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Faculty of Engineering

Department of Electrical and Electronic Engineering

TRAFFIC LAMP CONTROL SYSTEM WİTH PLC

Graduation Project
EE – 400

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ABSTRACT

As PLC technology has advanced, so have programming languages and communications capabilities, along with many other important features. Today's PLCs offer faster scan times, space efficient high-density input/output systems, and special interfaces to allow non-traditional devices to be attached directly to the PLC.

Not only can they communicate with other control systems, they can also perform reporting functions and diagnose their own failures, as well as the failure of a machine or process. Size is typically used to categorize today's PLC, and is often an indication of the features and types of applications it will accommodate.

In this project CPU 212 8 inputs, 6 outputs, 24 volt DC input 24 Volt AC output PLC is used, and an automation of a Lamp and an industrial motor is realized by PLC programs.

Real life application is performed and the Lamp and AC motor is physically operated.

TABLE OF CONTENTS

INTRODUCTION

A Programmable Logic Controller was defined by Capiel (1982) as: "Adigitallyoperating electronic system designed for use in an industrial environment, which uses a programmable memory for the internal storage of instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic to control through analog or digital input/output modules, various types of machines or processes." Which explains the device perfectly. In the late 1960's PLC's were first introduced. The first PLC can be traced back to 1968 when Bedford Associates, a company in Bedford, MA, developed a device called a Modular Digital Controller for General Motors (GM). The MODICON, as it was known, was developed to help GM eliminate traditional relay-based machine control systems.

The aim of this project is the control traffic lamp automation system with SIMATICS-7 200 PLC.

The project consists of the ten chapters, conclusion and reference.

Chapter-1Types of PLC, PLC layout, PLC operating system and chapter concluded with brief information about.

Chapter-2 PLC operation, plc status, memory types, and software based PLCs

Chapter-3 Ladder diagram fundamentals, machine control terminology

Chapter-4 Discrete and Analog Inputs/Outputs

Chapter-5 Presents the Information about Siemens SIMATIC S7-200 micro controller.

Chapter-6 Equipment of Traffic Lamps

CHAPTER ONE
PROGRAMMABLE LOGIC CONTROLLER STRUCTURE

1.1 What is a PLC ?

A programmable logic controller (PLC) is a device that was invented to replace the necessary sequential relay circuits for machine control. The PLC works by looking at its inputs and depending upon their state, turning on / off its outputs. The user enters a program, usually via software, that gives the desired results.

PLC's are used in many real world applications. If there is industry present, changes are good that there is a PLC present. If industrial process involved machining, packaging material handling, and automated assembly or countless other industries are probably already using them. If not, it is wasting of money and time. Almost any application that needs some type of electrical control has a need for PLC. For example, let's assume that when a switch turned on,it is wanted to turn on a solenoid for 5 seconds and then turn it off regularly of how long the switch is on.

This can be done with a simple external timer. But what will happen if the process included 10 switches and solenoids? it would need 10 external timers. What will happen if the process also needed to count how many times the switches individually turned on? it would need a lot of external counters.

As it observed if the process becomes more complicated, then it is desire to use a device the simplify that use PLC for this process. PLC could be programed to count its inputs and turn the solenoids for the specified time.

To find easy ways about writing PLC programs for more complicated then the simple than above. have a look at what is considered to be the 'top 20' PLC instructions. It can be safely estimated that with a firm understanding of these instructions, that just one of them can solve more than 80 % of the applications in existence.

1.2 PLC History

In the late 1960's PLC's were first introduced. The primary reason for designing such a device was eliminating the large cost involved in replacing the complicated relay based machine control systems. Bedford Associates (Bedford, MA) proposed something called a modular digital controller (MODICON) to a major US car manufacturer. Other companies at the time proposed computer based upon the PDP – 8. The MODICON 084 brought the world's first PLC into commercial production.

When production requirements changed so did the control system. This becomes very expensive when the change is frequent. Since relays are mechanical devices they also have a limited lifetime that required strict adhesion to maintenance schedules. Troubleshooting was also quite tedious when so many relays are involved. Now picture a machine control panel that included many, possible hundreds or thousands, of individual relays. The size could be mind-boggling. How about the complicated initial wiring of so many individual devices! These relays would be individually wired together in a manner that would yield the desired outcome.

These new controllers also had to be easily programmed by maintenance and plant engineers. The lifetime had to be long and programming changes easily performed. The also had to survive the harsh industrial environment. That's a lot to ask! The answers were to use a programming technique most people were already familiar with and replace mechanical parts with solid-state ones.

In the mid70's the dominant PLC techniques were sequencer state machines and the bitslice based CPU. The AMD 2901 and 2903 were quite popular in MODICON and A-B PLC's. Conventional microprocessors lacked the power to quickly solve PLC logic in all but the smallest PLC's. As conventional microprocessors evolved, larger and larger PLC's were being based upon them. However, even today some are still based upon the 2903. MODICON has yet the build a faster PLC then their 984A/B/X, which was based upon the 2901.

Communications abilities began to appear in approximately 1973. The first such system was MODICON's MODBUS. The PLC could now talk to other PLC's and they could be far away from the actual machine they were controlling. They could also now be used to send and eceive varying voltages to allow them to enter the analogue world.

Unfortunately, the lack of standardization coupled with continually changing technology has made PLC communications a nightmare of incompatible protocols and physical networks.

The 80's saw an attempt to standardize communications with General Motor's manufacturing automation protocol. It was also a time for reducing the size of the PLC and making them software programmable through symbolic programming on personal computers instead of dedicated programming terminals or handheld programmers.

The 90's have seen a gradual reduction in the introduction new protocols, and the modernization of the physical layers of same of the more popular protocols that survived the 1980's. The latest standard has tried to merge PLC- programming languages under one international standard. We now have PLC's that are programmable in function block diagrams, instruction list, C and structured text all at the same time!

PC's are also being used to replace PLC's in some applications. The original company who commissioned the MODICON 084 has actually switched to a PC based control system.

1.3 PLC Layout

As we have seen, a switch is a logic element and so can be used to provide a logic signal input to a PLC. Each PLC input is energized (turned on) when 24V dc is applied to it from a switching device. Normally a 24V dc supply is internally generated from the mains input and is used for wiring up input devices. Switches that are connected to the input lines can be of the normally open or normally closed contact type. When the run input is energized, the outputs are switched according to the program and the condition of the inputs.

The output loads can be switched from relay, transistor or triac contacts inside the PLC. Relays are widely used this is fine provided that the maximum current rating for the relay contacts is not exceeded. For a heavy current load, a PLC output relay is used to drive a secondary switching device such as a solid-state relay or a contactor.

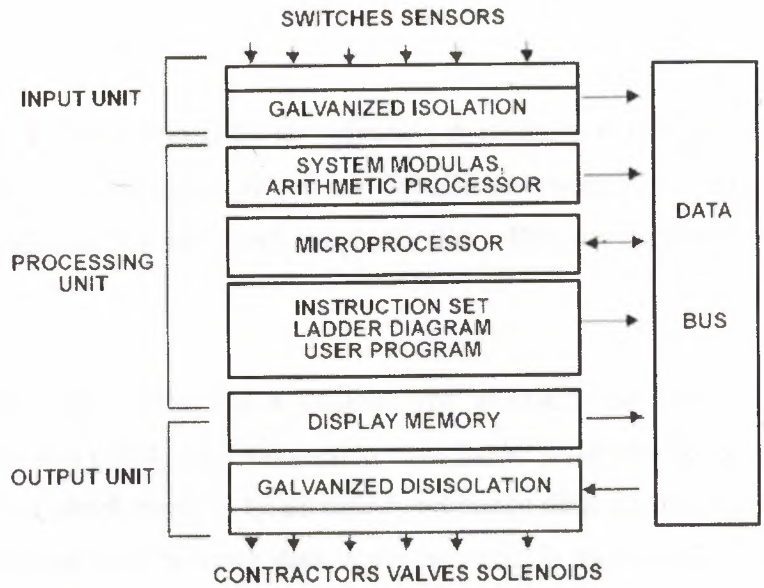


Figure : 1.1 Block diagram represantation of the internal structure of PLC

1.3.1 Central Processing Unit (CPU)

The CPU controls and supervises all operations with in the PLC, carrying out programmed instructions stored in the memory. An internal communication highway or bus system carries information to and from the CPU, memory, and I/O units under control of CPU. The CPU is supplied with a clock frequency by an external quartz crystal or RC oscillator, typically between 1 and 8 megahertz depending on the microprocessor used and the area of application. The clock determines the operating speed of the PLC and provides timing / synchronization for all elements in the system. It should be clear from this preamble that we use the memory to store various types of information. This information might be an image of input and output ports, the users program, the operating system or data. Different types of memory devices are used for different types of information.

1.3.2 Memory

Memory is characterized by its volatility. A memory is volatile if it loses its data when the power to it is switched off and non-volatile otherwise. Common types of memory include semiconductor memory and magnetic disk. The some types of semiconductor memory are:

1.3.2.1 RAM

Random access memory is a flexible type of read/write memory. All PLCs will have some amount of RAM, which is used to store ladder programs being developed by the user program data which needs to be modified and image data. Ram is volatile. This means that RAM cannot be used to store data while the PLC is turned off unless the RAM is battery backed. A type of RAM called CMOS RAM (complementary metal-oxide semiconductor RAM) is suitable for use with batteries because it consumes very little power and operates over a very wide range of supply voltage.

1.3.2.2 ROM

A read only memory is programmed during its manufacture using a mask. It is a nonvolatile memory and provides permanent storage for the operating system.

1.3.2.3 EPROM

Erasable programmable read only memory is a type of ROM which can be programmed by electrical pulses and erased by exposing a transparent quartz window found in the top of each device to ultraviolet light. EPROM is nonvolatile memory and provides permanent storage for ladder programs.

1.3.2.4 EEPROM

Electrically erasable programmable read only memory is similar to EPROM but is erased by using electrical pulses rather than ultraviolet light. It has the flexibility of battery backed CMOS RAM. However, writing data in to an EEPROM takes much longer than into a RAM. In addition to program storage, a programmable controller may require memory for other function: Temporary storage for statuse of internal functions, e.g. timers, counters, marker relays, etc. Since these consist of changing data they require RAM read/write memory, which may be battery backed in section.

