



NEAR EAST UNIVERSITY

Faculty of Engineering

**Department of Electrical and Electronics
Engineering**

**PROGRAMMABLE LOGIC CONTROLLER
(SIEMENS S7 FAMILY)**

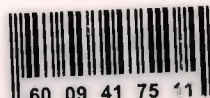
**Graduation Project
EE – 400**

Student: Muhammad Tariq Rasool

Supervisor: Mr. ÖZGÜR CEMAL ÖZERDEM

Lefkoşa - 2003

infog devices



NEU

60 09 41 75 11

TABLE OF CONTENTS



AKNOWLEDGEMENT	i
ABSTRACT	ii
INTRODUCTION	iii
1. BASICS OF PLCs	1
1.1 PLC	1
1.2 Basic PLC operation	1
1.3 Hard-Wire control	3
1.4 Advantages of PLCs	3
1.5 SIEMENS PLCs	4
1.5.1 S7-200	4
1.5.2 S7-300 and S7-400	4
1.6 Terminology	6
1.6.1 Sensor	6
1.6.2 Actuators	7
1.6.3 Discrete input	7
1.6.4 Analog input	9
1.6.5 Discrete outputs	10
1.6.6 Analog outputs	10
1.6.7 CPU	11
1.7 Basic requirement	12
1.7.1 PLC	13
1.7.2 Programming devices	13

1.7.3 Software	14
1.7.4 Connection cables (PPI)	15
1.8 Number System	18
1.8.1 Decimal System	18
1.8.2 Binary System	18
1.9 Converting Binary to Decimal	19
1.10 Bits, Bytes and Word	20
1.11 Logic 0, Logic 1	21
1.12 BCD	21
1.13 Hexadecimal	22
1.14 Conversion of Number	23
1.15 Programming	25
1.15.1 Ladder Logic	25
1.15.2 Ladder Logic Diagram	25
1.15.3 Statement List	26
1.15.4 Function Block Diagram	27
1.15.5 PLC Scan	28
1.15.6 Software	28
1.15.7 Hardware	28
1.16 Memory Size	29
1.16.1 RAM	30
1.16.2 ROM	30
1.16.3 EPROM	30
1.16.4 Firmware	31

1.17 Putting it Together	31
2. S7-200 MICRO PLC	33
2.1 S7-200 Models	33
2.2 S7-200 Features	34
2.3 Mode Switch and Analog Adjustment	37
2.4 Optional Cartridge	37
2.5 Expansion Modules	38
2.6 Available Expansion	39
2.7 Status Indicators	40
2.8 Installing	41
2.9 External Power Supply Source	42
2.10 I/O Numbering	43
2.11 Inputs	44
2.11.1 Input Simulator	45
2.12 Outputs	46
2.13 Operational Connector	47
2.14 Removable Terminal	48
2.15 Super Capacitor	49
2.16 Connecting External Devices	50
2.16.1 TD 200	51
2.16.2 Freeport Mode	51
2.16.3 Printer	52
2.16.4 Interconnection	53

3. PROGRAMMING APPLICATION	54
3.1 Standard Instructions	54
3.2 Special Instructions	54
3.3 High Speed Instruction	54
3.4 Symbols	55
3.4.1 Contacts	55
3.4.2 Coils	56
3.4.3 Boxes	56
3.5 Entering Elements	57
3.6 An AND Operation	57
3.7 An OR Operation	59
3.8 Testing a Program	61
3.9 Status Functions	61
3.10 Forcing	62
3.11 Program instructions	64
3.12 Motor Starter Example	65
3.12.1 Program Instruction	67
3.12.2 Expending the Application	71
3.12.3 Adding a limit Switch	72
3.13 Application Example	74
3.14 Timers	75
3.14.1 S7-200 Timer	77
3.14.2 On-Delay (TON)	77
3.14.3 Retentive On-Delay (TONR)	80

3.14.4 Off-Delay (TOF)	81
3.14.5 S7-200 Timers	82
3.14.6 Timer Examples	82
3.15 Counters	83
3.15.1 S7-200 Counter	84
3.15.2 Up-Counters	85
3.15.3 Down Counters	86
3.15.4 Up/Down Counter	86
3.15.5 Counter Examples	86
4. PRACTICAL	88
4.1 Statement List	89
4.2 Ladder diagram	90
4.3 Applications of PLC	93
CONCLUSION	94
REFERENCES	95

ACKNOWLEDGMENTS

First of all I am very thankful to ALLAH ALL MIGHTY, as thy blessed me with strength and helped me mentally and physically to achieve my goal.

I also want to thank Mr. ÖZGÜR CEMAL ÖZERDEM to be my advisor. I successfully overcome many difficulties and learn a lot about Programmable Controllers. In each discussion, he explained my questions patiently, and I felt quick progress from his advises. He always helped me a lot in my study. I asked him many questions in electrical and electronics and he always answered my questions quickly and in detail.

Special thanks to my friend Muhammad Aamir Khan with him make my four years in NEU full of fun.

Finally, I want to thanks my family, especially my grandfather and my parents. Without their endless affection and everlasting prayers it shouldn't be possible for me to be at this stage.

ABSTRACT

The need for low cost, versatile and commission controller has resulted in the development of programmable control system standard units based on a hardware CPU and memory for the control of machines or processes. Originally designed as a replacement for the hard wired relay and timer logic to be found in traditional control panels. PLCs provide ease and flexibility of control based on programming and executing simple logic instructions in the form of ladder diagram. PLCs has internal functions such as timers, counters and shift registers make sophisticated control possible using even the smallest PLC.

There are many types of PLCs available in the market in theses days and can choose by different properties of doing job. Micro PLCs are use for simple system with limited I/O points. And medium/large PLCs are used for complex systems.

SIEMENS have many types of PLCs but in S7 family there are three types of PLCs, S7-200, S7-300 and S7-400.

The S7-200 is referred to as a MICROPLC because of its small size. It has brick design which means that the power supply and I/O points are on board. The S7 can be used on smaller, stand-alone application.

The S7-300 and S7-400 PLCs are used in complex application with a greater numbers of I/O points. Both PLCs are modular and expandable. These types of PLCs power supply and I/O consist of separate modules connected to the PLCs. Choosing either the S7-300 or S7 400 depends on the complexity of the task and possible future expansion.

Now a days PLCs are use in very widely range in daily life use and also industrial applications. Fourth chapter is about the application example of PLC. There is a program from which we are controlling a motor which runs for 5 sec. and then stop for 5 sec. After repeating this process twice the process will be stop.

INTRODUCTION

A PLC is a 'digital electronic device that use a programmable memory to store instructions and to implement specific functions such as logic, sequence, timing, counting and arithmetic to control machines and process'.

The internal operation of any PLC is essentially similar to any other microprocessor base system. Differences occur in the manner of input/output handling and the interface hardware providing. PLCs are specially design to connect to most common industrial control systems, which are hardware specific, but they offer great flexibility through programming.

Now days virtually every manufacturer of electronic control equipment markets a range of programmable controllers with facilities ranging from simple switched I/O through sophisticated continuous control. Development in this area is continuing at a rate almost equal to the field of personal computing. Because of this, the power and operating speed of all programmable controllers is constantly improving.

The first chapter has general information about PLCs. Identifies the major components of PLCs and describes their functions. Conversion of numbers from decimal to binary, BCD and hexadecimal. Terminologies of PLCs. Identify typical discrete and analog inputs and outputs. Basic of ladder diagram and statement list.

Second chapter about SIEMENS S7-200 PLC. The operation of S7-200 and the operational differences between different S7-200 models. Connect a simple discrete input and out put to S7-200. parts of S7-200, Expansion of S7-200, Installing and loading a program in S7-200 type PLC.

Third chapter about the basics of programming, Elements of ladder diagram, Logic shown in ladder diagram, the use of timers, counters. Some daily life examples and controlling of a electric motor with a PLC.

Fourth chapter devoted to the practical, implementation and writing the PLCs program for S7-200

1. BASICS OF PLCS

1.1 PLCs

Programmable Logic Controllers (PLCs), also referred to as programmable controllers, are in the computer family. They are used in commercial and industrial applications. A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine.

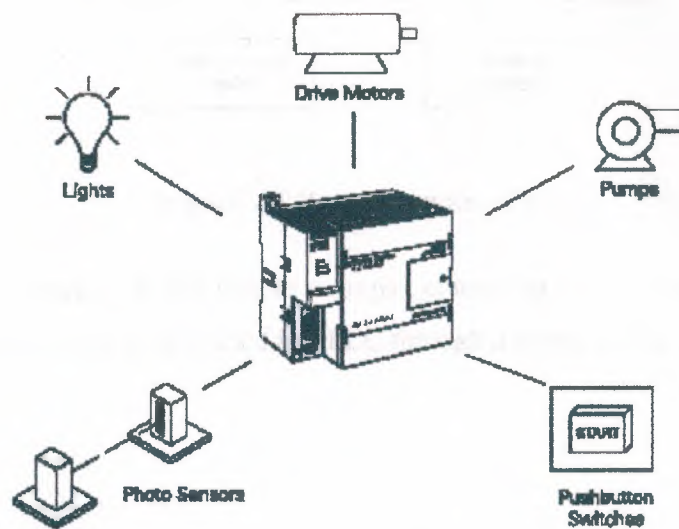


Figure 1.1 Basic PLC

1.2 Basic PLC Operation

PLCs consist of input modules or points, a Central Processing Unit (CPU), and output modules or points. An input accepts a variety of digital or analog signals from various field devices (sensors) and converts them into a logic signal that can be used by the CPU. The CPU makes decisions and executes control instructions based on program instructions in memory. Output modules convert control instructions from the CPU

into a digital or analog signal that can be used to control various field devices (actuators). A programming device is used to input the desired instructions. These instructions determine what the PLC will do for a specific input. An operator interface device allows process information to be displayed and new control parameters to be entered.

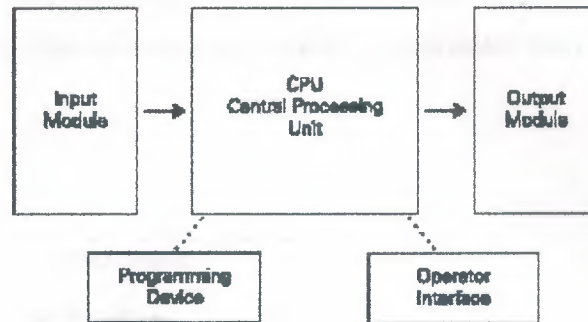


Figure 1.2 Basic operation of PLC

Pushbuttons (sensors), in this simple example, connected to PLC inputs, can be used to start and stop a motor connected to a PLC through a motor starter (actuator).

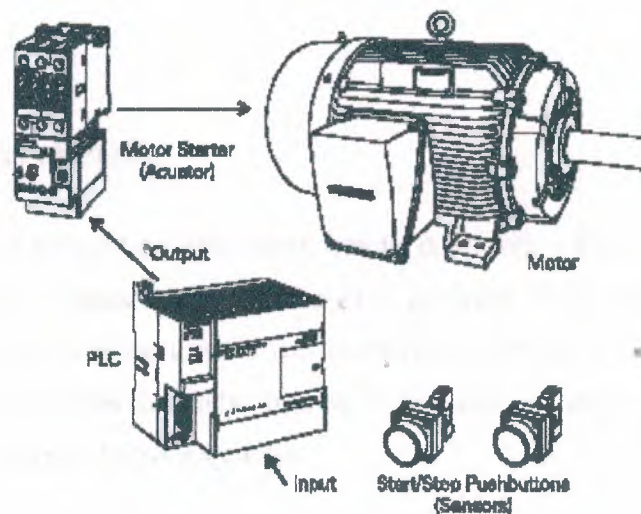


Figure 1.3 PLC with pushbutton sensor

1.3 Hard-Wired Control

Prior to PLCs, many of these control tasks were solved with contactor or relay controls. This is often referred to as hardwired control. Circuit diagrams had to be designed, electrical components specified and installed, and wiring lists created. Electricians would then wire the components necessary to perform a specific task. If an error was made the wires had to be reconnected correctly. A change in function or system expansion required extensive component changes and rewiring.

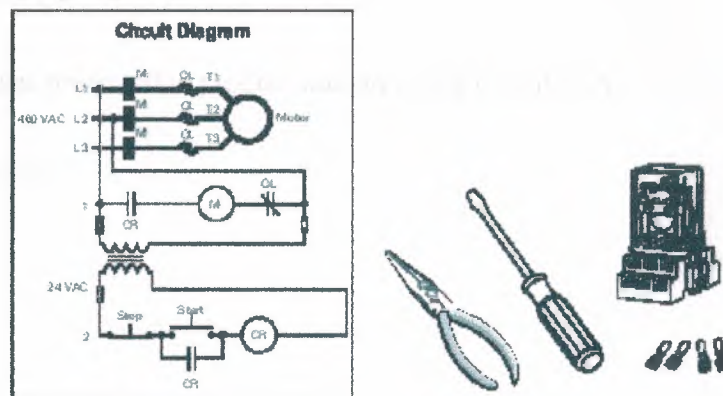


Figure 1.4 Circuit diagram of motor control

1.4 Advantages of PLCs

The same, as well as more complex tasks, can be done with a PLC. Wiring between devices and relay contacts is done in the PLC program. Hard-wiring, though still required to connect field devices, is less intensive. Modifying the application and correcting errors are easier to handle. It is easier to create and change a program in a PLC than it is to wire and rewire a circuit.

Following are just a few of the advantages of PLCs:

- Smaller physical size than hard-wire solutions.

- Easier and faster to make changes.
- PLCs have integrated diagnostics and override functions.
- Diagnostics are centrally available.
- Applications can be immediately documented.
- Applications can be duplicated faster and less expensively.

1.5 Siemens PLCs

Siemens makes several PLC product lines in the SIMATIC® S7

Family. They are:

S7-200,

S7-300,

And S7-400.

1.5.1 S7-200

The S7-200 is referred to as a micro PLC because of its small size. The S7-200 has a brick design which means that the power supply and I/O are on-board. The S7-200 can be used on smaller, stand-alone applications such as elevators, car washes, or mixing machines. It can also be used on more complex industrial applications such as bottling and packaging machines.

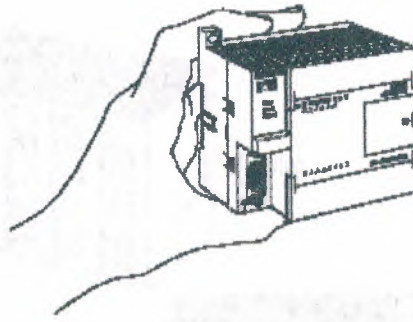


Figure 1.5 S7-200 PLC

1.5.2 S7-300 and S7-400

The S7-300 and S7-400 PLCs are used in more complex applications that support a greater number of I/O points. Both PLCs are modular and expandable. The power supply and I/O consist of separate modules connected to the CPU. Choosing either the S7-300 or S7-400 depends on the complexity of the task and possible future expansion. Your Siemens sales representative can provide you with additional information on any of the Siemens PLCs.

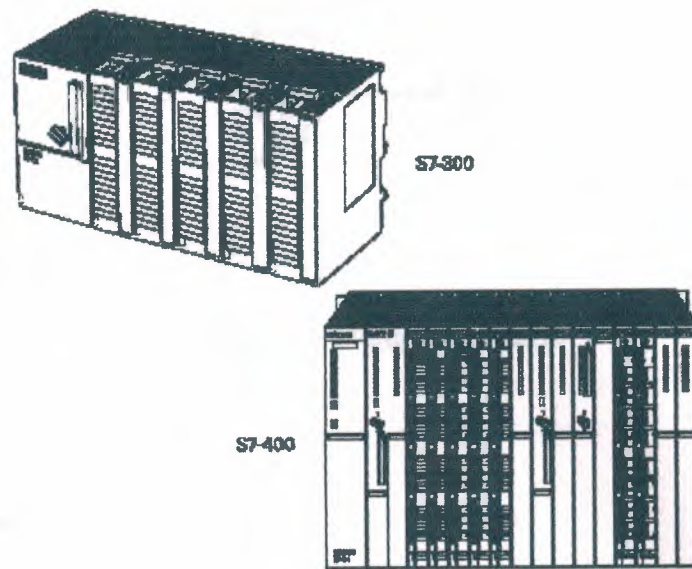


Figure 1.6 S7-300 and S7400 PLCs

1.6 Terminology

The language of PLCs consists of a commonly used set of terms; many of which are unique to PLCs. In order to understand the ideas and concepts of PLCs, an understanding of these terms is necessary.

