination 8 x 24 VDC Inputs/8 x 24 VDC Outputs

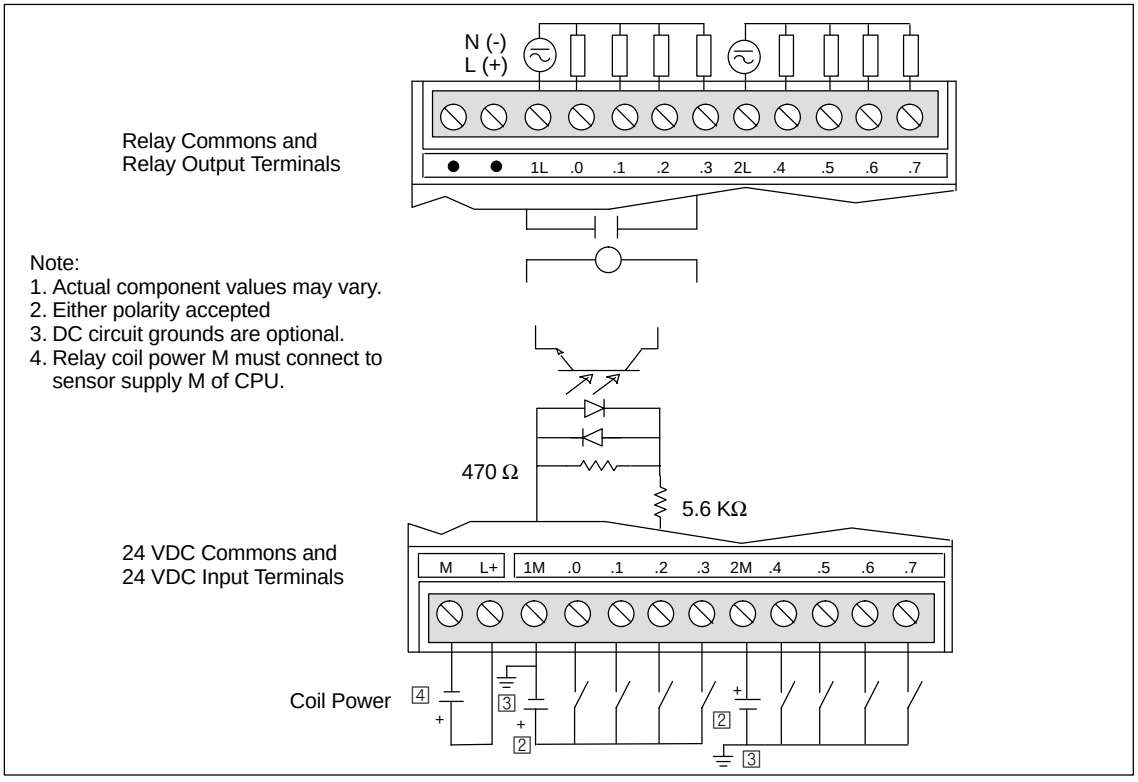


Figure A-16 Connector Terminal Identification for EM 223 Digital 8 x 24 VDC Input/8 x Relay Output

A.10 Specifications for the EM 223 Digital Combination Modules, 16 Inputs/16 Outputs

Table A-10 Specifications for EM 223 24 VDC 16 In/16 Out and EM 223 24 VDC 16 In/16 Relay Out

Description Order Number	EM 223 DI16/DO16 X DC24V 6ES7 223-1BL20-0XA0	EM 223 DI16/DO16 X DC24V/Rly 6ES7 223-1PL20-0XA0
Physical Size		
Dimensions (W x H x D)	137.3 mm x 80 mm x 62 mm	137.3 mm x 80 mm x 62 mm
Weight	360 g	400 g
Power loss (dissipation)	6 W	6 W
Input Features		
Number of inputs	16 inputs	16 inputs
Input type	Sink/Source (IEC Type 1 sink)	Sink/Source (IEC Type 1 sink)
Input Voltage		
Maximum continuous permissible	30 VDC	30 VDC
Surge	35 VDC for 0.5 s	35 VDC for 0.5 s
Rated value	24 VDC at 4 mA, nominal	24 VDC at 4 mA, nominal
Logic 1 signal (minimum)	15 VDC at 2.5 mA, minimum	15 VDC at 2.5 mA, minimum
Logic 0 signal (maximum)	5 VDC at 1 mA, maximum	5 VDC at 1 mA, maximum
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	500 VAC for 1 minute
Isolation groups of	8 points	8 points
Input Delay Times		
Maximum	4.5 ms	4.5 ms
Connection of 2-Wire Proximity Sensor (Bero)		
Maximum	1 mA	1 mA
Cable Length		
Unshielded	300 m	300 m
Shielded	500 m	500 m
Number of Inputs On Simultaneously		
40 ° C	16	16
55 ° C	16	16

Table A-10 Specifications for EM 223 24 VDC 16 In/16 Out and EM 223 24 VDC 16 In/16 Relay Out

Description Order Number	EM 223 DI16/DO16 X DC24V 6ES7 223-1BL20-0XA0	EM 223 DI16/DO16 X DC24V/Rly 6ES7 223-1PL20-0XA0
Output Features		
Number of integrated outputs	16 points	16 points
Output type	Solid State-MOSFET	Relay, dry contact
Output Voltage		
Permissible range	20.4 to 28.8 VDC	5 to 30 VDC or 5 to 250 VAC
Rated value	24 VDC	-
Logic 1 signal at maximum current	20 VDC, minimum	-
Logic 0 signal with 10K Ω load	0.1 VDC, maximum	-
Output Current		
Logic 1 signal	0.75 A	2.00 A
Number of output groups	3	4
Number of outputs on (maximum)	16	16
Per group - horizontal mounting (maximum)	4/4/8	4
Per group - vertical mounting (maximum)	4/4/8	4
Maximum current per common/group	3/3/6 A	8 A
Lamp load	5 W	30 W DC/200 W AC
ON state resistance (contact resistance)	0.3 Ω	0.2 Ω, maximum when new
Leakage current per point	10 µA, maximum	-
Surge current	8 A for 100 ms, maximum	7 A with contacts closed
Overload protection	No	No
Isolation		
Optical isolation (galvanic)	500 VAC for 1 minute	-
Isolation resistance	-	100 M Ω, minimum when new
Isolation coil to contact	-	1500 VAC for 1 minute
Isolation between open contacts	-	750 VAC for 1 minute
In groups of	4/4/8 points	4 points
Inductive Load Clamping		
Repetitive Energy dissipation $< 0.5 LI^2$ x switching rate	1 W, all channels	-
Clamp voltage limits	L+ minus 48V	-
Output Delay		
Off to On	50 µs, maximum	-
On to Off	200 µs, maximum	-
Relay		
Switching delay	-	10 ms, maximum
Lifetime mechanical (no load)	-	10,000,000 open/close cycles
Lifetime contacts at rated load	-	100,000 open/close cycles
Cable Length		
Unshielded	150 m	150 m
Shielded	500 m	500 m
Power Consumption		
From +5 VDC (from I/O bus)	160 mA	150 mA
From L+	-	9 mA per output when On
L+ coil power voltage range	-	20.4 to 28.8 VDC

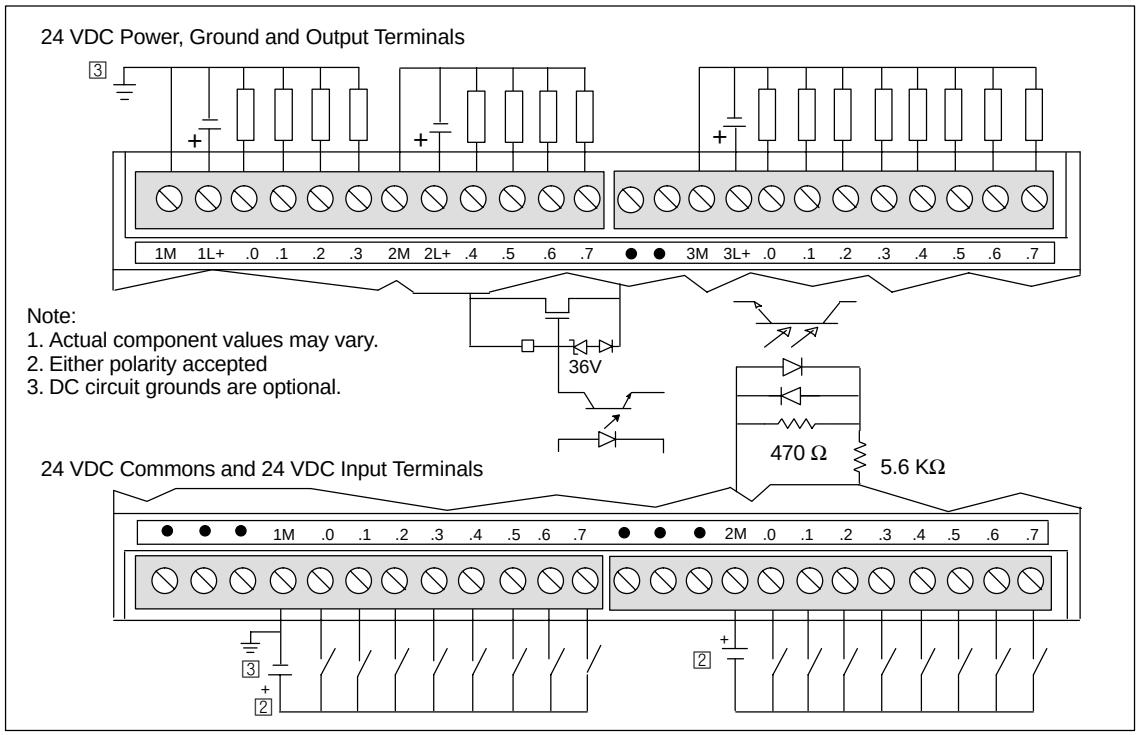


Figure A-17 Connector Terminal Identification for EM 223 16 x 24 VDC In/ 16 x 24 VDC Out

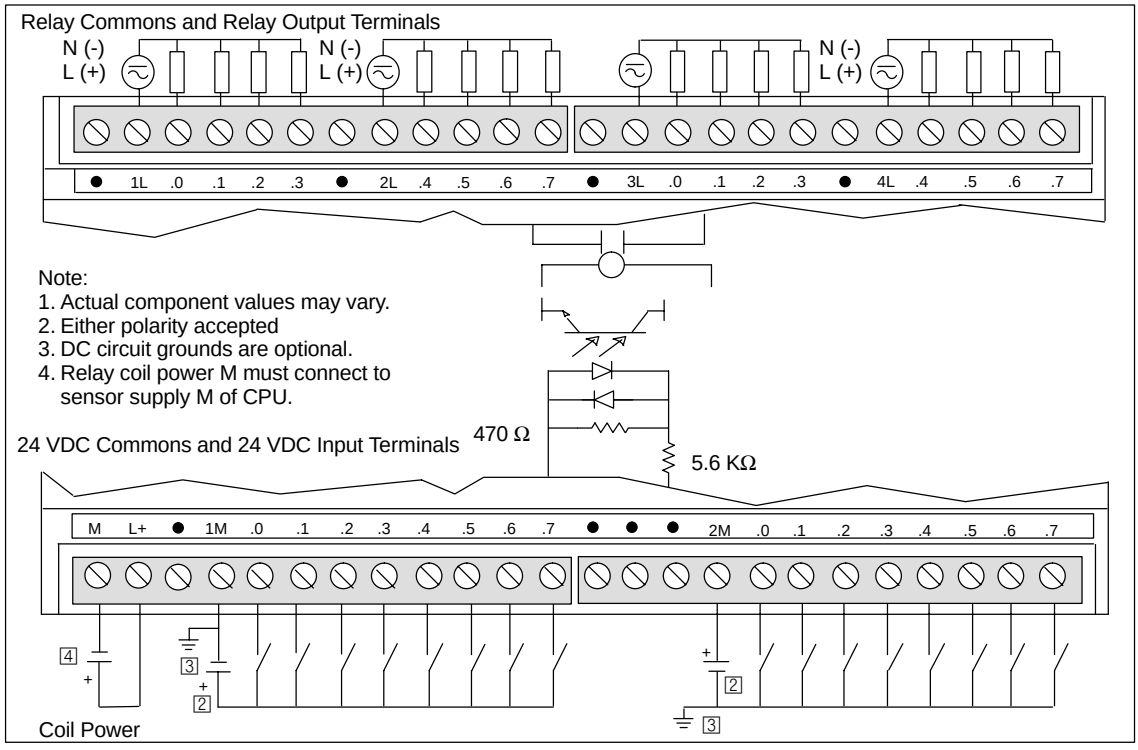


Figure A-18 Connector Terminal Identification for EM 223 24 VDC 16 In/16 Relay Out

A.11 Specifications for the EM 231, EM 232, and EM 235 Analog Input, Output, and Combination Modules

Table A-11 Specifications for EM 231, EM 232, EM 235 Analog Input, Output, and Combination Modules

Description Order Number	EM 231 AI4 x 12 Bit 6ES7 231-0HC20-0XA0	EM 232 AQ2 x 12 Bit 6ES7 232-0HB20-0XA0	EM 235 AI4/AQ1 x 12 Bit 6ES7 235-0KD20-0XA0	
	Input Specifications	**Output Specifications**	**Input Specifications**	**Output Spec.**
General Specifications				
Dimensions (W x H x D) Weight Power loss (dissipation)	71.2 mm x 80 mm x 62 mm 183 g 2 W	46 mm x 80 mm x 62 mm 148 g 2 W	71.2 mm x 80 mm x 62 mm 186 g 2 W	
Number of physical I/O	4 analog input points	2 analog output points	4 analog input points, 1 analog output point	
Power Consumption From +5 VDC (from I/O bus) From L+ L+ voltage range, Class 2 or DC sensor supply	 20 mA 60 mA 20.4 to 28.8	 20 mA 70 mA (with both outputs at 20 mA) 20.4 to 28.8	 30 mA 60 mA (with output at 20 mA) 20.4 to 28.8	
LED indicator	24 VDC Power Supply Good ON = no fault, OFF = no 24 VDC power	24 VDC Power Supply Good, ON = no fault, OFF = no 24 VDC power	24 VDC Power Supply Good, ON = no fault, OFF = no 24 VDC power	
Analog Input Specifications				
Data word format Bipolar, full-scale range Unipolar, full-scale range	(see Figure A-21) -32000 to +32000 0 to 32000		(see Figure A-21) -32000 to +32000 0 to 32000	
Input impedance	≥10 MΩ		≥ 10 MΩ	
Input filter attenuation	-3 db @ 3.1 Khz		-3 db @ 3.1 Khz	
Maximum input voltage	30 VDC		30 VDC	
Maximum input current	32 mA		32 mA	
Resolution	12 bit A/D converter		12 bit A/D converter	
No. of Analog Input Points	4		4	
Isolation (Field side to logic circuit)	None		None	
Input type	Differential		Differential	
Input ranges Voltage (unipolar) Voltage (bipolar) Current	 0 to 10 V, 0 to 5 V ±5 V, ± 2.5 V 0 to 20 mA		 0 to 10 V, 0 to 5 V, 0 to 1 V, 0 to 500 mV, 0 to 100 mV, 0 to 50 mV ± 10 V, ± 5 V, ± 2.5 V, ± 1 V, ± 500 mV, ± 250 mV, ± 100 mV, ± 50 mV, ± 25 mV 0 to 20 mA	
Input Resolution Voltage (unipolar) Voltage (bipolar) Current	see Table A-5		see Table A-13	
Analog to digital conversion time	< 250 µs		< 250 µs	
Analog input step response	1.5 ms to 95%		1.5 ms to 95%	
Common mode rejection	40 dB, DC to 60 Hz		40 dB, DC to 60 Hz	
Common mode voltage	Signal voltage plus common mode voltage (must be ≤ 12 V)		Signal voltage plus common mode voltage (must be ≤ 12 V)	

Description Order Number	EM 231 AI4 x 12 Bit 6ES7 231-0HC20-0XA0	EM 232 AQ2 x 12 Bit 6ES7 232-OHB20-0XA0	EM 235 AI4/AQ1 x 12 Bit 6ES7 235-0KD20-0XA0	
	Input Specifications	**Output Specifications**	**Input Specifications**	**Output Specifications**
Analog Output Specifications				
No. of Analog Output Points		2		1
Isolation (Field side to logic circuit)		None		None
Signal range Voltage output Current output		 ± 10 V 0 to 20 mA		 ± 10 V 0 to 20 mA
Resolution, full-scale Voltage Current		 12 bits 11 bits		 12 bits 11 bits
Data word format Voltage Current		 -32000 to +32000 0 to +32000		 -32000 to +32000 0 to +32000
Accuracy Worst case, 0° to 55° C Voltage output Current output Typical, 25° C Voltage output Current output		 ± 2% of full-scale ± 2% of full-scale ± 0.5% of full-scale ± 0.5% of full-scale		 ± 2% of full-scale ± 2% of full-scale ± 0.5% of full-scale ± 0.5% of full-scale
Settling time Voltage output Current output		 100 µS 2 mS		 100 µS 2 mS
Maximum drive Voltage output Current output		 5000 Ω minimum 500 Ω maximum		 5000 Ω minimum 500 Ω maximum

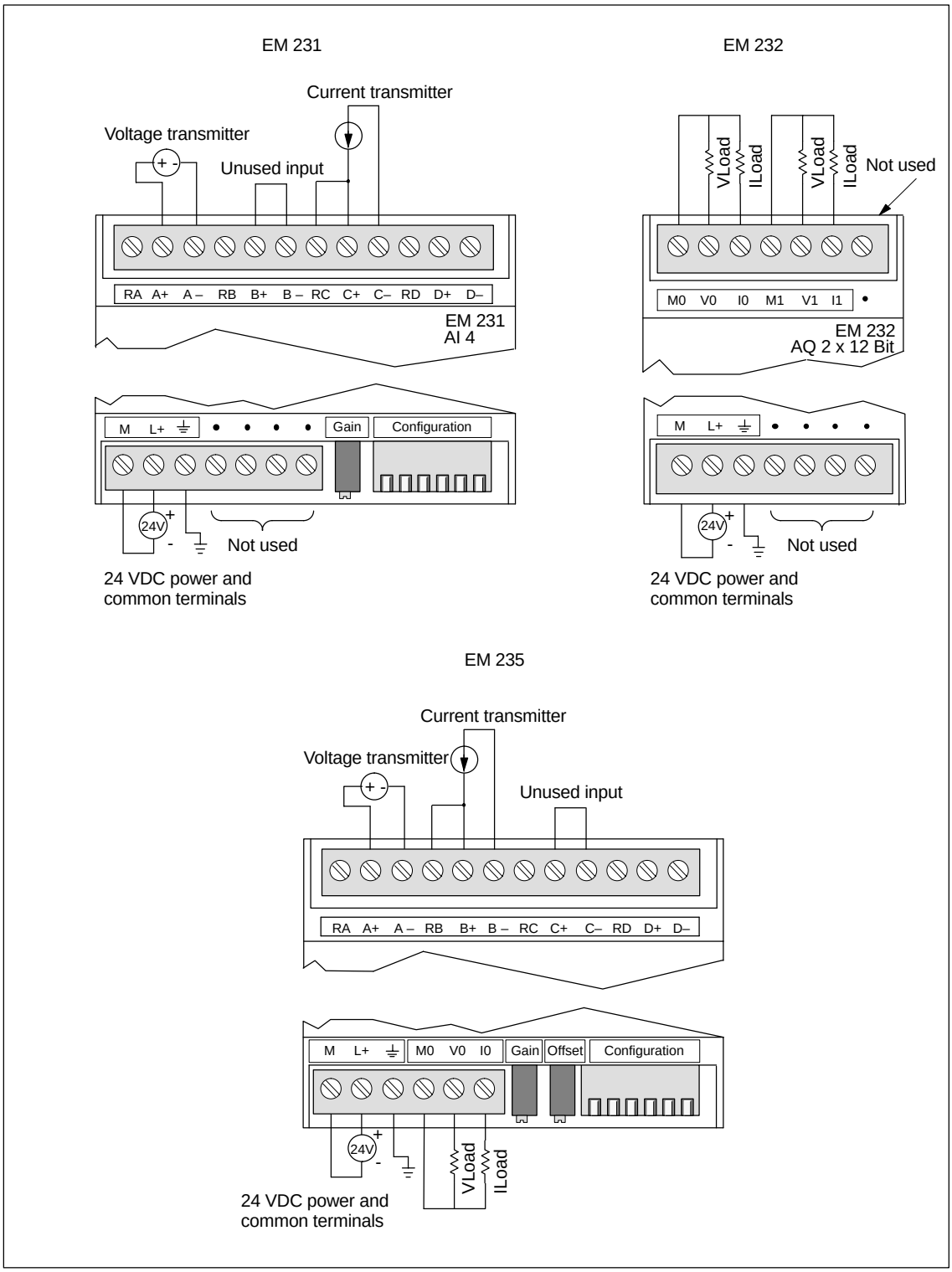


Figure A-19 Connector Terminal Identification for Expansion Modules EM 231, EM 232, and EM 235

Input Calibration

The calibration adjustments affect the instrumentation amplifier stage that follows the analog multiplexer (see Figure A-22). Therefore, calibration affects all user input channels. Variations in the component values of each input circuit preceeding the analog multiplexer will cause slight differences in the readings between channels connected to the same input signal even after calibration.

To meet the specifications contained in this data sheet, you should enable analog input filters for all inputs of the module. Select 64 or more samples in calculating the average value.

To calibrate the input, use the following steps.

1. Turn off the power to the module. Select the desired input range.
2. Turn on the power to the CPU and module. Allow the module to stabilize for 15 minutes.
3. Using a transmitter, a voltage source, or a current source, apply a zero value signal to one of the input terminals.
4. Read the value reported to the CPU by the appropriate input channel.
5. Adjust the OFFSET potentiometer until the reading is zero, or the desired digital data value.
6. Connect a full-scale value signal to one of the input terminals. Read the value reported to the CPU.
7. Adjust the GAIN potentiometer until the reading is 32000, or the desired digital data value.
8. Repeat OFFSET and GAIN calibration as required.

Calibration and Configuration Location for EM 231 and EM 235

The calibration potentiometer and configuration DIP switches are located on the right of the bottom terminal block of the module, as shown in Figure A-20.

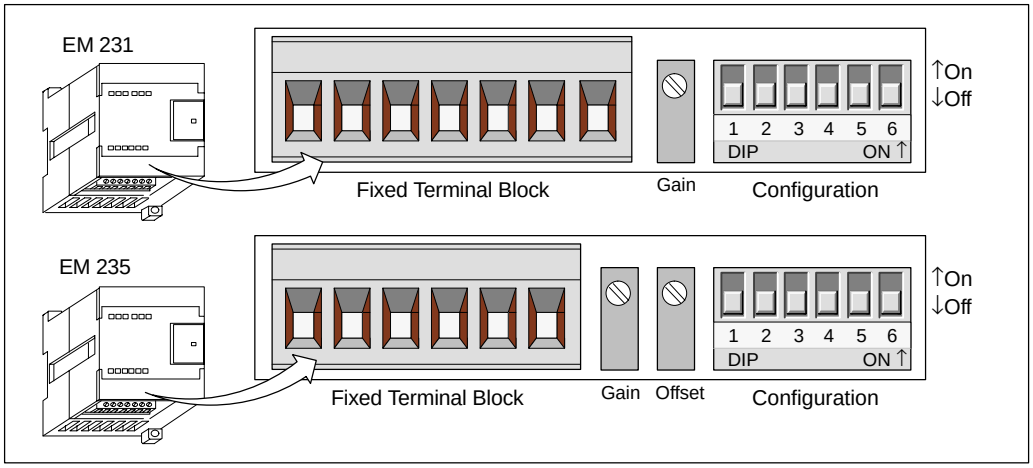


Figure A-20 Calibration Potentiometer and Configuration DIP Switches for EM 231, EM 235

Configuration for EM 231

Table A-12 shows how to configure the EM 231 module using the configuration DIP switches. Switches 1, 2, and 3 select the analog input range. All inputs are set to the same analog input range. In this table, ON is closed, and OFF is open.

Table A-12 EM 231 Configuration Switch Table to Select Analog Input Range

Unipolar			**Full-Scale Input**	**Resolution**
SW1	**SW2**	**SW3**		
ON	OFF	ON	0 to 10 V	2.5 mV
	ON	OFF	0 to 5 V	1.25 mV
			0 to 20 mA	5 μA
Bipolar			**Full-Scale Input**	**Resolution**
SW1	**SW2**	**SW3**		
OFF	OFF	ON	± 5 V	2.5 mV
	ON	OFF	± 2.5 V	1.25 mV

Configuration for EM 235

Table A-13 shows how to configure the EM 235 module using the configuration DIP switches. Switches 1 through 6 select the analog input range and resolution. All inputs are set to the same analog input range and format. Table A-14 shows how to select for unipolar/bipolar (switch 6), gain (switches 4 and 5), and attenuation (switches 1, 2, and 3). In these tables, ON is closed, and OFF is open.

Table A-13 EM 235 Configuration Switch Table to Select Analog Input Range and Resolution

Unipolar						**Full-Scale Input**	**Resolution**
SW1	**SW2**	**SW3**	**SW4**	**SW5**	**SW6**		
ON	OFF	OFF	ON	OFF	ON	0 to 50 mV	12.5 μV
OFF	ON	OFF	ON	OFF	ON	0 to 100 mV	25 μV
ON	OFF	OFF	OFF	ON	ON	0 to 500 mV	125 μV
OFF	ON	OFF	OFF	ON	ON	0 to 1 V	250 μV
ON	OFF	OFF	OFF	OFF	ON	0 to 5 V	1.25 mV
ON	OFF	OFF	OFF	OFF	ON	0 to 20 mA	5 μA
OFF	ON	OFF	OFF	OFF	ON	0 to 10 V	2.5 mV
Bipolar						**Full-Scale Input**	**Resolution**
SW1	**SW2**	**SW3**	**SW4**	**SW5**	**SW6**		
ON	OFF	OFF	ON	OFF	OFF	±25 mV	12.5 μV
OFF	ON	OFF	ON	OFF	OFF	±50 mV	25 μV
OFF	OFF	ON	ON	OFF	OFF	±100 mV	50 μV
ON	OFF	OFF	OFF	ON	OFF	±250 mV	125 μV
OFF	ON	OFF	OFF	ON	OFF	±500 mV	250 μV
OFF	OFF	ON	OFF	ON	OFF	±1 V	500 μV
ON	OFF	OFF	OFF	OFF	OFF	±2.5 V	1.25 mV
OFF	ON	OFF	OFF	OFF	OFF	±5 V	2.5 mV
OFF	OFF	ON	OFF	OFF	OFF	±10 V	5 mV

Table A-14 EM 235 Configuration Switch Table to Select Unipolar/Bipolar, Gain, and Attenuation

EM 235 Configuration Switches						Unipolar/Bipolar Select	Gain Select	Attenuation Select
SW1	SW2	SW3	SW4	SW5	SW6			
					ON	Unipolar		
					OFF	Bipolar		
			OFF	OFF			x1	
			OFF	ON			x10	
			ON	OFF			x100	
			ON	ON			invalid	
ON	OFF	OFF						0.8
OFF	ON	OFF						0.4
OFF	OFF	ON						0.2

Input Data Word Format for EM 231 and EM 235

Figure A-21 shows where the 12-bit data value is placed within the analog input word of the CPU.