1.3.3 Memory Storage Capacity

The storage capacity of a memory device is determined by the number of binary digits, i.e. the binary number 2_{10}. A 4K-byte memory is capable of storing 4*1024 words, each of 8 bits, and has a total storage capacity of 32768 bits.

Clearly, the storage capacity of the user memory will determine the maximum program size. As a guide, a 1K-byte memory will hold 1024 program instructions and data if these are stored as groups of 8 bits.

1.3.4 Memory Size

Smaller programmable controllers normally have a fixed memory size, due in part to the physical dimensions of the unit. This varies in capacity between 300 and 1000 instructions depending on the manufacturer. This capacity may not appear large enough to be very useful, but it has been estimated that 90% of all binary control tasks can be solved using less than 1000 instructions, so there is sufficient space to meet most user's needs.

Larger PLCs utilize memory modules of between 1K and 64K in size allowing the system to be expanded by fitting additional RAM or PROM memory cards to the PLC rack. As integrated circuit memory costs continue to fall, the PLC manufacturers are providing larger program memories on all products.

1.3.5 Memory Map

Memory mapping is used to describe the situation in which input/output ports are controlled by writing data into the allocation of memory addresses of ROM, RAM and I/O is called a memory map. Figure 1.2 illustrates a memory map for a typical PLC. In this, image bits are stored in RAM above the user's program and data for flags, counters, and timers. Flags, counters, and timers are discussed below with most PLCs the memory map is already configured by the manufacturer. This means that the program capacity, the number of input/output ports and the number of internal flags, counters and timers are fixed.

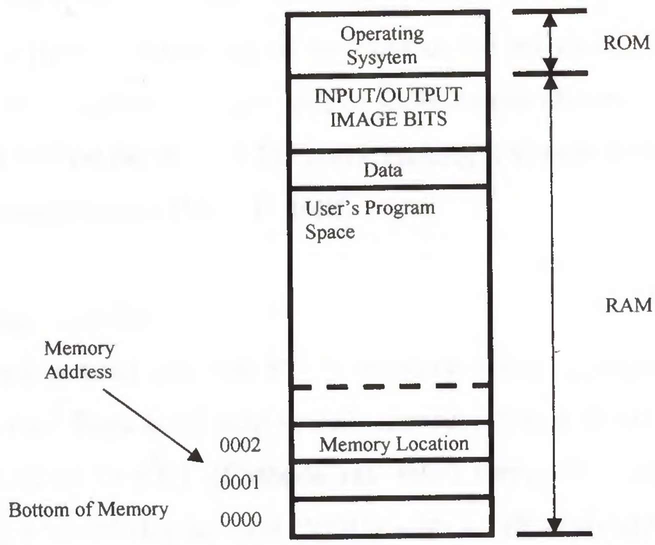


Figure 1.2 Memory map

1.3.6 Input / Output Units

Most PLCs operate internally at between 5 and 15V dc. (Common TTL and CMOS voltages), whilst process signals can be much greater, typically 24V dc to 240V ac at several amperes.

Input (Choice of): 5V

(TTL level) switched I/P

24V switched I/P

110V switched I/P

240V switched I/P

Output (Choice of): 24V 100mA switched O/P

110V lamp

240V lA ac (triac)

240V 2A ac (relay)

In all cases the input/output units are designed with the aim of simplifying the connections to process transducers and actuators to the programmable controller. For this purpose all PLCs are equipped with standard screw terminals or plugs on every I/O point, allowing the rapid and simple removal and replacement of a faulty I/O card. Ever input/output point has a unique address or channel number, which is used during program development to specify the monitoring of an input or the activating of a particular output with in the program. Indication of the status of input/output channels is provided by light emitting diodes (LEDs) on the PLC or I/O units, making it simple to check the operation of process inputs and outputs from the PLC itself.

1.3.7 Programming Consoles

Programs are entered into the PLC's memory using a program console (ladder). Program consoles vary from hand held system incorporating a small keyboard and liquid crystal displays (LCDs) to CRT (Cathode ray tube) terminals. Larger PLCs are often programmed using a visual display unit (VDU) with a full keyboard and screen display, connected to the controller via a serial link. VDUs provide improved programming facilities such as screen graphics and the inclusion of text comments that assist in the readability of a program.

CHAPTER TWO
PLC OPERATION

2.1 Introduction

For simple programming the relay model of the PLC is sufficient. As more complex functions are used the more complex VonNeuman model of the PLC must be used. A VonNeuman computer processes one instruction at a time. Most computers operate this way, although they appear to be doing many things at once. Consider the computer components shown in Figure 2.1.

Objectives:

• Understand the operation of a PLC.

• The computer structure of a PLC

• The sanity check, input, output and logic scans

• Status and memory types

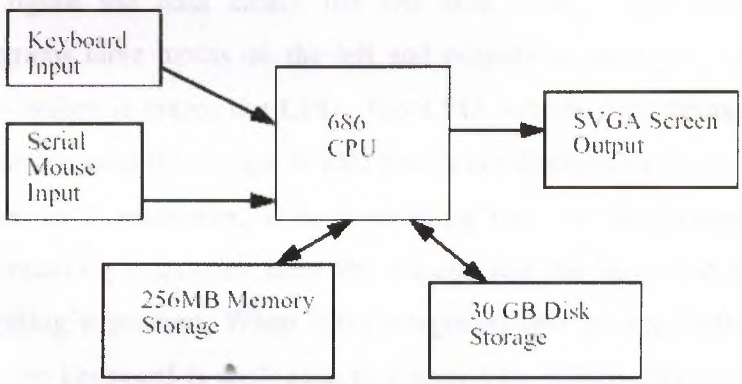


Figure 2.1 Simplified Personal Computer Architecture

Input is obtained from the keyboard and mouse, output is sent to the screen, and the disk and memory are used for both input and output for storage. (Note: the directions of these arrows are very important to engineers, always pay attention to indicate where information is flowing.) This figure can be redrawn as in Figure 2.2 to clarify the role of plc operation.

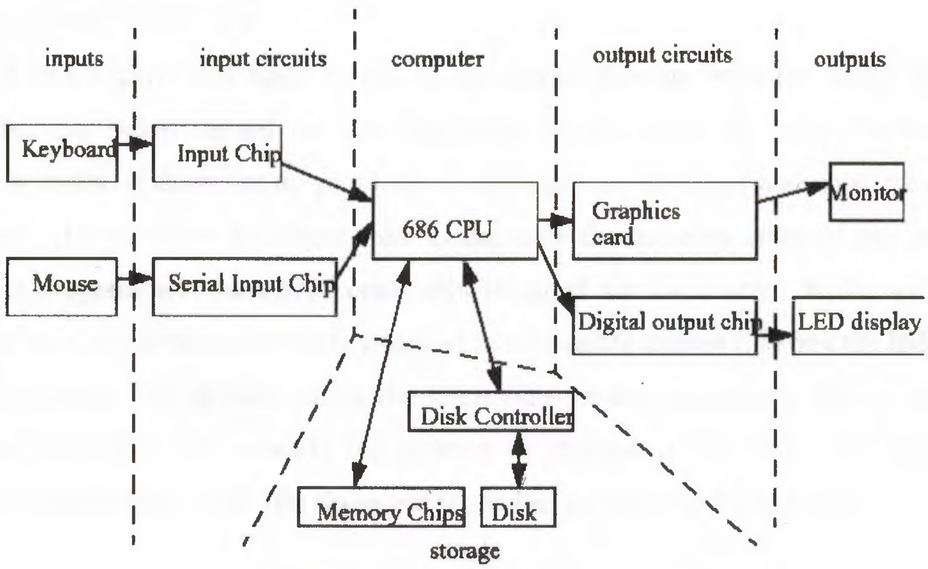


Figure2.2 An Input-Output Oriented Architecture

In this figure the data enters the left side through the inputs. (Note: most engineering diagrams have inputs on the left and outputs on the right.) It travels through bufferingcircuits before it enters the CPU. The CPU outputs data through other circuits. Memoryand disks are used for storage of data that is not destined for output. If we look at a personalcomputer as a controller, it is controlling the user by outputting stimuli on thescreen, and inputting responses from the mouse and the keyboard.A PLC is also a computer controlling a process. When fully integrated into an application the analogies become;inputs - the keyboard is analogous to a proximity switch input circuits - the serial input chip is like a 24Vdc input cardcomputer - the 686 CPU is like a PLC CPU unit output circuits - a graphics card is like a triac output card outputs - a monitor is like a light storage - memory in PLCs is similar to memories in personal computers plc operation.

It is also possible to implement a PLC using a normal Personal Computer,although this is not advisable. In the case of a PLC the inputs and outputs are designed tobe more reliable and rugged for harsh production environments.

2.2 Operation Sequence

All PLCs have four basic stages of operations that are repeated many times per second. Initially when turned on the first time it will check it's own hardware and softwarefor faults. If there are no problems it will copy all the input and copy their values intomemory, this is called the input scan. Using only the memory copy of the inputs the ladderlogic program will be solved once, this is called the logic scan. While solving the ladderlogic the output values are only changed in temporary memory. When the ladder scan isdone the outputs will updated using the temporary values in memory, this is called the outputscan. The PLC now restarts the process by starting a self check for faults. This processtypically repeats 10 to 100 times per second as is shown in Figure 2.3.

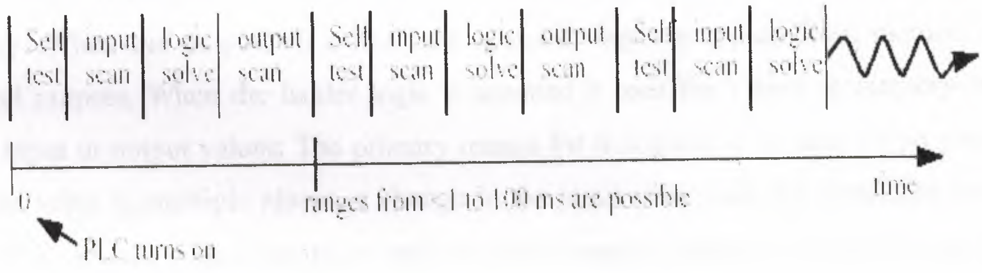


Figure 2.3 PLC Scan Cycle

SELF TEST - Checks to see if all cards error free, reset watch-dog timer, etc. (A watchdog timer will cause an error, and shut down the PLC if not reset within a short period of time - this would indicate that the ladder logic is not being scanned normally).INPUT SCAN - Reads input values from the chips in the input cards, and copies their values to memory. This makes the PLC operation faster, and avoids cases where an input changes from the start to the end of the program (e.g., an emergency stop). There are special PLC functions that read the inputs directly, and avoid the input tables. LOGIC SOLVE/SCAN - Based on the input table in memory, the program is executed 1step at a time, and outputs are updated. This is the focus of the later sections.OUTPUT SCAN - The output table is copied from memory to the output chips. These chips then drive the output devices.