1.6.1 Sensor

A sensor is a device that converts a physical condition into an electrical signal for use by the PLC. Sensors are connected to the input of a PLC. A pushbutton is one example of a sensor that is connected to the PLC input. An electrical signal is sent from the pushbutton to the PLC indicating the condition (open/ closed) of the pushbutton contacts.

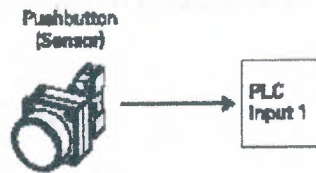


Figure 1.7 Pushbutton sensor

1.6.2 Actuators

Actuators convert an electrical signal from the PLC into a physical condition. Actuators are connected to the PLC output. A motor starter is one example of an actuator that is connected to the PLC output. Depending on the output PLC signal the motor starter will either start or stop the motor.

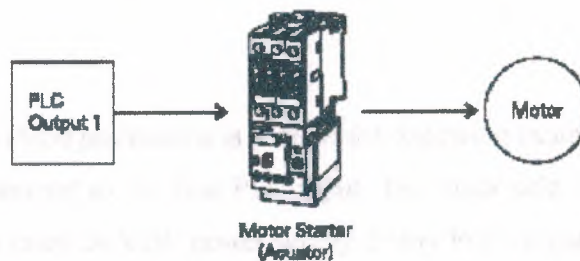


Figure 1.8 Motor starter actuator

1.6.3 Discrete Input

A discrete input, also referred to as a digital input, is an input that is either in an ON or OFF condition. Pushbuttons, toggle switches, limit switches, proximity switches, and contact closures are examples of discrete sensors which are connected to the PLCs discrete or digital inputs. In the ON condition a discrete input may be referred

to as a logic 1 or a logic high. In the OFF condition a discrete input may be referred to as a logic 0 or a logic low.

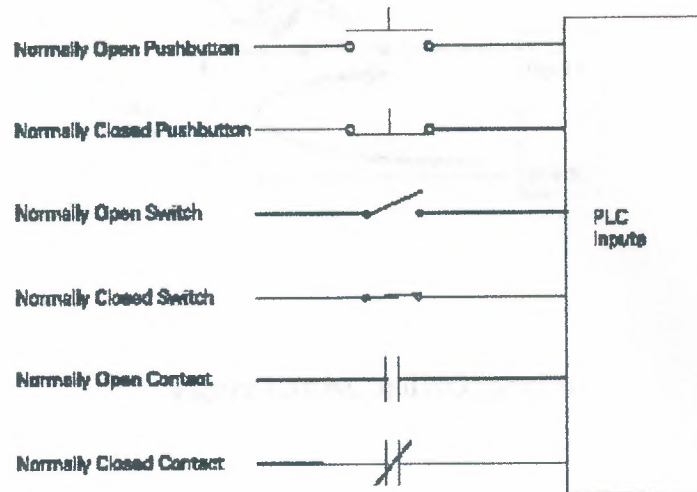


Figure 1.9 Discrete inputs of PLC

A Normally Open (NO) pushbutton is used in the following example. One side of the pushbutton is connected to the first PLC input. The other side of the pushbutton is connected to an internal 24 VDC power supply. Many PLCs require a separate power supply to power the inputs. In the open state, no voltage is present at the PLC input. This is the OFF condition. When the pushbutton is depressed, 24 VDC is applied to the PLC input. This is the ON condition.

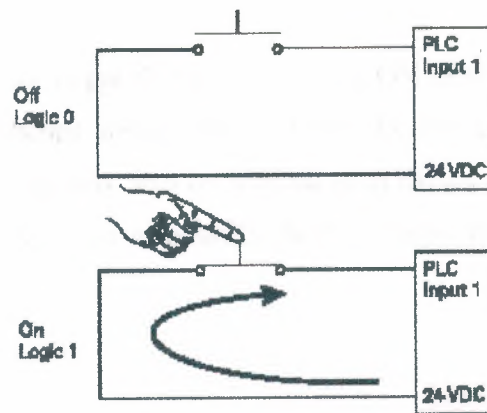


Figure 1.10 NC and NO switches

1.6.4 Analog Input

An analog input is an input signal that has a continuous signal. Typical analog inputs may vary from 0 to 20 milliamps, 4 to 20 milliamps, or 0 to 10 volts. In the following example, a level transmitter monitors the level of liquid in a tank. Depending on the level transmitter, the signal to the PLC can either increase or decrease as the level increases or decreases.

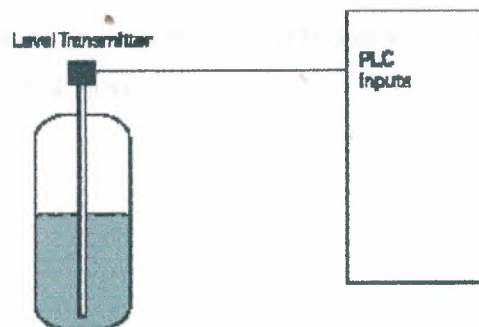


Figure 1.11 PLC input by level sensor

1.6.5 Discrete Outputs

A discrete output is an output that is either in an ON or OFF condition. Solenoids, contactor coils, and lamps are examples of actuator devices connected to discrete outputs. Discrete outputs may also be referred to as digital outputs. In the following example, a lamp can be turned on or off by the PLC output it is connected to.

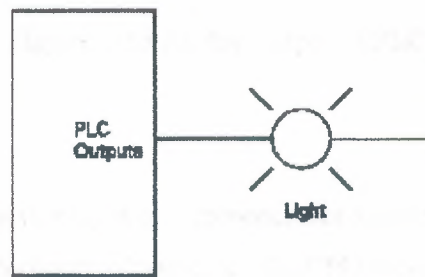


Figure 1.12 Output of PLC

1.6.6 Analog Outputs

An analog output is an output signal that has a continuous signal. The output may be as simple as a 0-10 VDC level that drives an analog meter. Examples of analog meter outputs are speed, weight, and temperature. The output signal may also be used on more complex applications such as a current-to-pneumatic transducer that controls an air-operated flow-control valve.

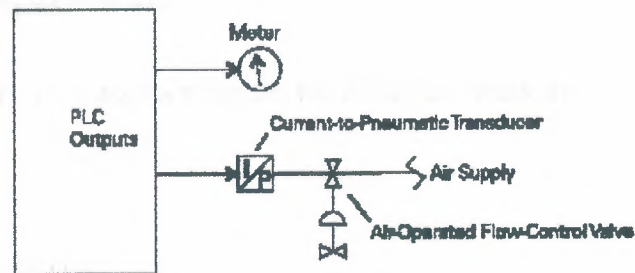


Figure 1.13 Analog output of PLC

1.6.7 CPU

The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decisionmaking unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory. The CPU performs relay, counting, timing, data comparison, and sequential operations.

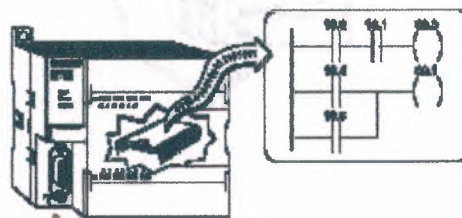


Figure 1.14 CPU of PLC

1.7 Basic Requirements

In order to create or change a program, the following items are needed:

- PLC
- Programming Device
- Programming Software
- Connector Cable

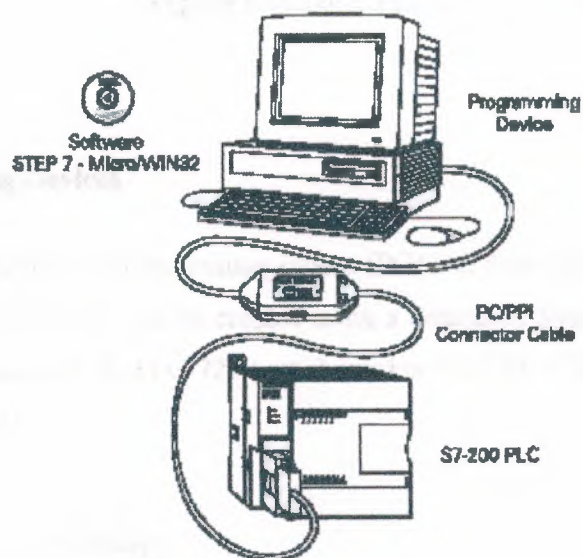


Figure 1.15 PLC connect with PC

1.7.1 PLC

Throughout this course we will be using the S7-200 because of its ease of use.

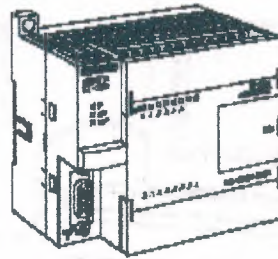


Figure 1.16 Basic PLC

1.7.2 Programming Devices

The program is created in a programming device (PG) and then transferred to the PLC. The program for the S7-200 can be created using a dedicated Siemens SIMATIC S7 programming device, such as a PG 720 (not shown) or PG 740, if STEP 7 Micro/WIN software is installed.

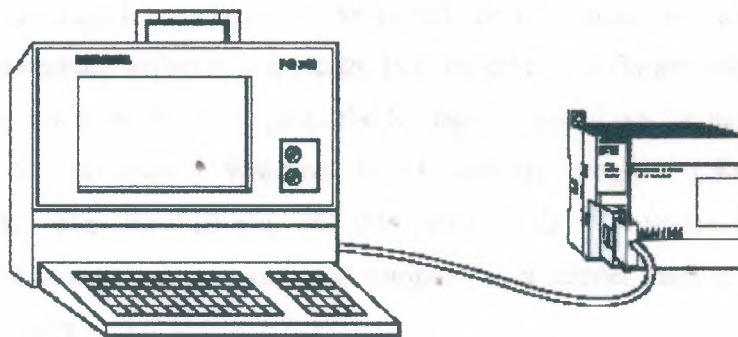


Figure 1.17 PLC connect with programming devaice

A personal computer (PC), with STEP 7 Micro/WIN installed, can also be used as a programming device with the S7-200.

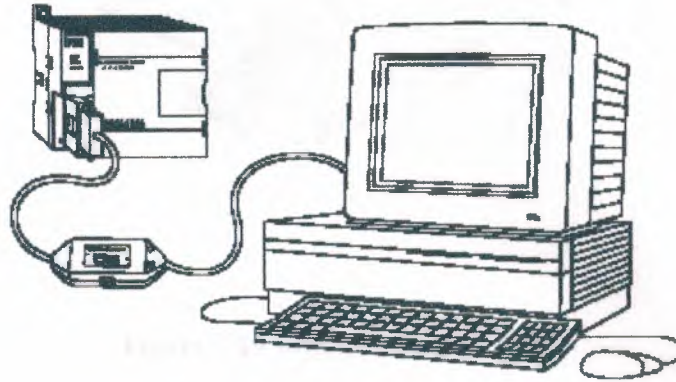


Figure 1.18 PLC connect with programming device

1.7.3 Software

A software program is required in order to tell the PLC what instructions it must follow. Programming software is typically PLC specific. A software package for one PLC, or one family of PLCs, such as the S7 family, would not be useful on other PLCs. The S7-200 uses a Windows based software program called STEP 7-Micro/WIN32. The PG 720 and PG 740 have STEP 7 software pre-installed. Micro/WIN32 is installed on a personal computer in a similar manner to any other computer software.



Figure 1.19 Writing a PLC program

1.7.4 Connector Cables PPI (Point-to-Point Interface)

Connector cables are required to transfer data from the programming device to the PLC. Communication can only take place when the two devices speak the same language or protocol. Communication between a Siemens programming device and the S7-200 is referred to as PPI protocol (point-to-point interface). An appropriate cable is required for a programming device such as a PG 720 or PG 740. The S7-200 uses a 9-pin, D-connector. This is a straight-through serial device that is compatible with Siemens programming devices (MPI port) and is a standard connector for other serial interfaces.

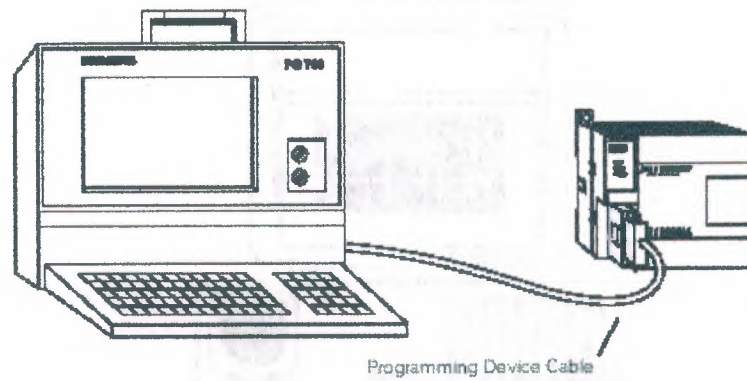


Figure 1.20 Programming device cable

A special cable, referred to as a PC/PPI cable, is needed when a personal computer is used as a programming device. This cable allows the serial interface of the PLC to communicate with the RS-232 serial interface of a personal computer. DIP switches on the PC/PPI cable are used to select an appropriate speed (baud rate) at which information is passed between the PLC and the computer.

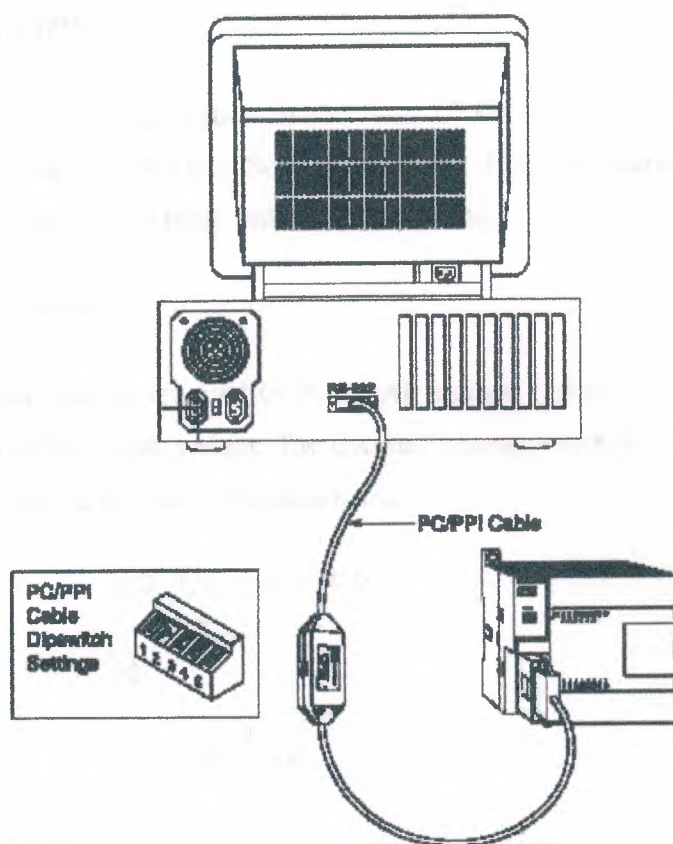


Figure 1.21 PLC PC/PPI cable

1.8 Number system

a computer, it stores information in the form of On or Off conditions (1 or 0), referred to as binary digits (bits). Sometimes binary digits are used individually and sometimes they are used to represent numerical values.

1.8.1 Decimal System

Various number systems are used by PLCs. All number systems have the same three characteristics: digits, base, weight. The decimal system, which is commonly used in everyday life, has the following characteristics:

Ten digits 1, 2, 3, 4, 5, 6, 7, 8, 9

Base 10

Weights 1, 10, 100, 1000,

1.8.2 Binary System

The binary system is used by programmable controllers. The binary system has the following characteristics:

Two digits 0, 1

Base 2

Weights Powers of base 2 (1, 2, 4, 8, 16, ...)

In the binary system 1s and 0s are arranged into columns. Each column is weighted. The first column has a binary weight of 2⁰. This is equivalent to a decimal 1. This is referred to as the least significant bit. The binary weight is doubled with each

succeeding column. The next column, for example, has a weight of 2¹, which is equivalent to a decimal 2. The decimal value is doubled in each successive column. The number in the far left hand column is referred to as the most significant bit. In this example, the most significant bit has a binary weight of 2⁷. This is equivalent to a decimal 128.

Most Significant Bit				Least Significant Bit			
↓							↓
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
0	0	0	1	1	0	0	0

Figure 1.22 Binary system

1.9 Converting Binary to Decimal

The following steps can be used to interpret a decimal number from a binary value.