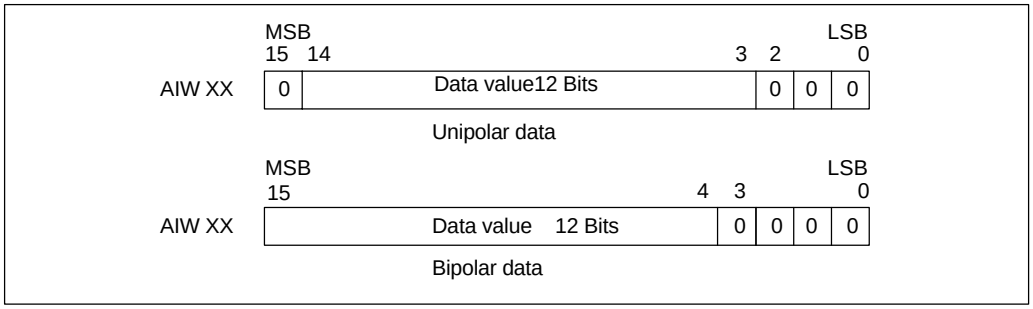


Figure A-21 Input Data Word Format for EM 231 and EM 235

Note

The 12 bits of the analog-to-digital converter (ADC) readings are left-justified in the data word format. The MSB is the sign bit: zero indicates a positive data word value. In the unipolar format, the three trailing zeros cause the data word to change by a count of eight for each one-count change in the ADC value. In the bipolar format, the four trailing zeros cause the data word to change by a count of sixteen for each one count change in the ADC value.

Input Block Diagram for EM 231 and EM 235

Figure A-22 shows the EM 231 and EM 235 input block diagrams.

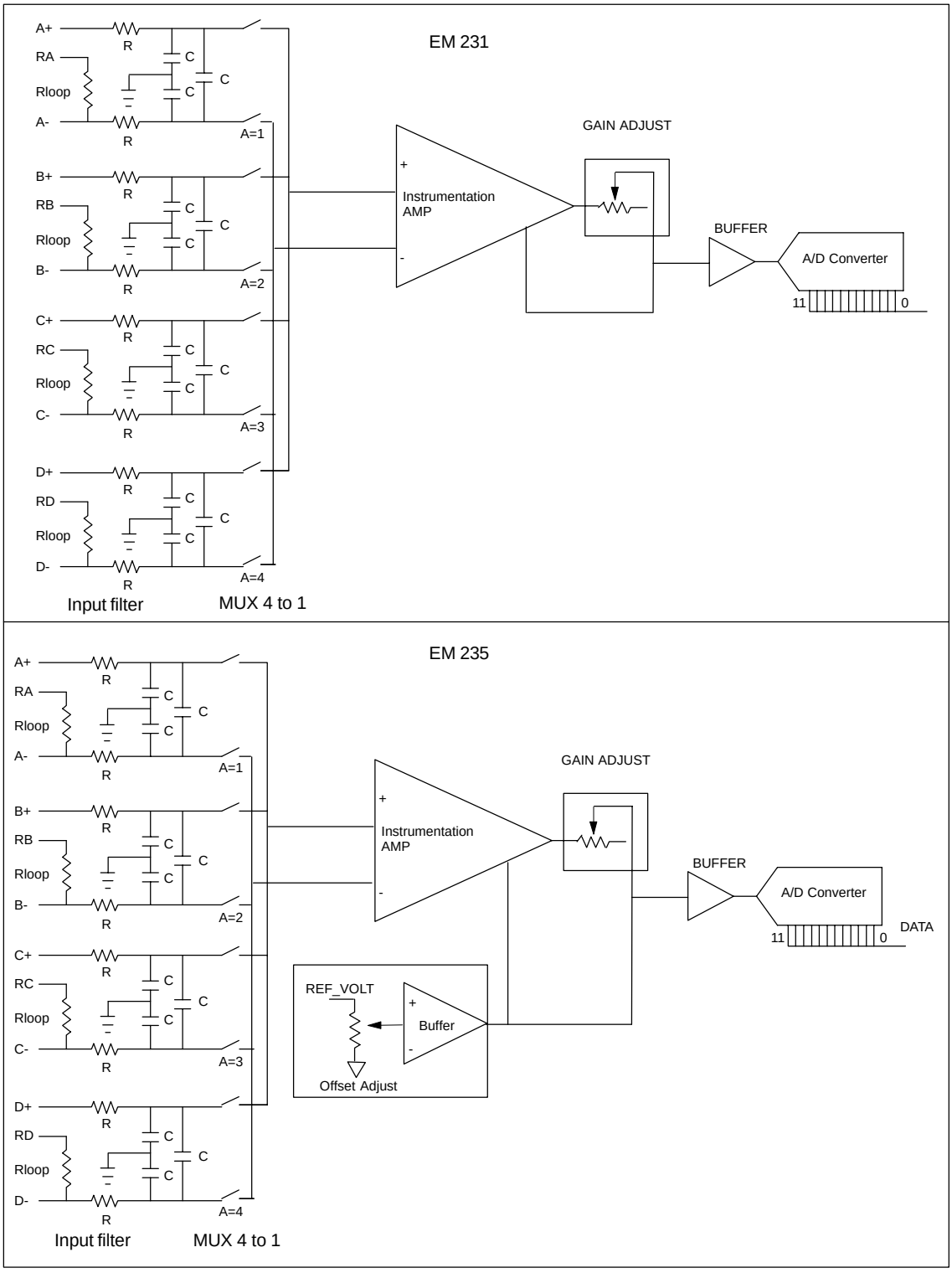


Figure A-22 EM 231 and EM 235 Input Block Diagram

Output Data Word Format for EM 232 and EM 235

Figure A-23 shows where the 12-bit data value is placed within the analog output word of the CPU.

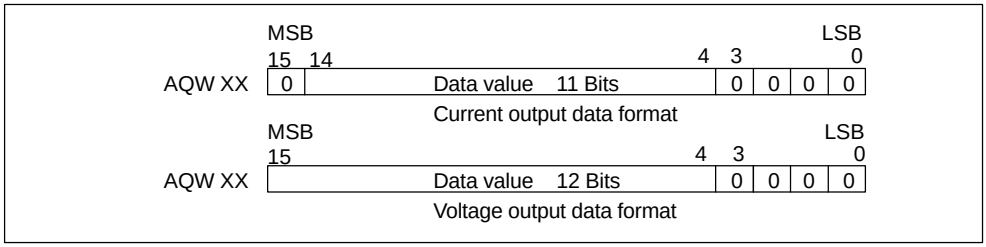


Figure A-23 Output Data Word Format for EM 232 and EM 235

Note

The 12 bits of the digital-to-analog converter (DAC) readings are left-justified in the output data word format. The MSB is the sign bit: zero indicates a positive data word value. The four trailing zeros are truncated before being loaded into the DAC registers. These bits have no effect on the output signal value.

Output Block Diagram for EM 232 and EM 235

Figure A-24 shows the EM 232 and EM 235 output block diagrams.

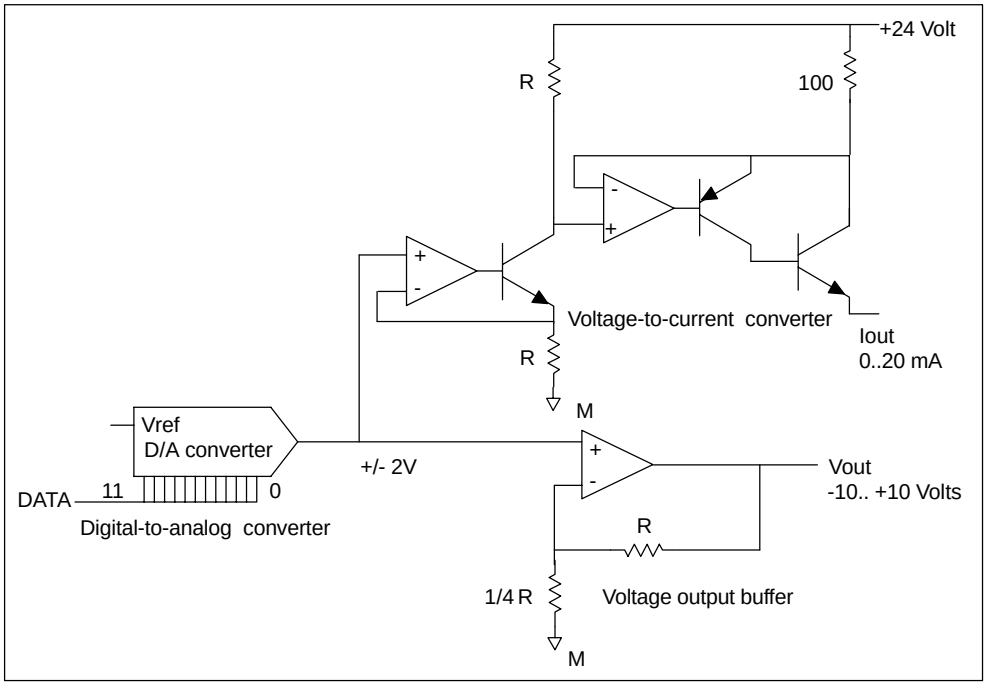


Figure A-24 EM 232 and EM 235 Output Block Diagram

Installation Guidelines

Use the following guidelines to ensure good accuracy and repeatability:

- Ensure that the 24-VDC Sensor Supply is free of noise and is stable.
- Use the shortest possible sensor wires.
- Use shielded twisted pair wiring for sensor wires.
- Terminate the shield at the Sensor location only.
- Short the inputs for any unused channels, as shown in Figure A-19.
- Avoid bending the wires into sharp angles.
- Use wireways for wire routing.
- Avoid placing signal wires parallel to high-energy wires. If the two wires must meet, cross them at right angles.
- Ensure that the input signals are within the common mode voltage specification by isolating the input signals or referencing them to the external 24V common of the analog module.

Note
The EM 231 and EM 235 expansion modules are not recommended for use with thermocouples.

Understanding and Using the Analog Input Module: Accuracy and Repeatability

The EM 231 and EM 235 analog input modules are low-cost, high-speed 12 bit analog input modules. The modules are capable of converting an analog input to its corresponding digital value in 149 µsec. Conversion of the analog signal input is performed each time the analog point is accessed by your program. These times must be added to the basic execution time of the instruction used to access the analog input.

The EM 231 and EM 235 provide an unprocessed digital value (no linearization or filtering) that corresponds to the analog voltage or current presented at the module's input terminals. Since the modules are high-speed modules, they can follow rapid changes in the analog input signal (including internal and external noise). Reading-to-reading variations caused by noise for a constant or slowly changing analog input signal can be minimized by averaging a number of readings. As the number of readings used in computing the average value increases, a correspondingly slower response time to changes in the input signal can be observed.

The specifications for repeatability describe the reading-to-reading variations of the module for an input signal that is not changing. The repeatability specification defines the limits within which 99% of the readings will fall. The mean accuracy specification describes the average value of the error (the difference between the average value of individual readings and the exact value of the actual analog input signal). The repeatability is described in Figure A-25 by the bell curve. This figure shows the 99% repeatability limits, the mean or average value of the individual readings, and the mean accuracy in a graphical form. Table A-15 gives the repeatability specifications and the mean accuracy as they relate to each of the configurable ranges.

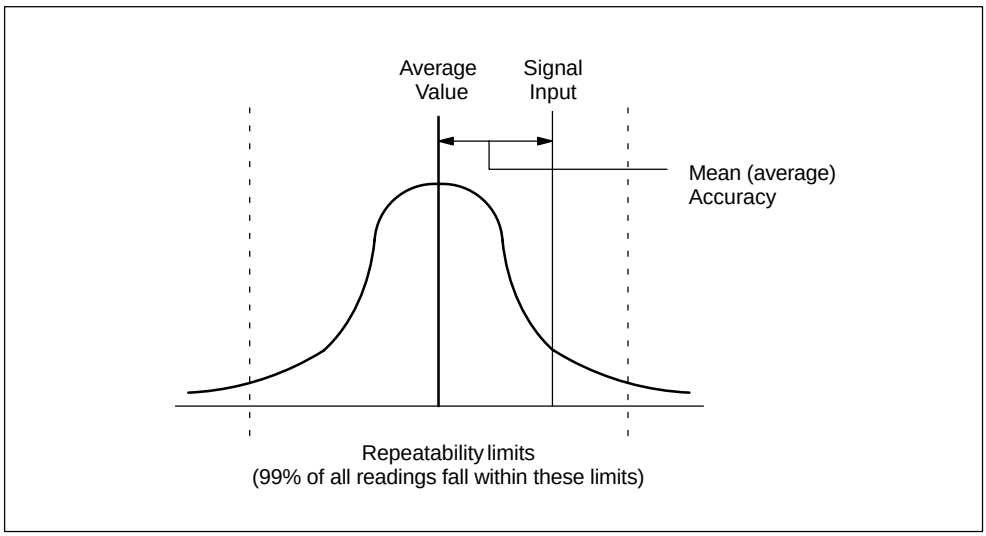


Figure A-25 Accuracy Definitions

Table A-15 EM 231 and EM 235 Specifications

Full Scale Input Range	Repeatability[1]		Mean (average) Accuracy[1,2,3,4]	
	% of Full Scale	Counts	% of Full Scale	Counts
EM 231 Specifications				
0 to 5 V	± 0.075%	± 24	± 0.01%	± 32
0 to 20 mA				
0 to 10 V				
± 2.5 V		± 48	± 0.05%	
± 5 V				
EM 235 Specifications				
0 to 50 mV	± 0.075%	± 24	± 0.25%	± 80
0 to 100 mV			± 0.2%	± 64
0 to 500 mV			± 0.05%	± 16
0 to 1 V				
0 to 5 V				
0 to 20 mA				
0 to 10 V				
± 25 mV	± 0.075%	± 48	± 0.25%	± 160
± 50 mV			± 0.2%	± 128
± 100 mV			± 0.1%	± 64
± 250 mV			± 0.05%	± 32
± 500 mV				
± 1 V				
± 2.5 V				
± 5 V				
± 10 V				

1 Measurements made after the selected input range has been calibrated.
2 The offset error in the signal near zero analog input is not corrected, and is not included in the accuracy specifications.
3 There is a channel-to-channel carryover conversion error, due to the finite settling time of the analog multiplexer. The maximum carryover error is 0.1% of the difference between channels.
4 Mean accuracy includes effects of non-linearity and drift from 0 to 55 degrees C.

Definitions of the Analog Specifications

- Accuracy: deviation from the expected value on a given point.
- Resolution: the effect of an LSB change reflected on the output.

Agency Standards

These modules adhere to the following agency standards: UL 508 Listed (Industrial Control Equipment); CSA C22.2 Number 142 Certified (Process Control Equipment); FM Class I, Division 2, Groups A, B, C, & D Hazardous Locations, T4A; VDE 0160: Electronic equipment for use in electrical power installations; European Community (CE) Low Voltage Directive 73/23/EEC, EN 61131-2: Programmable controllers - Equipment requirements; European Community (CE) EMC Directive 89/336/EEC.

A.12 Specifications for the EM 277 PROFIBUS-DP Module

Table A-16 Specifications for the EM 277 PROFIBUS-DP Module

Description Order Number	EM 277 PROFIBUS-DP 6ES7 277-0AA20-0XA0
Physical Size	
Dimensions (W x H x D)	71 mm x 80 mm x 62 mm
Weight	175 g
Power loss (dissipation)	2.5 W
Communication Features	
Number of Ports	1 port
Electrical interface	RS-485
Isolation (external signal to PLC logic)	500 VAC (Galvanic)
PROFIBUS-DP/MPI baud rates (set automatically)	9.6, 19.2, 45.45, 93.75, 187.5, and 500K baud; 1, 1.5, 3, 6, and12M baud
Protocols	PROFIBUS-DP slave and MPI slave
Cable Length	
Up to 93.75K baud	1200 m
187.5K baud	1000 m
500K baud	400 m
1 to 1.5M baud	200 m
3 to 12M baud	100 m
Network Capabilities	
Station address settings	0 - 99 (set by rotary switches)
Maximum stations per segment	32
Maximum stations per network	126, up to 99 EM277 stations
MPI Connections	6 total, 2 reserved (1 for PG and 1 for OP)
Power Consumption	
+5 VDC (from I/O bus)	150 mA
24 VDC Input Power Requirements	
Voltage range	20.4 to 28.8 VDC (Class 2 or sensor power from PLC)
Maximum current	
Module only with port active	30 mA
Add 90 mA of 5V port load	60 mA
Add 120 mA of 24V port load	180 mA
Ripple noise (<10 MHz)	<1 V peak to peak (maximum)
[1]Isolated (input power to module logic)	500 VAC for 1 minute
5 VDC Power on Communication Port	
Maximum current per port	90 mA
Transformer isolation from module logic and from 24 VDC input power	500 VAC for 1 minute
24 VDC Power on Communication Port	
Voltage range	20.4 to 28.8 VDC
Maximum current per port	120 mA
Current limit	0.7 to 2.4 A
Isolated	Not isolated, same circuit as input 24 VDC

[1] No power is supplied to module logic by the 24 VDC supply. 24 VDC supplies power for the communication port.

Compatibility

The EM 277 PROFIBUS-DP slave module is an intelligent expansion module designed to work with the S7-200 PLCs shown in Table A-17.

Table A-17 EM 277 PROFIBUS-DP Module Compatibility with S7-200 PLCs

CPU	Description	Order Number
CPU 222 Rel. 1.10 or greater	CPU 222 DC/DC/DC	6ES7 212-1AB21-0XB0
	CPU 222 AC/DC/Relay	6ES7 212-1BB21-0XB0
CPU 224 Rel. 1.10 or greater	CPU 224 DC/DC/DC	6ES7 214-1AD21-0XB0
	CPU 224 AC/DC/Relay	6ES7 214-1BD21-0XB0
CPU 226 Rel. 1.00 or greater	CPU 226 DC/DC/DC	6ES7 216-2AD21-0XB0
	CPU 226 AC/DC/Relay	6ES7 216-2BD21-0XB0

Address Switches and LEDs

The address switches and status LEDs are located on the front of the module as shown in Figure A-26. The EM 277 status LEDs are shown in Table A-20.

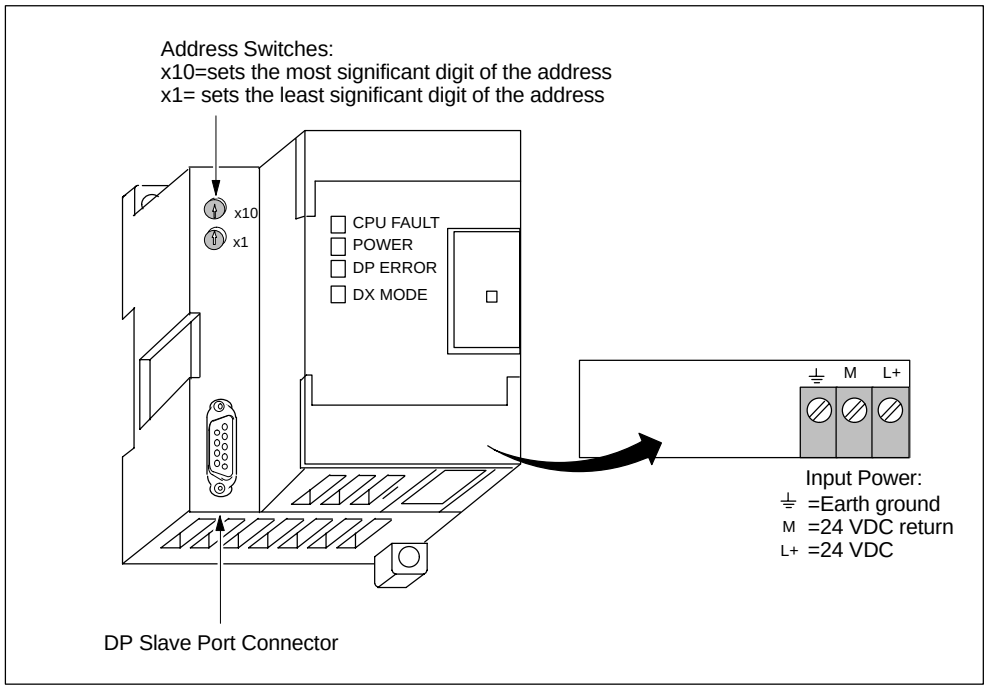


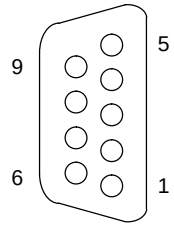
Figure A-26 Front View of the EM 277 PROFIBUS-DP Module

DP Slave Port Connector

The pin-out for the DP slave port connector is shown in Figure A-27.

9-Pin Sub D Connector Pin-out

9-pin D Female Connector



Pin #	Description
1	Chassis ground, tied to the connector shell
2	24V Return (same as M on terminal block)
3	Isolated Signal B (RxD/TxD+)
4	Isolated Request to Send (TTL level)
5	Isolated +5V Return
6	Isolated +5V at 90 mA
7	+24V (120 mA maximum, with reverse voltage protection diode)
8	Isolated Signal A (RxD/TxD-)
9	No Connection

Note: Isolated means 500V of isolation from digital logic and 24V input power.

Figure A-27 Pin-out for the DP Slave Port Connector

Distributed Peripheral (DP) Standard Communications

PROFIBUS-DP (or DP Standard) is a remote I/O communication protocol defined by the European Standard EN 50170. Devices that adhere to this standard are compatible even though they are manufactured by different companies. DP stands for distributed peripherals, that is, remote I/O. PROFIBUS stands for Process Field Bus.

The EM 277 PROFIBUS-DP module has implemented the DP Standard protocol as defined for slave devices in the following communication protocol standards:

- EN 50 170 (PROFIBUS) describes the bus access and transfer protocol and specifies the properties of the data transfer medium.
- EN 50 170 (DP Standard) describes the high-speed cyclic exchange of data between DP masters and DP slaves. This standard defines the procedures for configuration and parameter assignment, explains how cyclic data exchange with distributed I/O functions, and lists the diagnostic options which are supported.

A DP master is configured to know the addresses, slave device types, and any parameter assignment information that the slaves require. The master is also told where to place data that is read from the slaves (inputs) and where to get the data to write to the slaves (outputs). The DP master establishes the network and then initializes its DP slave devices. The master writes the parameter assignment information and I/O configuration to the slave. The master then reads the diagnostics from the slave to verify that the DP slave accepted the parameters and the I/O configuration. The master then begins to exchange I/O data with the slave. Each transaction with the slave writes outputs and reads inputs. The data exchange mode continues indefinitely. The slave devices can notify the master if there is an exception condition and the master then reads the diagnostic information from the slave.

Once a DP master has written the parameters and I/O configuration to a DP slave, and the slave has accepted the parameters and configuration from the master, the master now owns that slave. The slave only accepts write requests from the master that owns it. Other masters on the network can read the slave's inputs and outputs, but they cannot write anything to the slave.

Using the EM 277 to Connect an S7-200 CPU to the Network as a DP Slave

The S7-200 CPU can be connected to a PROFIBUS-DP network through the EM 277 PROFIBUS-DP expansion slave module. The EM 277 is connected to the S7-200 CPU through the serial I/O bus. The PROFIBUS network is connected to the EM 277 PROFIBUS-DP module through its DP communication port. This port operates at any PROFIBUS baud rate between 9600 baud and 12 Mbaud. (See Table A-16 for supported baud rates.) As a DP slave device, the EM 277 module accepts several different I/O configurations from the master to transfer different amounts of data to and from the master. This feature allows you to tailor the amount of data transferred to meet the requirements of the application. Unlike many DP devices, the EM 277 module does not transfer only I/O data. The EM 277 moves data to and from a block of variable memory defined in the S7-200 CPU. This allows you to exchange any type of data with the master. Inputs, counter values, timer values, or other calculated values can be transferred to the master by first moving the data to the variable memory in the S7-200 CPU. Likewise, data from the master is stored in variable memory in the S7-200 CPU and can be moved to other data areas.

The DP port of the EM 277 PROFIBUS-DP module can be attached to a DP master on the network and still communicate as an MPI slave with other master devices such as SIMATIC programming devices or S7-300/S7-400 CPUs on the same network.

Figure A-28 shows a PROFIBUS network with a CPU 224 and an EM 277 PROFIBUS-DP module. In this situation, the CPU 315-2 is the DP master and has been configured by a SIMATIC programming device with STEP 7 programming software. The CPU 224 is a DP slave owned by the CPU 315-2. The ET 200 I/O module is also a slave owned by the CPU 315-2. The S7-400 CPU is attached to the PROFIBUS network and is reading data from the CPU 224 by means of XGET instructions in the S7-400 CPU user program.

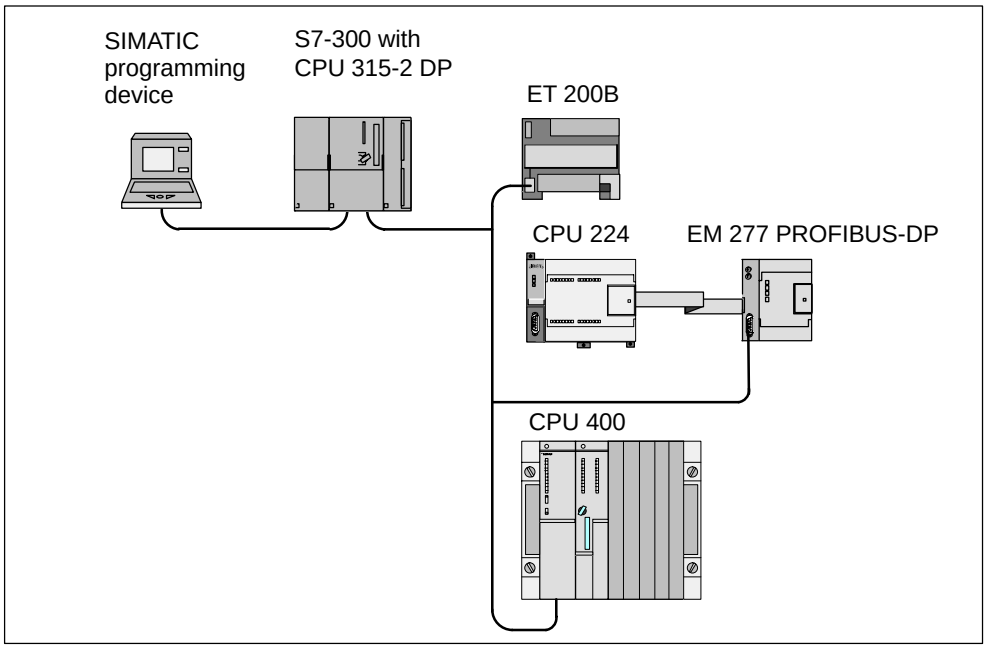


Figure A-28 EM 277 PROFIBUS-DP Module and CPU 224 on a PROFIBUS Network

Configuration

To use the EM 277 as a DP slave, you must set the station address of the DP port to match the address in the configuration of the master. The station address is set with the rotary switches on the EM 277 module. You must power cycle the CPU after you have made a switch change in order for the new slave address to take effect.

The master device exchanges data with each of its slaves by sending information from its output area to the slave's output buffer (called a "Receive mailbox"). The slave responds to the message from the master by returning an input buffer (called a "Send mailbox") which the master stores in an input area (see Figure A-29).