The input and output scans often confuse the beginner, but they are important. The input scan takes a *snapshot* of the inputs, and solves the logic. This prevents potential problems that might occur if an input that is used in multiple places in the ladder logic program changed while half way through a ladder scan. Thus changing the behaviors of half of the ladder logic program. This problem could have severe effects on complex programs that are developed later in the book. One side effect of the input scan is that if a change in input is too short in duration, it might fall between input scans and be missed. When the PLC is initially turned on the normal outputs will be turned off. This does not affect the values of the inputs.

2.2.1 The Input and Output Scans

When the inputs to the PLC are scanned the physical input values are copied into memory. When the outputs to a PLC are scanned they are copied from memory to the physical outputs. When the ladder logic is scanned it uses the values in memory, not the actual input or output values. The primary reason for doing this is so that if a program uses an input value in multiple places, a change in the input value will not invalidate the logic. Also, if output bits were changed as each bit was changed, instead of all at once at the end of the scan the PLC would operate much slower.

2.2.2 The Logic Scan

Ladder logic programs are modelled after relay logic. In relay logic each element in the ladder will switch as quickly as possible. But in a program elements can only be examines one at a time in a fixed sequence. Consider the ladder logic in Figure 2.4, the ladder logic will be interpreted left-to-right, top-to-bottom. In the figure the ladder logic scan begins at the top rung. At the end of the rung it interprets the top output first, then the output branched below it. On the second rung it solves branches, before moving along the ladder logic rung.

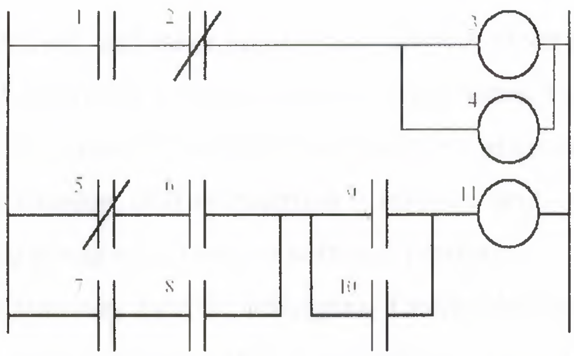


Figure 2.4 Ladder Logic Execution Sequence

The logic scan sequence become important when solving ladder logic programs which use outputs as inputs, as we will see i n Chapter 8. It also becomes important when considering output usage. Consider Figure 8.5, the first line of ladder logic will examine input *A* and set output *X* to have the same value. The second line will examine input *B* and set the output *X* to have the opposite value. So the value of *X* was only equal to *A* until the second line of ladder logic was scanned. Recall that during the logic scan the outputs are only changed in memory, the actual outputs are only updated when the ladder logic scan is complete. Therefore the output scan would update the real outputs based upon the second line of ladder logic, and the first line of ladder logic would be ineffective.

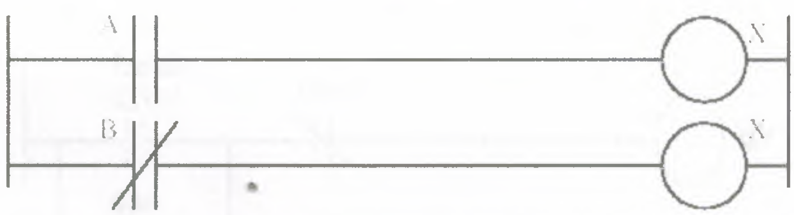


Figure 2.5 A Duplicated Output Error

It is a common mistake for beginners to unintentionally repeat the same ladder logic output more than once. This will basically invalidate the first output, in this case the first line will never do anything

2.3 PLC Status

The lack of keyboard, and other input-output devices is very noticeable on a PLC. On the front of the PLC there are normally limited status lights. Common lights indicate; power on - this will be on whenever the PLC has power program running - this will often indicate if a program is running, or if no program is running fault - this will indicate when the PLC has experienced a major hardware or software problem

These lights are normally used for debugging. Limited buttons will also be provided for PLC hardware. The most common will be a run/program switch that will be switched to program when maintenance is being conducted, and back to run when in production. This switch normally requires a key to keep unauthorized personnel from altering the PLC program or stopping execution. A PLC will almost never have an on-off switch or reset button on the front. This needs to be designed into the remainder of the system.

The status of the PLC can be detected by ladder logic also. It is common for programs to check to see if they are being executed for the first time, as shown in Figure 2.6 The 'first scan' input will be true the very first time the ladder logic is scanned, but false on every other scan. In this case the address for 'first scan' in a PLC-5 is 'S2:1/14'. With the logic in the example the first scan will seal on 'light', until 'clear' is turned on. So the light will turn on after the PLC has been turned on, but it will turn off and stay off after 'clear' is turned on. The 'first scan' bit is also referred to at the 'first pass' bit.

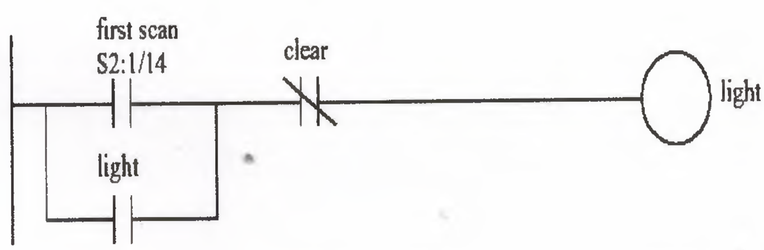


Figure 2.6 An program that checks for the first scan of the PLC

2.4 Software Based PLC's

The dropping cost of personal computers is increasing their use in control, including the replacement of PLCs. Software is installed that allows the personal computer to solve ladder logic, read inputs from sensors and update outputs to actuators. These are important to mention here because they don't obey the previous timing model. For example, if the computer is running a game it may slow or halt the computer. This issue and others are currently being investigated and good solutions should be expected soon.

2.5 Summary

- A PLC and computer are similar with inputs, outputs, memory, etc.
- The PLC continuously goes through a cycle including a sanity check, input scan, logic scan, and output scan.
- While the logic is being scanned, changes in the inputs are not detected, and the outputs are not updated.
- PLCs use RAM, and sometime EPROMs are used for permanent programs.

CHAPTER THREE

LADDER DİAGRAM FUNDEMENTALS

3.1 Objectives

Upon completion of this chapter, you will be able to

- Identify the parts of an electrical machine control diagram including rungs, branches, rails, contacts, and loads.
- Correctly design and draw a simple electrical machine control diagram.
- Recognize the difference between an electronic diagram and an electrical machine diagram.
- Recognize the diagramming symbols for common components such as switches, control transformers, relays, fuses, and time delay relays.
- Understand the more common machine control terminology.

3.2 Introduction

Machine control design is a unique area of engineering that requires the knowledge of ertain specific and unique diagramming techniques called ladder diagramming. Although there are similarities between control diagrams and electronic diagrams, many of the component symbols and layout formats are different. This chapter provides a study of the fundamentals of eveloping, drawing and understanding ladder diagrams. We will begin with a description of some of the fundamental components used in ladder diagrams.

The basic symbols will then be used in a study of boolean logic as applied to relay diagrams. More complicated circuits will then be discussed.

3.3 Basic Components and Their Symbols

We shall begin with a study of the fundamental components used in electrical machine controls and their ladder diagram symbols. It is important to understand that the material covered in this chapter is by no means a comprehensive coverage of all types of machine control components. Instead, we will discuss only the most commonly used ones. Some of the more exotic components will be covered in later chapters.

3.3.1 Control Transformers

For safety reasons, machine controls are low voltage components. Because the switches, lights and other components must be touched by operators and maintenance personnel, it is contrary to electrical code in the United States to apply a voltage higher than 120VAC to the terminals of any operator controls. For example, assume a maintenance person is changing a burned-out indicator lamp on a control panel and the lamp is powered by 480VAC. If the person were to touch any part of the metal bulb base while it is in contact with the socket, the shock could be lethal.

However, if the bulb is powered by 120VAC or less, the resulting shock would likely be much less severe. In order to make large powerful machines efficient and cost effective and reduce line current, most are powered by high voltages (240VAC, 480VAC, or more). This means the line voltage must be reduced to 120VAC or less for the controls. This is done using a control transformer. Figure 1.1 shows the electrical diagram symbol for a control transformer.

The most obvious peculiarity here is that the symbol is rotated 90° with the primaries on top and secondary on the bottom. As will be seen later, this is done to make it easier to draw the remainder of the ladder diagram. Notice that the transformer has two primary windings. These are usually each rated at 240VAC. By connecting them in parallel, we obtain a 240VAC primary, and by connecting them in series, we have a 480VAC primary. The secondary windings are generally rated at 120VAC, 48VAC or 24VAC. By offering control transformers with dual primaries, transformer manufacturers can reduce the number of transformer types in their product line, make their transformers more versatile, and make them less expensive.

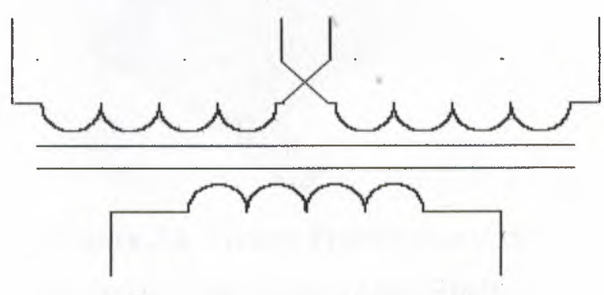


Figure 3.1 Control Transformer

3.3.2 Fuses

Control circuits are always fuse protected. This prevents damage to the control transformer in the event of a short in the control circuitry.