- 1) Search from least to most significant bit for 1s.
- 2) Write down the decimal representation of each column containing a 1.
- 3) Add the column values. In the following example, the fourth and fifth columns from the right contain a 1. The decimal value of the fourth column from the right is 8, and the decimal value of the fifth column from the right is 16. The decimal equivalent of this binary number is 24. The sum of all the weighted columns that contain a 1 is the decimal number that the PLC has stored.

128	64	32	16	8	4	2	1
0	0	0	1	1	0	0	0

							8
							+ 16
							<hr/> 24

Figure 1.23 Converting Binary to Decimal

In the following example the fourth and sixth columns from the right contain a 1. The decimal value of the fourth column from the right is 8, and the decimal value of the sixth column from the right is 32. The decimal equivalent of this binary number is 40.

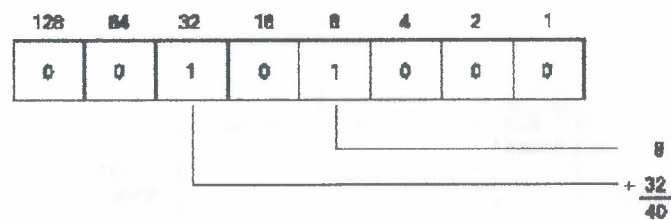


Figure 1.24 Converting Binary to Decimal

1.10 Bits, Bytes, and Words

Each binary piece of data is a bit. Eight bits make up one byte. Two bytes, or 16 bits, make up one word.

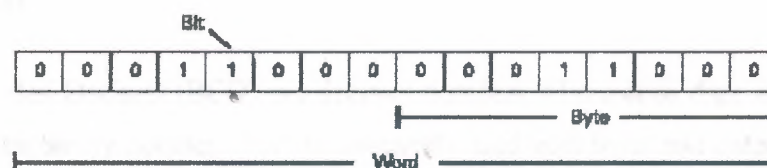


Figure 1.25 Bits, Bytes, and Words

1.11 Logic 0, Logic 1

Programmable controllers can only understand a signal that is On or Off (present or not present). The binary system is a system in which there are only two numbers, 1 and 0. Binary 1 indicates that a signal is present, or the switch is On. Binary 0 indicates that the signal is not present, or the switch is Off.

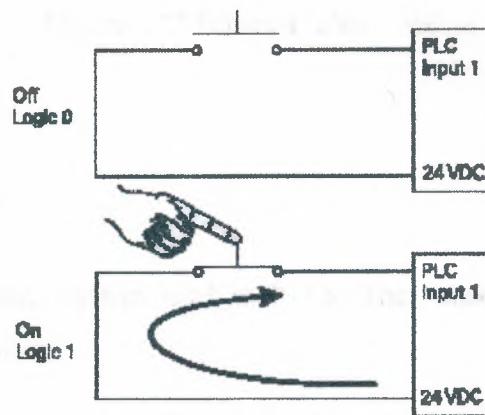


Figure 1.26 Logic 0, Logic 1

1.12 BCD

Binary-Coded Decimal (BCD) are decimal numbers where each digit is represented by a four-bit binary number. BCD is commonly used with input and output devices. A thumbwheel switch is one example of an input device that uses BCD. The binary numbers are broken into groups of four bits, each group representing a decimal equivalent. A four-digit thumbwheel switch, like the one shown here, would control 16 (4×4) PLC inputs.

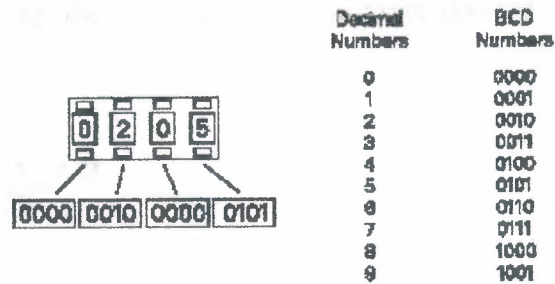


Figure 1.27 Binary-Coded Decimal

1.13 Hexadecimal

Hexadecimal is another system used in PLCs. The hexadecimal system has the following characteristics:

16 digits	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
Base	16
Weights	Powers of base 16 (1, 16, 256, 4096 ...)

The ten digits of the decimal system are used for the first ten digits of the hexadecimal system. The first six letters of the alphabet are used for the remaining six digits.

A = 10 D = 13

B = 11 E = 14

C = 12 F = 15

The hexadecimal system is used in PLCs because it allows the status of a large number of binary bits to be represented in a small space such as on a computer screen or programming device display. Each hexadecimal digit represents the exact status of four binary bits. To convert a decimal number to a hexadecimal number the decimal

number is divided by the base of 16. To convert decimal 28, for example, to hexadecimal:

$$\begin{array}{r} 1 \text{ r } 12 \\ 16 \overline{) 28} \end{array}$$

Decimal 28 divided by 16 is 1 with a remainder of 12. Twelve is equivalent to C in hexadecimal. The hexadecimal equivalent of decimal 28 is 1C.

The decimal value of a hexadecimal number is obtained by multiplying the individual hexadecimal digits by the base 16 weight and then adding the results. In the following example the hexadecimal number 2B is converted to its decimal equivalent of 43.

$$16^1 = 16$$

$$16^0 = 1$$

$$B = 11$$

16^1	16^0
2	B

$$\begin{array}{r} 11 \times 1 = 11 \\ 2 \times 16 = 32 \\ \hline 43 \end{array}$$

1.14 Conversion of Numbers

The following chart shows a few numeric values in decimal, binary, BCD, and hexadecimal representation.

Table 1.1 Conversions of Numbers

Decimal	Binary	BCD	Hexadecimal
0	0	0000	0
1	1	0001	1
2	10	0010	2
3	11	0011	3
4	100	0100	4
5	101	0101	5
6	110	0110	6
7	111	0111	7
8	1000	1000	8
9	1001	1001	9
10	1010	0001 0000	A
11	1011	0001 0001	B
12	1100	0001 0010	C
13	1101	0001 0011	D
14	1110	0001 0100	E
15	1111	0001 0101	F
16	1 0000	0001 0110	10
17	1 0001	0001 0111	11
18	1 0010	0001 1000	12
19	1 0011	0001 1001	13
20	1 0100	0001 0000	14
.			.
.			.
126	111 1110	0001 0010 0110	7E
127	111 1111	0001 0010 0111	7F

.			.
.			.
511	1 1111 1111	0101 0001 0001	1FE
512	10 0000 0000	0101 0001 0010	200

1.15 Programming

A program consists of one or more instructions that accomplish a task. Programming a PLC is simply constructing a set of instructions. There are several ways to look at a program such as ladder logic, statement lists, or function block diagrams.

1.15.1 Ladder Logic

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control.

1.15.2 Ladder Logic Diagram

The left vertical line of a ladder logic diagram represents the power or energized conductor. The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

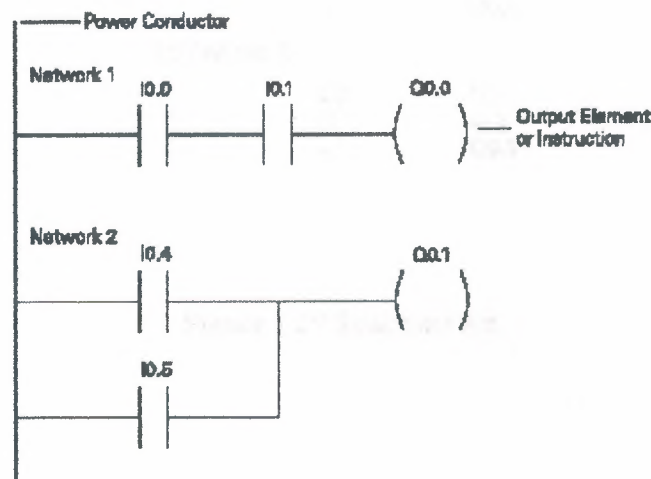


Figure 1.28 Ladder Logic Diagram

In the example program shown example I0.0, I0.1 and Q0.0 represent the first instruction combination. If inputs I0.0 and I0.1 are energized, output relay Q0.0 energizes. The inputs could be switches, pushbuttons, or contact closures. I0.4, I0.5, and Q1.1 represent the second instruction combination. If either input I0.4 or I0.5 are energized, output relay Q0.1 energizes.

1.15.3 Statement list

A statement list (STL) provides another view of a set of instructions. The operation, what is to be done, is shown on the left. The operand, the item to be operated on by the operation, is shown on the right. A comparison between the statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure. The set of instructions in this statement list perform the same task as the ladder diagram.

NETWORK 1		
LD		I0.0
A		I0.1
=		Q0.0
NETWORK 2		
LD		I0.4
O		I0.5
=		Q0.1

Figure 1.29 Statement list

1.15.4 Function Block Diagrams

Function Block Diagrams (FBD) provide another view of a set of instructions. Each function has a name to designate its specific task. Functions are indicated by a rectangle. Inputs are shown on the left-hand side of the rectangle and outputs are shown on the right-hand side. The function block diagram shown below performs the same function as shown by the ladder diagram and statement list.

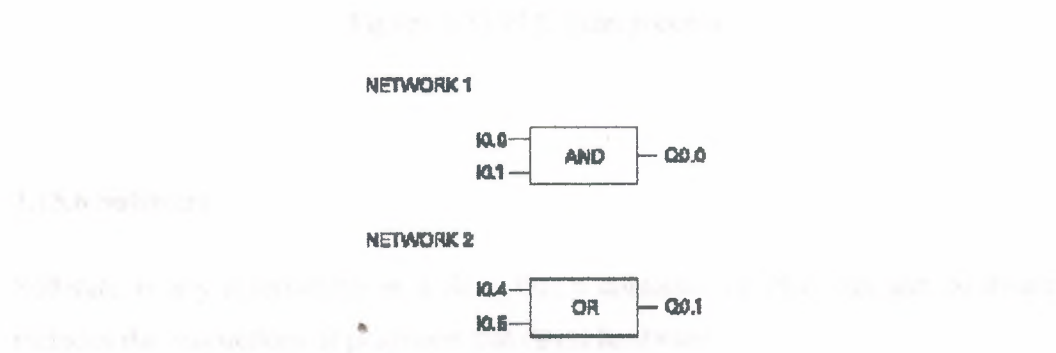


Figure 1.30 Function Block Diagrams

1.15.5 PLC Scan

The PLC program is executed as part of a repetitive process referred to as a scan. A PLC scan starts with the CPU reading the status of inputs. The application program is executed using the status of the inputs. Once the program is completed, the CPU performs internal diagnostics and communication tasks. The scan cycle ends by updating the outputs, then starts over. The cycle time depends on the size of the program, the number of I/Os, and the amount of communication required.



Figure 1.31 PLC Scan process

1.15.6 Software

Software is any information in a form that a computer or PLC can use. Software includes the instructions or programs that direct hardware.

1.15.7 Hardware

Hardware is the actual equipment. The PLC, the programming device, and the connecting cable are examples of hardware.

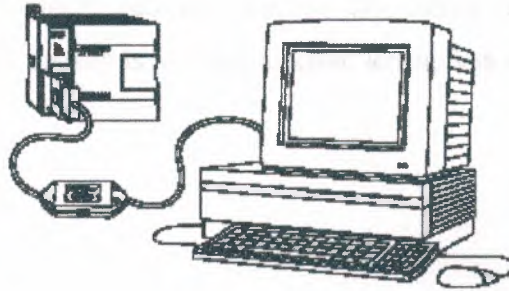


Figure 1.32 Hardware

1.16 Memory Size

Kilo, abbreviated K, normally refers to 1000 units. When talking about computer or PLC memory, however, 1K means 1024. This is because of the binary number system ($2^{10}=1024$). This can be 1024 bits, 1024 bytes, or 1024 words, depending on memory type.

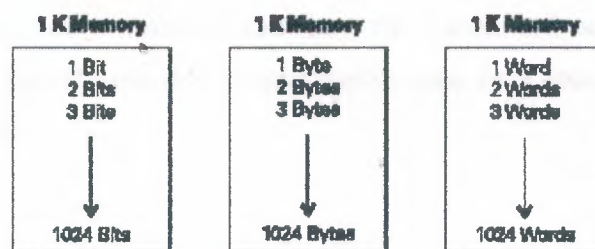


Figure 1.33 PLC memory size

1.16.1 RAM

Random Access Memory (RAM) is memory where data can be directly accessed at any address. Data can be written to and read from RAM. RAM is used as a temporary storage area. RAM is volatile, meaning that the data stored in RAM will be lost if power is lost. A battery backup is required to avoid losing data in the event of a power loss.

1.16.2 ROM

Read Only Memory (ROM) is a type of memory that data can be read from but not written to. This type of memory is used to protect data or programs from accidental erasure. ROM memory is nonvolatile. This means a user program will not lose data during a loss of electrical power. ROM is normally used to store the programs that define the capabilities of the PLC.

1.16.3 EPROM

Erasable Programmable Read Only Memory (EPROM) provides some level of security against unauthorized or unwanted changes in a program. EPROMs are designed so that data stored in them can be read, but not easily altered. Changing

EPROM data requires a special effort. UVEPROMs (ultraviolet erasable programmable read only memory) can only be erased with an ultraviolet light. EEPROM (electronically erasable programmable read only memory), can only be erased electronically.

1.16.4 Firmware

Firmware is user or application specific software burned into EPROM and delivered as part of the hardware. Firmware gives the PLC its basic functionality.



Figure 1.34 Memory chip of PLC

1.17 Putting it together

The memory of the S7-200 is divided into three areas: program space, data space, and configurable parameter space.

- Program space stores the ladder logic (LAD) or statement list (STL) program instructions. This area of memory controls the way data space and I/O points are used. LAD or STL instructions are written using a programming device such as a PC, then loaded into program memory of the PLC.
- Data space is used as a working area, and includes memory locations for calculations, temporary storage of intermediate results and constants. Data space includes memory locations for devices such as timers, counters, high-speed counters, and analog inputs and outputs. Data space can be accessed under program control.
- Configurable parameter space, or memory, stores either the default or modified configuration parameters.

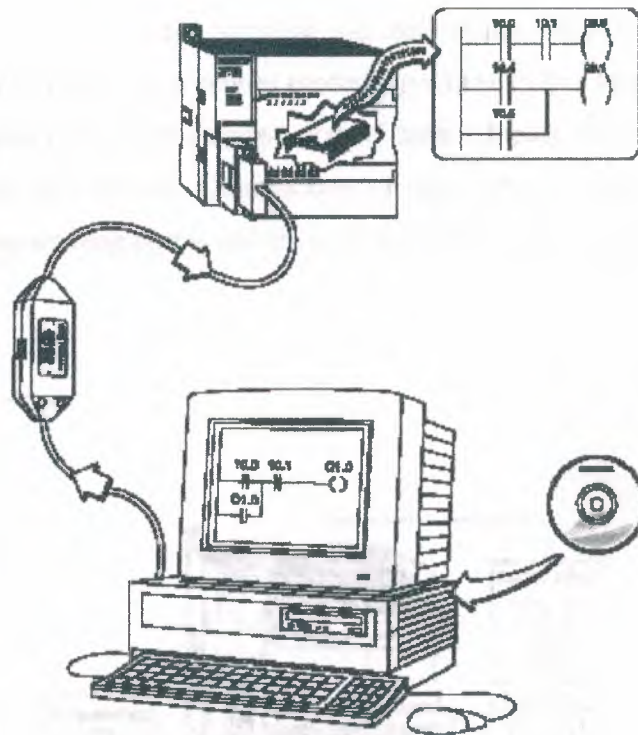


Figure 1.35 Loading of program in the PLC

2S7-200 Micro PLCs

The S7-200 Micro PLC is the smallest member of the SIMATIC S7 family of programmable controllers. The central processing unit (CPU) is internal to the PLC. Inputs and outputs (I/O) are the system control points. Inputs monitor field devices, such as switches and sensors. Outputs control other devices, such as motors and pumps. The programming port is the connection to the programming device.

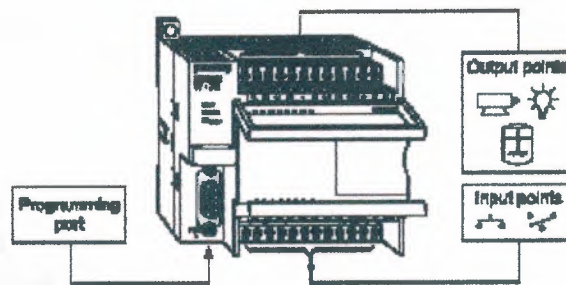


Figure 2.1 S7-200 Micro PLC

2.2 S7-200 Models

There are four S7-200 CPU types: S7-221, S7-222, S7-224, S7-226, and S7-226XM and three power supply configurations for each type.