The EM 277 can be configured by the DP master to accept output data from the master and return input data to the master. The output and input data buffers reside in the variable memory (V memory) of the S7-200 CPU. When you configure the DP master, you define the byte location in V memory where the output data buffer should start as part of the parameter assignment information for the EM 277. You also define the I/O configuration as the amount of output data to be written to the S7-200 CPU and amount of input data to be returned from the S7-200 CPU. The EM 277 determines the size of the input and output buffers from the I/O configuration. The DP master writes the parameter assignment and I/O configuration information to the EM 277 PROFIBUS DP module. The EM 277 then transfers the V memory address and input and output data lengths to the S7-200 CPU.

Figure A-29 shows a memory model of the V memory in a CPU 224 and the I/O address areas of a DP master CPU. In this example, the DP master has defined an I/O configuration of 16 output bytes and 16 input bytes, and a V memory offset of 5000. The output buffer and input buffer lengths in the CPU 224 (determined from the I/O configuration) are both 16 bytes long. The output data buffer starts at V5000; the input buffer immediately follows the output buffer and begins at V5016. The output data (from the master) is placed in V memory at V5000. The input data (to the master) is taken from the V memory at V5016.

Note
If you are working with a data unit (consistent data) of three bytes or data units (consistent data) greater than four bytes, you must use SFC14 to read the inputs of the DP slave and SFC15 to address the outputs of the DP slave. For more information, see the S*ystem Software for S7-300 and S7-400 System and Standard Functions Reference Manual*.

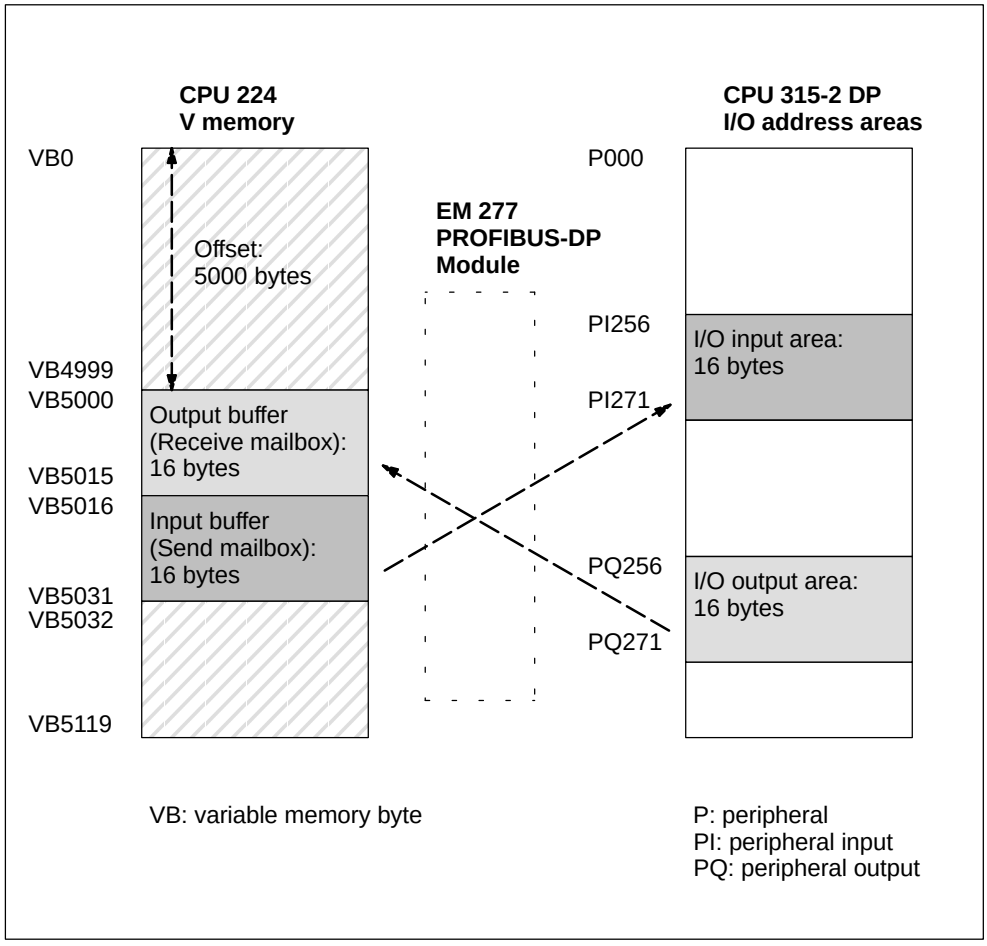


Figure A-29 Example of a CPU 224 V Memory and I/O Address Area of a PROFIBUS-DP Master

Table A-18 list the configurations that are supported by the EM 277 PROFIBUS-DP module. The default configuration for the EM 277 module is two words of input and two words of output.

Table A-18 EM 277 Configuration Options

Configuration	Inputs to Master	Outputs from Master	Data Consistency
1	1 word	1 word	Word Consistency
2	2 words	2 words	
3	4 words	4 words	
4	8 words	8 words	
5	16 words	16 words	
6	32 words	32 words	
7	8 words	2 words	
8	16 words	4 words	
9	32 words	8 words	
10	2 words	8 words	
11	4 words	16 words	
12	8 words	32 words	
13	2 bytes	2 bytes	Byte Consistency
14	8 bytes	8 bytes	
15	32 bytes	32 bytes	
16	64 bytes	64 bytes	
17	4 bytes	4 bytes	Buffer Consistency
18	8 bytes	8 bytes	
19	12 bytes	12 bytes	
20	16 bytes	16 bytes	

The location of the input and output buffers may be configured to be anywhere in the V memory of the S7-200 CPU. The default address for the input and output buffers is VB0. The location of the input and output buffers is part of the parameter assignment information that the master writes to the S7-200 CPU. The master must be configured to recognize its slaves and to write the required parameters and I/O configuration to each of its slaves.

Use the following tools to configure the DP master:

- For SIMATIC S5 masters, use COM PROFIBUS Windows software
- For SIMATIC S7 masters, use STEP 7 programming software
- For SIMATIC 505 masters, use COM PROFIBUS and either TISOFT2 or SoftShop

For detailed information about using these configuration and programming software packages, refer to the manuals for these devices. For detailed information about the PROFIBUS network and its components, refer to the *ET 200 Distributed I/O System Manual*.

Data Consistency

PROFIBUS supports three types of data consistency:

- Byte consistency ensures that bytes are transferred as whole units.
- Word consistency ensures that word transfers cannot be interrupted by other processes in the CPU. This means that the two bytes composing the word are always moved together and cannot be split.
- Buffer consistency ensures that the entire buffer of data is transferred as a single unit, uninterrupted by any other process in the CPU.

Word and buffer consistency force the CPU to halt any other processes, such as user interrupts, while manipulating or moving the DP I/O data within the CPU. Word consistency should be used if the data values being transferred are integers. Buffer consistency should be used if the data values are double words or floating point values. Buffer consistency should also be used when a group of values all relate to one calculation or item.

You set the data consistency as part of the I/O configuration in the master. The data consistency selection is written to the DP slave as part of the initialization of the slave. Both the DP master and the DP slave use the data consistency selection to be sure that data values (bytes, words, or buffers) are transferred uninterrupted within master and slave. Figure A-30 shows the different types of consistency.

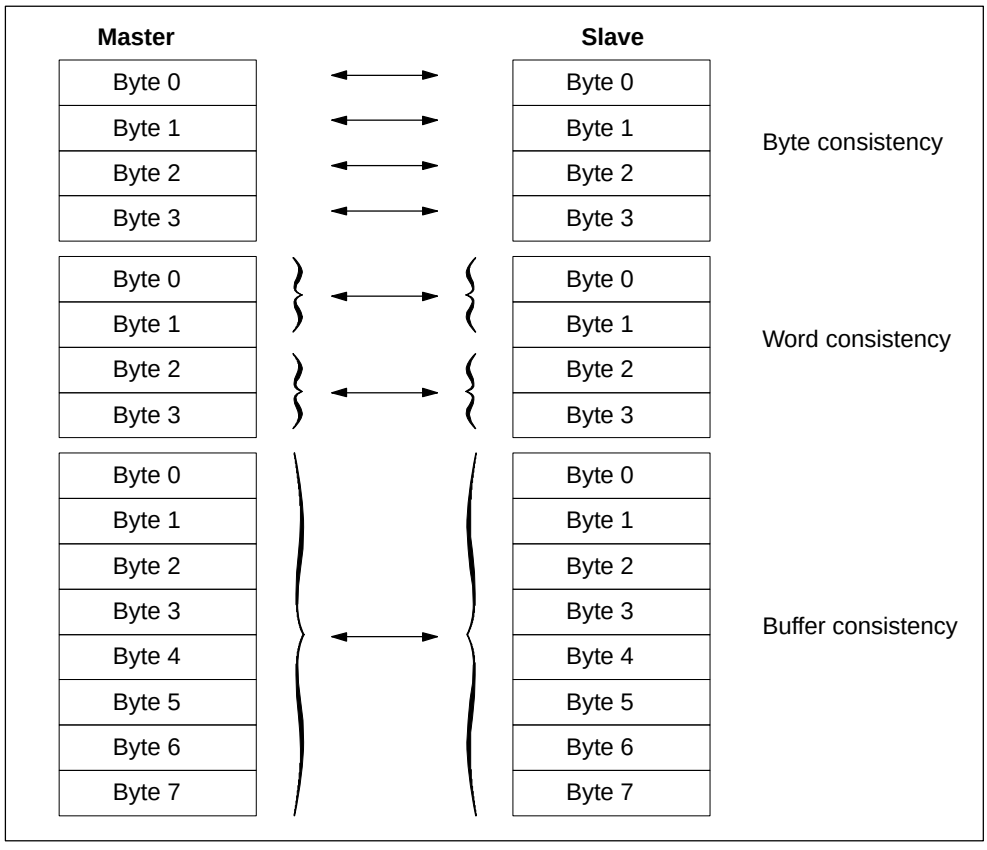


Figure A-30 Byte, Word, and Buffer Data Consistency

User Program Considerations

Once the EM 277 PROFIBUS-DP module has been successfully configured by a DP master, the EM 277 and the DP master enter data exchange mode. In data exchange mode, the master writes output data to the EM 277 PROFIBUS-DP module, the EM 277 module then responds with most current S7-200 CPU input data. The EM 277 module continuously updates its inputs from the S7-200 CPU in order to provide the most recent input data to the DP Master. The module then transfers the output data to the S7-200 CPU. The output data from the master is placed into V memory (the output buffer) starting at the address that the DP master supplied during initialization. The input data to the master is taken from the V memory locations (the input buffer) immediately following the output data.

The starting address of the data buffers in V memory and the size of the buffers must be known at the time the user program for the S7-200 CPU is created. The output data from the master must be moved by the user program in the S7-200 CPU from the output buffer to the data areas where it is to be used. Likewise, the input data to the master must be moved from the various data areas to the input buffer for transfer to the master.

Output data from the DP master is placed into V memory immediately after the user program portion of the scan has been executed. Input data (to the master) is copied from V memory to the EM 277 for transfer to the master at this same time. Output data from the master is only written into V memory when there is new data available from the master. Input data to the master are transmitted to the master on the next data exchange with the master.

SMB200 through SMB249 provide status information about the EM 277 PROFIBUS-DP slave module if it is the first intelligent module in the I/O chain. If the EM 277 is the second intelligent module in the I/O chain, then the EM 277 status is obtained from SMB250 through SMB299. These SM locations show default values if DP communication has not been established with a master. After a master has written parameters and I/O configuration to the EM 277 PROFIBUS-DP module, these SM locations show the configuration set by the DP master. You should check SMB224 to be sure that the EM 277 is currently in data exchange mode with the master before using the information in SMB225 through SMB229 (see Table A-19), or data in the V memory buffer.

Note
You cannot configure the EM 277 PROFIBUS-DP I/O buffer sizes or buffer location by writing to memory locations SMB225 through SMB229 or SMB275 through SMB279. Only the DP master can configure the EM 277 PROFIBUS-DP module for DP operation.

Table A-19 Special Memory Bytes SMB200 to SMB299

DP is First Intelligent Module	DP is Second Intelligent Module	Description
SMB200 to SMB215	SMB250 to SMB265	Module name (16 ASCII characters) “EM277 ProfibusDP”
SMB216 to SMB219	SMB266 to SMB269	S/W revision number (4 ASCII characters) xxxx
SMW220	SMW270	Error code 16#0000 No error 16#0001 No user power 16#0002 to 16#FFFF Reserved
SMB222	SMB272	DP slave module’s station address as set by address switches (0 - 99 decimal)
SMB223	SMB273	Reserved
SMB224	SMB274	DP standard protocol status byte MSB LSB 0 0 0 0 0 0 S1 S0 S1 S0 DP Standard status byte description 0 0 DP communication not initiated since power on 0 1 Configuration/parameterization error detected 1 0 Currently in data exchange mode 1 1 Dropped out of data exchange mode
SMB225	SMB275	DP standard protocol - address of the slave’s master (0 to 126)
SMW226	SMW276	DP standard protocol - V memory address of the output buffer as an offset from VB0.
SMB228	SMB278	DP standard protocol - number of bytes of output data
SMB229	SMB279	DP standard protocol - number of bytes of input data
SMB230 to SMB249	SMB280 to SMB299	Reserved - cleared on power up

Note: SMB225 to SMB229, and SMB275 to SMB279 are updated each time the DP slave module accepts configuration/ parameterization information. These locations are updated even if a configuration/parameterization error is detected. The locations are cleared on each power up.

EM 277 PROFIBUS-DP LED Status Indicators

The EM 277 PROFIBUS-DP module has four status LEDs on the front panel to indicate the operational state of the DP port:

- After the S7-200 CPU is turned on, the DX MODE LED remains off as long as DP communication is not attempted.
- Once DP communication has been successfully initiated (the EM 277 PROFIBUS-DP module has entered data exchange mode with the master), the DX MODE LED turns green and remains on until data exchange mode is exited.
- If DP communication is lost, which forces the EM 277 module to exit data exchange mode, the DX MODE LED turns OFF and the DP ERROR LED turns red. This condition persists until the S7-200 CPU is powered off or data exchange is resumed.
- If there is an error in the I/O configuration or parameter information that the DP master is writing to the EM 277 module, the DP ERROR LED flashes red.
- If user 24 VDC is not provided, the POWER LED will be off.

Table A-20 summarizes the status indications signified by the EM 277 status LEDs.

Table A-20 EM 277 PROFIBUS-DP Module Status LEDs

LED	OFF	RED	FLASHING RED	GREEN
CPU Fault	Module is good	Internal Module Failure	--	--
POWER	No 24 VDC User Power	--	--	24 VDC User Power Good
DP ERROR	No Error	Left Data Exchange Mode	Parameterization/ Configuration Error	--
DX MODE	Not in Data Exchange Mode	--	--	In Data Exchange Mode

Note When the EM 277 PROFIBUS-DP module is used exclusively as an MPI slave, only the green Power LED is on.

Additional Configuration Features

The EM 277 PROFIBUS-DP module can be used as a communication interface to other MPI masters, whether or not it is being used as a PROFIBUS-DP slave. The module can provide a connection from the S7-300/400 to the S7-200 using the XGET/XPUT functions of the S7-300/400. STEP 7-Micro/WIN and a network card (such as the CP5611) using the MPI or PROFIBUS parameter set, an OP device or the TD 200 (Rel. 2.0 or greater, order number 6ES7 272-0AA20-0YA0) can be used to communicate with the S7-200 through the EM 277 PROFIBUS-DP module.

A maximum of six connections (six devices) in addition to the DP master can be connected to the EM 277 PROFIBUS-DP module. One connection is reserved for a programming device (PG) and one is reserved for an operator panel (OP). The other four connections can be used by any MPI master. In order for the EM 277 PROFIBUS-DP module to communicate with multiple masters, all masters must be operating at the same baud rate. See Figure A-31 for one possible network configuration.

When the EM 277 PROFIBUS-DP module is used for MPI communication, the MPI master must use the station address of the module for all messages that are sent to the S7-200 to which the module is connected. MPI messages sent to the EM 277 PROFIBUS-DP module are passed on to the S7-200.

The EM 277 PROFIBUS-DP module is a slave module and cannot be used for communication between S7-200 PLCs using the NETR and NETW functions. The EM 277 PROFIBUS-DP module cannot be used for Freeport communication, which is a feature of the S7-200 communication ports.

Figure A-31 shows the PROFIBUS-DP MPI Network.

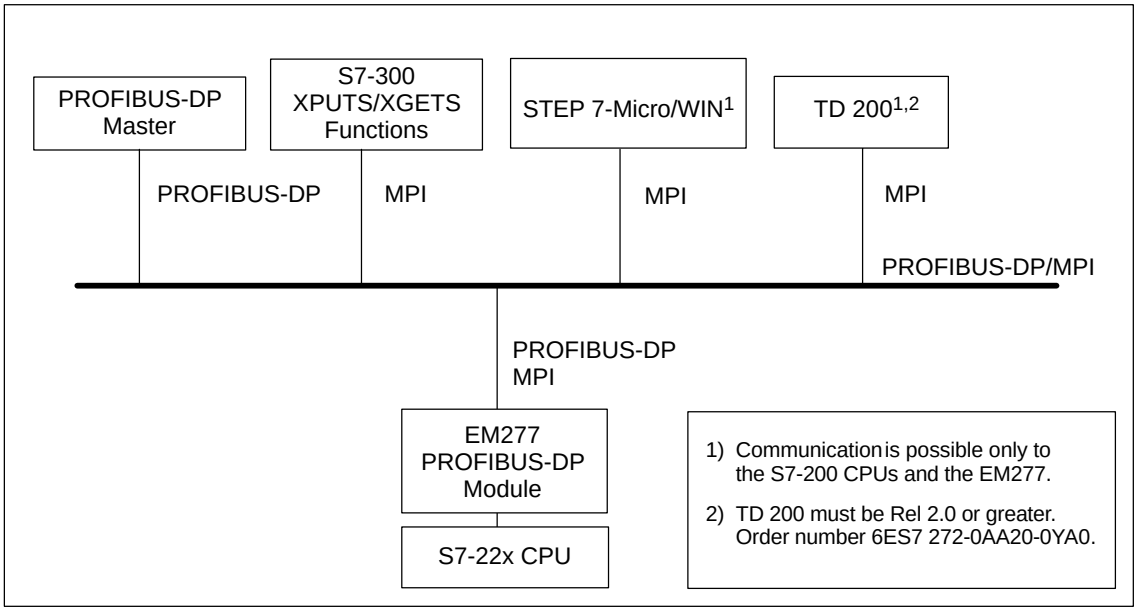


Figure A-31 PROFIBUS-DP/MPI Network

Device Database File: GSD

Different PROFIBUS devices have different performance characteristics. These characteristics differ with respect to functionality (for example, the number of I/O signals and diagnostic messages) or bus parameters such as transmission speed and time monitoring. These parameters vary for each device type and vendor, and are usually documented in a technical manual. To help you achieve a simple configuration of PROFIBUS, the performance characteristics of a particular device are specified in an electronic data sheet called a device database file, or GSD file. Configuration tools based on GSD files allow simple integration of devices from different vendors in a single network.

The device database file provides a comprehensive description of the characteristics of a device in a precisely defined format. These GSD files are prepared by the vendor for each type of device and made available to the PROFIBUS user. The GSD file allows the configuration system to read in the characteristics of a PROFIBUS device and use this information when configuring the network.

The latest versions of the COM PROFIBUS or STEP 7 software include configuration files for the EM 277 PROFIBUS-DP Module. If your version of software does not include a configuration file for the EM 277, you can access the latest GSD file (SIEM089D.GSD) at website www.profibus.com.

If you are using a non-Siemens master device, refer to the documentation provided by the manufacturer on how to configure the master device by using the GSD file.

Listing of the EM 277 PROFIBUS-DP GSD File

```
;=====================================================
; GSD File for the EM 277 PROFIBUS-DP with a DPC31
; MLFB  : 6ES7 277-0AA20-0XA0
; DATE  : 07-Oct-1999
;=====================================================
#Profibus_DP
;General parameters
GSD_Revision         = 1
Vendor_Name          = ”Siemens”
Model_Name           = ”EM 277 PROFIBUS-DP”
Revision             = ”V1.00”
Ident_Number         = 0x089D
Protocol_Ident       = 0
Station_Type         = 0
FMS_supp             = 0
Hardware_Release     = ”1.00”
Software_Release     = ”1.00”
9.6_supp             = 1
19.2_supp            = 1
45.45_supp           = 1
93.75_supp           = 1
187.5_supp           = 1
500_supp             = 1
1.5M_supp            = 1
3M_supp              = 1
```

```
6M_supp              = 1
12M_supp             = 1
MaxTsdr_9.6          = 60
MaxTsdr_19.2         = 60
MaxTsdr_45.45        = 250
MaxTsdr_93.75        = 60
MaxTsdr_187.5        = 60
MaxTsdr_500          = 100
MaxTsdr_1.5M         = 150
MaxTsdr_3M           = 250
MaxTsdr_6M           = 450
MaxTsdr_12M          = 800
Redundancy           = 0
Repeater_Ctrl_Sig    = 2
24V_Pins             = 2

; Slave-Specification:
OrderNumber=”6ES7 277-0AA20-0XA0”
Periphery=”SIMATIC S5”
Slave_Family=10@TdF@SIMATIC

Freeze_Mode_supp     = 1
Sync_Mode_supp       = 1
Set_Slave_Add_Supp   = 0
Auto_Baud_supp       = 1
Min_Slave_Intervall  = 1
Fail_Safe            = 0
Max_Diag_Data_Len    = 6
Modul_Offset         = 0
Modular_Station      = 1
Max_Module           = 1
Max_Input_len        = 128
Max_Output_len       = 128
Max_Data_len         = 256

; UserPrmData-Definition
ExtUserPrmData=1 ”I/O Offset in the V-memory”
Unsigned16 0 0-5119
EndExtUserPrmData
; UserPrmData: Length and Preset:
User_Prm_Data_Len=3
User_Prm_Data= 0,0,0
Max_User_Prm_Data_Len=3
Ext_User_Prm_Data_Const(0)=0x00,0x00,0x00
Ext_User_Prm_Data_Ref(1)=1

; Module Definition List
Module = ”2 Bytes Out/ 2 Bytes In      -” 0x31
EndModule
Module = ”8 Bytes Out/ 8 Bytes In      -” 0x37
EndModule
Module = ”32 Bytes Out/ 32 Bytes In    -” 0xC0,0x1F,0x1F
EndModule
Module = ”64 Bytes Out/ 64 Bytes In    -” 0xC0,0x3F,0x3F
EndModule
Module = ”1 Word Out/ 1 Word In        -” 0x70
EndModule
Module = ”2 Word Out/ 2 Word In        -” 0x71
EndModule
```

```
Module = ″4 Word Out/ 4 Word In        -″ 0x73
EndModule
Module = ″8 Word Out/ 8 Word In        -″ 0x77
EndModule
Module = ″16 Word Out/ 16 Word In      -″ 0x7F
EndModule
Module = ″32 Word Out/ 32 Word In      -″ 0xC0,0x5F,0x5F
EndModule
Module = ″2 Word Out/ 8 Word In        -″ 0xC0,0x41,0x47
EndModule
Module = ″4 Word Out/ 16 Word In       -″ 0xC0,0x43,0x4F
EndModule
Module = ″8 Word Out/ 32 Word In       -″ 0xC0,0x47,0x5F
EndModule
Module = ″8 Word Out/ 2 Word In        -″ 0xC0,0x47,0x41
EndModule
Module = ″16 Word Out/ 4 Word In       -″ 0xC0,0x4F,0x43
EndModule
Module = ″32 Word Out/ 8 Word In       -″ 0xC0,0x5F,0x47
EndModule
Module = ″4 Byte buffer I/O            -″ 0xB3
EndModule
Module = ″8 Byte buffer I/O            -″ 0xB7
EndModule
Module = ″12 Byte buffer I/O           -″ 0xBB
EndModule
Module = ″16 Byte buffer I/O           -″ 0xBF
EndModule
```

Sample Program for DP Communication to a CPU 224

A sample program in Statement List for a CPU 224 that uses the DP port information in SM memory is shown in Figure A-32. Figure A-33 shows the same program in ladder logic. This program determines the location of the DP buffers from SMW226 and the sizes of the buffers from SMB228 and SMB229. This information is used in the program the copy the data in the DP output buffer to the process-image output register of the CPU 224. Similarly, the data in the process-image input register of the CPU 224 are copied into the V memory input buffer.

```
// Sample DP program
// The DP configuration data in the SM memory area provides the
// configuration of the DP slave.  The program uses the
// following data:
//
//   SMW220    DP Module Error Status
//   SMB224    DP STATUS
//   SMB225    Master Address
//   SMW226    V memory offset of outputs
//   SMB228    Number of bytes of output data
//   SMB229    Number of bytes of input data
//   VD1000    Output Data Pointer
//   VD1004    Input Data Pointer
//
NETWORK 1
//
// Calculate the Output data pointer into V memory.
//
LDB= SMB224, 2              // if ( in data exchange mode )
MOVD   &VB0, VD1000         // Output buffer is an offset from VB0.
ITD    SMW226, AC0          // Add Vmem offset to get output
+D     AC0, VD1000          // buffer offset

NETWORK 2
//
// Calculate the Input data pointer into V memory.
//
LDB=   SMB224, 2            // if ( in data exchange mode )
MOVD   VD1000, VD1004       // Get the output pointer address
BTI    SMB228, AC0          // Add the number of output bytes
ITD    AC0, AC0             // to the output pointer to get
+D     AC0, VD1004          // the starting input pointer.

NETWORK 3
//
// Set amount of data to be copied.
//
LDB=   SMB224, 2            // if ( in data exchange mode )
MOVB   SMB228, VB1008       // Get number of output bytes to copy
MOVB   SMB229, VB1009       // Get number of input bytes to copy

NETWORK 4
//
// Transfer Masters Outputs to CPU's Outputs. Copy CPU's inputs
// to the Master's inputs.
//
LDB= SMB224, 2              // if ( in data exchange mode )
BMB  *VD1000, QB0, VB1008   // Copy master outputs to CPU outputs
BMB  IB0, *VD1004, VB1009   // Copy CPU inputs to Master's Inputs
```