Figure 3.2 Fuse

The electrical symbol for a fuse is shown in Figure 3.2. The fuse used in control circuits is generally a slo-blow fuse (i.e. it is generally immune to current transients which occur when power is switched on) and must be rated at a current that is less than or equal to the rated secondary current of the control transformer, and it must be connected in series with the transformer secondary. Most control transformers can be purchased with a fuse block (fuse holder) for the secondary fuse mounted on the transformer, as shown in Figure 3.3

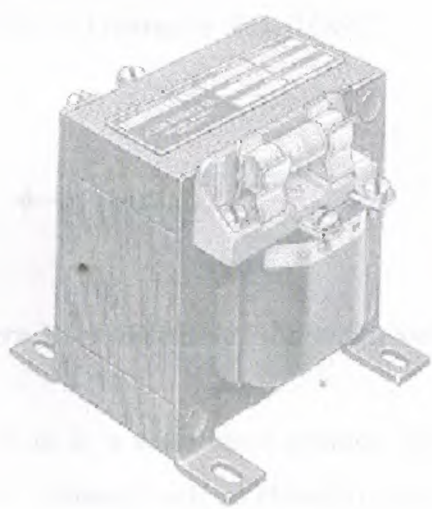


Figure 3.3 Control Transformer with
Secondary Fuse Holder (Allen Bradley)

3.3.3 Switches

There are two fundamental uses for switches. First, switches are used for operator input to send instructions to the control circuit. Second, switches may be installed on the moving parts of a machine to provide automatic feedback to the control system. There are many different types of switches, too many to cover in this text. However, with a basic understanding of switches, it is easy to understand most of the different types.

3.3.3.1 Pushbutton

The most common switch is the pushbutton. It is also the one that needs the least description because it is widely used in automotive and electronic equipment applications. There are two types of pushbutton, the momentary and maintained. The momentary pushbutton switch is activated when the button is pressed, and deactivated when the button is released. The deactivation is done using an internal spring. The maintained pushbutton activates when pressed, but remains activated when it is released. Then to deactivate it, it must be pressed a second time. For this reason, this type of switch is sometimes called a push-push switch. The on/off switches on most desktop computers and laboratory oscilloscopes are maintained pushbuttons. The contacts on switches can be of two types. These are normally open (N/O) and normally closed (N/C).

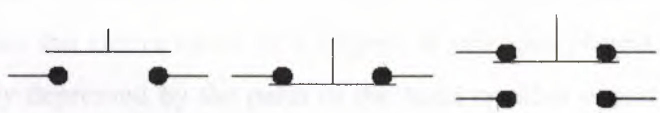


Figure 3.4 Momentary Pushbutton Switches

Whenever a switch is in it 's deactivated position, the N/O contacts will be open (non-conducting) and the N/C contacts will be closed (conducting). Figure 3.4 shows the schematic symbols for a normally open pushbutton (left) and a normally closed pushbutton (center). The symbol on the right of Figure 3.4 is a single pushbutton with both N/O and N/C contacts. There is no internal electrical connection between different contact pairs on the same switch. Most industrial switches can have extra contacts "piggy backed" on the switch, so as many contacts as needed of either type can be added by the designer.

The schematic symbol for the maintained pushbutton is shown

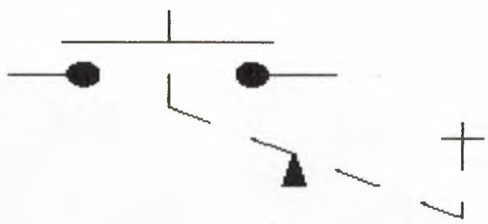


Figure 3.5 Maintained Switch

In Figure 3.5 note that it is the symbol for the momentary pushbutton with a "see-saw" mechanism added to hold in the switch actuator until it is pressed a second time. As with the momentary switch, the maintained switch can have as many contacts of eithertype as desired.

3.3.3.2 Pushbutton Switch Actuators

The actuator of a pushbutton is the part that you depress to activate the switch. These actuators come is several different styles as shown in Figure 3.6, each with a specific purpose. The switch on the left in Figure 3.6 has a guarded or shrouded actuator. In this case the pushbutton is recessed 1/4"-1/2" inside the sleeve and can only be depressed by an object smaller than the sleeve (such as a finger). It provides protection against the button being accidentally depressed by the palm of the hand or other object and is therefore used in situations where pressing the switch causes something potentially dangerous to happen. Guarded pushbuttons are used in applications such as START, RUN, CYCLE, JOG, or RESET operations. For example, the RESET pushbutton on your computer is likely a guarded pushbutton. The switch shown in the center of Figure 3.6 has an actuator that is aligned to be even with the sleeve. It is called a flush pushbutton. It provides similar protection against accidental actuation as the guarded pushbutton; however, since it is not recessed, the level of protection is not to the extent of the guarded pushbutton. This type of switch actuator works better in applications where it is desired to back light the actuator (called a lighted pushbutton).

The switch on the right is an extended pushbutton. Obviously, the actuator extends beyond the sleeve which makes the button easy to depress by finger, palm of the hand, or any object. It is intended for applications where it is desirable to make the switch as accessible as possible such as STOP, PAUSE, or BRAKES.

Figure 3.6 Switch Actuators

The three types of switch actuators shown in Figure 3.6 are not generally used for applications that would be required in emergency situations nor for operations that occur hundreds of times per day. For both of these applications, a switch is needed that is the most accessible of all switches. These types are the mushroom head or palm head pushbutton (sometimes called palm switches, for short), and are illustrated in Figure 3.7

Figure 3.7 Mushroom Head Pushbutton

Although these two applications are radically different, the switches look similar. The mushroom head switch shown on the left of Figure 3.7 is a momentary switch that may be used to cause a machine run one cycle of an operation. For safety reasons, they are usually used in pairs, separated by about 24", and wired so that they must both be pressed at the same time in order to cause the desired operation to commence. When arranged and wired such as this, we create what is called a 2-handed palming operation. By doing so, we know that when the machine is cycled, the operator has both hands on the pushbuttons and not in the machine. The switch on the right of Figure 3.7 is a detent pushbutton (i.e. when pressed in it remains in, and then to return it to its original position, it must be pulled out) and is called an Emergency Stop, or E-Stop switch. The mushroom head is always red and the switch is used to shutoff power to the controls of a machine when the switch is pressed in. In order to restart a machine, the E-Stop switch must be pulled to the out position to apply power to the controls before attempting to run the machine.

Figure 3-8 - Mushroom Switches

Mushroom head switches have special schematic symbols as shown in Figure 3.8. Notice that they are drawn as standard pushbutton switches but have a curved line on the top of the actuators to indicate that the actuators have a mushroom head.

3.3.3.3 Selector Switches

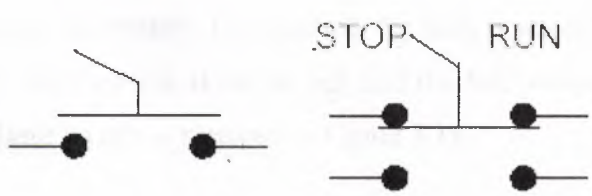


Figure 3.9 Selectors

A selector switch is also known as a rotary switch. An automobile ignition switch, and anoscilloscope's vertical gain and horizontal timebase switches are examples of selector switches. Selector switches use the same symbol as a momentary pushbutton, except a lever is added to the top of the actuator, as shown in Figure 3.9. The switch on the left is open when the selector is turned to the left and closed when turned to the right. The switch on the right side has two sets of contacts. The top contacts are closed when the switch selector is turned to the left position and open when the selector is turned to the right. The bottom set of contacts work exactly opposite. There is no electrical connection between the top and bottom pairs of contacts. In most cases, we label the selector positions the same as the labeling on the panel where the switch is located. For the switch on the right in Figure 3.9 , the control panel would be labeled with the STOP position to the left and the RUN position to the right.

3.3.3.4 Limit Switches

Figure 3.10 Limit Switches

Limit switches are usually not operator accessible. Instead they are activated by moving parts on the machine. They are usually mechanical switches, but can also be light activated (such as the automatic door openers used by stores and supermarkets), or magnetically operated (such as the magnetic switches used on home security systems that sense when a window has been opened). An example of a mechanically operated limit switch is the switch on the refrigerator door that turns on the light inside. They are sometimes called cam switches because any are operated by a camming action when a moving part passes by the switch. The symbols for both types of limit switches are shown in Figure 3.10. The N/O version is on the left and the N/C version is on the right. One of the many types of limit switch is pictured in Figure 3.11.

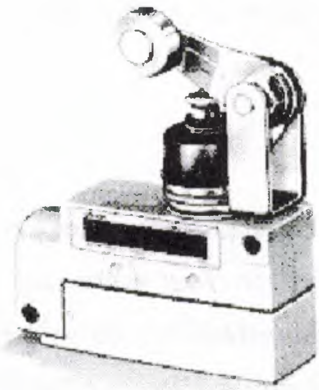


Figure 3.11 Limit Switch

3.3.4 Indicator Lamps

All control panels include indicator lamps. They tell the operator when power is applied to the machine and indicate the present operating status of the machine. Indicators are drawn as a circle with "light rays" extending on the diagonals as shown in Figure 3.12

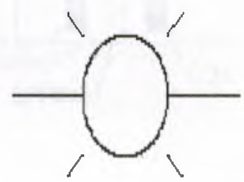


Figure 3.12 Lamp

Although the light bulbs used in indicators are generally incandescent (white), they are usually covered with colored lenses. The colors are usually red, green, or amber, but other colors are also available. Red lamps are reserved for safety critical indicators (power is on, the machine running, an access panel is open, or that a fault has occurred). Green usually indicates safe conditions (power to the motor is off, brakes are on, etc.). Amber indicates conditions that are important but not dangerous (fluid getting low, machine paused, machine warming up, etc.). Other colors icate information not critical to the safe operation of the machine (time for preventive maintenance,etc.). Sometimes it is important to attract the operator's attention with a lamp. In these cases, we usually flash the lamp continuously on and off.

3.3.5 Relays

Early electrical control systems were composed of mainly relays and switches. Switches are familiar devices, but relays may not be so familiar. Therefore, before continuing our discussion of machine control ladder diagramming, a brief discussion of relay fundamentals may be beneficial. A simplified drawing of a relay with one contact set is shown in Figure 3.13. Note that this is a cutaway (cross section) view of the relay.