Table 2.1 Types of S7-200

Model Description	Power Supply	Input types	Output Types
221 DC/DC/DC	20.4-28.8 VDC	6 DC Inputs	4 DC Outputs
221 AC/DC/Relay	85-264 VAC, 47-63 Hz	6 DC Inputs	4 Relay Outputs

222 DC/DC DC 222 AC/DC/Relay	20.4-28.8 VDC 85-264 VDC, 47-63 Hz	8 DC Inputs 8 DC Inputs	6 DC Outputs 6 Relay Outputs
224 DC/DC/DC 224 AC/DC/Relay	20.4-28.8 VDC 85-264 VDC, 47-63 Hz	14 DC Inputs 14 DC Inputs	10 DC Outputs 10 Relay Outputs
226/226XM DC/DC/DC	20.4-28.8 VDC	24 DC Inputs	16 DC Outputs
226/226XM AC/DC/Relay	85-264 VDC, 47-63 HZ	24 DC Outputs	16 Relay Outputs

The model description indicates the type of CPU, the power supply, the type of input, and the type of output.

Power Supply Input
CPU 222 DC/DC DC
Output

2.2 S7-200 Features

The S7-200 family includes a wide variety of CPUs and features. This variety provides a range of features to aid in designing a cost-effective automation solution. The following table provides a summary of the major features, many of which will be covered in this course.

Table 2.2 S7-200 family

Feature	CPU 221	CPU 222	CPU 224	CPU 226	CPU 226XM
Memory					
Program	2048 words	2048 words	4096 words	4096 words	8192 words
User Data	1024 words	1024 words	2560 words	2560 words	5120 words
Memory type	EEPROM	EEPROM	EEPROM	EEPROM	EEPROM
Memory cartridge	EEPROM	EEPROM	EEPROM	EEPROM	EEPROM
Data backup	50 hours	50 hours	190 hours	190 hours	190 hours
I/O					
Local digital I/O	6 In/4 out	8 In/6 out	14 In/10 out	24 In/16 out	24 In/16 out
Maximum number of expansion modules	None	2	7	7	7
Max. digital I/O with expansion	6 In/4 out	40 In/38 out	94 in/74 out	128 In/120 out	128 In/120 out
Max. analog I/O with expansion	None	8 in/2 out or 0 In/4 out	28 In/7 out or 0 In/14 out	28 In/7 out or 0 In/14 out	28 In/7 out or 0 in/14 out
Instructions					
Boolean execution speed	0.37 μ s/Inst.	0.37 μ s/Inst.	0.37 μ s/Inst.	0.37 μ s/Inst.	0.37 μ s/Inst.
Internal relays	256	256	256	256	256
Counters	256	256	256	256	256
Timers	256	256	256	256	256
Sequential control relays	256	256	256	256	256
For/Next loop	Yes	Yes	Yes	Yes	Yes
Integer math (+ - * /)	Yes	Yes	Yes	Yes	Yes
Real math (+ - * /)	Yes	Yes	Yes	Yes	Yes
Enhanced features					
Built-In high speed counter	4 (30 KHz)	4 (30 KHz)	6 (30 KHz)	6 (30 KHz)	6 (30 KHz)

Analog adjustments	1	1	2	2	2
Pulse output	2 (20 KHz, DC)	2 (20 KHz, DC)	2 (20 KHz, DC)	2 (20 KHz, DC)	2 (20 KHz, DC)
Communication interrupt	1 transmit /2 receive	1 transmit/2 receive	1 transmit/2 receive	1 transmit/2 receive	1 transmit/2 receive
Timed interrupts	2 (1ms-255ms)	2 (1ms-255ms)	2 (1ms-255ms)	2 (1ms-255ms)	2 (1ms-255ms)
Hardware input interrupt	4	4	4	4	4
Real time clock	Yes (cartridge)	Yes (cartridge)	Yes (built-in)	Yes (built-in)	Yes (built-in)
Password protection	Yes	Yes	Yes	Yes	Yes
Communication					
Number of port	1 (RS-485)	1 (RS-485)	1 (RS-485)	2 (RS-485)	2 (RS-485)
Protocols supported port	PPI,MP I slave, Freeport	PPI,MPI slave, Freeport	PPI,MPI slave, Freeport	PPI,MPI slave, Freeport	PPI,MPI slave, Freeport
Profibus peer-to-peer	(NETR/NETW)	(NETR/NETW)	(NETR/NETW)	(NETR/NETW)	(NETR/NETW)

2.3 Mode Switch and Analog Adjustment

When the mode switch is in the RUN position the CPU is in the run mode and executing the program. When the mode switch is in the STOP position the CPU is stopped. When the mode switch is in the TERM position the programming device can select the operating mode. The analog adjustment is used to increase or decrease values stored in special memory. These values can be used to update the value of a timer or counter, or can be used to set limits.

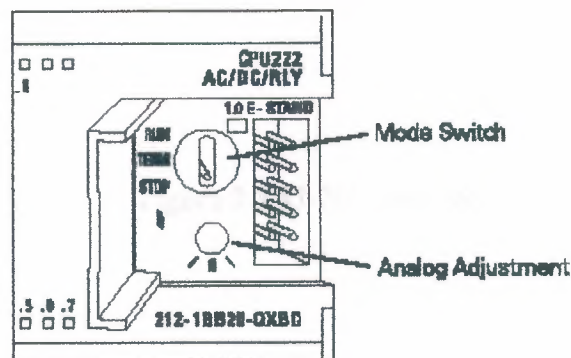


Figure 2.1 Mode Switch

2.4 Optional Cartridge

The S7-200 supports an optional memory cartridge that provides a portable EEPROM storage for your program. The cartridge can be used to copy a program from one S7-200 PLC to a like S7-200 PLC. In addition, two other cartridges are available. A real-time clock with battery is available for use on the S7-221 and S7-222. The battery provides up to 200 days of data retention time in the event of a

power loss. The S7-224 and S7-226 have a real-time clock built in. Another cartridge is available with a battery only.

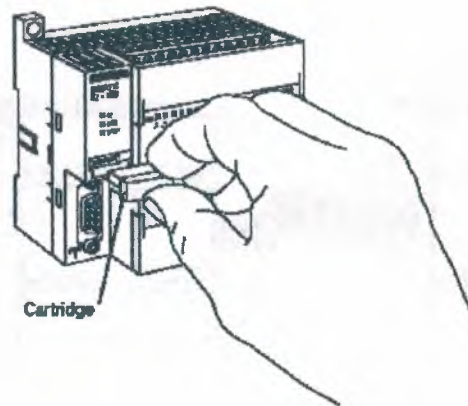


Figure 2.3 S7-200 cartridge

2.5 Expansion Modules

The S7-200 PLCs are expandable. Expansion modules contain additional inputs and outputs. These are connected to the base unit using a ribbon connector.

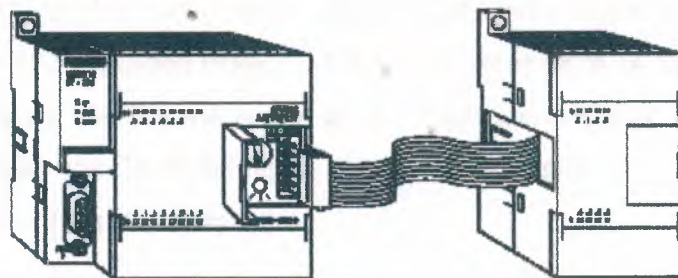


Figure 2.4 Expansion modules

The ribbon connector is protected by a cover on the base unit. Side-by-side mounting completely encloses and protects the ribbon connector.

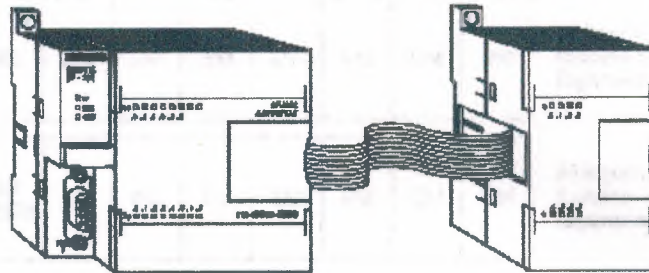


Figure 2.5 Expansion modules

The ribbon connector is protected by a cover on the base unit. Side-by-side mounting completely encloses and protects the ribbon connector.

2.6 Available Expansion

The S7-221 comes with 6 digital inputs and 4 digital outputs. These are not expandable. The S7-222 comes with 8 digital inputs and 6 digital outputs. The 222 will accept up to 2 expansion modules. The S7-224 comes with 14 digital inputs and 10 digital outputs. The 224 will accept up to 7 expansion modules. The S7-226 and S7-226XM come with 24 digital inputs and 16 digital outputs. The 226 and 226XM will accept up to 7 expansion modules.

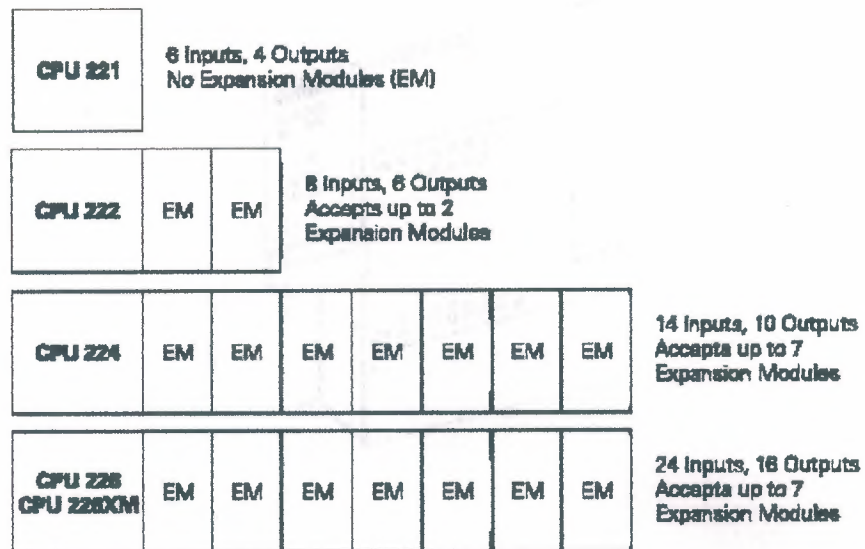


Figure 2.6 Available Expansion

2.7 Status Indicators

The CPU status indicators reflect the current mode of CPU operation. If, for example, the mode switch is set to the RUN position, the green RUN indicator is lit. When the mode switch is set to the STOP position, the yellow STOP indicator is lit.

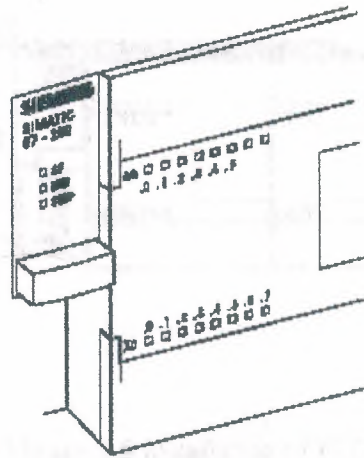


Figure 2.7 Status indicator

The I/O status indicators represent the On or Off status of corresponding inputs and outputs. When the CPU senses an input is on, the corresponding green indicator is lit.

2.8 Installing

The S7-200 can be installed in one of two ways. A DIN clip allows installation on a standard DIN rail. The DIN clip snaps open to allow installation and snaps closed to secure the unit on the rail. The S7-200 can also be panel mounted using installation holes located behind the access covers.

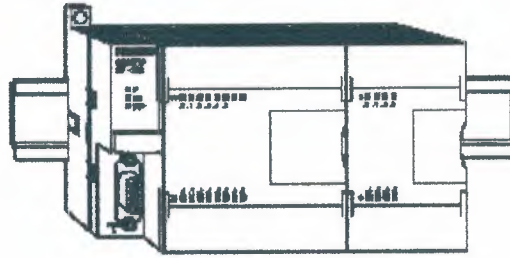


Figure 2.8 installation of PLC

2.9 External Power Supply Sources

An S7-200 can be connected to either a 24 VDC or a 120/230 VAC power supply depending on the CPU. An S7-200 DC/DC/ DC would be connected to a 24 VDC power supply.

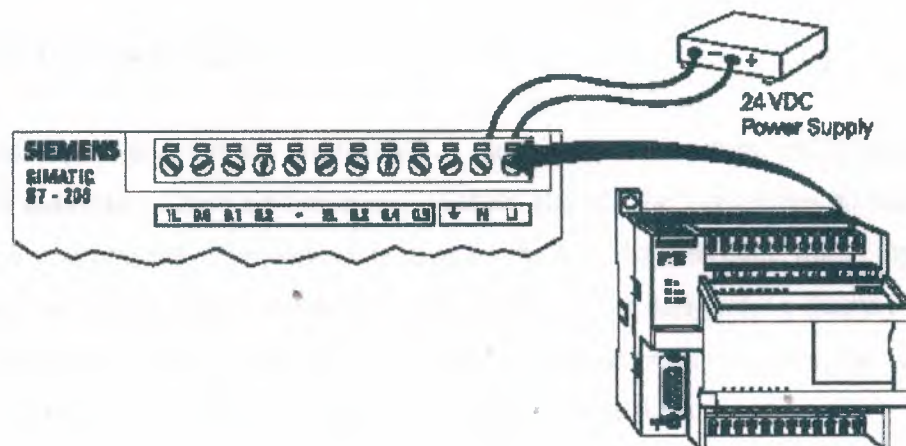


Figure 2.9 Power supply source

An S7-200 AC/DC/Relay would be connected to a 120 or 230 VAC power supply.

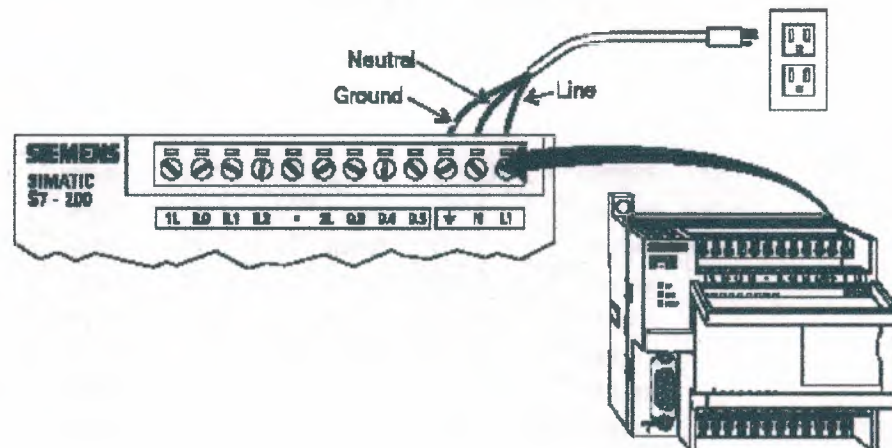


Figure 2.10 S7-200 AC/DC/Relay

2.10 I/O Numbering

S7-200 inputs and outputs are labeled at the wiring terminations and next to the status indicators. These alphanumeric symbols identify the I/O address to which a device is connected. This address is used by the CPU to determine which input is present and which output needs to be turned on or off. **I** designates a discrete input and **Q** designates a discrete output. The first number identifies the byte, the second number identifies the bit. Input I0.0, for example, is byte 0, bit 0.

I0.0 = Byte 0, Bit 0

I0.1 = Byte 0, Bit 1

I1.0 = Byte 1, Bit 0

I1.1 = Byte 1, Bit 1

The following table identifies the input and output designations.

Table 2.3 I/O numbering

I0.0	1 st input	I1.0	9 th input	Q 0.0	1 st output	Q 1.0	9 th output
I0.1	2 nd input	I1.1	10 th input	Q0.1	2 nd output	Q 1.1	10 th output
I0.2	3 rd input	I1.2	11 th input	Q0.2	3 rd output		
I0.3	4 th input	I1.3	12 th input	Q0.3	4 th output		
I0.4	5 th input	I1.4	13 th input	Q0.4	5 th output		
I0.5	6 th input	I1.5	14 th input	Q0.5	6 th output		
I0.6	7 th input			Q0.6	7 th output		
I0.7	8 th input			Q0.7	8 th output		

2.11 Inputs

Input devices, such as switches, pushbuttons, and other sensor devices are connected to the terminal strip under the bottom cover of the PLC.