Figure A-32 STL Sample Program for DP Communication to a CPU 224

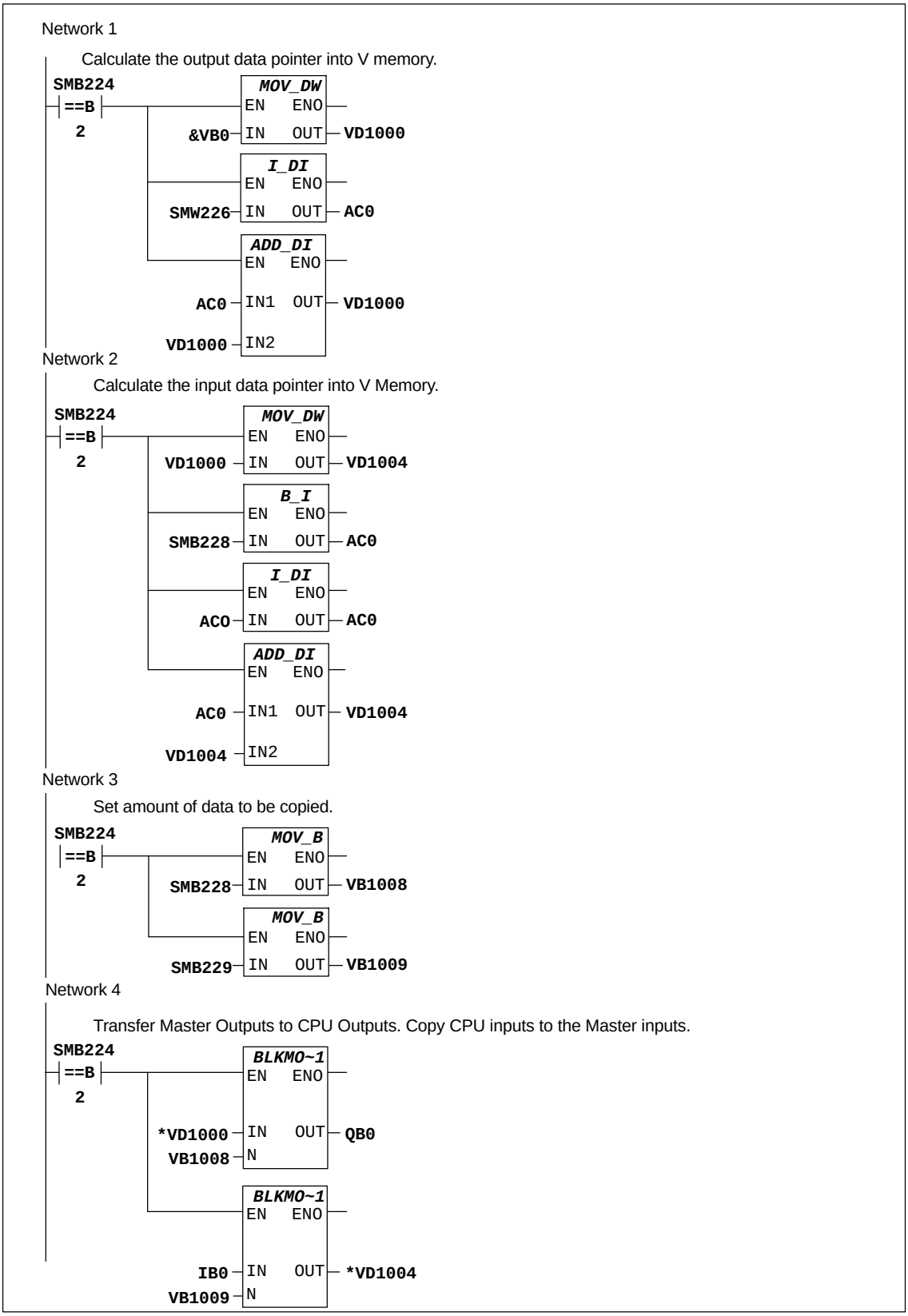


Figure A-33 LAD Sample Program for DP Communication to a CPU 224

A.13 Specifications for EM 231 Thermocouple, EM 231 RTD Modules

Table A-21 Specifications for EM 231 Thermocouple and EM 231 RTD Modules

Description Order Number	EM 231 AI 4 x Thermocouple 6ES7 231-7PD20-0XA0	EM 231 AI 2 x RTD 6ES7 231-7PB20-0XA0
General Specifications		
Dimensions (W x H x D) Weight Power loss (dissipation)	71.2 mm x 80 mm x 62 mm 210 g 1.8 W	71.2 mm x 80 mm x 62 mm 210 g 1.8 W
Number of physical I/O	4 analog input points	2 analog input points
Power Consumption From +5 VDC (from I/O bus) From L+ L+ voltage range, Class 2 or DC sensor supply	 87 mA 60 mA 20.4 to 28.8 VDC	 87 mA 60 mA 20.4 to 28.8 VDC
LED indicator	24 VDC Power Supply Good: ON = no fault, OFF = no 24 VDC power SF: ON = module failure, BLINKING = input signal error, OFF = no faults	24 VDC Power Supply Good: ON = no fault, OFF = no 24 VDC power SF: ON = module failure, BLINKING = input signal error, OFF = no faults
Analog Input Specifications		
Isolation Field side to logic Field side to 24 VDC 24 VDC to logic	 500 VAC 500 VAC 500 VAC	 500 VAC 500 VAC 500 VAC
Common mode input range (input channel to input channel)	120 VAC	0
Common mode rejection	> 120 dB @ 120 VAC	> 120 dB @ 120 VAC
Input type	Floating TC	Module ground referenced RTD
Input ranges	TC types (select one): S, T, R, E, N, K, J Voltage range: +/- 80 mV	RTD types (select one): Pt -100Ω, 200Ω, 500Ω, 1000Ω (with α = 3850 ppm, 3920 ppm, 3850.55 ppm, 3916 ppm, 3902 ppm) Pt -10000Ω (α = 3850 ppm) Cu -9.035Ω (α = 4720 ppm) Ni -10Ω, 120Ω, 1000Ω (with α = 6720 ppm, 6178 ppm) R -150Ω, 300Ω, 600Ω FS
Input Resolution Temperature Voltage Resistance	 0.1° C / 0.1° F 15 bits plus sign	 0.1° C / 0.1° F 15 bits plus sign
Measuring Principle	Sigma-delta	Sigma-delta
Module update time: All channels	405 mS	405 ms (700 ms for Pt10000)
Wire length	100 meters to sensor max	100 meters to sensor max
Wire loop resistance	100Ω max	20Ω, 2.7Ω for Cu max
Suppression of interference	85 dB @ 50 Hz/60 Hz/ 400 Hz	85 dB @ 50 Hz/60 Hz/400 Hz
Data word format	Voltage: -27648 to + 27648	Resistance: -27648 to +27648
Maximum sensor dissipation		1m W
Input impedance	>1 MΩ	>10 MΩ
Maximum input voltage	30 VDC	30 VDC (sense), 5 VDC (source)
Resolution	15 bit + sign	15 bit + sign
Input filter attenuation	-3 dB @ 21 kHZ	-3 dB @ 3.6 kHz
Basic error	0.1% FS (voltage)	0.1% FS (resistance)
Repeatability	0.05% FS	0.05% FS
Cold junction error	±1.5 ° C	

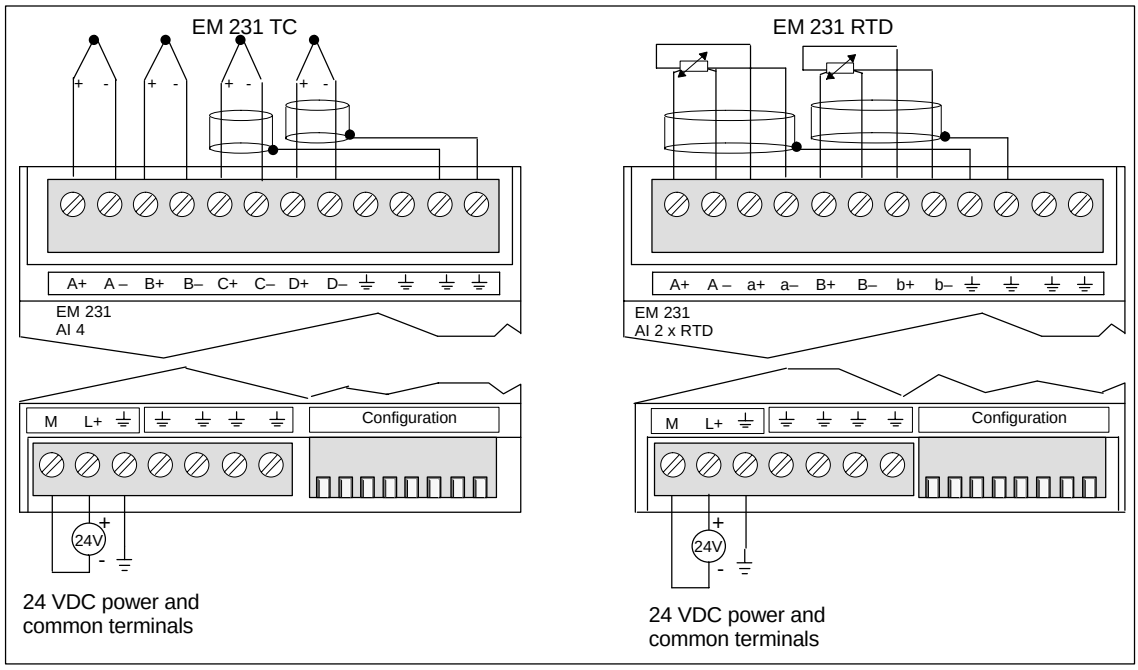


Figure A-34 Connector Terminal Identification for EM 231 Thermocouple and RTD

Compatibility

The RTD and Thermocouple modules are designed to work with the S7-200 CPU 222, CPU 224, and CPU 226.

These modules are designed to give maximum performance when installed in a stable temperature environment. The EM 231 Thermocouple module, for example, has special cold junction compensation circuitry that measures the temperature at the module connectors and makes necessary changes to the measurement to compensate for temperature differences between the reference temperature and the temperature at the module. If the ambient temperature is changing rapidly in the area where the EM 231 Thermocouple module is installed, additional errors are introduced. To achieve maximum accuracy and repeatability, Siemens recommends that the S7-200 RTD and thermocouple modules be mounted in locations that have stable ambient temperature.

EM 231 Thermocouple Module

The EM 231 Thermocouple module provides a convenient, isolated interface for the S7-200 family to seven thermocouple types: J, K, E, N, S, T, and R. It allows the S7-200 to connect to low level analog signals, ±80mV range. You must use DIP switches to select the thermocouple type, open wire check, temperature scale, cold junction compensation and burnout direction. All thermocouples attached to the module must be of the same type.

Configuring the EM 231 Thermocouple Module

The configuration DIP switches are located on the bottom of the module, as shown in Figure A-35. For the DIP switch settings to take effect, you need to power cycle the PLC and/or the user 24V power supply.

DIP switch 4 is reserved for future use. Set DIP switch 4 to the 0 (down) position. Refer to Table A-22 through Table A-26 for other DIP switch settings.

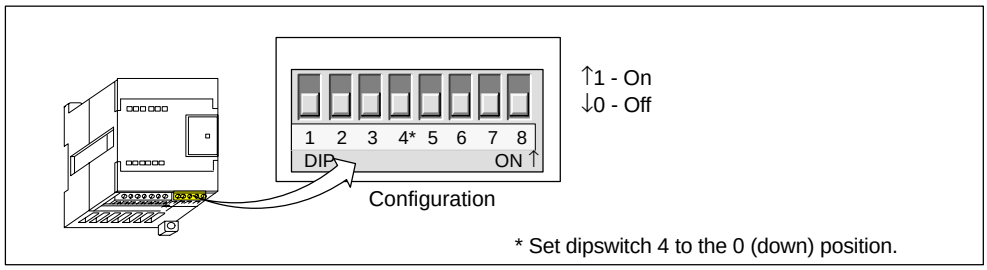


Figure A-35 Configuring DIP Switches for the EM 231 Thermocouple Module

Selecting the thermocouple type Select the thermocouple type by setting DIP switches 1, 2, and 3 as shown in Table A-42.

Table A-22 Selecting the Thermocouple Type

Thermocouple Type	SW1	SW2	SW3
J (Default)	0	0	0
K	0	0	1
T	0	1	0
E	0	1	1
R	1	0	0
S	1	0	1
N	1	1	0
+/-80mV	1	1	1

Selecting the sensor burnout direction Select the sensor burnout direction (either upscale or downscale) by setting DIP switch 5 as shown in Table A-23.

Table A-23 Selecting Sensor Burnout Direction

Burnout Direction	SW5
Upscale (+3276.7 degrees)	0
Downscale (-3276.8 degrees)	1

Selecting open wire check Open wire detection is performed by injecting a 25 µA current onto the input terminals. The open wire enable switch enables or disables the current source. The open wire range check is always performed, even when the current source is disabled. The EM 231 Thermocouple module detects open wire if the input signal exceeds approximately ±200mV. When an open wire is detected, the module reading is set to the value selected by the sensor burnout direction. Enable or disable the open wire current source by setting DIP switch 6 for the desired function as shown in Table A-24.

Table A-24 Selecting Open Wire Check

Open Wire	SW6
Enable open wire current	0
Disable open wire current	1

Note

- The open wire current source may interfere with signals from some low level sources such as Thermocouple simulators.
- Input voltages exceeding approximately ±200mV will trigger open wire detection even when the open wire current source is disabled.

Selecting temperature scale The EM 231 Thermocouple module can report temperatures in Celsius or Fahrenheit. The Celsius to Fahrenheit conversion is performed inside the module. Use DIP switch 7 to select the temperature scale as shown in Table A-25.

Table A-25 Selecting Temperature Scale

Scale	SW7
Celsius (°C)	0
Fahrenheit (°F)	1

Selecting cold junction operation Cold junction compensation must be enabled when you are using thermocouples. If cold junction compensation is not enabled, the conversions from the module will be in error because of the voltage that is created when the thermocouple wire is connected to the module connector. Cold junction is automatically disabled when you select the ±80mV range. Use DIP switch 8 to enable or disable cold junction compensation as shown in Table A-26.

Table A-26 Selecting Cold Junction Operation

Cold Junction Enable	SW8
Cold junction compensation enabled	0
Cold junction compensation disabled	1

Note

- Module error may exceed specifications while the ambient temperature is changing.
- Exceeding the module ambient temperature range specification may cause the module cold junction to be in error.

Wiring the EM 231 Thermocouple Module

Wire the thermocouple wires directly to the EM 231 Thermocouple module. Use shielded wires for best noise immunity. If you are using shielded wires, you should connect the shield to the grounds on pins 1 to 4 of the signal connector. This ground is the same ground that is present on the power connector pins 3 to 7. If a thermocouple input channel is not used, you should short the unused channel inputs, or connect them in parallel to another channel. This prevents errors (resulting from floating inputs) from blocking error indications from valid channels.

You must connect user power to pins 1 and 2 of the power connector. You must connect pin 3 of the power connector to a nearby chassis ground. See Figure A-36.

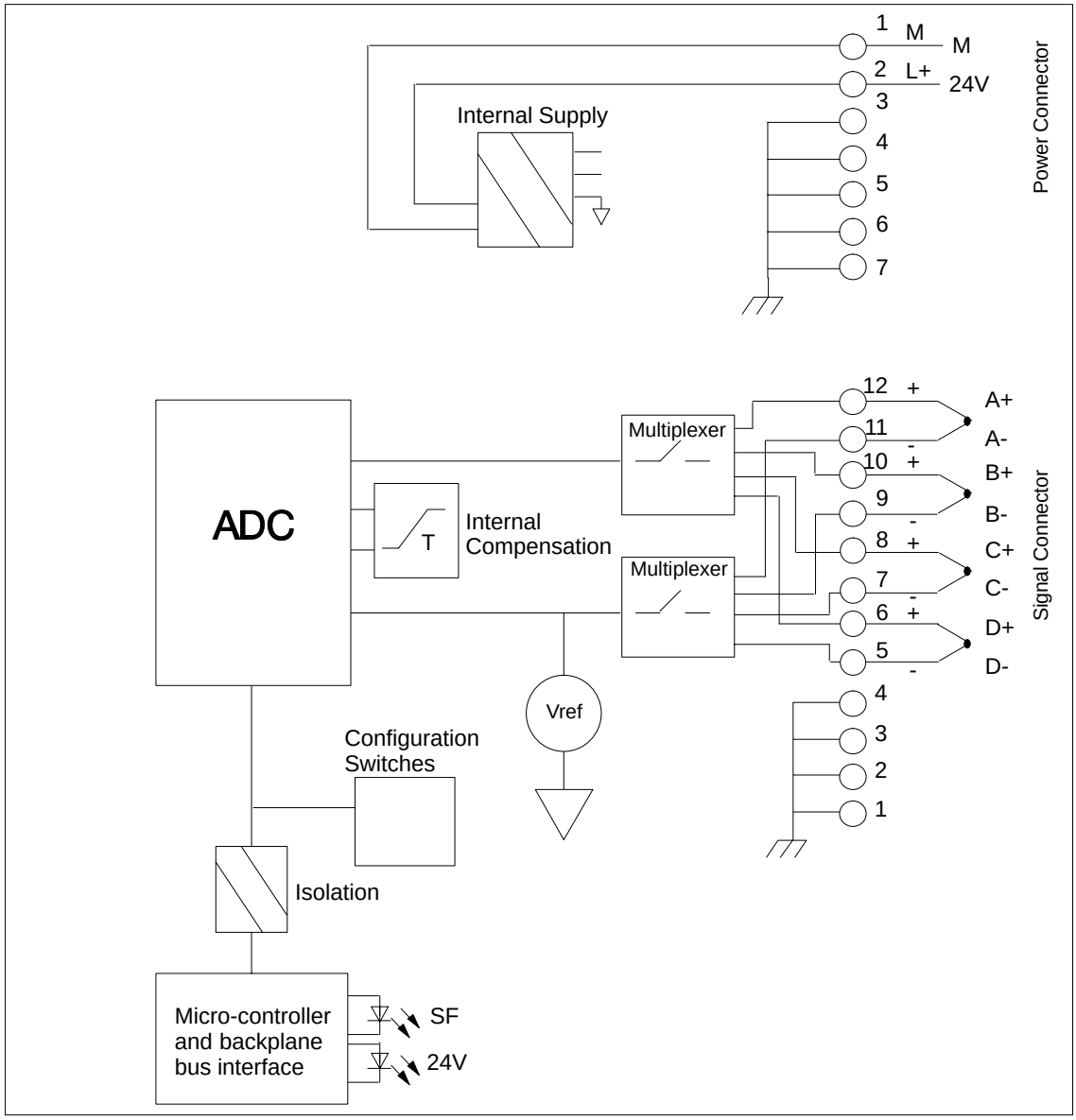


Figure A-36 Circuit Schematic of the Thermocouple Module

Using the Thermocouple: Status Indicators

The thermocouple module provides the PLC with data words that indicate temperatures or error conditions. Status bits indicate range error and user supply/module failure. LEDs indicate the status of the module. Your program should have logic to detect error conditions and respond appropriately for the application. Table A-27 shows the thermocouple status indicators.

Table A-27 Thermocouple Status Indicators

Error Condition	Channel Data	SF LED	24 V LED	Range Status Bit[1]	24 V Module Bad Status Bit[2]
No errors	Conversion data	OFF	ON	0	0
24V missing	32766	OFF	OFF	0	1
Open wire and current source enabled	-32768/32767	BLINK	ON	1	0
Out of range input	-32768/32767	BLINK	ON	1	0
Diagnostic error[3]	0000	ON	OFF	0	*

1 Range status bit is bit 3 in module error register byte (SMB9 for Module 1, SMB11 for Module 2, etc.)
2 Bad status bit is bit 2 in module error register byte (SMB 9, SMB 11, etc. Refer to Appendix C.)
3 Diagnostic errors cause a module configuration error. The module bad status bit may or may not be set before the module configuration error.

Note
The channel data format is 2's complement, 16-bit words. Temperature is presented in 0.1 degree units. (For example, if the measured temperature is 100.2 degrees, the reported data is 1002.) Voltage data are scaled to 27648. For example, -60.0mV is reported as -20736 (=-60mV/80mV * 27648).

All four channels are updated every 405 milliseconds if the PLC has read the data. If the PLC does not read the data within one update time, the module reports old data until the next module update after the PLC read. To keep channel data current, it is recommended that the PLC program read data at least as often as the module update rate.

Note
When you are using the thermocouple module, you need to disable analog filtering in the PLC. Analog filtering can prevent error conditions from being detected in a timely manner.

Thermocouple Basics

Thermocouples are formed whenever two dissimilar metals are electrically bonded to each other. A voltage is generated that is proportional to the junction temperature. This voltage is small; one microvolt may represent many degrees. Measuring the voltage from a thermocouple, compensating for extra junctions, and then linearizing the result forms the basis of temperature measurement using thermocouples.

When you connect a thermocouple to the EM 231 thermocouple module, the two dissimilar metal wires are attached to the module at the module signal connector. The place where the two dissimilar wires are attached to each other forms the sensor thermocouple. Two more thermocouples are formed where the two disimilar wires are attached to the signal connector. The connector temperature causes a voltage that adds to the voltage from the sensor thermocouple. If this voltage is not corrected, then the temperature reported will deviate from the sensor temperature. Cold junction compensation is used to compensate for the connector thermocouple. Thermocouple tables are based on a reference junction temperature, usually zero degrees Celsius. The module cold junction compensation compensates the connector to zero degrees Celsius. The cold junction compensation restores the voltage added by the connector thermocouples. The temperature of the module is measured, internally. This temperature is converted to a value to be added to the sensor conversion. The corrected sensor conversion is then linearized using the tables.

Thermocouple Module Ranges

Table A-28 and Table A-29 show temperature ranges and accuracy for each type of thermocouple.

Table A-28 Temperature Ranges (°C) and Accuracy for Thermocouple Types

Data Word (1 digit = 0.1°C)		Type J	Type K	Type T	Type E	Type R, S	Type N	±80mV	
Dec	Hex								
32767	7FFF	>1200.0 °C	>1372.0 °C	>400.0 °C	>1000.0°C	>1768.0°C	>1300.0°C	>94.071mV	OF
↑	↑							↑	↑
32511	7EFF							94.071mV	
:	:								OR
27649	6C01							80.0029mV	
27648	6C00					↑		80mV	
:	:								
17680	4510		↑			1768.0°C			
:	:								NR
13720	3598		1372.0°C				↑		
:	:		overrange						
13000	32C8	↑	1300.0°C				1300.0°C		
:	:								
12000	2EE0	1200.0°C			↑				
:	:								
10000	2710			↑	1000.0°C				
:	:								
4000	0FA0			400.0°C		400.0°C			
:	:								
1	0001	0.1°C	0.1°C	0.1°C	0.1°C	0.1°C	0.1°C	0.0029mV	
0	0000	0.0°C	0.0°C	0.0°C	0.0°C	0.0°C	0.0°C	0.0mV	
-1	FFFF	-0.1°C	-0.1°C	-0.1°C	-0.1°C	-0.1°C	-0.1°C	-0.0029mV	
:	:					underrange			
-500	FE0C					-50.0°C			
-1500	FA24	-150.0°C				↓			
:	:								
-2000	F830	underrange	-200.0°C						
:	:								
-2100	F7CC	-210.0°C							
:	:		underrange						
-2550	F60A			-255.0°C	-255.0°C				
:	:			underrange	underrange				
-2700	F574	↓	-270.0°C	-270.0°C	-270.0°C		-270.0°C		
:	:								
-27648	9400		↓	↓	↓		↓	-80.mV	
-27649	93FF							-80.0029mV	
:	:								
-32512	8100							-94.071mV	UR
↓	↓							↓	↓
-32768	8000	<-210.0°C	<-270.0°C	<-270.0°C	<-270.0°C	<-50.0°C	<-270.0°C	<-94.071mV	UF
Accuracy over full span		±0.1%	±0.3%	±0.6%	±0.1%	±0.6%	±0.1%	±0.1%	
Accuracy (nominal range without cold junction)		±1.5°C	±1.7°C	±1.4°C	±1.3°C	±3.7°C	±1.6°C	±0.10%	
Cold junction error		±1.5°C	±1.5°C	±1.5°C	±1.5°C	±1.5°C	±1.5°C	N/A	

*OF = Overflow; OR = Overrange; NR = Nominal range; UR = Underrange; UF = Underflow

↑ indicates that all analog values greater than this and below the open wire threshold report the overflow data value, 32767 (0x7FFF).
↓ indicates that all analog values less than this and greater than the open wire threshold report the underflow data value, -32768 (0x8000).

Table A-29 Temperature Ranges (°F) for Thermocouple Types

Data Word (1 digit = 0.1°F)		Type J	Type K	Type T	Type E	Type R, S	Type N	±80 mV	
Dec	Hex								
32767	7FFF	>2192.0 °F	>2502.0 °F	>752.0 °F	>1832.0°F	>3214.0°F	>2372.0°F	>94.071mV	OF
↑	↑					↑		↑	↑
32511	7EFF							94.071mV	
32140	7D90					3214.0°F			OR
27649	6C01							80.0029mV	
27648	6C00		↑			2764.8°F		80mV	
:	:								
25020	61B8		2502.0°F				↑		NR
:	:		overrange						
23720	5CA8	↑	2372.0°F				2372.0°F		
:	:								
21920	55A0	2192.0°F			↑				
:	:								
18320	4790			↑	1832.0°F				
:	:								
7520	1D60			752.0°F		752.0°F			
:	:								
320	0140					underrange	32.0°F		
:	:								
1	0001	0.1°F	0.1°F	0.1°F	0.1°F	0.1°F	0.1°F	0.0029mV	
0	0000	0.0°F	0.0°F	0.0°F	0.0°F	0.0°F	0.0°F	0.0mV	
-1	FFFF	-0.1°F	-0.1°F	-0.1°F	-0.1°F	-0.1°F	-0.1°F	-0.0029mV	
:	:								
-580	FDBC					-58.0°F			
:	:								
-2380	F6B4	-238.0°F							
:	:								
-3280	F330	underrange	-328.0°F				underrange		
:	:								
-3460	F27C	-346.0°F				↓			
:	:		underrange						
-4270	EF52			-427.0°F	-427.0°F				
:	:			underrange	underrange				
-4540	EE44	↓	-454.0°F	-454.0°F	-454.0°F		-454.0°F		
:	:								
-27648	9400		↓	↓	↓		↓	-80mV	
-27649	93FF							-80.0029mV	
:	:								
-32512	8100							-94.071mV	OR
↓	↓							↓	↓
-3268	8000	<-346.0° F	<-454.0° F	<-454.0° F	<-454.0° F	<-58.0° F	<-454.0° F	<-94.07 mV	UF

*OF = Overflow; OR = Overrange; NR = Normal range; UR = Underrange; UF = Underflow
↑ indicates that all analog values greater than this and below the open wire threshold report the overflow data value, 32767 (0x7FFF).
↓ indicates that all analog values less than this and greater than the open wire threshold report the underflow data value, -32768 (0x8000).

EM 231 RTD Module

The EM 231 RTD module provides a convenient interface for the S7-200 family to several different RTDs. It also allows the S7-200 to measure three different resistance ranges. You must use DIP switches to select RTD type, wiring configuration, temperature scale, and burnout direction. Both RTDs attached to the module must be of the same type.

Configuring the EM 231 RTD Module

The configuration DIP switches are located on the bottom of the module, as shown in Figure A-37. For the DIP switch settings to take effect, you need to power cycle the PLC and/or the user 24V power supply.

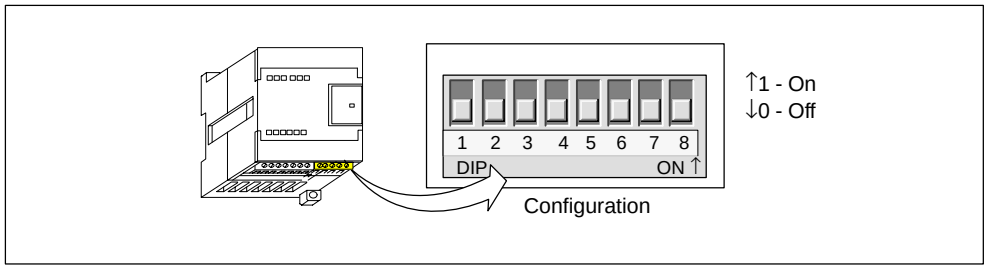


Figure A-37 Configuring DIP Switches for the RTD Module

Selecting the RTD type Select RTD type by setting DIP switches 1, 2, 3, 4, and 5 to correspond to the RTD as shown in Table A-30.