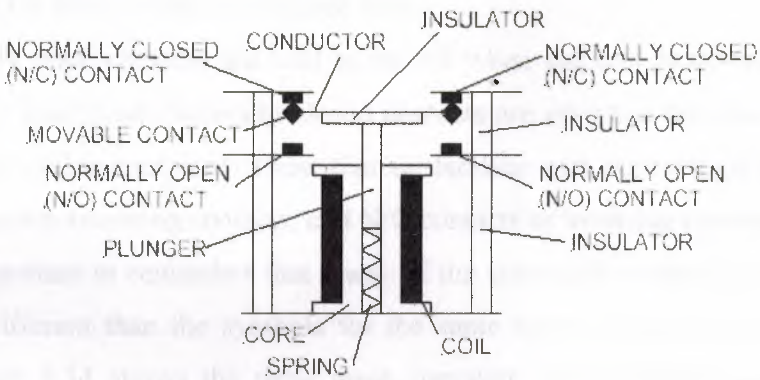


Figure 3.13 Relay or Contactor

A relay, or contactor, is an electromagnetic device composed of a frame (or core) with an electromagnet coil and contacts (some movable and some fixed). The movable contacts (and conductor that connects them) are mounted via an insulator to a plunger which moves within a bobbin. A coil of copper wire is wound on the bobbin to create an electromagnet. A spring holds the plunger up and away from the electromagnet. When the electromagnet is energized by passing an electric current through the coil, the magnetic field pulls the plunger into the core, which pulls the movable contacts downward. Two fixed pairs of contacts are mounted to the relay frame on electrical insulators so that when the movable contacts are not being pulled toward the core (the coil is de-energized) they physically touch the upper fixed pair of contacts and, when being pulled toward the coil, touches the lower pair of fixed contacts.

There can be several sets of contacts mounted to the relay frame. The contacts energize and de-energize as a result of applying power to the relay coil (connections to the relay coil are not shown). Referring to Figure 3.13, when the coil is de-energized, the movable contacts are connected to the upper fixed contact pair. These fixed contacts are referred to as the normally closed contacts because they are bridged together by the movable contacts and conductor whenever the relay is in its "power off" state. Likewise, the movable contacts are not connected to the lower fixed contact pair when the relay coil is de-energized. These fixed contacts are referred to as the normally open contacts. Contacts are named with the relay in the deenergized state.

Normally open contacts are said to be off when the coil is de-energized and on when the coil is energized. Normally closed contacts are on when the coil is deenergized and off when the coil is energized. Those that are familiar with digital logic tend to think of N/O contacts as non-inverting contacts, and N/C contacts as inverting contacts.

It is important to remember that many of the schematic symbols used in electrical diagrams are different than the symbols for the same types of components in electronic diagrams. Figure 3.14 shows the three most common relay symbols used in electrical machine diagrams. These three symbols are a normally open contact, normally closed contact and coil. Notice that the normally open contact on the left could easily be misconstrued by an electronic designer to be a capacitor. That is why it is important when working with electrical machines to mentally “shift gears” to think in terms of electrical symbols and not electronic symbols.

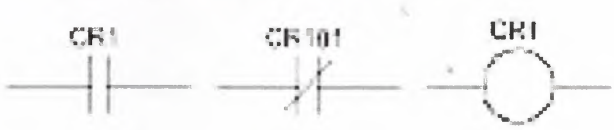


Figure 3.14 Relay Symbol

Notice that the normally closed and normally open contacts of Figure 3.14 each have lines extending from both sides of the symbol. These are the connection lines which, on a real relay, would be the connection points for wires. The reader is invited to refer back to Figure 3.13 and identify the relationship between the normally open and normally closed contacts on the physical relay and their corresponding symbols in Figure 3.14. The coil symbol shown in Figure 3.14 represents the coil of the relay we have been discussing. The coil, like the contacts, has two connection lines extending from either side. These represent the physical wire connections to the coil on the actual relay.

Notice that the coil and contacts in the figure each have a reference designator label above the symbol. This label identifies the contact or coil within the ladder diagram. Coil CR1 is the coil of relay CR1. When coil CR1 is energized, all the normally open CR1 contacts will be closed and all the normally closed CR1 contacts will be open. Likewise, if coil CR1 is deenergized,all the normally open CR1 contacts will be open and all the normally closed CR1 contacts will be closed. Most coils and contacts we will use will be labeled as CR (CR is the abbreviation for "control relay"). A contact labeled CR indicates that it is associated with a relay coil. Each relay will have a specific number associated with it. The range of numbers used will depend upon the number of relays in the system.

Figure 3.15 shows the same relay symbols as in Figure 3.14, however, they have not been drawn graphically. Instead they are drawn using standard ASCII printer characters (hyphens, vertical bars, forward slashes, and parentheses). This is a common method used when the ladder diagram is generated by a computer on an older printer, or when it is desired to rapidly print the ladder diagram (ASCII characters print very quickly). This printing method is usually limited to ladder diagrams of PLC programs as we will see later. Machine electrical diagrams are rarely drawn using this method.

```
    CR1          CR101           CR1
----| |----  ----|/|----  ----(     )----
```

Figure 3.15 ASCII Relay Symbols

3.3.6 Time Delay Relays

It is possible to construct a relay with a built-in time delay device that causes the relay to either switch on after a time delay, or to switch off after a time delay. These types of relays are called time delay relays, or TDR's. The schematic symbols for a TDR coil and contacts are the same as for a conventional relay, except that the coil symbol has the letters "TDR" or "TR" written inside, or next to the coil symbol. The relay itself looks similar to any other relay except that it has a control knob on it that allows the user to set the amount of time delay. There are two basic types of time delay relay. They are the delay-on timer, sometimes called a TON (pronounced Tee-On), and the delay off timer, sometimes called a TOF (pronounced Tee-Off). It is important to understand the difference between these relays in order to specify and apply them correctly.

3.3.6.1 Delay-On Timer (TON) Relay

When an on-timer is installed in a circuit, the user adjusts the control on the relay for the desired time delay. This time setting is called the preset. Figure 3.16 shows a timing diagram of a delay-on time delay relay. Notice on the top waveform that we are simply turning on power to the relay's coil and some undetermined time later, turning it off (the amount of time that the coil is energized makes no difference to the operation of the relay). When the coil is energized, the internal timer in the relay begins running (this can be either a motor driven mechanical timer or an electronic timer). When the time value contained in the timer reaches the preset value, the relay energizes. When this happens, all normally open (N/O) contacts on the relay close and all normally closed (N/C) contacts on the relay open. Notice also that when power is removed from the relay coil, the contacts immediately return to their de-energized state, the timer is reset, and the relay is ready to begin timing again the next time power is applied. If power is applied to the coil and then switched off before the preset time is reached, the relay contacts never activate.

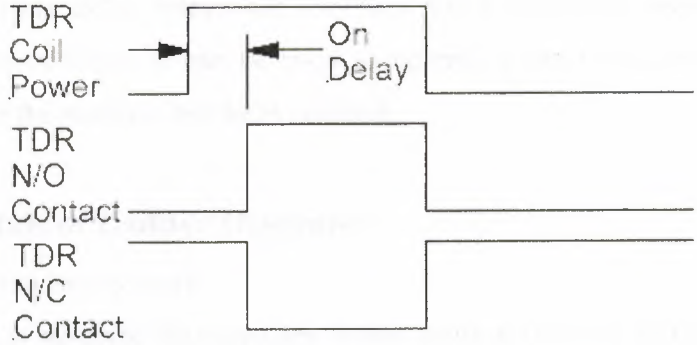


Figure 3.16 Delay-On Timer Relay

Delay-on relays are useful for delaying turn-on events. For example, when the motor is started on a machine, a TON time delay relay can be used to disable all the other controls for a few seconds until the motor has had time to achieve running speed.

3.3.6.2 Delay-Off Timer (TOF) Relay

Figure 3.17 shows a timing diagram for a delay off timer. In this case, at the instant power is applied to the relay coil, the contacts activate - that is, the N/O contacts close, and the N/C contacts open. The time delay occurs when the relay is switched off. After power is removed from the relay coil, the contacts stay activated until the relay times-out. If the relay coil is re-energized before the relay times-out, the timer will reset, and the relay will remain energized until power is removed, at which time it will again begin the delay-off cycle.

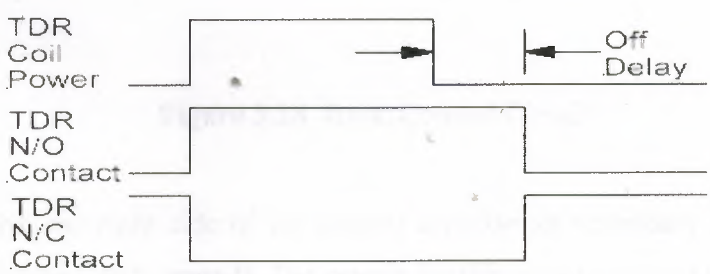


Figure 3.17 Delay-Off Timer Relay

Delay-off time delay relays are excellent for applications requiring time to be "stretched". As an example, it can be used to operate a fan that continues to cool the machine even after the machine has been stopped.

3.4 Fundamentals of Ladder Diagrams

3.4.1 Basic Diagram Framework

All electrical machine diagrams are drawn using a standard format. This format is called the ladder diagram. Beginning with the control transformer, we add a protective fuse on the left side. As mentioned earlier, in many cases the fuse is part of the transformer itself. From the transformer/fuse combination, horizontal lines are drawn to both sides and then drawn vertically down the page as shown in Figure 3.18. These vertical lines are called power rails or simply rails or uprights. The voltage difference between the two rails is equal to the transformer secondary voltage, so any component connected between the two rails will be powered.