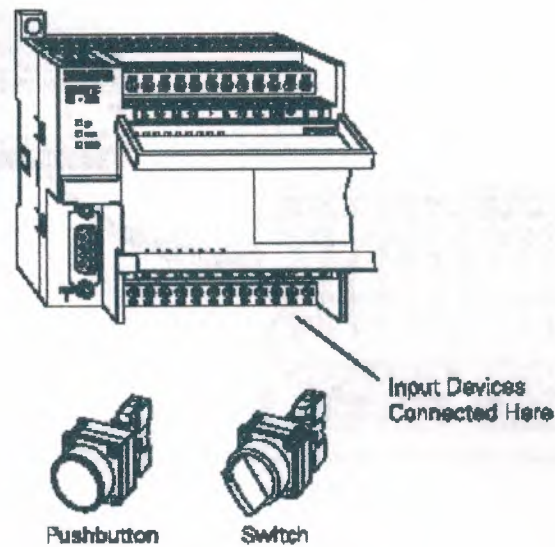


Figure 2.11 Inputs of PLC

2.11.1 Input Simulator

A convenient method of testing a program is to wire toggle switches to the inputs. Input simulators with prewired toggle switches are available for the S7-200s. Switches are wired between the 24 VDC power supply (L+) and the inputs. Forexample, the switch on the far left is wired between the first input (0.0) and L+. When the switch is closed, 24 VDC is applied to the input. This is referred to as a logic 1. When the switch is open, 0 VDC is applied to the input. This is referred to as a logic 0.

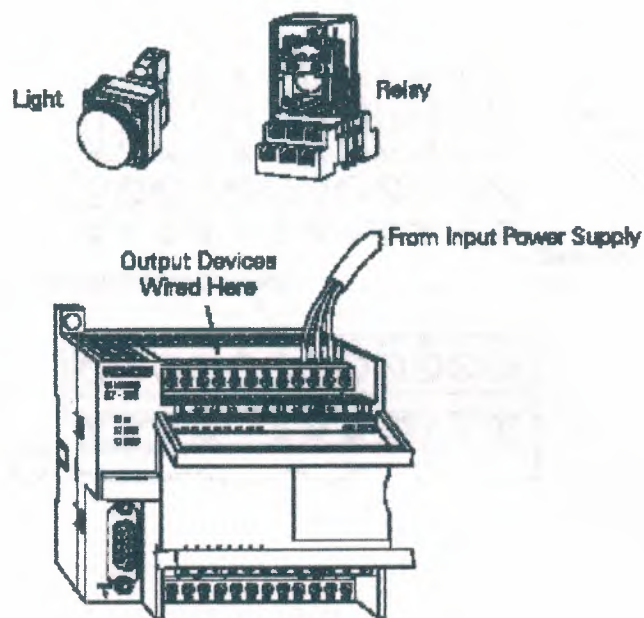


Figure 2.13 Output terminal strip

2.13 Optional Connector

An optional fan-out connector allows for field wiring connections to remain fixed when removing or replacing an S7-221 or 222. The appropriate connector slides into either the input, output, or expansion module terminals.

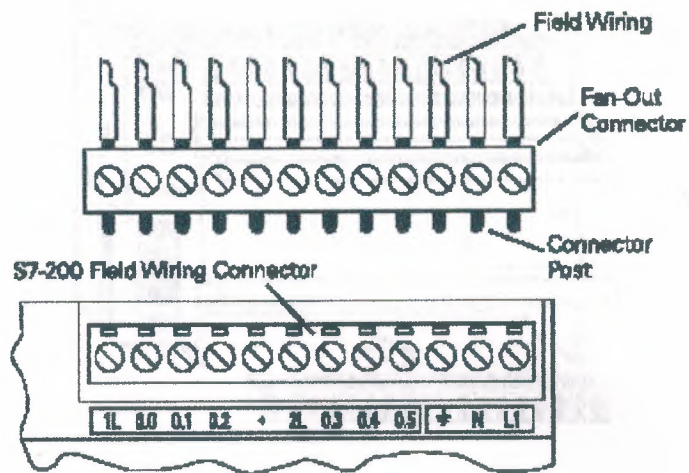


Figure 2.14 fan-out connector

2.14 Removable Terminal Strip

The S7-224 and S7-226 do not have an optional fan-out connector. Instead, the terminal strips are removable. This allows the field wiring connections to remain fixed when removing or replacing the S7-224 and S7-226.

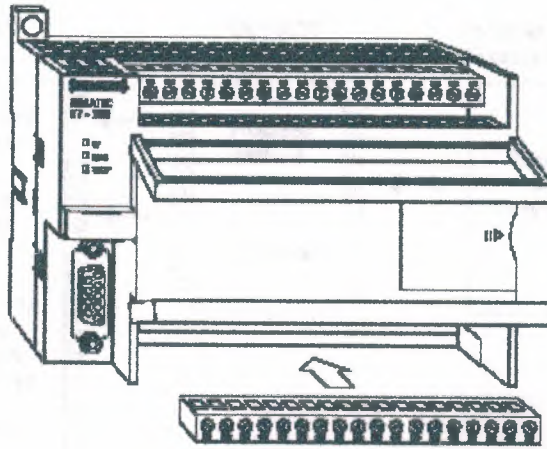


Figure 2.15 wiring connections

2.15 Super Capacitor

A super capacitor, so named because of its ability to maintain a charge for a long period of time, protects data stored in RAM in the event of a power loss. The RAM memory is typically backed up on the S7-221 and 222 for 50 hours, and on the S7-224 and 226 for 190 hours.

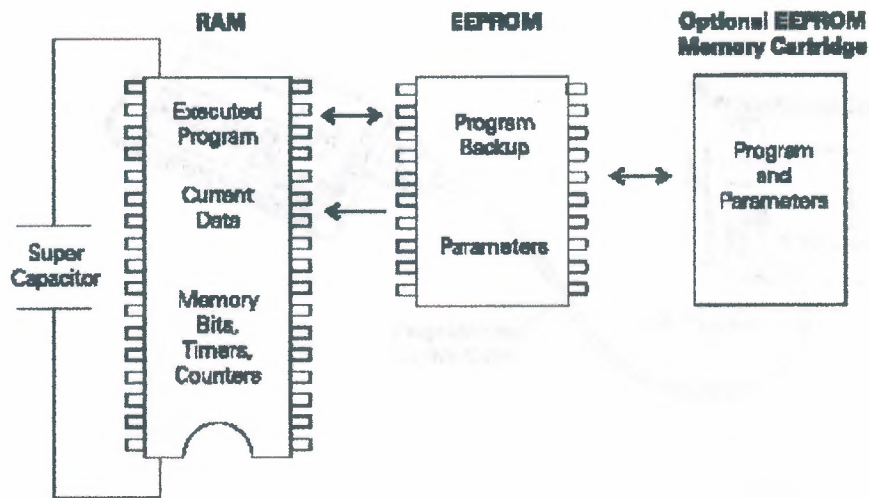


Figure 2.16 Super Capacitor

2.16 Connecting External Devices

2.16.1 TD200

The S7-200 programming port can be used to communicate with a variety of external devices. One such device is the TD200 text display unit. The TD200 displays messages read from the S7-200, allows adjustment of designated program variables, provides the ability to force, and permits setting of the time and date. The TD200 can be connected to an external power supply or receive its power from the S7-200.

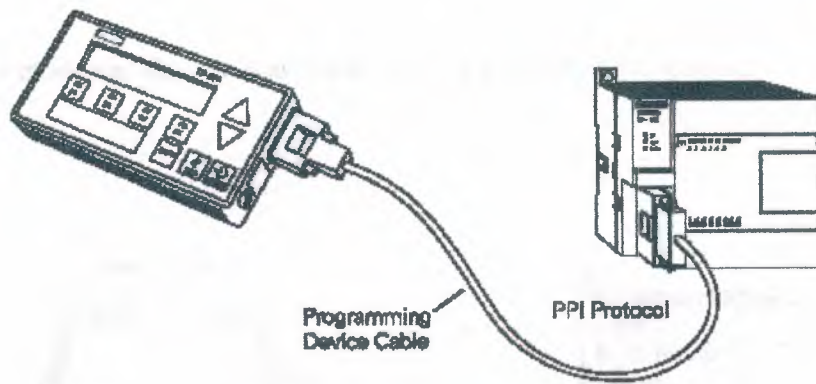


Figure 2.17 S7-200 programming port

2.16.2 Freeport Mode

The programming port has a mode called freeport mode. Freeport mode allows connectivity to various intelligent sensing devices such as a bar code reader.

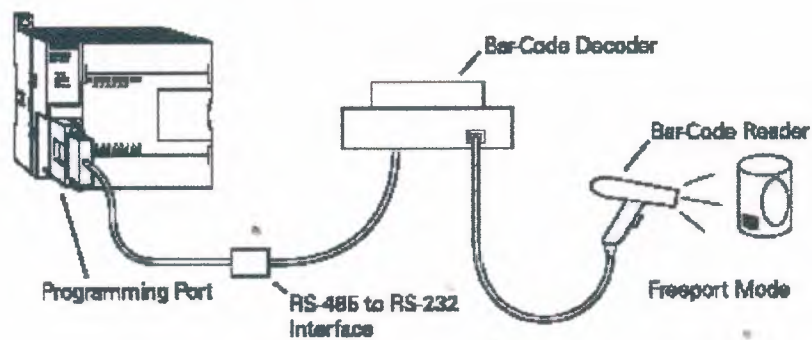


Figure 2.18 Freeport mode

2.16.3 Printer

Freeport mode can also be used to connect to a non-SIMATIC printer.

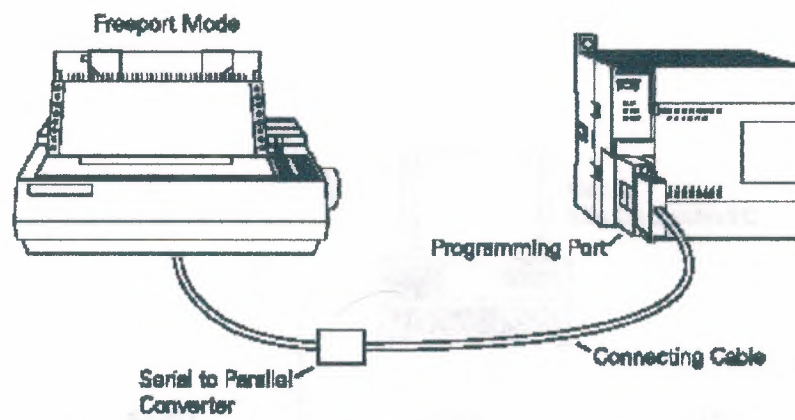


Figure 2.19 Freeport mode with non-SIMATIC printer

2.16.4 Interconnection

It is possible to use one programming device to address multiple S7-200 devices on the same communication cable. A total of 31 units can be interconnected without a repeater.

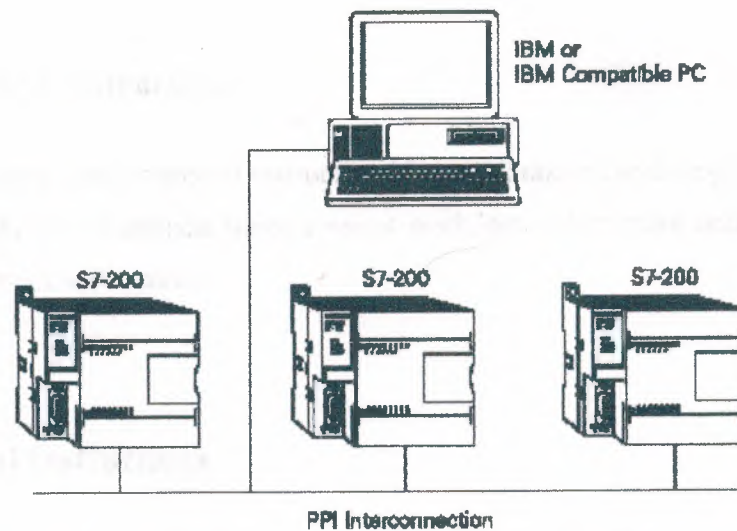


Figure 2.20 Interconnection

3. PROGRAMMING APPLICATION

STEP 7-Micro/WIN32 is the program software used with the S7-200 PLC to create the PLC operating program. STEP 7 consists of a number of instructions that must be arranged in a logical order to obtain the desired PLC operation. These instructions are divided into three groups: standard instructions, special instructions, and high-speed instructions.

3.1 Standard Instructions

Standard instructions consist of instructions that are found in most programs. Standard instructions include; timer, counter, math, logical, increment/decrement/invert, move, and block instructions.

3.2 Special Instructions

Special instructions are used to manipulate data. Special instructions include shift, table, find, conversion, for/next, and real-time instructions.

3.3 High-Speed Instructions

High-speed instructions allow for events and interrupts to occur independent of the PLC scan time. These include high-speed counters, interrupts, output, and transmit instructions.

3.4 Symbols

In order to understand the instructions a PLC is to carry out, an understanding of the language is necessary. The language of PLC ladder logic consists of a commonly used set of symbols that represent control components and instructions.

3.4.1 Contacts

One of the most confusing aspects of PLC programming for first-time users is the relationship between the device that controls a status bit and the programming function that uses a status bit. Two of the most common programming functions are the normally open (NO) contact and the normally closed (NC) contact. Symbolically, power flows through these contacts when they are closed. The normally open contact (NO) is true (closed) when the input or output status bit controlling the contact is 1. The normally closed contact (NC) is true (closed) when the input or output status bit controlling the contact is 0.



Figure 3.1 Contacts

3.4.2 Coils

Coils represent relays that are energized when power flows to them. When a coil is energized, it causes a corresponding output to turn on by changing the state of the status bit controlling that output to 1. That same output status bit may be used to control normally open and normally closed contacts elsewhere in the program.



Figure 3.2 coil

3.4.3 Boxes

Boxes represent various instructions or functions that are executed when power flows to the box. Typical box functions are timers, counters, and math operations.

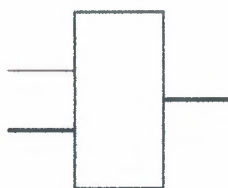


Figure 3.3 Boxes

3.5 Entering Elements

Control elements are entered in the ladder diagram by positioning the cursor and selecting the element from lists. In the following example the cursor has been placed in the position to the right of I0.2. A coil was selected from a pull down list and inserted in this position.

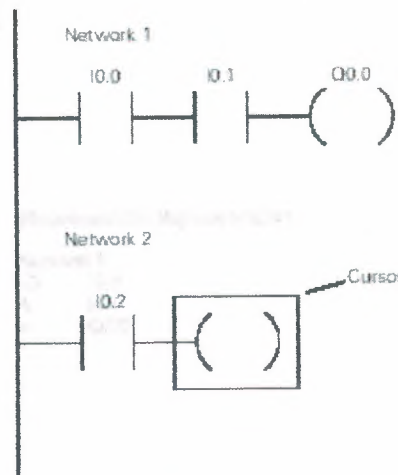


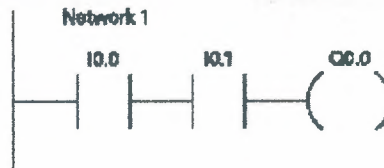
Figure 3.4 Control elements

3.6 An AND Operation

Each rung or network on a ladder represents a logic operation. The following programming example demonstrates an AND operation. Two contact closures and one output coil are placed on network 1. They were assigned addresses I0.0, I0.1, and Q0.0. Note that in the statement list a new logic operation always begins with a load instruction (LD). In this example I0.0 (input 1) and (A in the statement list) I0.1 (input 2) must be true in order for output Q0.0 (output 1) to be true. It can also be seen That

I0.0 and I0.1 must be true for Q0.0 to be true by looking at the function block diagram representation.

Ladder Diagram Representation



Statement List Representation

Network 1
 LD I0.0
 A I0.1
 = Q0.0

Function Block Diagram Representation

Network 1



Figure 3.5 And operation

Another way to see how an AND function works is with a Boolean logic diagram. In Boolean logic an AND gate is represented by a number of inputs on the left side. In this case there are two inputs. The output is represented on the right side. It can be seen from the table that both inputs must be a logic 1 in order for the output to be a logic 1.

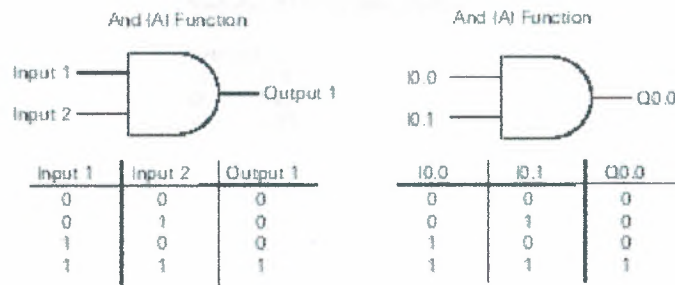


Figure 3.6 And function

3.7 An OR Operation

In this example an OR operation is used in network 1. It can be seen that if either input I0.2 (input 3) or (O in the statement list) input I0.3 (input 4), or both are true, then output Q0.1 (output 2) will be true.