Table A-30 Selecting the RTD Type

RTD Type and Alpha	SW1	SW2	SW3	SW4	SW5
100Ω Pt 0.003850 (Default)	0	0	0	0	0
200Ω Pt 0.003850	0	0	0	0	1
500Ω Pt 0.003850	0	0	0	1	0
1000Ω Pt 0.003850	0	0	0	1	1
100Ω Pt 0.003920	0	0	1	0	0
200Ω Pt 0.003920	0	0	1	0	1
500Ω Pt 0.003920	0	0	1	1	0
1000Ω Pt 0.003920	0	0	1	1	1
100Ω Pt 0.00385055	0	1	0	0	0
200Ω Pt 0.00385055	0	1	0	0	1
500Ω Pt 0.00385055	0	1	0	1	0
1000Ω Pt 0.00385055	0	1	0	1	1
100Ω Pt 0.003916	0	1	1	0	0
200Ω Pt 0.003916	0	1	1	0	1
500Ω Pt 0.003916	0	1	1	1	0
1000Ω Pt 0.003916	0	1	1	1	1
100Ω Pt 0.00302	1	0	0	0	0
200Ω Pt 0.003902	1	0	0	0	1
500Ω Pt 0.003902	1	0	0	1	0
1000Ω Pt 0.003902	1	0	0	1	1
SPARE	1	0	1	0	0
100Ω Ni 0.00672	1	0	1	0	1
120Ω Ni 0.00672	1	0	1	1	0
1000Ω Ni 0.00672	1	0	1	1	1
100Ω Ni 0.006178	1	1	0	0	0
120Ω Ni 0.006178	1	1	0	0	1
1000Ω Ni 0.006178	1	1	0	1	0
10000Ω Pt 0.003850	1	1	0	1	1
10Ω Cu 0.004270	1	1	1	0	0
150Ω FS Resistance	1	1	1	0	1
300Ω FS Resistance	1	1	1	1	0
600Ω FS Resistance	1	1	1	1	1

Selecting sensor burnout direction Use DIP switch 6 to set the sensor burnout direction as shown in Table A-31.

Table A-31 Selecting Sensor Burnout Direction

Burnout Direction	SW6
Upscale (+3276.7 degrees)	0
Downscale (-3276.8 degrees)	1

Selecting the temperature scale The RTD module can report temperatures in Celsius or Fahrenheit. The Celsius to Fahrenheit conversion is performed inside the module. Use switch 7 to select the temperature scale as shown in Table A-32.

Table A-32 Selecting Temperature Scale

Scale	SW7
Celsius (°C)	0
Fahrenheit (°F)	1

Selecting the wiring scheme Use switch 8 to select the wiring scheme as shown in Table A-33.

Table A-33 Wiring Scheme

Wiring Scheme	SW8
3 wire	0
2 wire or 4 wire	1

Wiring the EM 231 RTD Module

You can wire the EM 231 RTD module directly to the S7-200 module, or you can use extension wires. Use shielded wires for best noise immunity. If you use shielded wires, connect the shield to the grounds on pins 1 to 4 of the signal connector. This ground is the same ground as is present on the power connector pins 3 to 7. If you do not use an RTD input channel, you should wire a resistor to the unused channel inputs to prevent errors from floating inputs from blocking error indications from valid channels.

Connect user power to the power connector pins 1 and 2. You must connect pin 3 to a nearby chassis ground (Figure A-38).

You can wire the RTD module to the sensor in three ways (shown in Figure A-39). The most accurate is 4 wire (see Figure A-39). The least accurate is 2 wire, which is only recommended if errors due to wiring can be ignored in your application.

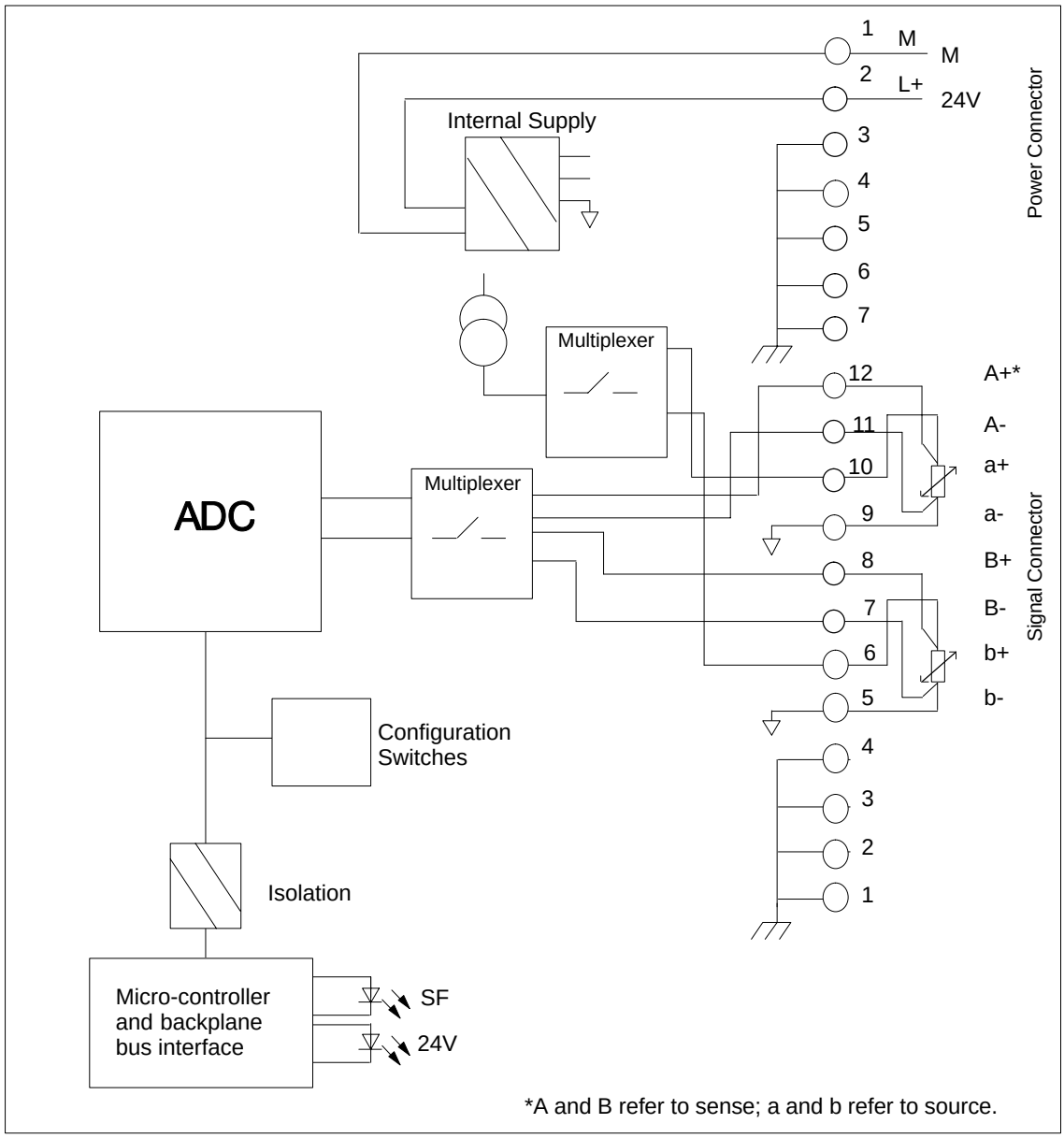


Figure A-38 Circuit Schematic of the RTD Module

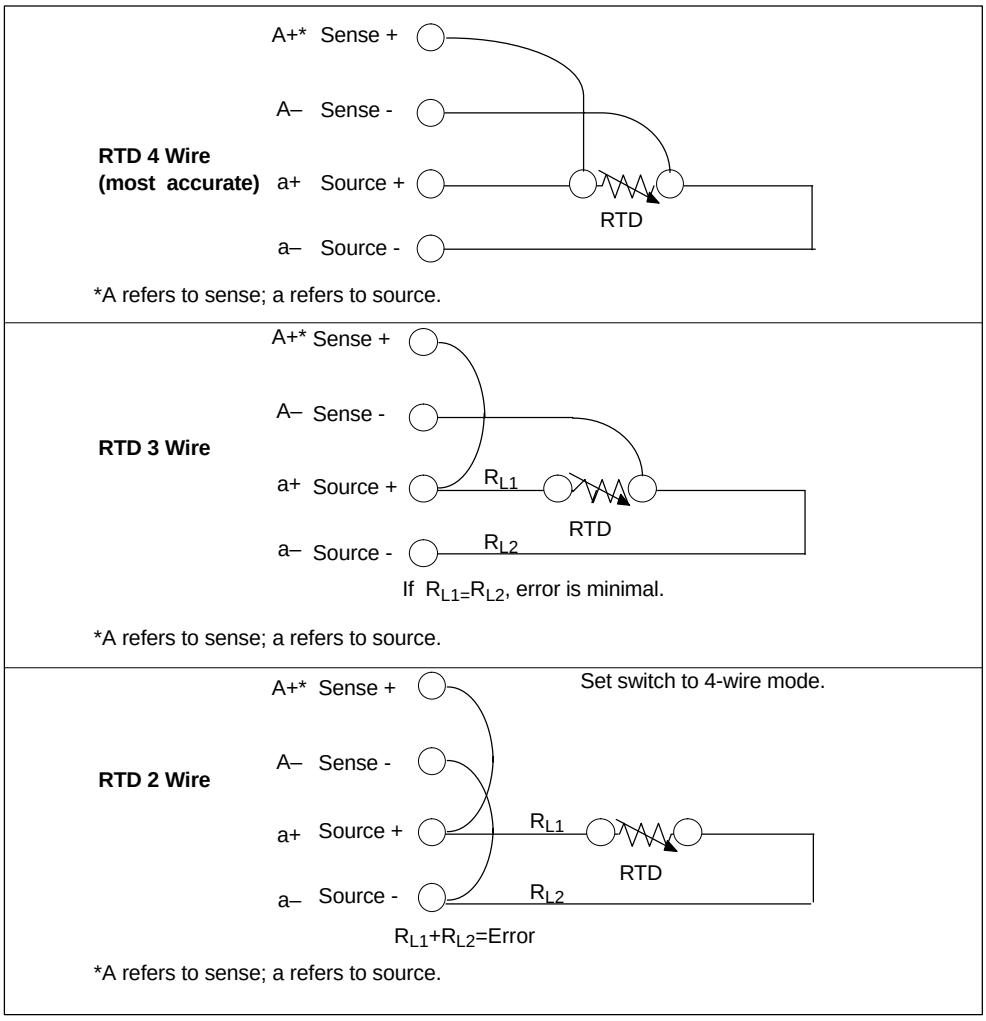


Figure A-39 Wiring the RTD to the Sensor by 4, 3 and 2 Wire

EM 231 RTD Status Indicators

The RTD module provides the PLC with data words that indicate temperatures or error conditions. Status bits indicate range error and user supply/module failure. LEDs indicate the status of the module. Your program should have logic to detect error conditions and respond appropriately for the application. Table A-34 shows the status indicators provided by the EM 231 RTD module.

Note
The channel data format is 2's complement, 16-bit words. Temperature is presented in 0.1 degree units. (For example, if the measured temperature is 100.2 degrees, the reported data is 1002.) Resistance data are scaled to 27648. For example, 75% of full scale resistance is reported as 20736 (=225Ω /300Ω * 27648).

Table A-34 EM 231 RTD Status Indicators

Error Condition	Channel Data	SF LED	24 V LED	Range Status Bit[1]	24 V Module Bad Status Bit[2]
No errors	Conversion data	OFF	ON	0	0
24V missing	32766	OFF	OFF	0	1
SW detects open wire	-32768/32767	BLINK	ON	1	0
Out of range input	-32768/32767	BLINK	ON	1	0
Diagnostic error[3]	0000	ON	OFF	0	*

[1] Range status bit is bit 3 in module error register byte (SMB9 for Module 1, SMB11 for Module 2, etc.)
[2] Bad status bit is bit 2 in module error register byte (SMB 9, SMB 11, etc. Refer to Appendix C.)
[3] Diagnostic errors cause a module configuration error. The module bad status bit may or may not be set before the module configuration error.

Channel data is updated every 405 milliseconds, if the PLC has read the data. If the PLC does not read the data within one update time, the module reports old data until the next module update after the PLC read. To keep channel data current, it is recommended that the PLC program read data at least as often as the module update rate.

Note
When you are using the RTD module, be sure to disable analog filtering in the PLC. Analog filtering can prevent error conditions from being detected in a timely manner.

Open wire detection is performed by software internal to the RTD module. Out of range inputs are declared and open wire data is reported as burnout data. Open wire detection takes a minimum of three module scan cycles and can take longer, depending on which wire(s) are open. Open Source+ and/or Source- wires are detected in the minimum time. Open Sense+ and/or Sense- wires can take 5 seconds or more to detect. Open sense lines may randomly present valid data, with open wire detected intermittently, especially in electrically noisy environments. Electrical noise may also extend the time it takes to detect the open wire condition. It is recommended that open wire/out of range indications be latched in the application program after valid data has been reported.

EM 231 RTD Module Ranges

Table A-35 and Table A-36 show temperature ranges and accuracy for each type of RTD module.

Table A-35 Temperature Ranges (°C) and Accuracy for RTD Types

System Word (1 digit = 0.1 °C)		Pt10000	Pt100, Pt200, Pt500, Pt1000	Ni100, Ni120, Ni1000	Cu9.035	0 - 150Ω	0 - 300Ω	0 - 160Ω	
Decimal	Hex								
32767	7FFF								
32766	7FFE					↑	↑	↑	
32511	7EFF					176.383Ω	352.767Ω	705.534Ω	
29649	6C01					150.005Ω	300.011Ω	600.022Ω	
27648	6C00					150.000Ω	300.000Ω	600.000Ω	
25000	61A8								↑
18000	4650								OR
15000	3A98								
13000	32C8	↑	↑						
10000	2710	1000.0°C	1000.0°C						
8500	2134		850.0°C						
6000	1770	600.0°C			↑				
3120	0C30			↑	312.0°C				
2950	0B86			295.0°C					
2600	0A28				260.0°C				
2500	09C4			250.0°C					
1	0001	0.1°C	0.1°C	0.1°C	0.1°C	0.005Ω	0.011Ω	0.022Ω	
0	0000	0.0°C	0.0°C	0.0°C	0.0°C	0.000Ω	0.000Ω	0.000Ω	
-1	FFFF	-0.1°C	-0.1°	-0.1°C	-0.1°C	(negative values are not possible)			NR
						↓	↓	↓	
-600	FDA8			-60.0°C					
-1050	FBE6			-105.0°C					
				↓					
-2000	F830	-200.0°C	-200.0°		-200.0°C				
-2400	F6A0				-240.0°C				
-2430	F682	-243.0°C	-243.0°C		↓				
		↓	↓						
-5000	EC78								
-6000	E890								UR
-10500	D6FC								↓
-12000	D120								
-20000	4E20								
-32767	8001								
-32768	8000								
Accuracy over full span		±0.4%	±0.1%	±0.2%	±0.5%	±0.1%	±0.1%	±0.1%	
Accuracy (nominal range)		±4°C	±1°C	±0.6°C	±2.8°C	±0.15Ω	±0.3Ω	±0.6Ω	

*OF = Overflow; OR = Overrange; NR = Nominal range; UR = Underrange; UF = Underflow

↑ or ↓ indicate that all analog values exceeding the limits report the selected burnout value, 32767 (0x7FFF) or -32768 (0x8000).

Table A-36 Temperature Ranges (°F) for RTD Types

System Word (1 digit = 0.1 °F)		PT1000	PT100, Pt200, Pt500, Pt1000	Ni100, Ni120, Ni1000	Cu 9.035	
Decimal	Hexadecimal					
32767	7FFF					
32766	7FFE					
						↑
						Overrange
		↑	↑			
18320	4790	1832.0°F	1832.0 °F			
15620	3D04		1562.0°F			
11120	2B70	1112.0°F				
					↑	
5936	1730			↑	593.6°F	
5630	15FE			563.0°F		
5000	1388				500.0°F	
4820	12D4			482.0°F		
						Normal Range
1	0001	0.1°F	0.1°F	0.1°F	0.1°F	
0	0000	0.0°F	0.0°F	0.0°F	0.0°F	
-1	FFFF	-0.1°F	-0.1°F	-0.1°F	-0.1°F	
-760	FD08			-76.0°F		
-1570	F9DE			-157.0°F		
				↓		
-3280	F330	-328.0°F	-328.0°F		-328.0°F	
-4000	F060				-400.0°F	
-4054	F02A	-405.4°F	-405.4°F		↓	
		↓	↓			
-5000	EC78					
-6000	E890					Underrange
-10500	D6FC					↓
-32767	8001					
-32768	8000					

↑ or ↓ indicate that all analog values exceeding the limits report the selected burnout value, 32767 (0x7FFF) or -32768 (0x8000).

A.14 CP 243-2 Communications Processor

Description Order Number	CP 243-2 Communications Processor 6GK7 243-2AX00-0XA0
AS-Interface master profile	M0/M1
Interfaces - Allocation of address area in PLC - Connection to AS-Interface	 Corresponds to 2 I/O modules (DI/8 DO8 and AI/8/AQ8) Terminal connection
Power consumption - via AS-Interface - via backplane bus	 100 mA, max. 220 mA at DC 5 V, typically
Power loss	2 W, approximately
Permissible environmental conditions - Operating temperature horizontal mounting vertical mounting - Transport/storage temperature - Relative humidity	 0° C to +55° C 0° C to +45° C -40° C to +70° C 95% at +25° C
Construction - Module format - Dimensions (W x H x D) in mm - Weight	 S7-22x expansion module 71.2 x 80 x 62 250 g, approximately

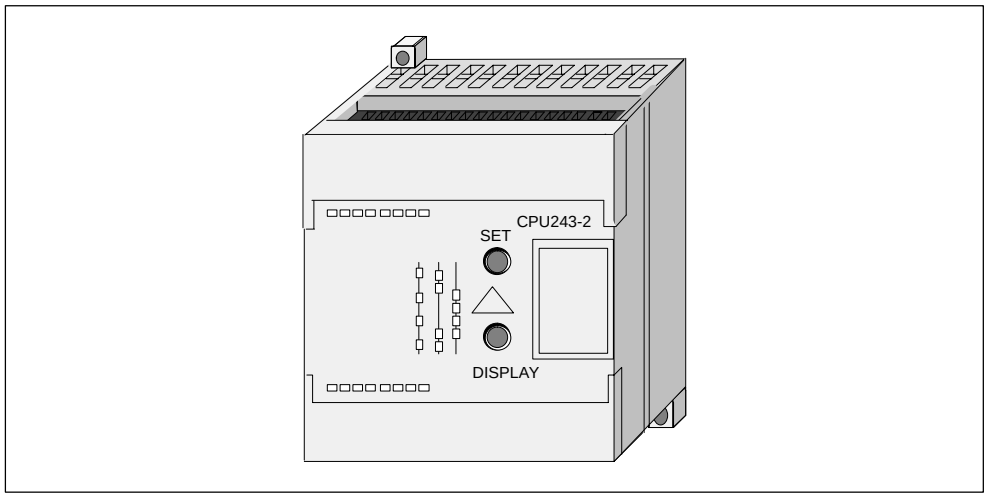


Figure A-40 CP 243-2 Communications Processor

Overview

The CP 243-2 is the AS-Interface master for the S7-200 CPU 22x series. The new communications processor has the following functions:

- Up to 31 AS-Interface slaves can be connected.
- Supports all AS-Interface master functions.
- Status displays of operating statuses and display of readiness of connecting slaves by means of LEDs in the front plate.
- Error displays (including AS-Interface voltage error, configuration error) by means of LEDs in the front plate.
- Compact casing in the design of the innovative SIMATIC S7-200 generation.

Application

The CP 243-2 is the AS-Interface master connection designed exclusively for the S7-200 CPU 22x. Connection to the AS-Interface significantly increases the number of available digital inputs and outputs for S7-200 (maximum 124 DI/124 DO on AS-Interface per CP). Up to two CP 243-2 can be operated on the S7-200 at the same time.

Design

The CP 243-2 is connected to the S7-200 in the same way as an expansion module. It has:

- Two terminal connections for direct connection of the AS-Interface cable.
- LEDS in the front plate to display the status and readiness of all connected and activated slaves.
- Two buttons to display the status information of the slaves, to switch operating mode and to adopt the existing configuration as the SET configuration.

Operation

In the process image of the S7-200, the CP 243-2 occupies a digital input byte (status byte), a digital output byte (control byte), and 8 analog input and 8 analog output words. Therefore the CP 243-2 takes up two logical module positions. The status and the control byte can be used to set the mode of the CP 243-2 via a user program. Depending on its mode, the CP 243-2 stores either the I/O data of the AS-Interface slave or diagnostics values, or enables master calls (e.g. changing a slave address) in the analog address area of the S7-200.

All the connected AS-Interface slaves can be configured at the touch of a button. Further configuration of the CP is not necessary.

Caution

When you use the CP 243-2 module, you must disable analog filtering in the PLC.

If analog filtering is not disabled in the PLC, the digital point data will be destroyed, and error conditions will not be returned as bit values in the analog word.

Ensure that analog filtering in the PLC is disabled.

Functions

The CP 243-2 is the AS-Interface master for the M1 master class, which means that it supports all the specified functions. This makes it possible to operate up to 31 digital slaves on the AS-Interface by means of double address assignment (A-B).

The CP 243-2 can be set to two different modes:

- Standard mode: access to the I/O data of the AS-Interface slave
- Extended mode: master calls (e.g. write parameters) or diagnostic value request.

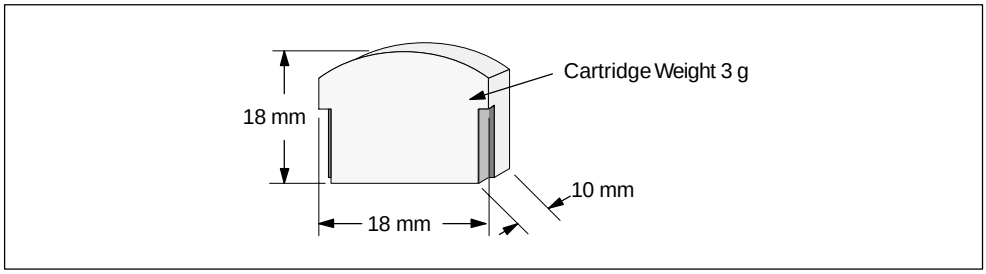
Designed for Industry

- More flexible, more varied applications for the SIMATIC S7-200 thanks to the significant increase in the available digital and analog inputs/outputs.
- Reduced setup times because of the ability to configure at the touch of a button
- Reduced downtime and service time in the event of an error thanks to the LED displays:
  - Status of the CP
  - Display of all connected slaves and their readiness
  - Monitoring of AS-Interface mains voltage

A.15 Optional Cartridges

Order Number	Cartridge Function
6ES7 291 8GE20 0XA0	User program
6ES7 297 1AA20 0XA0	Real-Time Clock with battery
6ES7 291 8BA20 0XA0	Battery Cartridge

Cartridge Options	
Memory cartridge storage	Program, Data, and Configuration
Battery cartridge (data retention time)	200 days, typical
Clock cartridge accuracy	2 minutes/month @ 25°C 7 minutes/month @ 0°C to 55°C



General Features	
Battery	3 V, 30 mA hour, Renata CR 1025
Size	9.9 x 2.5 mm
Type	Lithium < 0.6 g
Shelf life	10 years

A.16 I/O Expansion Cable

Order Number: 6ES7 290-6AA20-0XA0

General Features	
Cable length	0.8 m (32 in.)
Weight	25 g (.88 lb.)
Connector type	10 pin ribbon

Typical Installation of the I/O Expansion Cable

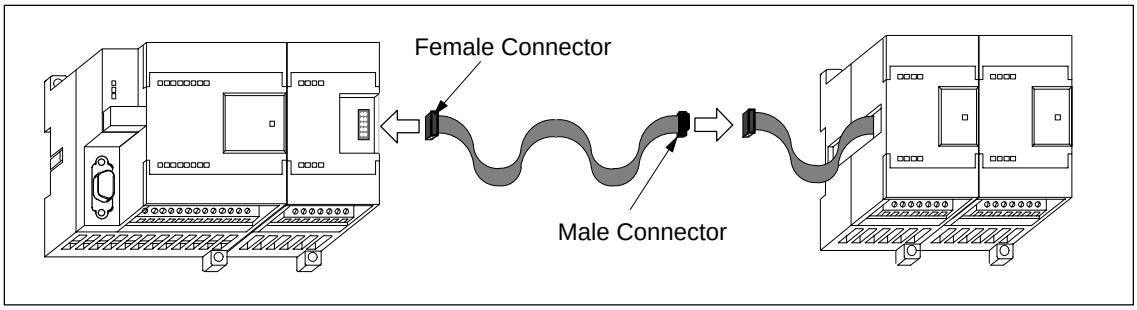


Figure A-41 Typical Installation of an I/O Expansion Cable

Note

Only one expansion cable should be included in a CPU/expansion module chain.