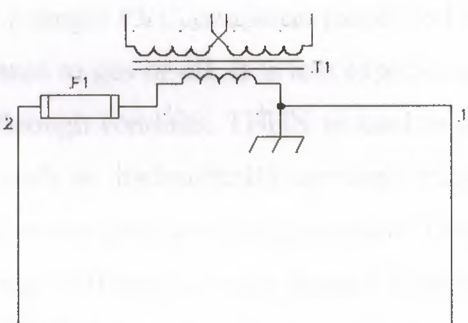


Figure 3.18 Basic Control Circuit

Notice that the right side of the control transformer secondary is grounded to the frame of the machine (earth ground). The reason for this is that, without this ground, should the transformer short internally from primary to secondary, it could apply potentially lethal line voltages to the controls. With the ground, an internal transformer short will cause a fuse to blow or circuit breaker to trip farther "upstream" on the line voltage side of the transformer which will shutdown power to the controls.

3.4.2 Wiring

The wires are numbered. In our diagram, the left rail is wire number 2 and the right rail is wire number 1. When the system is constructed, the actual wires used to connect the components will have a label on each end (called a wire marker), as shown in Figure 3.19, indicating the same wire number. This makes it easier to build, troubleshoot, and modify the circuitry. In addition, by using wire markers, all the wires will be identified,making it unnecessary to use more than one color wire to wire the system, which reduces the cost to construct the machine. Generally, control circuits are wired with all black, red, or white wire (do not use green - it is reserved for safety ground wiring). Notice that in Figure 3.18 the wire connecting T1 to F1 is not numbered. This is because in our design we will be using a transformer with the fuse block included. Therefore, this will be a permanent metal strap on the transformer and will not be a wire. The wire generally used within the controls circuitry is AWG14 or AWG16 stranded copper, type MTW or THHN. MTW is an abbreviation for "machine tool wire" and THHN indicates thermoplastic heat-resistant nylon-coated. MTW has a single PVC insulation jacket and is used in applications where the wire will not be exposed to gas or oil. It is less expensive, more flexible, and easier to route, bundle, and pull through conduits. THHN is used in areas where the wire may be exposed to gas or oil (such as hydraulically operated machines). It has a transparent, oilresistant nylon coating on the outside of the insulation. The drawback to THHN is that it is more expensive, is more difficult to route around corners, and because of its larger diameter, reduces the maximum number of conductors that can be pulled into tight places (such as inside conduits). Since most control components use low currents, AWG14 or AWG16 wire is much larger than is needed. However, it is generally accepted for panel and controls wiring because the larger wire is tough, more flexible, easier to install, and can better withstand the constant vibration created by heavy machinery.

3.4.3 Reference Designators

For all electrical diagrams, every component is given a reference designator. This is a label assigned to the component so that it can be easily located. The reference designator for each component appears on the schematic diagram, the mechanical layout diagram, the parts list, and sometimes is even stamped on the actual component itself. The reference designator consists of an alphabetical prefix followed by a number. The prefix identifies what kind of part it is (control relay, transformer, limit switch, etc.), and the number indicates which particular part it is. Some of the most commonly used reference designator prefixes are, T represents transformer, CR represents control relay, R represents resistor, C represents capacitor, LS represents limit switch PB represents pushbutton, S represents switch, SS represents selector switch, TDR or TR represents time delay relay, M represents motor or motor relay, L represents indicator lamp or line phase, F represents fuse, CB represents circuit breaker and OL represents overload switch or overload contact.

The number of the reference designator is assigned by the designer beginning with the number 1. For example, control relays are numbered CR1, CR2, etc, fuses are F1, F2, etc. and so on. It is generally a courtesy of the designer to state on the electrical drawing the "Last Used Reference Designators". This is done so that anyone who is assigned the job of later modifying the machine will know where to "pick up" in the numbering scheme for any added components. For example, if the drawing stated "Last Used Reference Designators: CR15, T2, F3", then in a modification which adds a control relay, the added relay would be assigned the next sequential reference designator, CR16.

This eliminates the possibility of skipping a number or having duplicate numbers. Also, if components are deleted as part of a modification, it is a courtesy to add a line of text to the drawing stating "Unused Reference Designators:" This prevents someone who is reading the drawing from wasting time searching for a component that no longer exists. Some automation equipment and machine tool manufacturers use a reversed component numbering scheme that starts with the number and ends with the alphabetical designator. For example, instead of CR15, T2, and F3, the reference designators 15CR, 2T, and 3F are used. The components in our diagram example shown in Figure 3-18 are numbered with reference designators. The transformer is T1 and the fuse is F1. Other components will be assigned reference designators as they are added to the diagram.

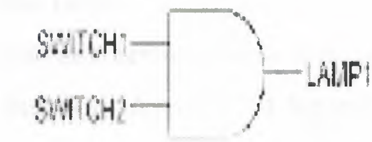


Figure 3.21 AND Circuit

To represent the circuit of Figure 3.21 in ladder logic form in an electrical machine diagram, we would utilize the power from the rails and simply add the two switches (we have assumed these are to be pushbutton switches) and lamp in series between the rails as shown in Figure 3.22. This added circuit forms what is called a rung. The reason for the name "rung" is that as we add more circuitry to the diagram, it will begin to resemble a ladder with two uprights and many rungs.

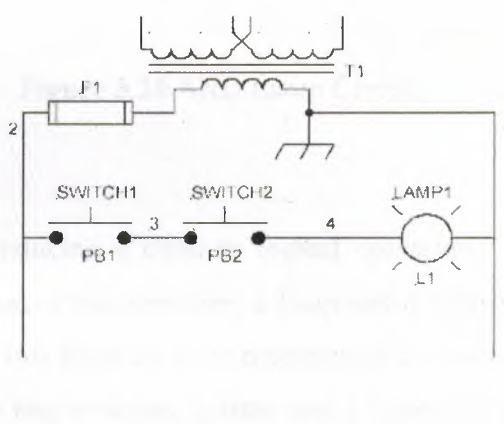


Figure 3.22 Ladder Diagram

There are a few important details that have been added along with the switches and lamp. Note that the added wires have been assigned the wire numbers 3 and 4 and the added components have been assigned the reference designators PB1, PB2, and L1. Also note that the switches are on the left and the lamp is on the right. This is a Standard convention when designing and drawing machine circuits. The controlling devices (in this case the switches) are always positioned on the left side of the rung, and the controlled devices (in this case the lamp) are always positioned on the right side of the rung. This

3.4.4 Boolean Logic and Relay Logic

Since the relays in a machine perform some type of control operation, it can be said that they perform a logical function. As with all logical functions, these control circuits must consist of the fundamental AND, OR, and INVERT logical operations. Relay coils, N/C contacts, and N/O contacts can be wired to perform these same fundamental logical functions. By properly wiring relay contacts and coils together, we can create any logical function desired.

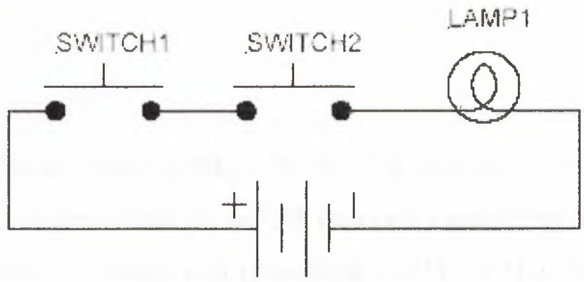


Figure 3.20 AND Lamp Circuit

3.4.4.1 AND

Generally when introducing a class to logical operations, an instructor uses the analogy of a series connection of two switches, a lamp and a battery to illustrate the AND function. Relay logic allows this function to be represented this way. Figure 3.20 shows the actual wiring connection for two switches, a lamp and a battery in an AND configuration. The lamp, LAMP1, will illuminate only when SWITCH1 AND SWITCH2 are ON. The Boolean expression for this is

$$\text{Lamp1} = (\text{Switch 1}) * (\text{Switch 2}) \qquad \dots (3.1)$$

If we were to build this function using digital logic chips, the logic diagram for Equation 3.1 and Figure 3.20 would appears as shown in Figure 3.21. However, keep in mind that we will not be doing this for machine controls.

wiring scheme is also done for safety reasons. Assume for example that we put the lamp on the left side and the switches on the right. Should there develop a short to ground in the wire from the lamp to the switches, the lamp would light without either of the switches being pressed. For a lamp to inadvertently light is not a serious problem, but assume that instead of a lamp, we had the coil of a relay that started the machine. This would mean that a short circuit would start the machine without any warning. By properly wiring the controlled device (called the load) on the right side, a short in the circuit will cause the fuse to blow when the rung is activated, thus de-energizing the machine controls and shutting down the machine.

3.4.4.2 OR

The same approach may be taken for the OR function. The circuit shown in Figure 3.23 illustrates two switches wired as an OR function controlling a lamp, LAMP2. As can be seen from the circuit, the lamp will illuminate if SWITCH 1 OR SWITCH 2 is closed; that is,depressing either of the switches will cause the lamp LAMP2 to illuminate. The Boolean expression for this circuit is

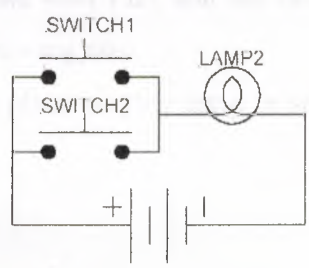


Figure 3.23 OR Lamp Circuit

$$Lamp2 = (Switch1) + (Switch2) \qquad .....(3.2)$$

For those more familiar with logic diagramming, the OR gate representation of the OR circuit in Figure 3.23 and Equation 3.2 is shown in Figure 3.24. Again, when drawing machine controls diagrams, we do not use this schematic representation.

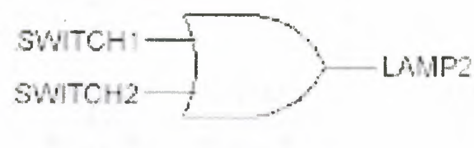


Figure 3.24 OR Circuit

We can now add this circuit to our ladder diagram as another rung as shown in Figure 3.25. Note that since the switches SWITCH1 and SWITCH2 are the same ones used in the top rung, they will have the same names and the same reference designators when drawn in rung 2.

This means that each of these two switches have two N/O contacts on the switch assembly. Some designers prefer to place dashed lines between the two PB1 switches and another between the two PB2 switches to clarify that they are operated by the same switch actuator (in this case the actuator is a pushbutton) When we have two or more components in parallel in a rung, each parallel path is called a branch. In our diagram in Figure 3.25, rung two has two branches, one with PB1 and the other with PB2. It is possible to have branches on the load side of the rung also.