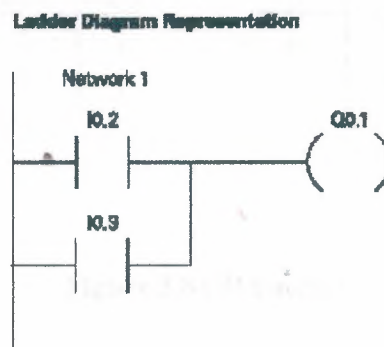


Figure 3.7(a) An OR operation

Statement List Representation

Network 1
LD I0.2
O I0.3
= Q0.1

Figure 3.7(b) An OR operation

Another way to see how an OR function works is with a Boolean logic diagram. The symbol differs slightly from an AND function. The OR function is represented by a number of inputs on the left side. In this case there are two inputs. The output is represented on the right side. It can be seen from the table that any input can be a logic 1 in order for the output to be a logic 1.

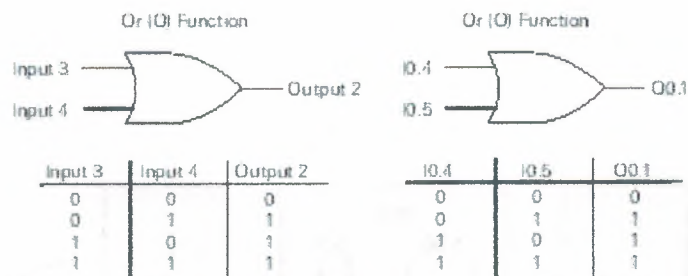


Figure 3.8 OR function

3.8 Testing a Program

Once a program has been written it needs to be tested and debugged. One way this can be done is to simulate the field inputs with an input simulator, such as the one made for the S7-200. The program is first downloaded from the programming device to the CPU. The selector switch is placed in the RUN position. The simulator switches are operated and the resulting indication is observed on the output status indicator lamps.

3.9 Status Functions

After a program has been loaded and is running in the PLC, the actual status of ladder elements can be monitored using STEP 7 Micro/WIN32 software. The standard method of showing a ladder element is by indicating the circuit condition it produces when the device is in the deenergized or non operated state. In the following illustration input 1 (I0.0) is programmed as a normally open (NO) contact. In this condition, power will not flow through the contacts to the output (Q0.0).

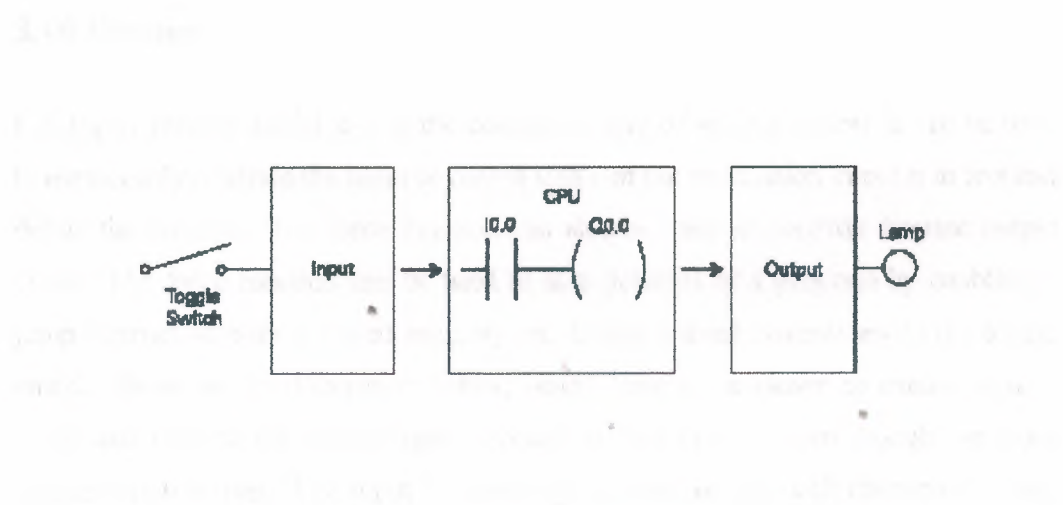


Figure 3.9 statuses of ladder elements

When viewing the ladder diagram in the status mode, control elements that are active, or true (logic 1), are highlighted. In the example shown the toggle switch connected to input 1 has been closed. Power can now flow through the control element associated with input 1 (I0.0) and activate the output (Q0.0). The lamp will illuminate.

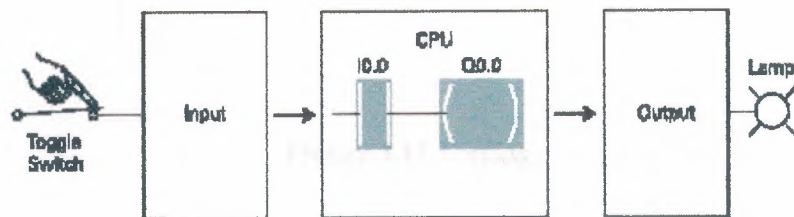


Figure 3.10 control elements

3.10 Forcing

Forcing is another useful tool in the commissioning of an application. It can be used to temporarily override the input or output status of the application in order to test and debug the program. The force function can also be used to override discrete output points. The force function can be used to skip portions of a program by enabling a jump instruction with a forced memory bit. Under normal circumstances the toggle switch, shown in the illustration below, would have to be closed to enable input 1 (I0.0) and turn on the output light. Forcing enables input 1 even though the input toggle switch is open. With input 1 forced high the output light will illuminate. When a function is forced the control bit identifier is highlighted. The element is also highlighted because it is on.

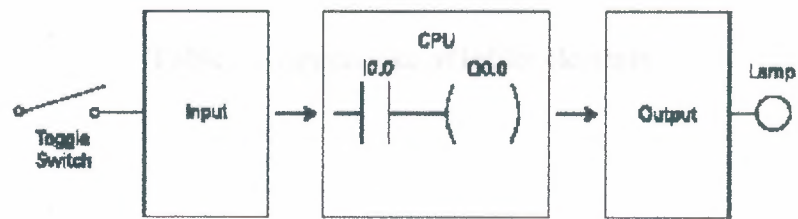


Figure 3.11 Forcing

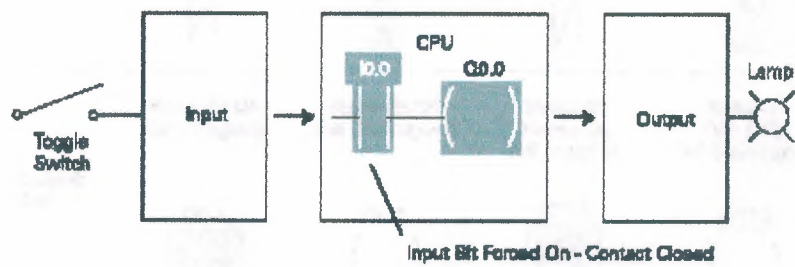














Figure 3.12 Forcing

The following table shows the appearance of ladder elements in the Off, forced, and On condition.

Table 3.1 Appearance of ladder elements

	Status Bit On Contacts Closed	Status Bit Off Contacts Open	Status Bit Forced On Contacts Closed	Status Bit Forced Off Contacts Open
Normally Open Contacts				
	Status Bit On Contacts Open	Status Bit Off Contacts Closed	Status Bit Forced On Contacts Open	Status Bit Forced Off Contacts Closed
Normally Closed Contacts				
	Status Bit On Coil Energized	Status Bit Off Coil Deenergized	Status Bit Forced On Coil Energized	Status Bit Forced Off Coil Deenergized
Output Coils				

3.11 Program Instruction

When the switch is open the CPU receives a logic 0 from input I0.0. The CPU sends a logic 0 to output Q0.0 and the light is off.

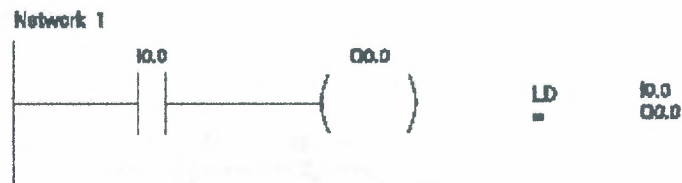


Figure 3.13 Network

When the switch is closed the CPU receives a logic 1 from input I0.0. The CPU sends a logic 1 to output Q0.0, thus activating Q0.0. The light turns on.

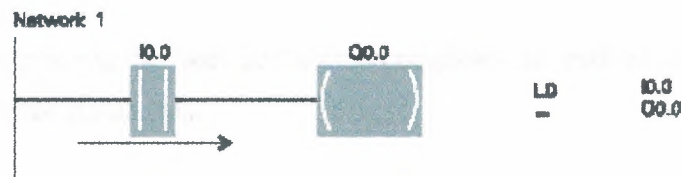


Figure 3.14 Active network

3.12 Motor Starter Example

The following example involves a motor start and stop circuit. The line diagram illustrates how a normally open and a normally closed pushbutton might be used in a control circuit. In this example a motor started (M) is wired in series with a normally

open momentary pushbutton (Start), a normally closed momentary pushbutton (Stop), and the normally closed contacts of an overload relay (OL).

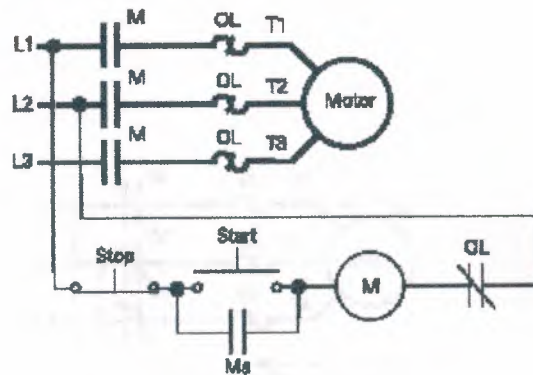


Figure 3.15 Circuit diagram of motor control

Momentarily depressing the Start pushbutton completes the path of current flow and energizes the motor starter (M).

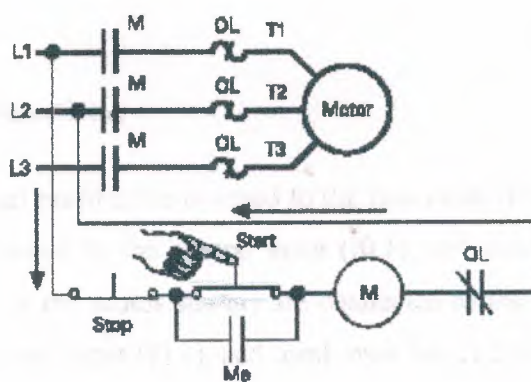


Figure 3.16 Energizes the motor starter

This closes the associated M and Ma (auxiliary contact located in the motor starter) contacts. When the Start button is released a holding circuit exists to the M contactor through the auxiliary contacts Ma. The motor will run until the normally closed Stop button is depressed, or the overload relay opens the OL contacts, breaking the path of current flow to the motor starter and opening the associated M and Ma contacts.

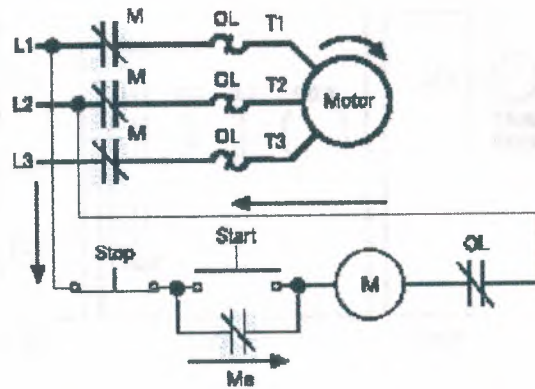


Figure 3.17 Motor in running position

This control task can also be accomplished with a PLC.

3.12.1 Program Instruction

A normally open Start pushbutton is wired to the first input (I0.0), a normally closed Stop pushbutton is wired to the second input (I0.1), and normally closed overload relay contacts (part of the motor starter) are connected to the third input (I0.2). The first input (I0.0), second input (I0.1), and third input (I0.2) form an AND circuit and are used to control normally open programming function contacts on Network 1. I0.1

status bit is a logic 1 because the normally closed (NC) Stop Pushbutton is closed. I0.2 status bit is a logic 1 because the normally closed (NC) overload relay (OL) contacts are closed. Output Q0.0 is also programmed on Network 1. In addition, a normally open set of contacts associated with Q0.0 is programmed on Network 1 to form an OR circuit. A motor starter is connected to output Q0.0.

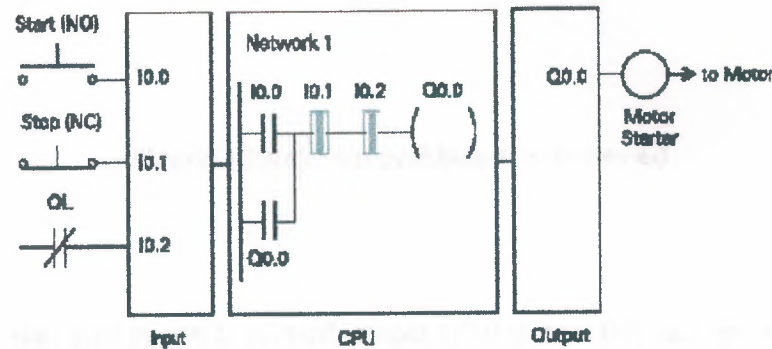


Figure 3.18 Program Instruction

When the Start pushbutton is depressed the CPU receives a logic 1 from input I0.0. This causes the I0.0 contact to close. All three inputs are now a logic 1. The CPU sends a logic 1 to output Q0.0. The motor starter is energized and the motor starts.

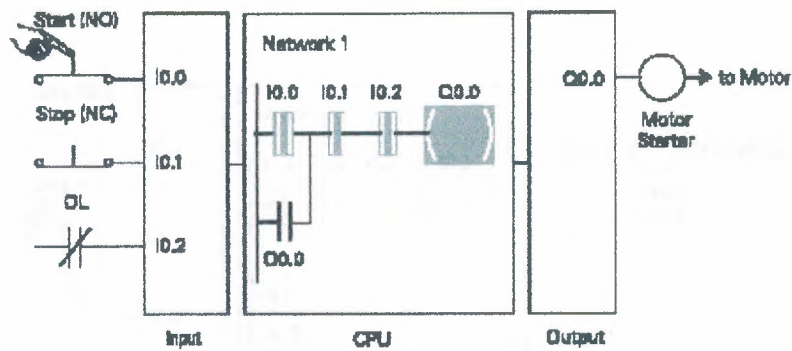


Figure 3.19(a) Start pushbutton is depressed

When the Start pushbutton is pressed, output Q0.0 is now true and on the next scan, when normally open contact Q0.0 is solved, the contact will close and output Q0.0 will stay on even if the Start pushbutton has been released.

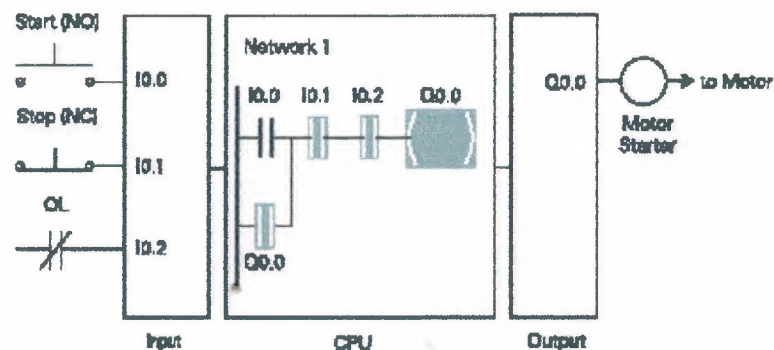


Figure 3.19(b) Q0.0 is active

The motor will continue to run until the Stop pushbutton is depressed. Input I0.1 will now be a logic 0 (false). The CPU will send a binary 0 to output Q0.0. The motor will turn off.