A.17 PC/PPI Cable

Order Number: 6ES7 901-3BF20-0XA0

General Characteristics	
Supply voltage	14.4 to 28.8 VDC
Supply current @ 24 V nominal supply	50 mA RMS max.
Direction change delay: RS-232 start bit edge received to RS-485 start bit edge transmitted	1.2 µS max.
Direction change delay: RS-232 stop bit edge received to RS-485 transmission disabled	1.4 character times max. (1.4 x 11/baud) = 1.6 ms @ 9600 baud
Propagation delay	4 µS max., RS-485 to RS-232, 1.2 µS max., RS-232 to RS-485
Isolation	500 VDC
RS-485 Side Electrical Characteristics	
Common mode voltage range	-7 V to +12 V, 1 second 3 V RMS continuous
Receiver input impedance	5.4K Ω min., including termination
Termination/bias	10K Ω to +5V on B, PROFIBUS pin 3 10K Ω to GND on A, PROFIBUS pin 8
Receiver threshold/sensitivity	+/- 0.2 V, 60 mV typ. hysteresis
Transmitter differential output voltage	2 V min. @ R_L = 100 Ω 1.5 V min. @ R_L = 54 Ω
RS-232 Side Electrical Characteristics	
Receiver input impedance	3K Ω min., minimum
Receiver threshold/sensitivity	0.8 V min. low, 2.4 V max. high, 0.5 V typical hysteresis
Transmitter output voltage	+/- 5 V min. @ R_L = 3K Ω

PC/PPI Cable Dimensions

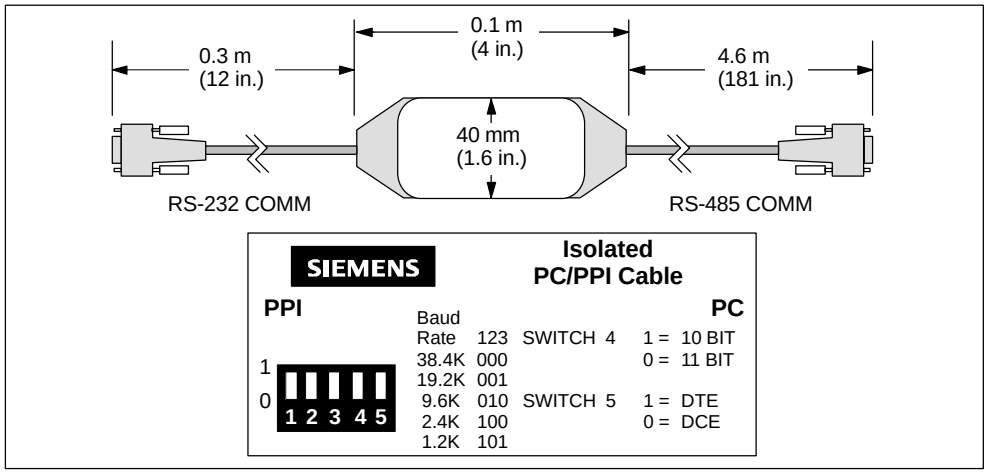


Figure A-42 PC/PPI Cable Dimensions

Table A-37 Baud Rate Switch Selections on the PC/PPI Cable

Baud Rate	Switch (1 = Up)
38400	000
19200	001
9600	010
4800	011
2400	100
1200	101
600	110

Table A-38 Modem Operation for PC/PPI Cable

Modem Operation	Switch (1 = Up)
11-bit modem	0
10-bit modem	1

Table A-39 Pin-out of PC/PPI Cable

Pin-out	Switch (1 = Up)
DCE	0
DTE	1

Table A-40 Pin-outs for RS-485 to RS-232 DCE Connector

RS-485 Connector Pin-out		RS-232 DCE Connector Pin-out	
Pin Number	**Signal Description**	**Pin Number**	**Signal Description**
1	Ground (RS-485 logic ground)	1	Data Carrier Detect (DCD) (not used)
2	24 V Return (RS-485 logic ground)	2	Receive Data (RD) (output from PC/PPI cable)
3	Signal B (RxD/TxD+)	3	Transmit Data (TD) (input to PC/PPI cable)
4	RTS (TTL level)	4	Data Terminal Ready (DTR) (not used)
5	Ground (RS-485 logic ground)	5	Ground (RS-232 logic ground)
6	+5 V (with 100 Ω series resistor)	6	Data Set Ready (DSR) (not used)
7	24 V Supply	7	Request To Send (RTS) (not used)
8	Signal A (RxD/TxD-)	8	Clear To Send (CTS) (not used)
9	Protocol select	9	Ring Indicator (RI) (not used)

Table A-41 Pin-outs for RS-485 to RS-232 DTE Connector

RS-485 Connector Pin-out		RS-232 DTE Connector Pin-out[1]	
Pin Number	**Signal Description**	**Pin Number**	**Signal Description**
1	Ground (RS-485 logic ground)	1	Data Carrier Detect (DCD) (not used)
2	24 V Return (RS-485 logic ground)	2	Receive Data (RD) (input to PC/PPI cable)
3	Signal B (RxD/TxD+)	3	Transmit Data (TD) (output from PC/PPI cable)
4	RTS (TTL level)	4	Data Terminal Ready (DTR) (not used)
5	Ground (RS-485 logic ground)	5	Ground (RS-232 logic ground)
6	+5 V (with 100 Ω series resistor)	6	Data Set Ready (DSR) (not used)
7	24 V Supply	7	Request To Send (RTS) (output from PC/PPI cable)
8	Signal A (RxD/TxD-)	8	Clear To Send (CTS) (not used)
9	Protocol select	9	Ring Indicator (RI) (not used)

[1] A conversion from female to male, and a conversion from 9-pin to 25-pin is required for modems

A.18 Input Simulators

Table A-42 Specifications for Input Simulators

Order Number	8 Position Simulator 6ES7 274-1XF00-0XA0	14 Position Simulator 6ES7 274-1XH00-0XA0	24 Position Simulator 6ES7 274-1XK00-0XA0
Size (L x W x D)	61 x 36 x 22 mm (2.4 x 1.4 x 0.85 in.)	91 x 36 x 22 mm (3.6 x 1.4 x 0.85 in.)	147 x 36 x 25 mm (3.6 x 1.4 x 0.85 in.)
Weight	0.02 Kg (0.04 lb.)	0.03 Kg (0.06 lb.)	0.04 Kg (0.08 lb.)
Points	8	14	24

User Installation

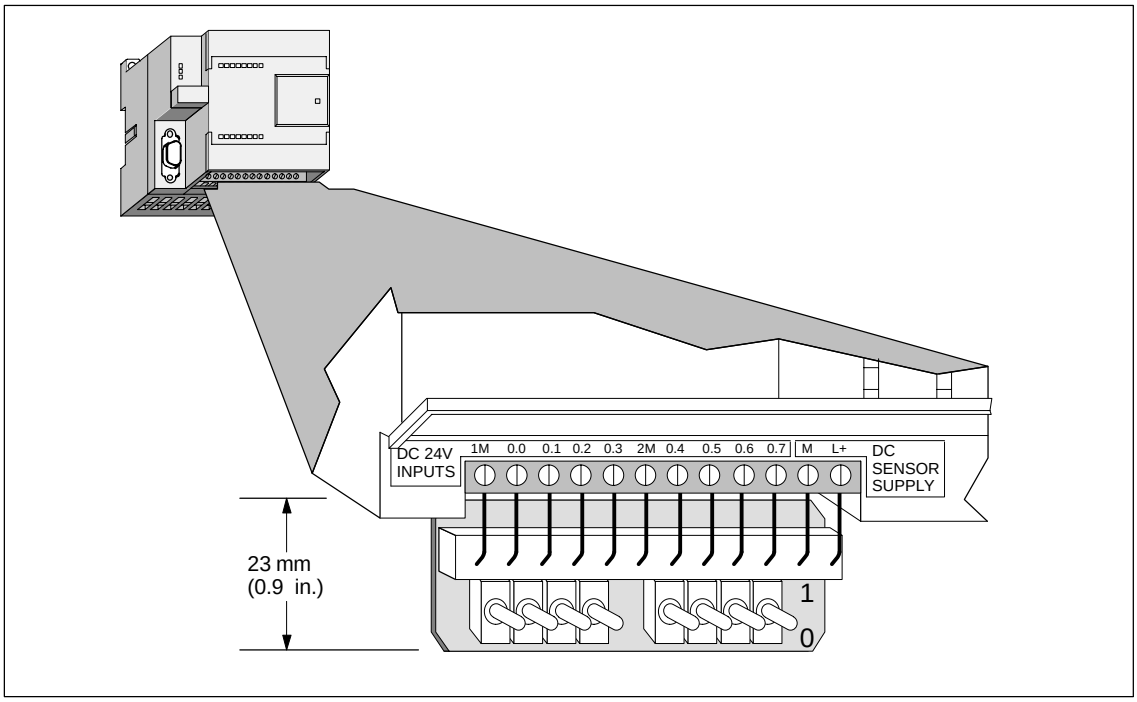


Figure A-43 Installation of the Input Simulator

Caution

These input simulators are not approved for use in Class I DIV 2 or Class I Zone 2 hazardous locations. The switches present a potential spark hazard.

Do not use input simulators in Class I DIV 2 or Class I Zone 2 hazardous locations.

Error Codes

B

The information about error codes is provided to help you identify problems with your S7-200 CPU module.

Chapter Overview

Section	Description	Page
B.1	Fatal Error Codes and Messages	B-2
B.2	Run-Time Programming Problems	B-3
B.3	Compile Rule Violations	B-4

B.1 Fatal Error Codes and Messages

Fatal errors cause the CPU to stop the execution of your program. Depending on the severity of the error, a fatal error can render the CPU incapable of performing any or all functions. The objective for handling fatal errors is to bring the CPU to a safe state from which the CPU can respond to interrogations about the existing error conditions.

The CPU performs the following tasks when a fatal error is detected:

- Changes to STOP mode
- Turns on both the System Fault LED and the Stop LED
- Turns off the outputs

The CPU remains in this condition until the fatal error is corrected. Table B-1 provides a list with descriptions for the fatal error codes that can be read from the CPU.

Table B-1 Fatal Error Codes and Messages Read from the CPU

Error Code	Description
0000	No fatal errors present
0001	User program checksum error
0002	Compiled ladder program checksum error
0003	Scan watchdog time-out error
0004	Internal EEPROM failed
0005	Internal EEPROM checksum error on user program
0006	Internal EEPROM checksum error on configuration parameters
0007	Internal EEPROM checksum error on force data
0008	Internal EEPROM checksum error on default output table values
0009	Internal EEPROM checksum error on user data, DB1
000A	Memory cartridge failed
000B	Memory cartridge checksum error on user program.
000C	Memory cartridge checksum error on configuration parameters
000D	Memory cartridge checksum error on force data
000E	Memory cartridge checksum error on default output table values
000F	Memory cartridge checksum error on user data, DB1
0010	Internal software error
0011	Compare contact indirect addressing error
0012	Compare contact illegal floating point value
0013	Memory cartridge is blank, or the program is not understood by this CPU

B.2 Run-Time Programming Problems

Your program can create non-fatal error conditions (such as addressing errors) during the normal execution of the program. In this case, the CPU generates a non-fatal run-time error code. Table B-2 lists the descriptions of the non-fatal error codes.

Table B-2 Run-Time Programming Problems

Error Code	Run-Time Programming Problem (Non-Fatal)
0000	No error
0001	HSC box enabled before executing HDEF box
0002	Conflicting assignment of input interrupt to a point already assigned to a HSC
0003	Conflicting assignment of inputs to an HSC already assigned to input interrupt or other HSC
0004	Attempted execution of ENI, DISI, SPA, or HDEF instructions in an interrupt routine
0005	Attempted execution of a second HSC/PLS with the same number before completing the first (HSC/PLS in an interrupt routine conflicts with HSC/PLS in main program)
0006	Indirect addressing error
0007	TODW (Time-of-Day Write) or TODR (Time-of-Day Read) data error
0008	Maximum user subroutine nesting level exceeded
0009	Execution of a XMT or RCV instruction while a different XMT or RCV instruction is in progress on Port 0
000A	Attempt to redefine a HSC by executing another HDEF instruction for the same HSC
000B	Simultaneous execution of XMT/RCV instructions on Port 1
000C	Clock cartridge not present
000D	Attempt to redefine pulse output while it is active
000E	Number of PTO profile segment was set to 0
0091	Range error (with address information): check the operand ranges
0092	Error in count field of an instruction (with count information): verify the maximum count size
0094	Range error writing to non-volatile memory with address information
009A	Attempt to switch to freeport mode while in a user interrupt

B.3 Compile Rule Violations

When you download a program, the CPU compiles the program. If the CPU detects that the program violates a compile rule (such as an illegal instruction), the CPU aborts the download and generates a non-fatal, compile-rule error code. Table B-3 lists the descriptions of the error codes that are generated by violations of the compile rules.

Table B-3 Compile Rule Violations

Error Code	Compile Errors (Non-Fatal)
0080	Program too large for the CPU to generate executable code; you must reduce the program size.
0081	Stack underflow; you must split network into multiple networks.
0082	Illegal instruction; check instruction mnemonics.
0083	Missing MEND or instruction not allowed in main program: add MEND instruction, or remove incorrect instruction.
0084	Reserved
0085	Missing FOR; add FOR instruction or delete NEXT instruction.
0086	Missing NEXT; add NEXT instruction or delete FOR instruction.
0087	Missing label (LBL, INT, SBR); add the appropriate label.
0088	Missing RET or instruction not allowed in a subroutine: add RET to the end of the subroutine or remove incorrect instruction.
0089	Missing RETI or instruction not allowed in an interrupt routine: add RETI to the end of the interrupt routine or remove incorrect instruction.
008A	Reserved
008B	Reserved
008C	Duplicate label (LBL, INT, SBR); rename one of the labels.
008D	Illegal label (LBL, INT, SBR); ensure the number of labels allowed was not exceeded.
0090	Illegal parameter; verify the allowed parameters for the instruction.
0091	Range error (with address information); check the operand ranges.
0092	Error in the count field of an instruction (with count information); verify the maximum count size.
0093	FOR/NEXT nesting level exceeded.
0095	Missing LSCR instruction (Load SCR)
0096	Missing SCRE instruction (SCR End) or disallowed instruction before the SCRE instruction
0097	Reserved
0098	Illegal edit in RUN mode
0099	Too many hidden program segments

Special Memory (SM) Bits

C

Special memory bits provide a variety of status and control functions, and also serve as a means of communicating information between the CPU and your program. Special memory bits can be used as bits, bytes, words, or double words.

SMB0: Status Bits

As described in Table C-1, SMB0 contains eight status bits that are updated by the S7-200 CPU at the end of each scan cycle.

Table C-1 Special Memory Byte SMB0 (SM0.0 to SM0.7)

SM Bits	Description (Read Only)
SM0.0	This bit is always on.
SM0.1	This bit is on for the first scan cycle. One use is to call an initialization subroutine.
SM0.2	This bit is turned on for one scan cycle if retentive data was lost. This bit can be used as either an error memory bit or as a mechanism to invoke a special startup sequence.
SM0.3	This bit is turned on for one scan cycle when RUN mode is entered from a power-up condition. This bit can be used to provide machine warm-up time before starting an operation.
SM0.4	This bit provides a clock pulse that is on for 30 seconds and off for 30 seconds, for a duty cycle time of 1 minute. It provides an easy-to-use delay, or a 1-minute clock pulse.
SM0.5	This bit provides a clock pulse that is on for 0.5 seconds and then off for 0.5 seconds, for a duty cycle time of 1 second. It provides an easy-to-use delay or a 1-second clock pulse.
SM0.6	This bit is a scan cycle clock which is on for one scan cycle and then off for the next scan cycle. This bit can be used as a scan counter input.
SM0.7	This bit reflects the position of the Mode switch (off is TERM position, and on is RUN position). If you use this bit to enable Freeport mode when the switch is in the RUN position, normal communication with the programming device can be enabled by switching to the TERM position.

SMB1: Status Bits

As described in Table C-2, SMB1 contains various potential error indicators. These bits are set and reset by instructions at execution time.

Table C-2 Special Memory Byte SMB1 (SM1.0 to SM1.7)

SM Bits	Description (Read Only)
SM1.0	This bit is turned on by the execution of certain instructions when the result of the operation is zero.
SM1.1	This bit is turned on by the execution of certain instructions either when an overflow results or when an illegal numeric value is detected.
SM1.2	This bit is turned on when a negative result is produced by a math operation.
SM1.3	This bit is turned on when division by zero is attempted.
SM1.4	This bit is turned on when the Add to Table instruction attempts to overfill the table.
SM1.5	This bit is turned on when either LIFO or FIFO instructions attempt to read from an empty table.
SM1.6	This bit is turned on when an attempt to convert a non-BCD value to binary is made.
SM1.7	This bit is turned on when an ASCII value cannot be converted to a valid hexadecimal value.

SMB2: Freeport Receive Character

SMB2 is the Freeport receive character buffer. As described in Table C-3, each character received while in Freeport mode is placed in this location for easy access from the ladder logic program.

Table C-3 Special Memory Byte SMB2

SM Byte	Description (Read Only)
SMB2	This byte contains each character that is received from Port 0 or Port 1 during Freeport communication.

SMB3: Freeport Parity Error

SMB3 is used for Freeport mode and contains a parity error bit that is set when a parity error is detected on a received character. As shown in Table C-4, SM3.0 turns on when a parity error is detected. Use this bit to discard the message.

Table C-4 Special Memory Byte SMB3 (SM3.0 to SM3.7)

SM Bits	Description (Read Only)
SM3.0	Parity error from Port 0 or Port 1 (0 = no error; 1 = error was detected)
SM3.1 to SM3.7	Reserved

SMB4: Queue Overflow

As described in Table C-5, SMB4 contains the interrupt queue overflow bits, a status indicator showing whether interrupts are enabled or disabled, and a transmitter-idle memory bit. The queue overflow bits indicate either that interrupts are happening at a rate greater than can be processed, or that interrupts were disabled with the global interrupt disable instruction.

Table C-5 Special Memory Byte SMB4 (SM4.0 to SM4.7)

SM Bits	Description (Read Only)
SM4.0[1]	This bit is turned on when the communication interrupt queue has overflowed.
SM4.1[1]	This bit is turned on when the input interrupt queue has overflowed.
SM4.2[1]	This bit is turned on when the timed interrupt queue has overflowed.
SM4.3	This bit is turned on when a run-time programming problem is detected.
SM4.4	This bit reflects the global interrupt enable state. It is turned on when interrupts are enabled.
SM4.5	This bit is turned on when the transmitter is idle (Port 0).
SM4.6	This bit is turned on when the transmitter is idle (Port 1).
SM4.7	This bit is turned on when something is forced.

1 Use status bits 4.0, 4.1, and 4.2 only in an interrupt routine. These status bits are reset when the queue is emptied, and control is returned to the main program.

SMB5: I/O Status

As described in Table C-6, SMB5 contains status bits about error conditions that were detected in the I/O system. These bits provide an overview of the I/O errors detected.

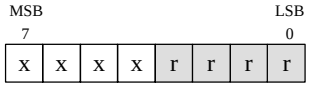
Table C-6 Special Memory Byte SMB5 (SM5.0 to SM5.7)

SM Bits	Description (Read Only)
SM5.0	This bit is turned on if any I/O errors are present.
SM5.1	This bit is turned on if too many digital I/O points have been connected to the I/O bus.
SM5.2	This bit is turned on if too many analog I/O points have been connected to the I/O bus.
SM5.3	This bit is turned on if too many intelligent I/O modules have been connected to the I/O bus.
SM5.4 to SM5.6	Reserved.
SM5.7	This bit is turned on if a DP standard bus fault is present

SMB6: CPU ID Register

As described in Table C-7, SMB6 is the CPU identification register. SM6.4 to SM6.7 identify the type of CPU. SM6.0 to SM6.3 are reserved for future use.

Table C-7 Special Memory Byte SMB6

SM Bits	Description (Read Only)
Format	 CPU ID register
SM6.4 to SM6.7	xxxx = 0000 = CPU 212/CPU 222 0010 = CPU 214/CPU 224 0110 = CPU 221 1000 = CPU 215 1001 = CPU 216/CPU 226
SM6.0 to SM6.3	Reserved

SMB7: Reserved

SMB7 is reserved for future use.

SMB8 to SMB21: I/O Module ID and Error Registers

SMB8 through SMB21 are organized in byte pairs for expansion modules 0 to 6. As described in Table C-8, the even-numbered byte of each pair is the module-identification register. These bytes identify the module type, the I/O type, and the number of inputs and outputs. The odd-numbered byte of each pair is the module error register. These bytes provide an indication of any errors detected in the I/O for that module.

Table C-8 Special Memory Bytes SMB8 to SMB21

SM Byte	Description (Read Only)
Format	**Even-Number Byte: Module ID Register** MSB 7 … LSB 0 M t t A i i Q Q M: Module present 0 = Present, 1 = Not present tt: 00 Non-intelligent I/O module; 01 Intelligent module; 10 Reserved; 11 Reserved A: I/O type 0 = Discrete, 1 = Analog ii: 00 No inputs; 01 2 AI or 8 DI; 10 4 AI or 16 DI; 11 8 AI or 32 DI QQ: 00 No outputs; 01 2 AQ or 8 DQ; 10 4 AQ or 16 DQ; 11 8 AQ or 32 DQ **Odd-Number Byte: Module Error Register** MSB 7 … LSB 0 C 0 0 b r P f t C: Configuration error b: bus fault or parity error r: Out-of-range error P: No user power error f: Blown fuse error t: Terminal block loose error
SMB8 SMB9	Module 0 ID register Module 0 error register
SMB10 SMB11	Module 1 ID register Module 1 error register
SMB12 SMB13	Module 2 ID register Module 2 error register
SMB14 SMB15	Module 3 ID register Module 3 error register
SMB16 SMB17	Module 4 ID register Module 4 error register
SMB18 SMB19	Module 5 ID register Module 5 error register
SMB20 SMB21	Module 6 ID register Module 6 error register

SMW22 to SMW26: Scan Times

As described in Table C-9, SMW22**,** SMW24, and SMW26 provide scan time information: minimum scan time, maximum scan time, and last scan time in milliseconds.

Table C-9 Special Memory Words SMW22 to SMW26

SM Word	Description (Read Only)
SMW22	This word provides the scan time of the last scan cycle.
SMW24	This word provides the minimum scan time recorded since entering the RUN mode.
SMW26	This word provides the maximum scan time recorded since entering the RUN mode.

SMB28 and SMB29: Analog Adjustment

As described in Table C-10, SMB28 holds the digital value that represents the position of analog adjustment 0. SMB29 holds the digital value that represents the position of analog adjustment 1.

Table C-10 Special Memory Bytes SMB28 and SMB29

SM Byte	Description (Read Only)
SMB28	This byte stores the value entered with analog adjustment 0. This value is updated once per scan in STOP/RUN.
SMB29	This byte stores the value entered with analog adjustment 1. This value is updated once per scan in STOP/RUN.

SMB30 and SMB130: Freeport Control Registers

SMB30 controls the Freeport communication for port 0; SMB130 controls the Freeport communication for port 1. You can read and write to SMB30 and SMB130. As described in Table C-11, these bytes configure the respective communication port for Freeport operation and provide selection of either Freeport or system protocol support.

Table C-11 Special Memory Byte SMB30

Port 0	Port 1	Description
Format of SMB30	Format of SMB130	MSB 7 … LSB 0 p p d b b b m m Freeport mode control byte
SM30.6 and SM30.7	SM130.6 and SM130.7	pp: Parity select 00 = no parity 01 = even parity 10 = no parity 11 = odd parity
SM30.5	SM130.5	d: Data bits per character 0 = 8 bits per character 1 = 7 bits per character
SM30.2 to SM30.4	SM130.2 to SM130.4	bbb: Freeport Baud rate 000 = 38,400 baud 001 = 19,200 baud 010 = 9,600 baud 011 = 4,800 baud 100 = 2,400 baud 101 = 1,200 baud 110 = 600 baud 111 = 300 baud
SM30.0 and SM30.1	SM130.0 and SM130.1	mm: Protocol selection 00 = Point-to-Point Interface protocol (PPI/slave mode) 01 = Freeport protocol 10 = PPI/master mode 11 = Reserved (defaults to PPI/slave mode) Note: When you select code mm = 10 (PPI master), the PLC will become a master on the network and allow the NETR and NETW instructions to be executed. Bits 2 through 7 are ignored in PPI modes.

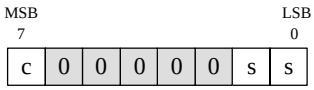
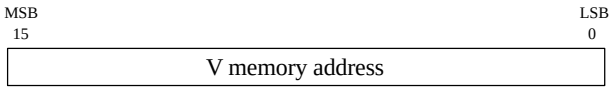
SMB31 and SMW32: Permanent Memory (EEPROM) Write Control

You can save a value stored in V memory to permanent memory (EEPROM) under the control of your program. To do this, load the address of the location to be saved in SMW32. Then, load SMB31 with the command to save the value. Once you have loaded the command to save the value, you do not change the value in V memory until the CPU resets SM31.7, indicating that the save operation is complete.

At the end of each scan, the CPU checks to see if a command to save a value to permanent memory was issued. If the command was issued, the specified value is saved to permanent memory.

As described in Table C-12, SMB31 defines the size of the data to be saved to permanent memory and also provides the command that initiates the execution of a save operation. SMW32 stores the starting address in V memory for the data to be saved to permanent memory.

Table C-12 Special Memory Byte SMB31 and Special Memory Word SMW32

SM Byte	Description
Format	SMB31: Software command  SMW32: V memory address 
SM31.0 and SM31.1	ss: Size of the value to be saved 00 = byte 01 = byte 10 = word 11 = double word
SM31.7	c: Save to permanent memory (EEPROM) 0 = No request for a save operation to be performed 1 = User program requests that the CPU save data to permanent memory. The CPU resets this bit after each save operation.
SMW32	The V memory address for the data to be saved is stored in SMW32. This value is entered as an offset from V0. When a save operation is executed, the value in this V memory address is saved to the corresponding V memory location in the permanent memory (EEPROM).

SMB34 and SMB35: Time Interval Registers for Timed Interrupts

As described in Table C-13, SMB34 specifies the time interval for timed interrupt 0, and SMB35 specifies the time interval for timed interrupt 1. You can specify the time interval (in 1-ms increments) from 1 ms to 255 ms. The time-interval value is captured by the CPU at the time the corresponding timed interrupt event is attached to an interrupt routine. To change the time interval, you must reattach the timed interrupt event to the same or to a different interrupt routine. You can terminate the timed interrupt event by detaching the event.

Table C-13 Special Memory Bytes SMB34 and SMB35

SM Byte	Description
SMB34	This byte specifies the time interval (in 1-ms increments from 1 ms to 255 ms) for timed interrupt 0.
SMB35	This byte specifies the time interval (in 1-ms increments from 1 ms to 255 ms) for timed interrupt 1.

SMB36 to SMB65: HSC0, HSC1, and HSC2 Register

As described in Table C-14, SMB36 through SM65 are used to monitor and control the operation of high-speed counters HSC0, HSC1, and HSC2.

Table C-14 Special Memory Bytes SMB36 to SMB65

SM Byte	Description
SM36.0 to SM36.4	Reserved
SM36.5	HSC0 current counting direction status bit: 1 = counting up
SM36.6	HSC0 current value equals preset value status bit: 1 = equal
SM36.7	HSC0 current value is greater than preset value status bit: 1 = greater than
SM37.0	Active level control bit for Reset: 0= Reset is active high, 1 = Reset is active low
SM37.1	Reserved
SM37.2	Counting rate selection for quadrature counters: 0 = 4x counting rate; 1 = 1 x counting rate
SM37.3	HSC0 direction control bit: 1 = count up
SM37.4	HSC0 update the direction: 1 = update direction
SM37.5	HSC0 update the preset value: 1 = write new preset value to HSC0 preset
SM37.6	HSC0 update the current value: 1 = write new current value to HSC0 current
SM37.7	HSC0 enable bit: 1 = enable
SMB38 SMB39 SMB40 SMB41	HSC0 new current value SMB38 is most significant byte, and SMB41 is least significant byte.
SMB42 SMB43 SMB44 SMB45	HSC0 new preset value SMB42 is most significant byte, and SMB45 is least significant byte.
SM46.0 to SM46.4	Reserved
SM46.5	HSC1 current counting direction status bit: 1 = counting up
SM46.6	HSC1 current value equals preset value status bit: 1 = equal
SM46.7	HSC1 current value is greater than preset value status bit: 1 = greater than
SM47.0	HSC1 active level control bit for reset: 0 = active high, 1 = active low
SM47.1	HSC1 active level control bit for start: 0 = active high, 1 = active low
SM47.2	HSC1 quadrature counter rate selection: 0 = 4x rate, 1 = 1x rate
SM47.3	HSC1 direction control bit: 1 = count up
SM47.4	HSC1 update the direction: 1 = update direction
SM47.5	HSC1 update the preset value: 1 = write new preset value to HSC1 preset
SM47.6	HSC1 update the current value: 1 = write new current value to HSC1 current

Table C-14 Special Memory Bytes SMB36 to SMB65 (continued)

SM Byte	Description
SM47.7	HSC1 enable bit: 1 = enable
SMB48 SMB49 SMB50 SMB51	HSC1 new current value SMB48 is most significant byte, and SMB51 is least significant byte.
SMB52 to SMB55	HSC1 new preset value SMB52 is most significant byte, and SMB55 is least significant byte.
SM56.0 to SM56.4	Reserved
SM56.5	HSC2 current counting direction status bit: 1 = counting up
SM56.6	HSC2 current value equals preset value status bit: 1 = equal
SM56.7	HSC2 current value is greater than preset value status bit: 1 = greater than
SM57.0	HSC2 active level control bit for reset: 0 = active high, 1 = active low
SM57.1	HSC2 active level control bit for start: 0 = active high, 1 = active low
SM57.2	HSC2 quadrature counter rate selection: 0 = 4x rate, 1 = 1x rate
SM57.3	HSC2 direction control bit: 1 = count up
SM57.4	HSC2 update the direction: 1 = update direction
SM57.5	HSC2 update the preset value: 1 = write new preset value to HSC2 preset
SM57.6	HSC2 update the current value: 1 = write new current value to HSC2 current
SM57.7	HSC2 enable bit: 1 = enable
SMB58 SMB59 SMB60 SMB61	HSC2 new current value SMB58 is the most significant byte, and SMB61 is the least significant byte.
SMB62 SMB63 SMB64 SMB65	HSC2 new preset value SMB62 is the most significant byte, and SMB65 is the least significant byte.