For example, we could place another lamp in parallel with LAMP2 thereby creating a branch on the load side.

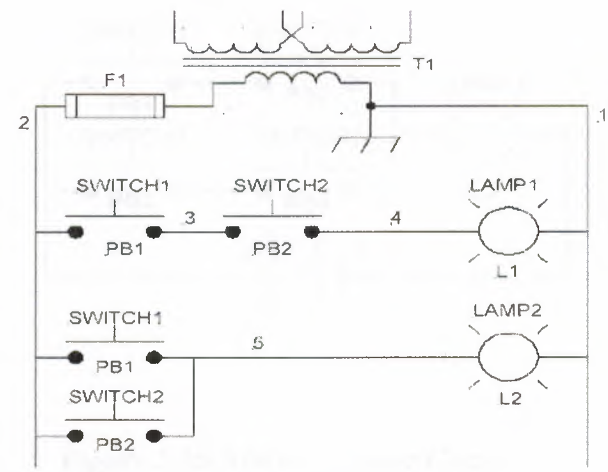


Figure 3.25 Add Rung

It is important to note that in our ladder diagram, it is possible to exchange rungs 1 and 2 without changing the way the lamps operate. This is one advantage of using ladder diagramming. The rungs can be arranged in any order without changing the way the machine operates. It allows the designer to compartmentalize and organize the control circuitry so that it is easier to understand and troubleshoot. However, keep in mind that, later in this text, when we begin PLC ladder programming, the rearranging of rungs is not recommended. In a PLC, the ordering of the rungs is critical and rearranging the order could change the way the PLC program executes.

3.4.4.3 AND OR and OR AND

Suppose that two more switches are added to the previous circuits and configure the original switch, battery and light circuit as in Figure 3.26.

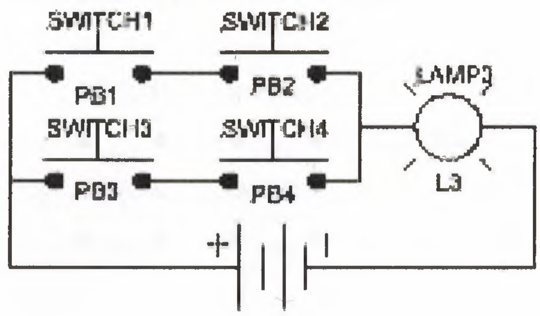


Figure 3.26 AND-OR Lamp Circuit

Notice that two switches have been added, SWITCH 3 and SWITCH 4. For this system to operate properly, the LAMP needs to light if SWITCH 1 AND SWITCH 2 are both on, OR if SWITCH 3 AND SWITCH 4 are both on. This circuit is called an AND-OR circuit. The Boolean expression for this is illustrated in Equation 3.3.

$$Lamp3 = (Switch1 * Switch2) + (Switch3 * Switch4) \quad ...(3.3)$$

The opposite of this circuit, called the OR-AND circuit is shown in Figure 3.27. For this circuit, LAMP4 will be on whenever SWITCH1 OR SWITCH2, AND SWITCH3 OR SWITCH4 are on. For circuits that are logically complicated, it sometimes helps to list all the possible combinations of inputs (switches) that will energize a rung.

For this OR-AND circuit, LAMP4 will be lit when the following combinations of switches are on:

SWITCH1 and SWITCH3

SWITCH1 and SWITCH4

SWITCH2 and SWITCH3

SWITCH2 and SWITCH4

SWITCH1 and SWITCH2 and SWITCH3

SWITCH1 and SWITCH2 and SWITCH4

SWITCH1 and SWITCH3 and SWITCH4

SWITCH2 and SWITCH3 and SWITCH4

SWITCHl and SWITCH2 and SWITCH3 and SWITCH4

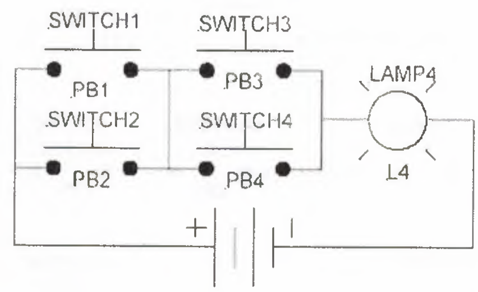


Figure 3.27 OR-AND lamp circuit

The Boolean expression for the OR-AND circuit is shown in Equation 3-4

Lamp3 = (Switch1+Switch2) * (Switch3+Switch4) .... (3.4)

These two rungs will now be added to our ladder diagram and are shown in Figure 3.28. Look closely at the circuit and follow the possible power paths to energize LAMP3 and LAMP4. You should see two possible paths for LAMP3: SWITCHl AND SWITCH2 SWITCH3 AND SWITCH4 Either of these paths will allow LAMP3 to energize. For LAMP4, you should see four

possible paths:

SWITCHl AND SWITCH3

SWITCHl AND SWITCH4

SWITCH2 AND SWITCH3

SWITCH2 AND SWITCH4.

Any one of these four paths will energize LAMP4.

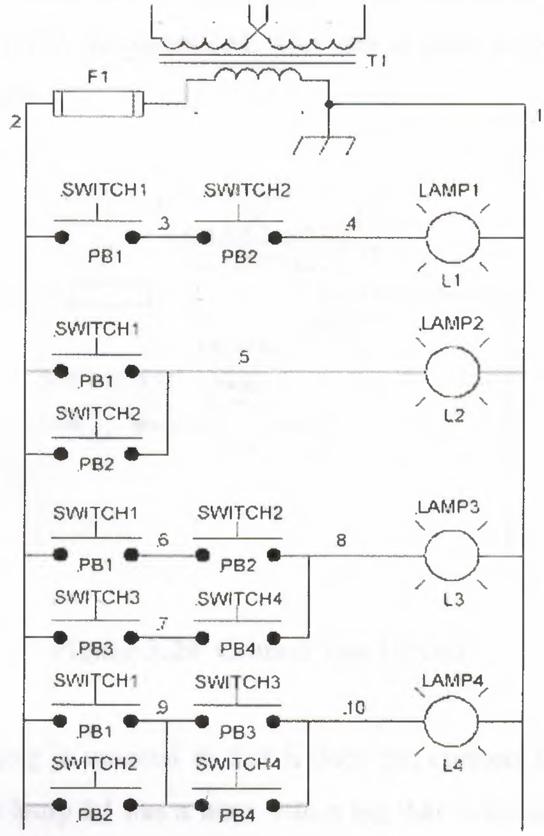


Figure 3.28 Add Rungs 3 & 4

Now that we have completed a fundamental study of ladder diagram, we should begin investigating some standard ladder logic circuits that are commonly used on electric machinery.

Keep in mind that these circuits are also used in programming programmable logic controllers.

3.4.5 Ground Test

Earlier, we drew a ladder diagram of some switch circuits which included the control transformer. We connected the right side of the transformer to ground (the frame of the machine). For safety reasons, it is necessary to occasionally test this ground to be sure that is it still connected because loss of the ground circuit will not affect the performance of the machine and will therefore go unnoticed. This test is done using a ground test circuit, and is shown in Figure 3.29.

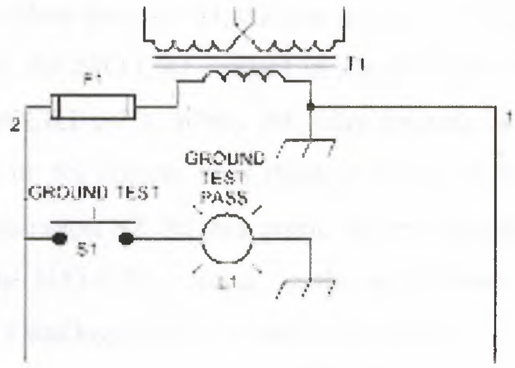


Figure 3.29 Ground Test Circuit

Notice that this rung is unusual in that it does not connect to the right rail. In this case, the right side fo the lamp L1 has a wire with a lug that is fastened to the frame of the machine under a screw. When the pushbutton S1 is pressed, the lamp L1 lights if there is a path for current to flow through the frame of the machine back to the X2 side of the control transformer. If the lamp fails to light, it is likely that the transformer is no longer grounded.

The machine should not be operated until an electrician checks and repairs the problem. In some cases, the lamp L1 is located inside the pushbutton switch S1 (this is called an illuminated switch).

3.4.6 The Latch (with Sealing/Latching Contacts)

Occasionally, it is necessary to have a relay "latch" on so that if the device that activated the relay is switched off, the relay remains on. This is particularly useful for making a momentary pushbutton switch perform as if it were a maintained switch. Consider, for example, the pushbuttons that switch a machine on and off. This can be done with momentary pushbuttons if we include a relay in the circuit that is wired as a latch as shown in the ladder diagram segment Figure 3.30 (the transformer and fuse are not shown for clarity). Follow in the diagram as we discuss how this circuit operates. First, when power is applied to the rails, CR1 is initially de-energized and the N/O CR1 contact in parallel with switch S1 is open also.

Since we are assuming S1 has not yet been pressed, there is no path for current to flow through the rung and it will be off. Next, we press the START switch S1. This provides a path for current flow through S1, S2 and the coil of CR1, which energizes CR1. As soon as CR1 energizes, the N/O CR1 contact in parallel with S1 closes (since the CR1 contact is operated by the CR1 coil). When the relay contact closes, we no longer need switch S1 to maintain a path for current flow through the rung. It is provided by the N/O CR1 contact and N/C pushbutton S2. At this point, we can release S1 and the relay CR1 will remain energized. The N/O CR1 contact "seals" or "latches" the circuit on, and the contact is therefore called a sealing contact or latching contact.

The circuit is de-energized by pressing the STOP switch S2. This breaks the flow of current through the rung, de-energizes the CR1 coil, and opens the CR1 contact in parallel with S1. When S2 is released, there will still be no current flow through the rung because both S1 and the CR1 N/O contact are open.