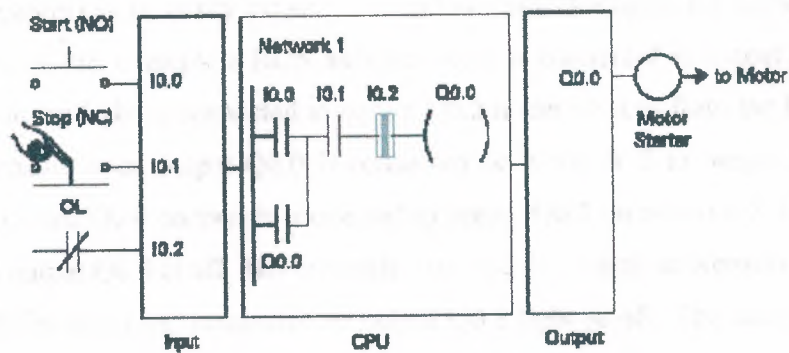


Figure 3.20 Stop pushbutton is depressed

When the Stop pushbutton is released I0.1 logic function will again be true and the program ready for the next time the Start pushbutton is pressed.

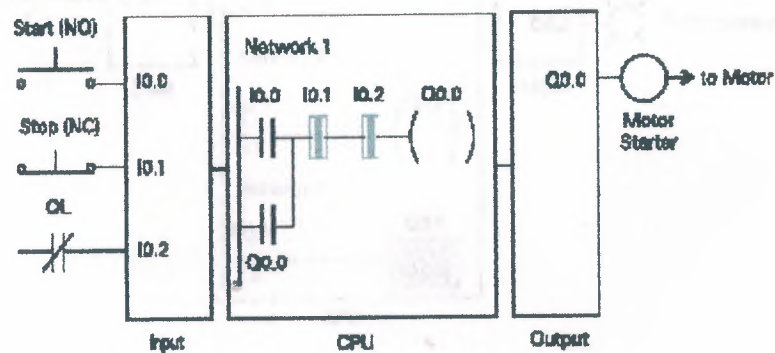


Figure 3.21 Motor is stopped

3.12.2 Expanding the Application

The application can be easily expanded to include indicator lights for RUN and STOP conditions. In this example a RUN indicator light is connected to output Q0.1 and a STOP indicator light is connected to output Q0.2. It can be seen from the ladder logic that a normally open output Q0.0 is connected on Network 2 to output Q0.1 and a normally closed Q0.0 contact is connected to output Q0.2 on network 3. In a stopped condition output Q0.0 is off. The normally open Q0.0 contacts on Network 2 are open and the RUN indicator, connected to output Q0.1 light is off. The normally closed Q0.0 on Network 3 lights are closed and the STOP indicator light, connected to output Q0.2 is on.

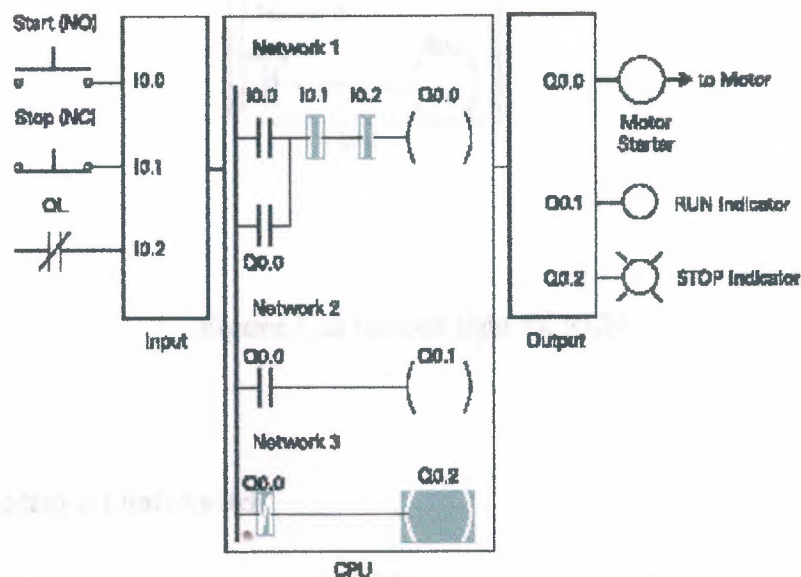


Figure 3.22 Indicator lights for RUN and STOP

When the PLC starts the motor output Q0.0 is now a logic high (On). The normally open Q0.0 contacts on Network 2 now switch to a logic 1 (closed) and output Q0.1 turns the RUN indicator on. The normally closed Q0.0 contacts on Network 3 switch to a logic 0 (open) and the STOP indicator light connected to output Q0.2 is now off.

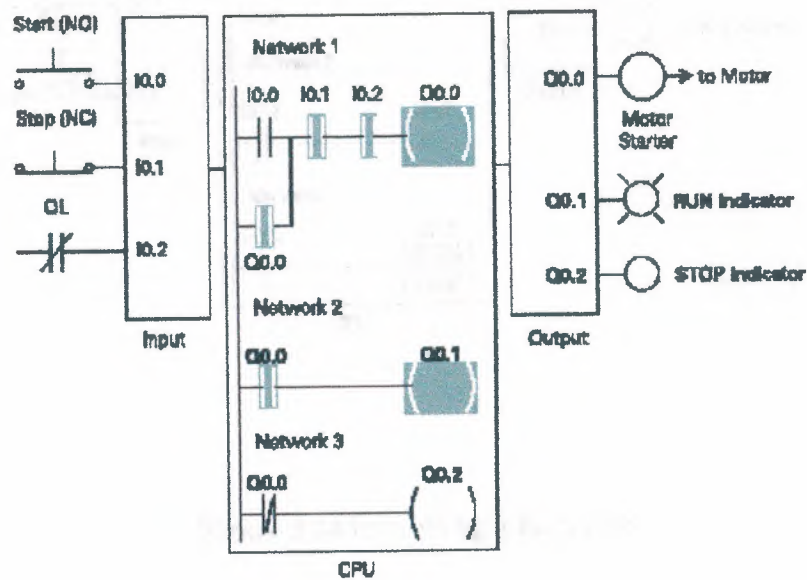


Figure 3.23 Indicate light for RUN

3.12.3 Adding a Limit Switch

The application can be further expanded by adding a limit switch with normally open contacts to input I0.3. A limit switch could be used to stop the motor or prevent the motor from being started. An access door to the motor, or its associated equipment, is one example of a limit switch's use. If the access door is open, the normally open contacts of LS1 connected to input I0.3 are open and the motor will not start.

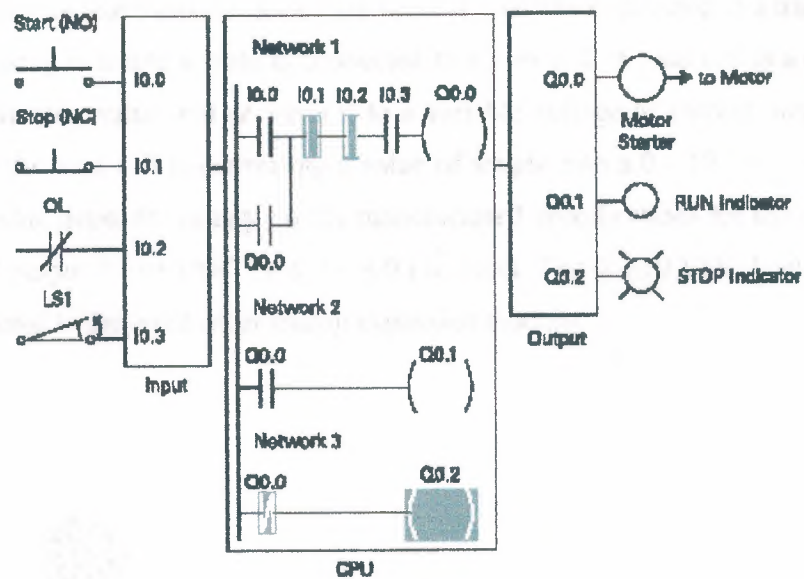


Figure 3.24 Indicate light for STOP

When the access door is closed, the normally open contacts on the limit switch (LS1) are closed. Input I0.3 is now on (logic 1), and the motor will start when the Start pushbutton is pressed.

3.13 Application Example

A field device that measures a varying value is typically connected to a transducer. In the following example a scale is connected to a load cell. A load cell is a device that takes a varying value and converts it to a variable voltage or current output. In this example the load cell is converting a value of weight into a 0 - 10 VDC output. The output value depends entirely on the manufactured specifications for the device. This load cell output 0 - 10 VDC for a 0 - 500 Lbs input. The 0 - 10 VDC load cell output is connected to the input of an analog expansion module.

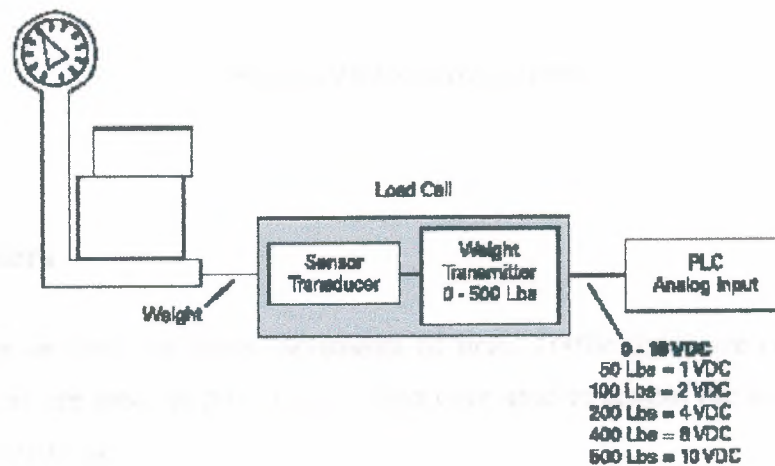


Figure 3.25 load cell

The example application can be expanded to include a conveyor system with a gate to direct packages of varying weight. As packages move along the conveyor they are weighed. A package that weighs at or greater than a specified value is routed along

one conveyor path. A package that weighs less than a specified value is routed along another conveyor path, where it will later be inspected for missing contents.

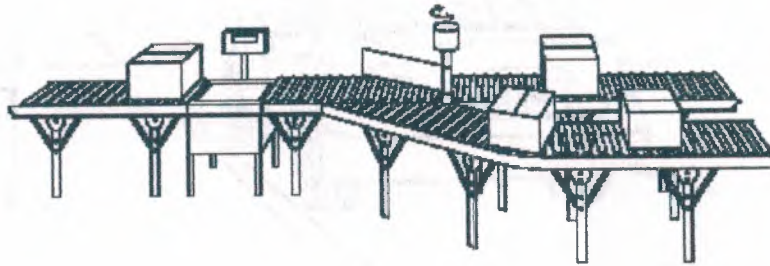


Figure 3.26 conveyor system

3.14 Timers

Timers are devices that count increments of time. Traffic lights are one example where timers are used. In this example timers are used to control the length of time between signal changes.

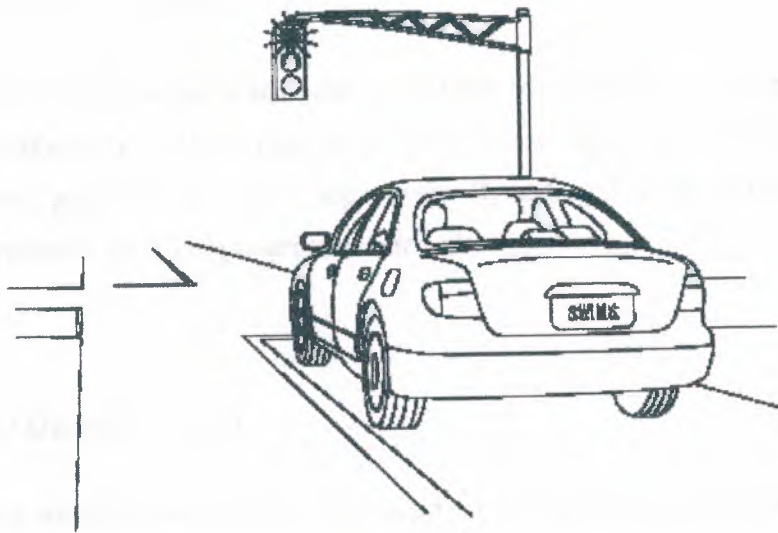


Figure 3.27 Traffic lights

Timers are represented by boxes in ladder logic. When a timer receives an enable, the timer starts to time. The timer compares its current time with the preset time. The output of the timer is a logic 0 as long as the current time is less than the preset time. When the current time is greater than the preset time the timer output is a logic 1. S7-200 uses three types of timers: On-Delay (TON), Retentive On-Delay (TONR), and Off-Delay (TOF).

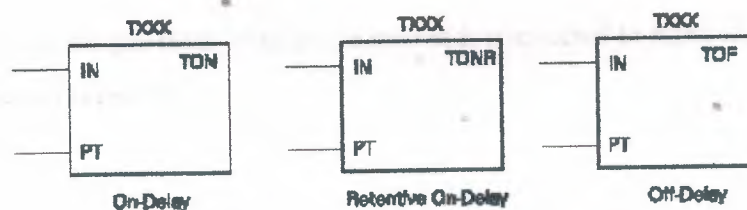


Figure 3.28 Types of timers

3.14.1 S7-200 Timers

S7-200 timers are provided with resolutions of 1 millisecond, 10 milliseconds, and 100 milliseconds. The maximum value of these timers is 32.767 seconds, 327.67 seconds, and 3276.7 seconds, respectively. By adding program elements, logic can be programmed for much greater time intervals.

3.14.2 On-Delay (TON)

When the On-Delay timer (TON) receives an enable (logic 1) at its input (IN), a predetermined amount of time (preset time - PT) passes before the timer bit (T-bit) turns on. The T-bit is a logic function internal to the timer and is not shown on the symbol. The timer resets to the starting time when the enabling input goes to a logic 0.

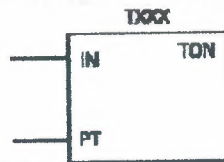


Figure 3.29 ON-Delay timers

In the following simple timer example, a switch is connected to input I0.3, and a light is connected to output Q0.1.

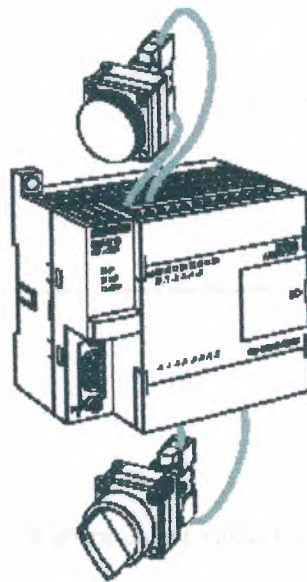


Figure 3.30 Switch is connected to input

When the switch is closed input 4 becomes a logic 1, which is loaded into timer T37. T37 has a time base of 100 ms (.100 seconds). The preset time (PT) value has been set to 150. This is equivalent to 15 seconds ($.100 \times 150$). The light will turn on 15 seconds after the input switch is closed. If the switch were opened before 15 seconds had passed, then reclosed, the timer would again begin timing at 0.

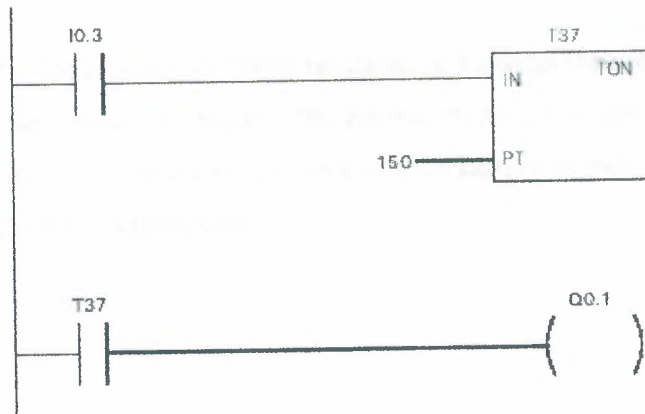


Figure 3.31 Ladder diagram

A small sample of the flexibility of PLCs is shown in the following program logic. By reprogramming the T37 contact as a normally closed contact, the function of the circuit is changed to cause the indicator light to turn off only when the timer times out. This function change was accomplished without changing or rewiring I/O devices.

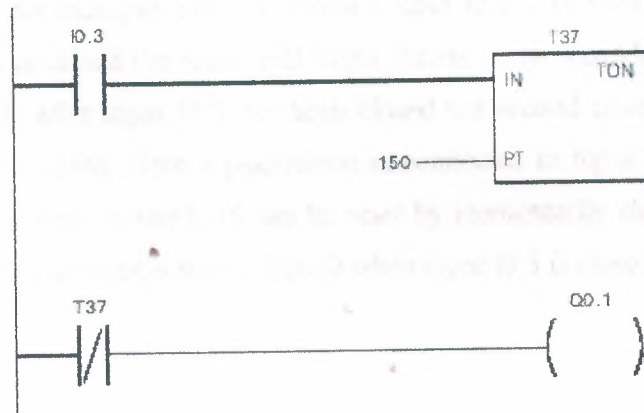


Figure 3.32 T37 contact as a normally closed contact

3.14.3 Retentive On-Delay (TONR)

The Retentive On-Delay timer (TONR) functions in a similar manner to the On-Delay timer (TON). There is one difference. The Retentive On-Delay timer times as long as the enabling input is on, but does not reset when the input goes off. The timer must be reset with a RESET (R) instruction.