SMB66 to SMB85: PTO/PWM Registers

As described in Table C-15, SMB66 through SMB85 are used to monitor and control the pulse train output and pulse width modulation functions. See the information on pulse output high-speed output instructions in Chapter 9 for a complete description of these bits.

Table C-15 Special Memory Bytes SMB66 to SMB85

SM Byte	Description
SM66.0 to SM66.3	Reserved
SM66.4	PTO0 profile aborted: 0 = no error, 1 = aborted due to a delta calculation error
SM66.5	PTO0 profile aborted: 0 = not aborted by user command, 1 = aborted by user command
SM66.6	PTO0 pipeline overflow (cleared by the system when using external profiles, otherwise must be reset by user): 0 = no overflow, 1 = pipeline overflow
SM66.7	PTO0 idle bit: 0 = PTO in progress, 1 = PTO idle
SM67.0	PTO0/PWM0 update the cycle time value: 1 = write new cycle time
SM67.1	PWM0 update the pulse width value: 1 = write new pulse width
SM67.2	PTO0 update the pulse count value: 1 = write new pulse count
SM67.3	PTO0/PWM0 time base: 0 = 1 µs/tick, 1 = 1 ms/tick
SM67.4	Update PWM0 synchronously: 0 = asynchronous update, 1 = synchronous update
SM67.5	PTO0 operation: 0 = single segment operation (cycle time and pulse count stored in SM memory), 1 = multiple segment operation (profile table stored in V memory)
SM67.6	PTO0/PWM0 mode select: 0 = PTO, 1 = PWM
SM67.7	PTO0/PWM0 enable bit: 1 = enable
SMB68 SMB69	PTO0/PWM0 cycle time value (2 to 65,535 units of time base); SMB68 is most significant byte, and SMB69 is least significant byte.
SMB70 SMB71	PWM0 pulse width value (0 to 65,535 units of the time base); SMB70 is most significant byte, and SMB71 is least significant byte.
SMB72 SMB73 SMB74 SMB75	PTO0 pulse count value (1 to 2^{32} -1); SMB72 is most significant byte, and SMB75 is least significant byte.
SM76.0 to SM76.3	Reserved
SM76.4	PTO1 profile aborted: 0 = no error, 1 = aborted because of delta calculation error
SM76.5	PTO1 profile aborted: 0 = not aborted by user command, 1 = aborted by user command

Table C-15 Special Memory Bytes SMB66 to SMB85 (continued)

SM Byte	Description
SM76.6	PTO1 pipeline overflow (cleared by the system when using external profiles, otherwise must be reset by the user): 0 = no overflow, 1 = pipeline overflow
SM76.7	PTO1 idle bit: 0 = PTO in progress, 1 = PTO idle
SM77.0	PTO1/PWM1 update the cycle time value: 1 = write new cycle time
SM77.1	PWM1 update the pulse width value: 1 = write new pulse width
SM77.2	PTO1 update the pulse count value: 1 = write new pulse count
SM77.3	PTO1/PWM1 time base: 0 = 1 µs/tick, 1 = 1 ms/tick
SM77.4	Update PWM1 synchronously: 0 = asynchronous update, 1 = synchronous update
SM77.5	PTO1 operation: 0 = single segment operation (cycle time and pulse count stored in SM memory), 1 = multiple segment operation (profile table stored in V memory)
SM77.6	PTO1/PWM1 mode select: 0 = PTO, 1 = PWM
SM77.7	PTO1/PWM1 enable bit: 1 = enable
SMB78 SMB79	PTO1/PWM1 cycle time value (2 to 65,535 units of the time base); SMB78 is most significant byte, and SMB79 is least significant byte.
SMB80 SMB81	PWM1 pulse width value (0 to 65,535 units of the time base); SMB80 is most significant byte, and SMB81 is least significant byte.
SMB82 SMB83 SMB84 SMB85	PTO1 pulse count value (1 to 2^{32} -1); SMB82 is most significant byte, and SMB85 is least significant byte.

SMB86 to SMB94, and SMB186 to SMB194: Receive Message Control

As described in Table C-16, SMB86 through SMB94 and SMB186 through SMB194 are used to control and read the status of the Receive Message instruction.

Table C-16 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194

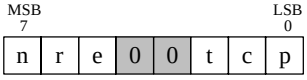
Port 0	Port 1	Description
SMB86	SMB186	 Receive Message status byte n: 1 = Receive message terminated by user disable command r: 1 = Receive message terminated: error in input parameters or missing start or end condition e: 1 = End character received t: 1 = Receive message terminated: timer expired c: 1 = Receive message terminated: maximum character count achieved p 1 = Receive message terminated because of a parity error

Table C-16 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194 (continued)

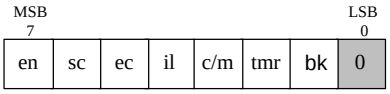
Port 0	Port 1	Description
SMB87	SMB187	 Receive Message control byte en: 0 =Receive Message function is disabled. 1=Receive Message function is enabled. The enable/disable receive message bit is checked each time the RCV instruction is executed. sc: 0 =Ignore SMB88 or SMB188. 1 =Use the value of SMB88 or SMB188 to detect start of message. ec: 0 =Ignore SMB89 or SMB189. 1 =Use the value of SMB89 or SMB189 to detect end of message. il: 0 =Ignore SMW90 or SMB190. 1 =Use the value of SMW90 to detect an idle line condition. c/m: 0 =Timer is an inter-character timer. 1 =Timer is a message timer. tmr: 0 =Ignore SMW92 or SMW192. 1 =Terminate receive if the time period in SMW92 or SMW192 is exceeded. bk: 0 =Ignore break conditions 1 =Use break condition as start of message detection The bits of the message interrupt control byte are used to define the criteria by which the message is identified. Both start of message and end of message criteria are defined. To determine the start of a message, either of two sets of logically ANDed start of message criteria must be true and must occur in sequence (idle line followed by start character, or break followed by start character). To determine the end of a message, the enabled end of the message criteria is logically ORed. The equations for start and stop criteria are given below: Start of Message = il * sc + bk * sc End of Message = ec + tmr + maximum character count reached Programming the start of message criteria for: 1. Idle line detection: il=1, sc=0, bk=0, SMW90>0 2. Start character detection: il=0, sc=1, bk=0, SMW90 is a don't care 3. Break Detection: il=0, sc=0, bk=1, SMW90 is a don't care 4. Any response to a request: il=1, sc=0, bk=0, SMW90=0 (Message timer can be used to terminate receive if there is no response.) 5. Break and a start character: il=0, sc=1, bk=1, SMW90 is a don't care 6. Idle line and a start character: il=1, sc=1, bk=0, SMW90 >0 7. Idle line and start character (Illegal): il=1, sc=1, bk=0, SMW90=0 Note: Receive will automatically be terminated by an overrun or a parity error (if enabled).
SMB88	SMB188	Start of message character

Table C-16 Special Memory Bytes SMB86 to SMB94, and SMB186 to SMB194 (continued)

Port 0	Port 1	Description
SMB89	SMB189	End of message character
SMB90 SMB91	SMB190 SMB191	Idle line time period given in milliseconds. The first character received after idle line time has expired is the start of a new message. SM90 (or SM190) is the most significant byte and SM91 (or SM191) is the least significant byte.
SMB92 SMB93	SMB192 SMB193	Inter-character/message timer time-out value (in milliseconds). If the time period is exceeded, the receive message is terminated. SM92 (or SM192) is the most significant byte, and SM93 (or SM193) is the least significant byte.
SMB94	SMB194	Maximum number of characters to be received (1 to 255 bytes). Note: This range must be set to the expected maximum buffer size, even if the character count message termination is not used.

SMB98 and SMB99

As described in Table C-17, SMB98 and SMB99 give you information about the number of errors on the expansion I/O bus.

Table C-17 Special Memory Bytes SMB98 and SMB99

SM Byte	Description
SMB98 SMB99	This location is incremented each time a parity error is detected on the expansion I/O bus. It is cleared upon power up, and by the user writing zero. SMB98 is the most significant byte.

SMB131 to SMB165: HSC3, HSC4, and HSC5 Register

As described in Table C-18, SMB131 through SMB165 are used to monitor and control the operation of high-speed counters HSC3, HSC4, and HSC5.

Table C-18 Special Memory Bytes SMB130 to SMB165

SM Byte	Description
SMB131 to SMB135	Reserved
SM136.0 to SM136.4	Reserved
SM136.5	HSC3 current counting direction status bit: 1 = counting up
SM136.6	HSC current value equals preset value status bit: 1 = equal
SM136.7	HSC3 current value is greater than preset value status bit: 1 = greater than
SM137.0 to SM137.2	Reserved
SM137.3	HSC3 direction control bit: 1 = count up

Table C-18 Special Memory Bytes SMB130 to SMB165 (continued)

SM Byte	Description
SM137.4	HSC3 update direction: 1 = update direction
SM137.5	HSC3 update preset value: 1 = write new preset value to HSC3 preset
SM137.6	HSC3 update current value: 1 = write new current value to HSC3 current
SM137.7	HSC3 enable bit: 1 = enable
SM138 to SM141	HSC3 new current value: SM138 is most significant byte and SM141 is least significant byte
SM142 to SM145	HSC3 new preset value: SM142 is most significant byte and SM145 is the least significant byte
SM146.0 to SM146.4	Reserved
SM146.5	HSC4 current counting direction status bit: 1 = counting up
SM146.7	HSC4 current value is greater than preset value status bit: 1 = greater than
SM147.0	Active level control bit for Reset: 0 = Reset is active high, 1 = Reset is active low
SM147.1	Reserved
SM147.2	Counting rate selection for quadrature counters: 0 = 4x counting rate, 1 = 1x counting rate
SM147.3	HSC4 direction control bit: 1 = count up
SM147.4	HSC4 update direction: 1 = update direction
SM147.5	HSC4 update preset value: 1 = write new preset value to HSC4 preset
SM147.6	HSC4 update current value: 1 = write new current value to HSC4 current
SM147.7	HSC4 enable bit: 1 = enable
SMB148 to SMB151	HSC4 new current value: SM148 is most significant byte and SM151 is least significant byte
SMB152 to SMB155	HSC4 new preset value: SM152 is most significant byte and SM155 is least significant byte
SM156.0 to SM156.4	Reserved
SM156.5	HSC5 current counting direction status bit: 1 = counting up
SM156.6	HSC5 current value equals preset value status bit: 1 = equal
SM156.7	HSC5 current value is greater than preset value status bit: 1 = greater than
SM157.0 to SM157.2	Reserved
SM157.3	HSC5 direction control bit: 1 = count up
SM157.4	HSC5 update direction: 1 = update direction
SM157.5	HSC5 update preset value: 1 = write new preset value to HSC5 preset
SM157.6	HSC5 update current value: 1 = write new current value to HSC5 current
SM157.7	HSC5 enable bit: 1 = enable

Table C-18 Special Memory Bytes SMB130 to SMB165 (continued)

SM Byte	Description
SMB158 to SMB161	HSC5 new current value: SM158 is most significant byte and SM161 is least significant byte
SMB162 to SMB165	HSC5 new preset value: SM162 is most significant byte and SM165 is least significant byte

SMB166 to SMB194: PTO0, PTO1 Profile Definition Table

As described in Table C-19, SMB166 through SMB194 are used to show the number of active profile steps and the address of the profile table in V memory.

Table C-19 Special Memory Bytes SMB166 to SMB194

SM Byte	Description
SMB166	Current entry number of the active profile step for PTO0
SMB167	Reserved
SMB168 SMB169	V memory address of the profile table for PTO0 given as an offset from V0. SM168 is the most significant byte of the address offset
SMB170 to SMB175	Reserved
SMB176	Current entry number of the active profile step for PTO1
SMB177	Reserved
SMB178 to SMB179	V memory address of the profile table for PTO1 given as an offset from V0. SM178 is the most significant byte of the address offset
SMB180 to SMB194	Reserved

SMB200 to SMB299: Intelligent Module Status

SMB200 through SMB299 are reserved for status information provided by intelligent expansion modules, such as the EM 277 PROFIBUS-DP module. SMB200 through SMB249 are reserved for the first intelligent expansion module in your system (the one closest to your CPU); SMB250 through SMB299 are reserved for the second intelligent module. Refer to your module's specifications in Appendix A to see how your module uses SMB200 through SMB299.

S7-200 Troubleshooting Guide

D

Table D-1 S7-200 Troubleshooting Guide

Problem	Possible Causes	Solution
Outputs stop working.	• The device being controlled has caused an electrical surge that damaged the output. • User program error • Wiring loose or incorrect • Excessive load • Output forced points	• When connecting to an inductive load (such as a motor or relay), a proper suppression circuit should be used. Refer to Section 2.4. • Correct user program • Check wiring and correct • Check load against point ratings • Check CPU for forced I/O
CPU SF (System Fault) light comes on.	The following list describes the most common causes: • User programming error – 0003 Watchdog error – 0011 Indirect addressing – 0012 Illegal floating point value • Electrical noise – 0001 through 0009 • Component damage – 0001 through 0010	Read the fatal error code number and refer to Section B.1: • For a programming error, check the usage of the FOR, NEXT, JMP, LBL, and Compare instructions. • For electrical noise: – Refer to the wiring guidelines in Section 2.3. It is very important that the control panel is connected to a good ground and that high voltage wiring is not run in parallel with low voltage wiring. – Connect the M terminal on the 24 VDC Sensor Power Supply to ground.
Power supply damaged.	Over-voltage on the power lines coming to the unit.	Connect a line analyzer to the system to check the magnitude and duration of the over-voltage spikes. Based on this information, add the proper type arrestor device to your system. Refer to the wiring guidelines in Section 2.3 for information about installing the field wiring.
Electrical noise problems	• Improper grounding • Routing on wiring within the control cabinet. • Input filters are configured for a speed that is too fast	Refer to the wiring guidelines in Section 2.3. It is very important that the control panel is connected to a good ground and that high voltage wiring is not run in parallel with low voltage wiring. Connect the M terminal on the 24 VDC Sensor Power Supply to ground. Increase the input filter delay in the system data block. Refer to Section 5.2.

Table D-1 S7-200 Troubleshooting Guide (continued)

Problem	Possible Causes	Solution
Communication network is damaged when connecting to an external device. (Either the port on the computer, the port on the PLC, or the PC/PPI cable is damaged.)	The communication cable can provide a path for unwanted currents if all non-isolated devices (such as PLCs, computers or other devices) that are connected to the network do not share the same circuit common reference. The unwanted currents can cause communication errors or damage to the circuits.	• Refer to the wiring guidelines in Section 2.3, and to the network guidelines in Chapter 7. • Purchase the isolated PC/PPI cable. • Purchase the isolated RS-485-to-RS-485 repeater when you connect machines that do not have a common electrical reference.
STEP 7–Micro/WIN 32 Communication problems		Refer to Chapter 7 for information about network communications.
Error Handling		Refer to Appendix B for information about error codes.

S7-200 Order Numbers

E

CPUs	Order Number
CPU 221 DC/DC/DC 6 Inputs/4 Outputs	6ES7 211-0AA21-0XB0
CPU 221 AC/DC/Relay 6 Inputs/4 Relays	6ES7 211-0BA21-0XB0
CPU 222 DC/DC/DC 8 Inputs/6 Outputs	6ES7 212-1AB21-0XB0
CPU 222 AC/DC/Relay 8 Inputs/6 Relays	6ES7 212-1BB21-0XB0
CPU 224 DC/DC/DC 14 Inputs/10 Outputs	6ES7 214-1AD21-0XB0
CPU 224 AC/DC/Relay 14 Inputs/10 Relays	6ES7 214-1BD21-0XB0
CPU 226 DC/DC/DC 24 Inputs/16 Outputs	6ES7 216-2AD21-0XB0
CPU 226 AC/DC/Relay 24 Inputs/16 Relays	6ES7 216-2BD21-0XB0

Expansion Modules	Order Number
EM 221 24 VDC Digital 8 Inputs	6ES7 221-1BF20-0XA0
EM 222 24 VDC Digital 8 Outputs	6ES7 222-1BF20-0XA0
EM 222 Digital Output 8 x Relay	6ES7 222-1HF20-0XA0
EM 223 24 VDC Digital Combination 4 Inputs/4 Outputs	6ES7 223-1BF20-0XA0
EM 223 24 VDC Digital Combination 4 Inputs/4 Relay Outputs	6ES7 223-1HF20-0XA0
EM 223 24 VDC Digital Combination 8 Inputs/8 Outputs	6ES7 223-1BH20-0XA0
EM 223 24 VDC Digital Combination 8 Inputs/8 Relay Outputs	6ES7 223-1PH20-0XA0
EM 223 24 VDC Digital Combination 16 Inputs/16 Outputs	6ES7 223-1BL20-0XA0
EM 223 24 VDC Digital Combination 16 Inputs/16 Relay Outputs	6ES7 223-1PL20-0XA0
EM 231 24 VDC Analog Input, 4 Inputs	6ES7 231-0HC20-0XA0
EM 232 24 VDC Analog Output, 2 Outputs	6ES7 232-0HB20-0XA0
EM 235 24 VDC Analog Combination 4 Inputs/1 Output	6ES7 235-0KD20-0XA0
EM 231 24 VDC Analog Input RTD, 2 Inputs	6ES7 231-7PB20-0XA0
EM 231 24 VDC Analog Input Thermocouple, 4 Inputs	6ES7 231-7PD20-0XA0
EM 277 PROFIBUS-DP	6ES7 277-0AA20-0XA0
CP 243-2 Communications Processor	6GK7 243-2AX00-0XA0

Cartridges and Cables	Order Number
MC 291, 32K x 8 EEPROM Memory Cartridge	6ES7 291-8GE20-0XA0
CC 292, CPU 22x Clock/Calendar with Battery Cartridge	6ES7 297-1AA20-0XA0
BC 293, CPU 22x Battery Cartridge	6ES7 291-8BA20-0XA0

Cartridges and Cables	Order Number
Cable, I/O Expansion, .8 meters, CPU 22x/EM	6ES7 290-6AA20-0XA0
Cable, PC/PPI, Isolated, 5-switch, 5 meters	6ES7 901-3BF20-0XA0

Programming Software	Order Number
STEP 7-Micro/WIN 32 (V3.1) Individual License (diskette)	6ES7 810-2BA01-0YX0
STEP 7-Micro/WIN 32 (V3.1) Upgrade License (diskette)	6ES7 810-2BA01-0YX3
STEP 7-Micro/WIN 32 (V3.1) Individual License (CD-ROM)	6ES7 810-2BC01-0YX0
STEP 7-Micro/WIN 32 (V3.1) Upgrade License (CD-ROM)	6ES7 810-2BC01-0YX3
STEP 7-Micro/WIN 32 Toolbox Individual License (CD-ROM)	6ES7 810-2PC01-0YX0

Communications Cards	Order Number
MPI Card: Short AT ISA	6ES7 793-2AA01-0AA0
CP 5411: Short AT ISA	6GK1 541-1AA00
CP 5511: PCMCIA, Type II	6GK1 551-1AA00
CP 5611: PCI card (version 3.0 or greater)	6GK1 561-1AA00

Manuals	Order Number
TD 200 Operator Interface User Manual	6ES7 272-0AA20-8BA0
S7-200 Point-to-Point Interface Communication Manual (English/German)	6ES7 298-8GA00-8XH0
CP 243-2 Communications Processor Manual (English)	6GK7 243-2AX00-8BA0
S7-200 Programmable Controller System Manual (German)	6ES7 298-8FA21-8AH0
S7-200 Programmable Controller System Manual (English)	6ES7 298-8FA21-8BH0
S7-200 Programmable Controller System Manual (French)	6ES7 298-8FA21-8CH0
S7-200 Programmable Controller System Manual (Spanish)	6ES7 298-8FA21-8DH0
S7-200 Programmable Controller System Manual (Italian)	6ES7 298-8FA21-8EH0

Cables, Network Connectors, and Repeaters	Order Number
MPI Cable	6ES7 901-0BF00-0AA0
PROFIBUS Network Cable	6XVI 830-0AH10
Network Bus Connector with Programming Port Connector, Vertical Cable Outlet	6ES7 972-0BB11-0XA0
Network Bus Connector (no programming port connector), Vertical Cable Outlet	6ES7 972-0BA11-0XA0
RS-485 Bus Connector with 35° Cable Outlet (no programming port connector)	6ES7 972-0BA40-0XA0
RS-485 Bus Connector with 35° Cable Outlet (with programming port connector)	6ES7 972-0BB40-0XA0
CPU 22x/EM Connector Block, 7 Terminal, Removable	6ES7 292-1AD20-0AA0
CPU 22x/EM Connector Block, 12 Terminal Removable	6ES7 292-1AE20-0AA0

Cables, Network Connectors, and Repeaters	Order Number
CPU 22x/EM Connector Block, 14 Terminal Removable	6ES7 292-1AF20-0AA0
CPU 22x/EM Connector Block, 18 Terminal Removable	6ES7 292-1AG20-0AA0
RS-485 IP 20 Repeater, Isolated	6ES7 972-0AA00-0XA0

Operator Interfaces	Order Number
TD 200 Operator Interface	6ES7 272-0AA20-0YA0
OP3 Operator Interface	6AV3 503-1DB10
OP7 Operator Interface	6AV3 607-1JC20-0AX1
OP17 Operator Interface	6AV3 617-1JC20-0AX1
TP070 Touch Panel	6AV6 545-0AA15-2AX0
TP170A Touch Panel	6AV6 545-0BA15-2AX0

Miscellaneous	Order Number
DIN Rail Stops	6ES5 728-8MAll
12-Position Fan Out Connector (CPU 221, CPU 222) 10-pack	6ES7 290-2AA00-0XA0
Spare Door Kit, contains 4 each of the following: terminal block covers for 7, 12, 14, 18, 2x12, 2x14 terminals; CPU access door, EM access door	6ES7 291-3AX20-0XA0
8 Position Simulator	6ES7 274 1XF00-0XA0
14 Position Simulator	6ES7 274 1XH00-0XA0
24 Position Simulator	6ES7 274 1XK00-0XA0

Execution Times for STL Instructions

F

Effect of Power Flow on Execution Times

The calculation of the basic execution time for an STL instruction (Table F-4) shows the time required for executing the logic, or function, of the instruction when power flow is present (where the top-of-stack value is ON or 1). For some instructions, the execution of that function is conditional upon the presence of power flow: the CPU performs the function only when power flow is present to the instruction (when the top-of-stack value is ON or 1). If power flow is not present to the instruction (the top-of-stack value is OFF or 0), use a “no powerflow” execution time to calculate the execution time of that instruction. Table F-1 provides the execution time of an STL instruction with no power flow (when the top-of-stack value is OFF or 0) for each S7-200 CPU module.

Table F-1 Execution Time for Instructions with No Power Flow

Instruction with No Power Flow	S7-200 CPU
All STL instructions	3 μs

Effect of Indirect Addressing on Execution Times

The calculation of the basic execution time for an STL instruction (Table F-4) shows the time required for executing the instruction, using direct addressing of the operands or constants. If your program uses indirect addressing, increase the execution time for each indirectly addressed operand by the figure shown in Table F-2.

Table F-2 Additional Time to Add for Indirect Addressing

Instruction for Indirect Addressing	S7-200 CPU
Each indirectly addressed operand	22 μs

Execution Times

Accessing certain memory areas, such as AI, AQ, L, and accumulators, requires additional execution time. Table F-3 provides a factor to be added to the basic execution time for each operand access of these memory areas.

Table F-3 Execution Time Adder for Accesses to Selected Memory Areas

Memory Area	S7-200 CPU
Analog Inputs (AI)	149 µs
Analog Outputs (AQ)	73 µs
Local memory (L)	5.4 µs
Accumulators (AC)	4.4 µs

Basic Execution Times for STL Instructions

Table F-4 lists the basic execution times of the STL instructions for each of the S7-200 CPU modules.