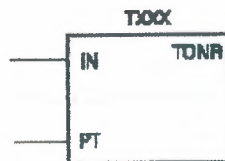


Figure 3.33 Retentive On-Delay timer (TONR)

The same example used with the On-Delay timer will be used with the Retentive On-Delay timer. When the switch is closed at input I0.3, timer T5 (Retentive timer) begins timing. If, for example, after 10 seconds input I0.3 is opened the timer stops. When input I0.3 is closed the timer will begin timing at 10 seconds. The light will turn on 5 seconds after input I0.3 has been closed the second time. A RESET (R) instruction can be added. Here a pushbutton is connected to input I0.2. If after 10 seconds input I0.3 were opened, T5 can be reset by momentarily closing input I0.2. T5 will be reset to 0 and begin timing from 0 when input I0.3 is closed again.

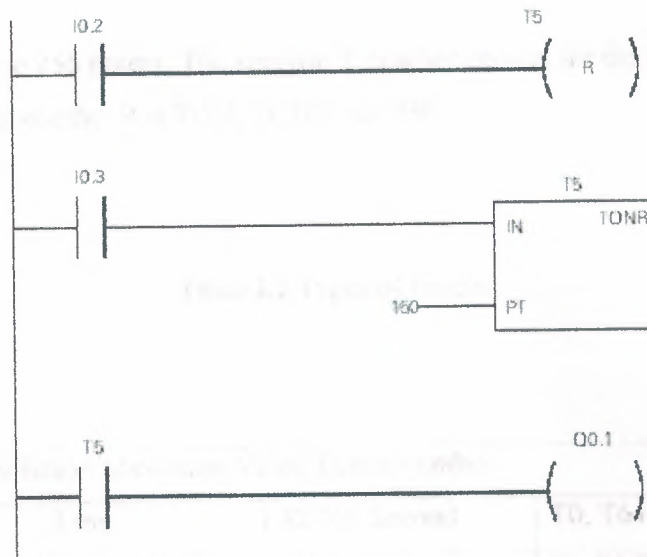


Figure 3.34 Ladder diagram of On-Delay timer

3.14.4 Off-Delay (TOF)

The Off-Delay timer is used to delay an output off for a fixed period of time after the input turns off. When the enabling bit turns on the timer bit turns on immediately and the value is set to 0. When the input turns off, the timer counts until the preset time has elapsed before the timer bit turns off.

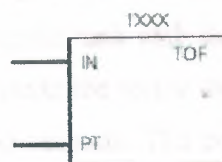


Figure 3.35 off-Delay timers

3.14.5 S7-200 Timers

The S7-200s have 256 timers. The specific T number chosen for the timer determines its time base and whether it is TON, TONR, or TOF.

Table 3.2 Types of timers

Timer Type Resolution Maximum Value Timer Number			
Toner	1 ms	32.767 Second	T0, T64
	10 ms	327.67 Second	T1, T4, T65-T68
	100 ms	3276.7 Second	T5, T31, T69, T95
TON, TOF	1 ms	327.67 Second	T33-T36, T97-T100
	10 ms	327.67 Second	T33-T36, T97-T100
	100 ms	3276.7 Second	T37-T63, T101-T225

3.14.6 Timer Example

In the following example a tank will be filled with two chemicals, mixed, and then drained. When the Start Button is pressed at input I0.0, the program starts pump 1 controlled by output Q0.0. Pump 1 runs for 5 seconds, filling the tank with the first chemical, then shuts off. The program then starts pump 2, controlled by output Q0.1. Pump 2 runs for 3 seconds filling the tank with the second chemical. After 3 seconds pump 2 shuts off. The program starts the mixer motor, connected to output Q0.2 and mixes the two chemicals for 60 seconds. The program then opens the drain valve controlled by output Q0.3, and starts pump 3 controlled by output Q0.4. Pump 3 shuts off after 8 seconds and the process stops. A manual Stop switch is also provided at input I0.1.

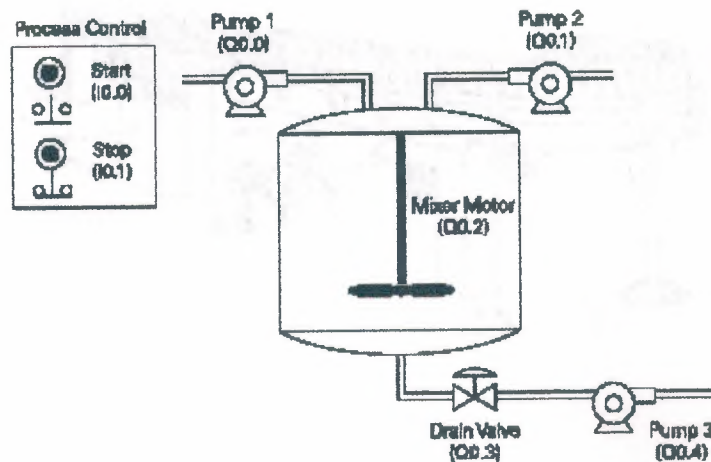


Figure 3.36 Tank system

3.15 Counters

Counters used in PLCs serve the same function as mechanical counters. Counters compare an accumulated value to a preset value to control circuit functions. Control applications that commonly use counters include the following:

- Count to a preset value and cause an event to occur
- Cause an event to occur until the count reaches a preset value

A bottling machine, for example, may use a counter to count bottles into groups of six for packaging.

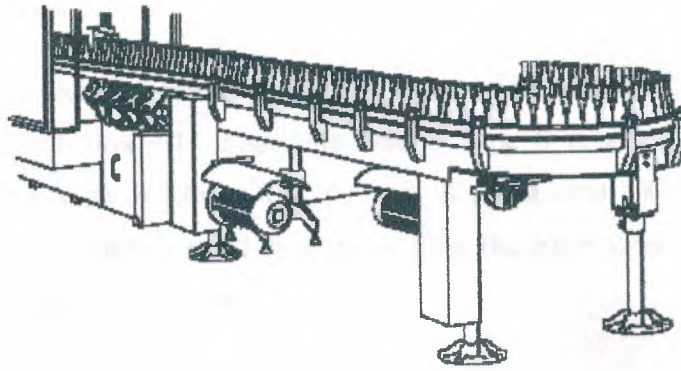


Figure 3.37 A bottling machine

Counters are represented by boxes in ladder logic. Counters increment/decrement one count each time the input transitions from off (logic 0) to on (logic 1). The counters are reset when a RESET instruction is executed. S7-200 uses three types of counters: up counter (CTU), down counter (CTD), and up/down counter (CTUD).

3.15.1 S7-200 Counters

There are 256 counters in the S7-200, numbered C0 through C255. The same number cannot be assigned to more than one counter. For example, if an up counter is assigned number 45, a down counter cannot also be assigned number 45. The maximum count value of a counter is $\pm 32,767$.

3.15.2 Up Counter

The up counter counts up from a current value to a preset value (PV). Input CU is the count input. Each time CU transitions from a logic 0 to a logic 1 the counter increments by a count of 1. Input R is the reset. A preset count value is stored in PV input. If the current count is equal to or greater than the preset value stored in PV, the output bit (Q) turns on (not shown).

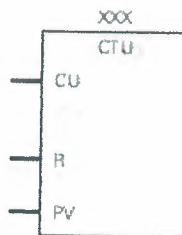


Figure 3.38 up Counter

3.15.3 Down Counter

The down counter counts down from the preset value (PV) each time CD transitions from a logic 0 to a logic 1. When the current value is equal to zero the counter output bit (Q) turns on (not shown). The counter resets and loads the current value with the preset value (PV) when the load input (LD) is enabled.

3.15.4 Up/Down Counter

The up/down counter counts up or down from the preset value each time either CD or CU transitions from a logic 0 to a logic 1. When the current value is equal to the preset value, 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 input (LD) 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.

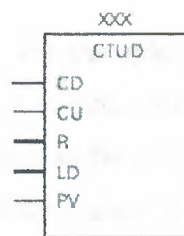


Figure 3.39 Up/Down Counter

3.15.5 Counter Example

A counter might be used to keep track of the number of vehicles in a parking lot. As vehicles enter the lot through an entrance gate, the counter counts up. As vehicles exit the lot through an exit gate, the counter counts down. When the lot is full a sign at the entrance gate turns on indicating the lot is full.

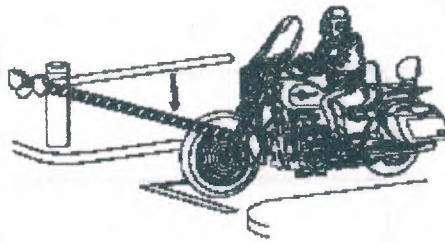


Figure 3.40 Count Vehicles in a parking

Up/down counter C48 is used in this example. A switch, connected to the entrance gate, has been wired to input I0.0. A switch, connected to the exit gate, has been wired to input I0.1. A reset switch, located at the collection booth, has been wired to input I0.2. The parking lot has 150 parking spaces. This value has been stored in the preset value (PV). The counter output has been directed to output Q0.1. Output 2 is connected to a "Parking Lot Full" sign. As cars enter the lot the entrance gate opens. Input I0.0 transitions from a logic 0 to a logic 1, incrementing the count by one. As cars leave the lot the exit gate opens. Input I0.1 transitions from a logic 0 to a logic 1, decrementing the count by 1. When the count has reached 150 output Q0.1 transitions from a logic 0 to a logic 1. The "Parking Lot Full" sign illuminates. When a car exits, decrementing the count to 149, the sign turns off.

4. PRACTICAL

CONTROL A MOTOR WITH THE SIMATIC S7-200

Write a PLC program for S7 200, which starts a motor for 5 seconds and then turns it off. This process is repeated twice and stops the process.

INPUTS

I0.0 Push button for system turns on
I0.1 Reset for counter

Outputs

Q0.0 system on
Q0.1 motor output (on)

TIMERS

T37, T38 (Time on delay)

COUNTERS

C0, C1, C2 (counter up)

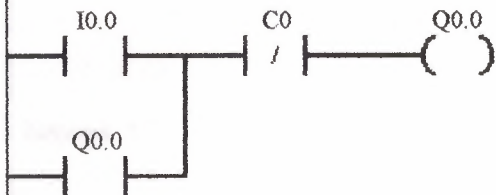

```

1  //MOTOR CONTROL
2  //
3  //LADDER DIAGRAM
4  //
5  //
6
7  NETWORK 1
8  //
9  //
10 LD      I0.0
11 O       Q0.0
12 AN      C0
13 =       Q0.0
14
15 NETWORK 2
16 LD      Q0.0
17 AN      C2
18 AN      T37
19 =       Q0.1
20
21 NETWORK 3
22 LD      Q0.1
23 AN      C2
24 TON     T37, +50
25
26 NETWORK 4
27 LDN     C1
28 AN      Q0.1
29 TON     T38, +50
30
31 NETWORK 5
32 LD      T37
33 LD      C0
34 A       I0.0
35 O       I0.1
36 CTU     C0, +2
37
38 NETWORK 6
39 LD      T38
40 LDN     Q0.1
41 CTU     C1, +1
42
43 NETWORK 7
44 LD      T37
45 LD      T38
46 CTU     C2, +1
47
48 NETWORK 8
49 MEND

```

MOTOR CONTROL
LADDER DIAGRAM

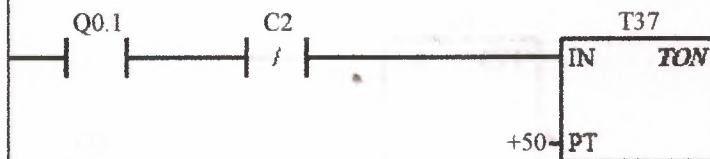
Network 1



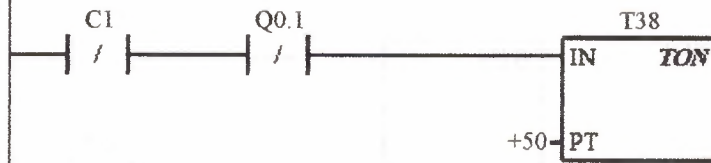
Network 2



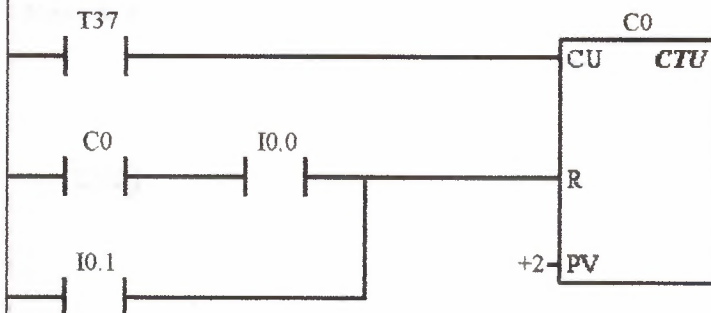
Network 3



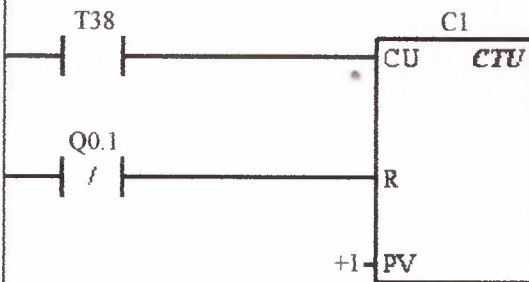
Network 4



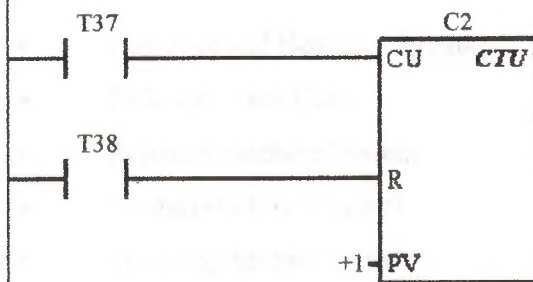
Network 5



Network 6



Network 7



Network 8

(END)

4.3 Applications of PLCs

We can find PLCs following applications

- Counting and Batching System
- Pick and Place Units
- Rejected machine System
- Production Line Control
- Start/stop Motor Control
- Motor Speed Control
- On/off Temperature Control
- Mixing Unit
- Car Wash System

CONCLUSION

In today's competitive world, a company must be efficient, cost effective and flexible if it wishes to survive. In the manufacturing and process industries, this has resulted in a greatly increased demand for industrial control system in order to stream line operations in terms of speed, reliability, and versatility and material throughput.

Established control media including relay, logic and computer systems can do and provide effective control of industrial process and plant. However each of the above control media has limitations or disadvantages that may often be overcome through the use of a programmable logic controller.

The increased rate of application of programmable controllers in the process industry has encouraged manufacturers to develop whole families of available PLCs now extends from small self-contained units with 20 digital input/output points and 500 programs steps up to sophisticated modular system with a range of add on function modules for tasks such as analog input/output and communication. This modular approach allows the expansion or upgrading of a control system with minimum cost and disturbance.

Staff may operate most modern computer controlled devices with relatively little knowledge of the underlying technologies that make up the system, and programmable controllers are at the forefront of 'user friendliness' in this respect. However it requires a greater insight than this to select the best controller or control system for a particular application and then to design successfully and produce the necessary control programs. The engineering requires an understanding of the operation and capabilities of the different programmable controllers available, together with an appreciation of common programming facilities and their use in various applications.

A modern programmable logic controller is a simple control system, which is easy to use and versatile. Most automated factories employ programmable logic controllers in the control of production and assembly processes.

REFERENCES

- [1] ÖZGÜR CEMAL ÖZERDEM “*Programmable Logic Controllers and Programming*” neu press, 2001
- [2] Siemens Step 2000 Series “*Basics of PLCs*”
- [3] Siemens Step 2000 Series “*Basics of Control Components*”
- [4] Siemens System Manual “*Simatic S7-200 Programmable Controller System*”

ONLINE SOURCES

- [1] www.google.com
- [2] www.ask.com
- [3] www.controlsystem.com
- [4] www.siemens.com.uk