Table F-4 Execution Times for the STL Instructions (in µs)

Instruction	Description	S7-200 CPU (in µs)
=	Basic execution time: I L SM, T, C, V, S, Q, M	0.37 19.2 1.8
+D	Basic execution time	55
-D	Basic execution time	55
*D	Basic execution time	92
/D	Basic execution time	376
+I	Basic execution time	46
-I	Basic execution time	47
*I	Basic execution time	71
/I	Basic execution time	115
=I	Basic execution time: local output expansion output	29 39
+R	Basic execution time Maximum execution time	110 163
-R	Basic execution time Maximum execution time	113 166
*R	Basic execution time Maximum execution time	100 130
/R	Basic execution time Maximum execution time	300 360

Table F-4 Execution Times for the STL Instructions (in µs) (continued)

Instruction	Description		S7-200 CPU (in µs)
A	Basic execution time:	I L SM, T, C, V, S, Q, M	0.37 10.8 1.1
AB < =, =, >=, >, <, <>	Basic execution time		35
AD < =, =, >=, >, <, <>	Basic execution time		53
AI	Basic execution time:	local input expansion input	27 35
ALD	Basic execution time		0.37
AN	Basic execution time:	I L SM, T, C, V, S, Q, M	0.37 10.8 1.1
ANDB	Basic execution time		37
ANDD	Basic execution time		55
ANDW	Basic execution time		48
ANI	Basic execution time:	local input expansion input	27 35
AR <=, =, >=, >, <, <>	Basic execution time		54
ATCH	Basic execution time		20
ATH	Total = Basic time + (Length * LM) Basic execution time (constant length) Basic execution time (variable length) Length multiplier (LM)		 41 55 20
ATT	Basic execution time		70
AW < =, =, >=, >, <, <>	Basic execution time		45
BCDI	Basic execution time		66
BIR	Basic execution time:	local inputs expansion inputs	43 51
BIW	Basic execution time:	local inputs expansion inputs	42 52
BMB	Total = Basic time + (Length * LM) Basic execution time (constant length) Basic execution time (variable length) Length multiplier (LM)		 21 51 11
BMD	Total = Basic time + (Length * LM) Basic execution time (constant length) Basic execution time (variable length) Length multiplier (LM)		 21 51 20
BMW	Total = Basic time + (Length * LM) Basic execution time (constant length) Basic execution time (variable length) Length multiplier (LM)		 21 51 16

Table F-4 Execution Times for the STL Instructions (in μs) (continued)

Instruction	Description	S7-200 CPU (in μs)
CALL	With no parameters: Execution time With parameters: Total execution time = Basic time + Σ (input operand handling time) Basic execution time Input operand handling time (bit operand) Input operand handling time (byte operand) Input operand handling time (word operand) Input operand handling time (Dword operand)	 15 32 23 21 24 27
COS	Basic execution time Maximum execution time	1525 1800
CRET	Total execution time = Basic time + Σ (output operand handling time) Basic execution time Output operand handling time (bit operand) Output operand handling time (byte operand) Output operand handing time (word operand) Output operand handling time (Dword operand)	 13 21 14 18 20
CRETI	Basic execution time	23
CTD	Basic execution time on transition of count input Basic execution time otherwise	48 36
CTU	Basic execution time on transition of count input Basic execution time otherwise	53 35
CTUD	Basic execution time on transition of count input Basic execution time otherwise	64 45
DECB	Basic execution time	30
DECD	Basic execution time	42
DECO	Basic execution time	36
DECW	Basic execution time	37
DISI	Basic execution time	18
DIV	Basic execution time	119
DTCH	Basic execution time	18
DTR	Basic execution time Maximum execution time	60 70
ED	Basic execution time	15
ENCO	Minimum execution time Maximum execution time	39 43
END	Basic execution time	0.9
ENI	Basic execution time	53
EU	Basic execution time	15
EXP	Basic execution time Maximum execution time	1170 1375

Table F-4 Execution Times for the STL Instructions (in µs) (continued)

Instruction	Description	S7-200 CPU (in µs)
FIFO	Total = Basic time + (Length * LM) Basic execution time Length multiplier (LM)	 70 14
FILL	Total = Basic time + (Length * LM) Basic execution time (constant length) Basic execution time (variable length) Length multiplier (LM)	 29 50 7
FND <, =, >, <>	Total = Basic time + (Length * LM) Basic execution time Length multiplier (LM)	 85 12
FOR	Total = Basic time + (Number of repetitions * LM) Basic execution time Loop multiplier (LM)	 64 50
GPA	Basic execution time	31
HDEF	Basic execution time	35
HSC	Basic execution time	37
HTA	Total = Basic time + (Length * LM) Basic execution time (constant length) Basic execution time (variable length) Length multiplier (LM)	 38 48 11
IBCD	Basic execution time	114
INCB	Basic execution time	29
INCD	Basic execution time	42
INCW	Basic execution time	37
INT	Typical execution time with 1 interrupt	47
INVB	Basic execution time	31
INVD	Basic execution time	42
INVW	Basic execution time	38
JMP	Basic execution time	0.9
LBL	Basic execution time	0.37
LD	Basic execution time: I L SM, T, C, V, S, Q, M SM0.0	0.37 10.9 1.1 0.37
LDB <=, =, >=, >, <, <>	Basic execution time	35
LDD <=, =, >=, >, <, <>	Basic execution time	52
LDI	Basic execution time: Local input Expansion input	26 34
LDN	Basic execution time: I L SM, T, C, V, S, Q, M	0.37 10.9 1.1

Table F-4 Execution Times for the STL Instructions (in µs) (continued)

Instruction	Description	S7-200 CPU (in µs)
LDNI	Basic execution time: Local input Expansion input	26 34
LDR<=, =, >=, >, <, <>	Basic execution time	55
LDS	Basic execution time	0.37
LDW <=, =, >=, >, <, <>	Basic execution time	42
LIFO	Basic execution time	70
LN	Basic execution time Maximum execution time	1130 1275
LPP	Basic execution time	0.37
LPS	Basic execution time	0.37
LRD	Basic execution time	0.37
LSCR	Basic execution time	12
MEND	Basic execution time	0.5
MOVB	Basic execution time	29
MOVD	Basic execution time	38
MOVR	Basic execution time	38
MOVW	Basic execution time	34
MUL	Basic execution time	70
NEXT	Basic execution time	0
NETR	Basic execution time	179
NETW	Total = Basic time + (Length * LM) Basic execution time Length multiplier (LM)	 175 8
NOP	Basic execution time	0.37
NOT	Basic execution time	0.37
O	Basic execution time: I L SM, T, C, V, S, Q, M	0.37 10.8 1.1
OB < =, =, >=, >, <, <>	Basic execution time	35
OD < =, =, >=, >, <, <>	Basic execution time	53
OI	Basic execution time: Local input Expansion input	27 35
OLD	Basic execution time	0.37
ON	Basic execution time: I L SM, T, C, V, S, Q, M	0.37 10.8 1.1
ONI	Basic execution time: Local input Expansion input	27 35
OR<=, =, >=, >, <, <>	Basic execution time	55

Table F-4 Execution Times for the STL Instructions (in µs) (continued)

Instruction	Description	S7-200 CPU (in µs)
ORB	Basic execution time	37
ORD	Basic execution time	55
ORW	Basic execution time	48
OW < =, =, >=, >, <, <>	Basic execution time	45
PID	Basic execution time	750
	Adder to recalculate ($K_c * T_s/T_i$) and ($K_c * T_d/T_s$) prior to the PID calculation. Recalculation occurs if the value of K_c, T_s, T_i, or T_s has changed from the previous execution of this instruction, or on a transition to auto control.	1000
PLS	Basic execution time: PWM PTO single segment PTO multiple segment	 57 67 92
R	For length=1 and specified as a constant (e.g. R V0.2,1) Execution time for operand = C Execution time for operand = T Execution time for all other operands Otherwise, Total execution time=Basic execution time +(Length * LM) Basic execution time for operand = C, T Basic execution time for all other operands Length multiplier (LM) for operand = C Length multiplier (LM) for operand = T Length multiplier (LM) for all other operands If the length is stored in a variable instead of being specified as a constant, increase the basic execution time by adding:	 17 24 5 19 28 8.6 16.5 0.9 29
RCV	Basic execution time	80
RET	Total execution time = Basic time + Σ (output operand handling time) Basic execution time Output operand handling time (bit operand) Output operand handling time (byte operand) Output operand handing time (word operand) Output operand handling time (Dword operand)	 13 21 14 18 20
RETI	Basic execution time	23
RI	Total = Basic time + (Length * LM) Basic execution time Length multiplier (local output) Length multiplier (expansion output) If the length is stored in a variable instead of being a constant, increase the basic execution time by adding:	 18 22 32 30
RLB	Total = Basic time + (Length * LM) Basic execution time Length multiplier (LM)	 42 0.6

Table F-4 Execution Times for the STL Instructions (in µs) (continued)

Instruction	Description	S7-200 CPU (in µs)
RLD	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 52 2.5
RLW	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 49 1.7
RRB	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 42 0.6
RRD	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 52 2.5
RRW	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 49 1.7
S	For length = 1 and specified as a constant (e.g., S V0.2, 1) Execution time Otherwise, Total execution time=Basic execution time +(Length ∗ LM) Basic execution time for all other operands Length multiplier (LM) for all other operands If the length is stored in a variable instead of being a constant, increase the basic execution time by adding:	 5 27 0.9 29
SBR	Basic execution time	0
SCRE	Basic execution time	0.37
SCRT	Basic execution time	17
SEG	Basic execution time	30
SHRB	Total = Basic time + (Length ∗ LM1) + ((Length/8) ∗ LM2) Basic execution time (constant length) Basic execution time (variable length) Length multiplier 1 (LM1) Length multiplier 2 (LM2)	 76 84 1.6 4
SI	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM) (local output) Length multiplier (LM) (expansion output) If the length is stored in a variable instead of being a constant, increase the basic execution time by adding:	 18 22 32 30
SIN	Basic execution time Maximum execution time	1525 1800
SLB	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 43 0.7

Table F-4 Execution Times for the STL Instructions (in µs) (continued)

Instruction	Description	S7-200 CPU (in µs)
SLD	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 53 2.6
SLW	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 51 1.3
SPA	Basic execution time	243
SQRT	Basic execution time Maximum execution time	725 830
SRB	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 43 0.7
SRD	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 53 2.6
SRW	Total = Basic time + (Length ∗ LM) Basic execution time Length multiplier (LM)	 51 1.3
STOP	Basic execution time	16
SWAP	Basic execution time	32
TAN	Basic execution time Maximum execution time	1825 2100
TODR	Basic execution time	2400
TODW	Basic execution time	1600
TOF	Basic execution time	64
TON	Basic execution time	64
TONR	Basic execution time	56
TRUNC	Basic execution time Maximum execution time	103 178
WDR	Basic execution time	16
XMT	Basic execution time	78
XORB	Basic execution time	37
XORD	Basic execution time	55
XORW	Basic execution time	48

S7-200 Quick Reference Information

G

This appendix contains information about the following:

- Special Memory Bits
- Descriptions of Interrupt Events
- Summary of S7-200 CPU Memory Ranges and Features
- High-Speed Counters HSC0, HSC1, HSC2, HSC3, HSC4, HSC5
- S7-200 Instructions

Table G-1 Special Memory Bits

Special Memory Bits			
SM0.0	Always On	SM1.0	Result of operation = 0
SM0.1	First Scan	SM1.1	Overflow or illegal value
SM0.2	Retentive data lost	SM1.2	Negative result
SM0.3	Power up	SM1.3	Division by 0
SM0.4	30 s off / 30 s on	SM1.4	Table full
SM0.5	0.5 s off / 0.5 s on	SM1.5	Table empty
SM0.6	Off 1 scan / on 1 scan	SM1.6	BCD to binary conversion error
SM0.7	Switch in RUN position	SM1.7	ASCII to hex conversion error

Table G-2 Interrupt Events in Priority Order

Event Number	Interrupt Description	Priority Group	Priority in Group
8	Port 0: Receive character	Communications (highest)	0
9	Port 0: Transmit complete		0
23	Port 0: Receive message complete		0
24	Port 1: Receive message complete		1
25	Port 1: Receive character		1
26	Port 1: Transmit complete		1
19	PTO 0 complete interrupt	Discrete (middle)	0
20	PTO 1 complete interrupt		1
0	Rising edge, I0.0		2
2	Rising edge, I0.1		3
4	Rising edge, I0.2		4
6	Rising edge, I0.3		5
1	Falling edge, I0.0		6
3	Falling edge, I0.1		7
5	Falling edge, I0.2		8
7	Falling edge, I0.3		9
12	HSC0 CV=PV (current value = preset value)		10
27	HSC0 direction changed		11
28	HSC0 external reset		12
13	HSC1 CV=PV (current value = preset value)		13
14	HSC1 direction input changed		14
15	HSC1 external reset		15
16	HSC2 CV=PV		16
17	HSC2 direction changed		17
18	HSC2 external reset		18
32	HSC3 CV=PV (current value = preset value)		19
29	HSC4 CV=PV (current value = preset value)		20
30	HSC4 direction changed		21
31	HSC4 external reset		22
33	HSC5 CV=PV (current value = preset value)		23
10	Timed interrupt 0	Timed (lowest)	0
11	Timed interrupt 1		1
21	Timer T32 CT=PT interrupt		2
22	Timer T96 CT=PT interrupt		3

Table G-3 Summary of S7-200 CPU Memory Ranges and Features

Description	Range Limit				Accessible as ...			
	CPU 221	**CPU 222**	**CPU 224**	**CPU 226**	**Bit**	**Byte**	**Word**	**Double Word**
User program size	2 Kwords	2 Kwords	4 Kwords	4 Kwords				
User data size	1 Kwords	1 Kwords	2.5 Kwords	2.5 Kwords				
Process-image input register	I0.0 to I15.7	I0.0 to I15.7	I0.0 to I15.7	I0.0 to I15.7	Ix.y	IBx	IWx	IDx
Process-image output register	Q0.0 to Q15.7	Q0.0 to Q15.7	Q0.0 to Q15.7	Q0.0 to Q15.7	Qx.y	QBx	QWx	QDx
Analog inputs (read only)	--	AIW0 to AIW30	AIW0 to AIW62	AIW0 to AIW62			AIWx	
Analog outputs (write only)	--	AQW0 to AQW30	AQW0 to AQW62	AQW0 to AQW62			AQWx	
Variable memory (V)[1]	VB0.0 to VB2047.7	VB0.0 to VB2047.7	VB0.0 to VB5119.7	VB0.0 to VB5119.7	Vx.y	VBx	VWx	VDx
Local memory (L)[2]	LB0.0 to LB63.7	LB0.0 to LB63.7	LB0.0 to LB63.7	LB0.0 to LB63.7	Lx.y	LBx	LWx	LDx
Bit memory (M)	M0.0 to M31.7	M0.0 to M31.7	M0.0 to M31.7	M0.0 to M31.7	Mx.y	MBx	MWx	MDx
Special Memory (SM)	SM0.0 to SM179.7	SM0.0 to SM179.7	SM0.0 to SM179.7	SM0.0 to SM179.7	SMx.y	SMBx	SMWx	SMDx
Read only	SM0.0 to SM29.7	SM0.0 to SM29.7	SM0.0 to SM29.7	SM0.0 to SM29.7				
Timers	256 (T0 to T255)	256 (T0 to T255)	256 (T0 to T255)	256 (T0 to T255)	Tx		Tx	
Ret. on-delay 1 ms	T0, T64	T0, T64	T0, T64	T0, T64				
Ret. on-delay 10 ms	T1 to T4, T65 to T68	T1 to T4, T65 to T68	T1 to T4, T65 to T68	T1 to T4, T65 to T68				
Ret. on-delay 100 ms	T5 to T31, T69 to T95	T5 to T31, T69 to T95	T5 to T31, T69 to T95	T5 to T31, T69 to T95				
On/Off delay 1 ms	T32, T96	T32, T96	T32, T96	T32, T96				
On/Off delay 10 ms	T33 to T36, T97 to T100	T33 to T36, T97 to T100	T33 to T36, T97 to T100	T33 to T36, T97 to T100				
On/Off delay 100 ms	T37 to T63, T101 to T255	T37 to T63, T101 to T255	T37 to T63, T101 to T255	T37 to T63, T101 to T255				
Counters	C0 to C255	C0 to C255	C0 to C255	C0 to C255	Cx		Cx	
High-speed counter	HC0, HC3. HC4, HC5	HC0, HC3, HC4, HC5	HC0 to HC5	HC0 to HC5				HCx
Sequential control relays (S)	S0.0 to S31.7	S0.0 to S31.7	S0.0 to S31.7	S0.0 to S31.7	Sx.y	SBx	SWx	SDx
Accumulator registers	AC0 to AC3	AC0 to AC3	AC0 to AC3	AC0 to AC3		ACx	ACx	ACx
Jumps/Labels	0 to 255	0 to 255	0 to 255	0 to 255				
Call/Subroutine	0 to 63	0 to 63	0 to 63	0 to 63				
Interrupt routines	0 to 127	0 to 127	0 to 127	0 to 127				
PID loops	0 to 7	0 to 7	0 to 7	0 to 7				
Port	Port 0	Port 0	Port 0	Port 0, Port 1				

[1] All V memory can be saved to permanent memory.
[2] LB60 to LB63 are reserved by STEP 7-Micro/WIN 32, version 3.0 or later.

Table G-4 High-Speed Counters HSC0, HSC3, HSC4, and HSC5

Mode	HSC0			HSC3	HSC4			HSC5
	I0.0	**I0.1**	**I0.2**	**I0.1**	**I0.3**	**I0.4**	**I0.5**	**I0.4**
0	Clk			Clk	Clk			Clk
1	Clk		Reset		Clk		Reset	
2								
3	Clk	Direction			Clk	Direction		
4	Clk	Direction	Reset		Clk	Direction	Reset	
5								
6	Clk Up	Clk Down			Clk Up	Clk Down		
7	Clk Up	Clk Down	Reset		Clk Up	Clk Down	Reset	
8								
9	Phase A	Phase B			Phase A	Phase B		
10	Phase A	Phase B	Reset		Phase A	Phase B	Reset	
11								

Table G-5 High-Speed Counters HSC1 and HSC2

Mode	HSC1				HSC2			
	I0.6	**I0.7**	**I1.0**	**I1.1**	**I1.2**	**I1.3**	**I1.4**	**I1.5**
0	Clk				Clk			
1	Clk		Reset		Clk		Reset	
2	Clk		Reset	Start	Clk		Reset	Start
3	Clk	Direction			Clk	Direction		
4	Clk	Direction	Reset		Clk	Direction	Reset	
5	Clk	Direction	Reset	Start	Clk	Direction	Reset	Start
6	Clk Up	Clk Down			Clk Up	Clk Down		
7	Clk Up	Clk Down	Reset		Clk Up	Clk Down	Reset	
8	Clk Up	Clk Down	Reset	Start	Clk Up	Clk Down	Reset	Start
9	Phase A	Phase B			Phase A	Phase B		
10	Phase A	Phase B	Reset		Phase A	Phase B	Reset	
11	Phase A	Phase B	Reset	Start	Phase A	Phase B	Reset	Start

Boolean Instructions		
LD	N	Load
LDI	N	Load Immediate
LDN	N	Load Not
LDNI	N	Load Not Immediate
A	N	AND
AI	N	AND Immediate
AN	N	AND Not
ANI	N	AND Not Immediate
O	N	OR
OI	N	OR Immediate
ON	N	OR Not
ONI	N	OR Not Immediate
LDBx	N1, N2	Load result of Byte Compare N1 (x:<, <=,=, >=, >, <>) N2
ABx	N1, N2	AND result of Byte Compare N1 (x:<, <=,=, >=, >, <>) N2
OBx	N1, N2	OR result of Byte Compare N1 (x:<, <=,=, >=, >, <>) N2
LDWx	N1, N2	Load result of Word Compare N1 (x:<, <=,=, >=, >, <>) N2
AWx	N1, N2	AND result of Word Compare N1 (x:<, <=,=, >=, >, <>) N2
OWx	N1, N2	OR result of Word Compare N1 (x:<, <=,=, >=, >, <>) N2
LDDx	N1, N2	Load result of DWord Compare N1 (x:<, <=,=, >=, >, <>) N2
ADx	N1, N2	AND result of DWord Compare N1 (x:<, <=,=, >=, >, <>) N2
ODx	N1, N2	OR result of DWord Compare N1 (x:<, <=,=, >=, >, <>) N2
LDRx	N1, N2	Load result of Real Compare N1 (x:<, <=,=, >=, >, <>) N2
ARx	N1, N2	AND result of Real Compare N1 (x:<, <=,=, >=, >, <>) N2
ORx	N1, N2	OR result of Real Compare N1 (x:<, <=,=, >=, >, <>) N2
NOT		Stack Negation
EU		Detection of Rising Edge
ED		Detection of Falling Edge
=	N	Assign Value
=I	N	Assign Value Immediate
R	S_BIT, N	Set bit Range
SI	S_BIT, N	Reset bit Range
RI	S_BIT, N	Set bit Range Immediate
		Reset bit Range Immediate

Math, Increment, and Decrement instructions		
+I	IN1, OUT	Add Integer, DWord or Real IN1+OUT=OUT
+D	IN1, OUT	
+R	IN1, OUT	
-I	IN1, OUT	Subtract Integer, DWord, or Real OUT-IN1=OUT
-D	IN1, OUT	
-R	IN1, OUT	
MUL	IN1, OUT	Multiply Integer (16*16->32) or Real
*R	IN1, OUT	Multiply Integer or Double Integer
*D, *I	IN1, OUT	IN1 * OUT = OUT
DIV	IN1, OUT	Divide Integer (16/16->32) or Real
/R	IN1, OUT	Divide Integer or Double Integer
/D, /I	IN1, OUT	IN1 / OUT = OUT
SQRT	IN, OUT	Square Root
LN	IN, OUT	Natural Logarithm
EXP	IN, OUT	Natural Exponential
SIN	IN, OUT	Sine
COS	IN, OUT	Cosine
TAN	IN, OUT	Tangent
INCB	OUT	Increment Byte, Word or DWord
INCW	OUT	
INCD	OUT	
DECB	OUT	Decrement Byte, Word, or DWord
DECW	OUT	
DECD	OUT	
PID	Table, Loop	PID Loop
Timer and Counter Instructions		
TON	Txxx, PT	On-Delay Timer
TOF	Txxx, PT	Off-Delay Timer
TONR	Txxx, PT	Retentive On-Delay Timer
CTU	Cxxx, PV	Count Up
CTD	Cxxx, PV	Count Down
CTUD	Cxxx, PV	Count Up/Down
Real Time Clock Instructions		
TODR	T	Read Time of Day clock
TODW	T	Write Time of Day clock
Program Control Instructions		
END		Conditional End of Program
STOP		Transition to STOP Mode
WDR		WatchDog Reset (300 ms)
JMP	N	Jump to defined Label
LBL	N	Define a Label to Jump to
CALL	N [N1,...]	Call a Subroutine [N1, ... up to 16 optional parameters]
CRET		Conditional Return from SBR
FOR	INDX,INIT, FINAL	For/Next Loop
NEXT		
LSCR	N	Load, Transition, and End Sequence Control Relay Segment
SCRT	N	
SCRE		

Move, Shift, Rotate, and Fill Instructions		
MOVB	IN, OUT	Move Byte, Word, DWord, Real Move Byte Immediate Read Move Byte Immediate Write
MOVW	IN, OUT	
MOVD	IN, OUT	
MOVR	IN, OUT	
BIR	IN, OUT	
BIW	IN, OUT	
BMB	IN, OUT, N	Block Move Byte, Word, DWord
BMW	IN, OUT, N	
BMD	IN, OUT, N	
SWAP	IN	Swap Bytes
SHRB	DATA, S_BIT, N	Shift Register Bit
SRB	OUT, N	Shift Right Byte, Word, DWord
SRW	OUT, N	
SRD	OUT, N	
SLB	OUT, N	Shift Left Byte, Word, DWord
SLW	OUT, N	
SLD	OUT, N	
RRB	OUT, N	Rotate Right Byte, Word, DWord
RRW	OUT, N	
RRD	OUT, N	
RLB	OUT, N	Rotate Left Byte, Word, DWord
RLW	OUT, N	
RLD	OUT, N	
FILL	IN, OUT, N	Fill memory space with pattern
Logic Operations		
ALD		And for combinations
OLD		Or for combinations
LPS		Logic Push (stack control)
LRD		Logic Read (stack control)
LPP		Logic Pop (stack control)
LDS		Load Stack (stack control)
AENO		And ENO
ANDB	IN1, OUT	Logical And of Byte, Word, and DWord
ANDW	IN1, OUT	
ANDD	IN1, OUT	
ORB	IN1, OUT	Logical Or of Byte, Word, and DWord
ORW	IN1, OUT	
ORD	IN1, OUT	
XORB	IN1, OUT	Logical XOr of Byte, Word, and DWord
XORW	IN1, OUT	
XORD	IN1, OUT	
INVW	OUT	Invert Byte, Word and DWord
INVD	OUT	(1's complement)

Table, Find, and Conversion Instructions		
ATT	TABLE,DATA	Add data to table
LIFO	TABLE,DATA	Get data from table
FIFO	TABLE,DATA	
FND=	SRC,PATRN, INDX	Find data value in table that matches comparison
FND<>	SRC,PATRN, INDX	
FND<	SRC,PATRN, INDX	
FND>	SRC,PATRN, INDX	
BCDI	OUT	Convert BCD to Integer
IBCD	OUT	Convert Integer to BCD
BTI	IN, OUT	Convert Byte to Integer
ITB	IN, OUT	Convert Integer to Byte
ITD	IN, OUT	Convert Integer to Double Integer
DTI	IN, OUT	Convert Double Integer to Integer
DTR	IN, OUT	Convert DWord to Real
TRUNC	IN, OUT	Convert Real to DWord
ROUND	IN, OUT	Convert Real to Double Integer
ATH	IN, OUT, LEN	Convert ASCII to Hex
HTA	IN, OUT, LEN	Convert Hex to ASCII
ITA	IN, OUT, FMT	Convert Integer to ASCII
DTA	IN, OUT, FM	Convert Double Integer to ASCII
RTA	IN, OUT, FM	Convert Real to ASCII
DECO	IN, OUT	Decode
ENCO	IN, OUT	Encode
SEG	IN, OUT	Generate 7-segment pattern
Interrupt		
CRETI		Conditional Return from Int.
ENI		Enable Interrupts
DISI		Disable Interrupts
ATCH	INT, EVENT	Attach Interrupt routine to event
DTCH	EVENT	Detach event
Communication		
XMT	TABLE,PORT	Freeport transmission
RCV	TABLE,PORT	Freeport receive message
NETR	TABLE,PORT	Network Read
NETW	TABLE,PORT	Network Write
GPA	ADDR,PORT	Get Port Address
SPA	ADDR,PORT	Set Port Address
High-Speed Instructions		
HDEF	HSC, Mode	Define High-Speed Counter mode
HSC	N	Activate High-Speed Counter
PLS	X	Pulse Output

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User program size	2 Kwords	2 Kwords	4 Kwords	4 Kwords
User data size	1 Kwords	1 Kwords	2.5 Kwords	2.5 Kwords
Process-image input register	I0.0 to I15.7	I0.0 to I15.7	I0.0 to I15.7	I0.0 to I15.7
Process-image output register	Q0.0 to Q15.7	Q0.0 to Q15.7	Q0.0 to Q15.7	Q0.0 to Q15.7
Analog inputs (read only)	—	AIW0 to AIW30	AIW0 to AIW62	AIW0 to AIW62
Analog outputs (write only)	—	AQW0 to AQW30	AQW0 to AQW62	AQW0 to AQW62
Variable memory (V)[1]	VB0.0 to VB2047.7	VB0.0 to VB2047.7	VB0.0 to VB5119.7	VB0.0 to VB5119.7
Local memory (L)[2]	LB0.0 to LB63.7	LB0.0 to LB63.7	LB0.0 to LB63.7	LB0.0 to LB63.7
Bit memory (M)	M0.0 to M31.7	M0.0 to M31.7	M0.0 to M31.7	M0.0 to M31.7
Special Memory (SM) Read only	SM0.0 to SM179.7 SM0.0 to SM29.7	SM0.0 to SM179.7 SM0.0 to SM29.7	SM0.0 to SM179.7 SM0.0 to SM29.7	SM0.0 to SM179.7 SM0.0 to SM29.7
Timers	256 (T0 to T255)	256 (T0 to T255)	256 (T0 to T255)	256 (T0 to T255)
Retentive on-delay 1 ms	T0, T64	T0, T64	T0, T64	T0, T64
Retentive on-delay 10 ms	T1 to T4, T65 to T68	T1 to T4, T65 to T68	T1 to T4, T65 to T68	T1 to T4, T65 to T68
Retentive on-delay 100 ms	T5 to T31, T69 to T95	T5 to T31, T69 to T95	T5 to T31, T69 to T95	T5 to T31, T69 to T95
On/Off delay 1 ms	T32, T96	T32, T96	T32, T96	T32, T96
On/Off delay 10 ms	T33 to T36, T97 to T100	T33 to T36, T97 to T100	T33 to T36, T97 to T100	T33 to T36, T97 to T100
On/Off delay 100 ms	T37 to T63, T101 to T255	T37 to T63, T101 to T255	T37 to T63, T101 to T255	T37 to T63, T101 to T255
Counters	C0 to C255	C0 to C255	C0 to C255	C0 to C255
High-speed counter	HC0, HC3, HC4, HC5	HC0, HC3, HC4, HC5	HC0 to HC5	HC0 to HC5
Sequential control relays (S)	S0.0 to S31.7	S0.0 to S31.7	S0.0 to S31.7	S0.0 to S31.7
Accumulator registers	AC0 to AC3	AC0 to AC3	AC0 to AC3	AC0 to AC3
Jumps/Labels	0 to 255	0 to 255	0 to 255	0 to 255
Call/Subroutine	0 to 63	0 to 63	0 to 63	0 to 63
Interrupt routines	0 to 127	0 to 127	0 to 127	0 to 127
PID loops	0 to 7	0 to 7	0 to 7	0 to 7
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[1] All V memory can be saved to permanent memory.
[2] LB60 to LB63 are reserved by STEP 7–Micro/WIN 32, version 3.0 or later.

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