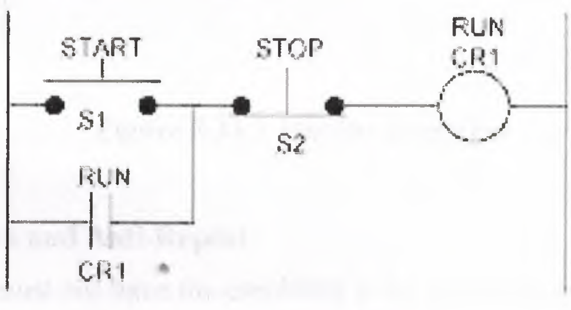


Figure 3.30 Latch Circuit

The latch circuit has one other feature that cannot be obtained by using a maintained switch. Should power fail while the machine is on, the latch rung will, of course, deenergize. However, when power is restored, the machine will not automatically restart. It must be manually restarted by pressing S1. This is a safety feature that is required on all heavy machines.

3.4.7 2-Handed Anti-Tie Down, Anti-Repeat

Many machines used in manufacturing are designed to go through a repeated fixed cycle. An example of this is a metal cutter that slices sheets of metal when actuated by an operator. By code, all cyclic machines must have 2-handed RUN actuation, and antirepeat and anti-tie down features. Each of these is explained below.

3.4.7.1 2-Handed RUN Actuation

This means that the machine can only be cycled by an operator pressing two switches simultaneously that are separated by a distance such that both switches cannot be pressed by one hand. This assures that both of the operator's hands will be on the switches and not in the machine when it is cycling. This is simply two palm switches in series operating a RUN relay CR1, as shown in Figure 3.31.

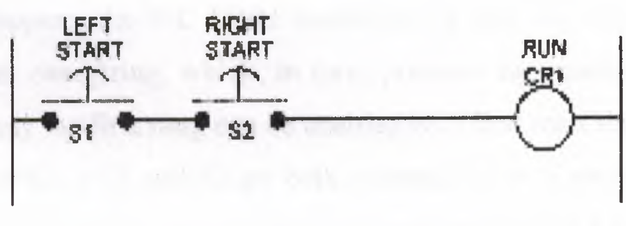


Figure 3.31 2-Handed Operation

3.4.7.2 Anti-Tie Down and Anti-Repeat

The machine must not have the capability to be cycled by tying or taping down one of the two RUN switches and using the second to operate the machine. In some cases, machine operators have done this so that they have one hand available to guide raw material into the machine while it is cycling, an extremely hazardous practice. Anti-tie down and anti-repeat go hand-in-hand by forcing both RUN switches to be cycled off and then on each time to make the machine perform one cycle. This means that both RUN switches must be pressed at the same time within a small time window, usually ½ second. If one switch is pressed and then the other is pressed after the time window has expired, the machine will not cycle. Since both switches must be pressed within a time window, we will need a time delay relay for this feature, specifically a delay-on, or TON, relay. Consider the circuit shown in Figure 3.32.

Notice that we have taken the 2-handed circuit that we constructed in Figure 3.31 and added additional circuitry to perform the anti-tie down. Follow along in the circuit as we analyze how it operates. The two palm switches S1 and S2 now each have two N/O contacts. In the first rung they are connected in series and in the second rung, they are connected in parallel. This means that in order to energize CR1, both S1 and S2 must be pressed, and in order to energize TDR1, either S1 or S2 must be pressed. When power is applied to the rails, assuming neither S1 nor S2 are pressed, both relays CR1 and TDR1 will be de-energized. Now we press either of the two palm switches. Since we did not yet press both switches, relay CR1 will not energize.

However, in the second rung, since one of the two switches is pressed, we have a current path through the pressed switch to the coil of TDR1. The time delay relay TDR1 begins to count time. As long as we hold either switch depressed, TDR1 will time out in ½ second. When this happens, the N/C TDR1 contact in the first rung will open, and the rung will be disabled from energizing, which, in turn, prevents the machine from running. At this point, the only way the first rung can be enabled is to first reset the time delay relay by releasing both S1 and S2. If S1 and S2 are both pressed within ½ second of each other, the TDR1 N/C contact in the first rung will have not yet opened and CR1 will be energized. When this happens, the N/O CR1 contact in the first rung seals across the TDR1 contact so that when the time delay relay TDR1 times out, the first rung will not be disabled.

As long as we hold both palm switches on, CR1 will remain on and TDR1 will remain timed out. If we momentarily release either of the palm switches, CR1 de-energizes. When this happens, we loose the sealing contact across the N/C TDR1 contact in the first rung. If we re-press the palm switch, CR1 will not re-energize because TDR1 is still timed out and is holding its N/C contact open in the first rung. The only way to get CR1 re-energized is to reset TDR1 by releasing both S1 and S2 and then pressing both again.

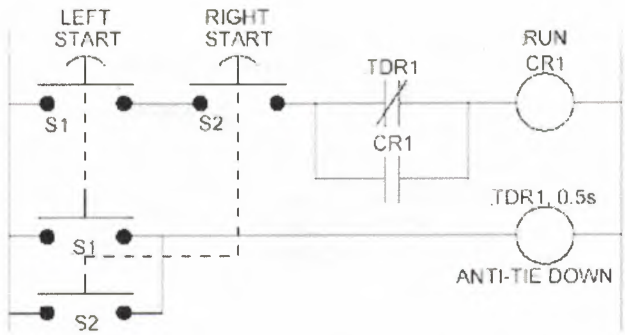


Figure 3.32 2-Handed Operation With Anti-tie Dow and Anti-repeat

3.4.8 Single Cycle

When actuated, the machine must perform only one cycle and then stop, even if the operator is still depressing the RUN switches. This prevents surprises and possible injury for the operator if the machine should inadvertently go through a second cycle. Therefore, circuitry is usually needed to assure that once the machine has completed one cycle of operation, it stops and waits for the RUN switch(es) to be released and then pressed again. In order for the circuitry to be able to determine where the machine is in its cycle, a cam-operated limit switch (like the one previously illustrated in Figure 3.11) must be installed on the machine as shown in Figure 3.33.

The cam is mounted on the mechanical shaft of the machine which rotates one revolution for each cycle of the machine. There is a spring inside the switch that pushes the actuator button, lever arm, and roller to the right and keeps the roller constantly pressed against the cam surface. The mechanism is adjusted so that when the cam rotates, the roller of the switch assembly rolls out of the detent in the cam which causes the lever arm to press the switch's actuator button. The actuator remains pressed until the cam makes one complete revolution and the detent aligns with the roller.

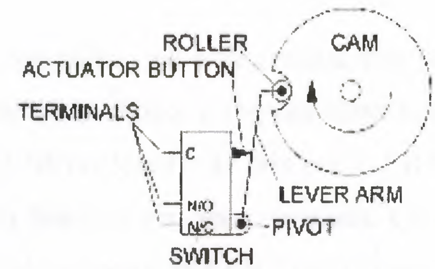


Figure 3.33 Cam-Operated Limit Switch

The cam is aligned on the shaft so that when the machine is at the stopping point in its cycle (i.e., between cycles), the switch roller is in the cam detent. The switch has three terminals, C (common, or wiper), N/O (normally open), and N/C (normally closed). When the machine is between cycles, the N/O terminal is open and the N/C is connected to C. While the machine is cycling, the N/O is connected to C and the N/C is open. The circuit to implement the single-cycle feature is shown in Figure 3.34. Note that we will be using both the N/O and N/C contacts of the cam-operated limit switch LS1. Also note that, for the time being, the START switch S1 is shown as a single pushbutton switch. Later we will add the 2-handed anti-tie down, and anti-repeat circuitry to make a complete cycle control system. Follow along on the ladder diagram as we analyze how this circuit works.

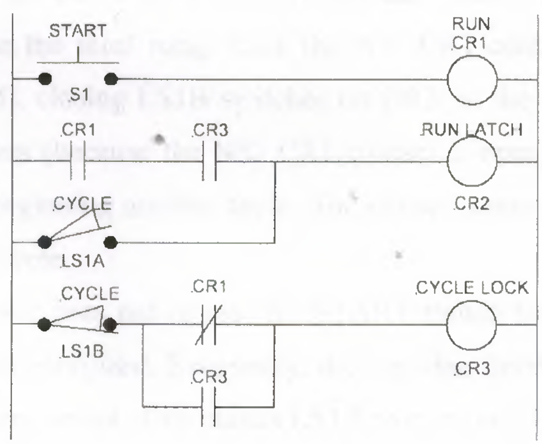


Figure 3.34 Single Cycle Circuit

When the rails are energized, we will assume that the machine is mechanically positioned so that the cam switch is sitting in the cam detent (i.e., the N/O contact LS1A is open and the N/C contact LS1B is closed). At this point, CR1 in the first rung will be off (because the START switch has not yet been pressed), CR2 in the second rung is off (because CR1 is off and LS1A is open), and CR3 in the third rung is on because LS1B is closed and the N/C CR1 contact is closed. As soon as CR3 energizes, the CR3 N/O contact in the third rung closes. At this point, the circuit is powered and the machine is stopped, but ready to cycle. Now we press the START switch S1. This energizes CR1. In the second rung, the N/O CR1 contact closes. Since the N/O CR3 contact is already closed (because CR3 is on), CR2 energizes. This applies power to the machine and causes the cycle to begin. As soon as the cam switch rides out of the cam detent, LS1A closes and LS1B opens. When this happens, LS1A in the second rung seals CR2 on. In the third rung, LS1B opens which de-energizes CR3. Since CR2 is still on, the machine continues in its cycle. The operator may or may not release the START switch during the cycle. However, in either case it will not affect the operation of the machine. We will analyze both cases:

- If the operator does release the START switch before the machine finishes it's cycle, CR1 will de-energize. However, in the second rung it has no immediate effect because the contacts CR1 and CR3 are sealed by LS1A. Also, in the third rung, it has no immediate affect because LS1B is open which disables the entire rung. Eventually, the machine finishes it's cycle and the cam switch rides into the cam detent. This causes LS1A to open and LS1B to close. In the third rung, since the N/C CR1 contact is closed (CR1 is off because S1 is released), closing LS1B switches on CR3. In the second rung, when LS1A opens CR2 de-energizes (because the N/O CR1 contact is open). This stops the machine and prevents it from beginning another cycle. The circuit is now back in it's original state and ready for another cycle.

- If the operator does not release the START switch before the machine finishes it's cycle, CR1 remains energized. Eventually, the machine finishes it's cycle and the cam switch rides into the cam detent. This causes LS1A to open and LS1B to close. In the third rung, the closing of LS1B has no effect because N/C CR1 is open. In rung 2, the opening of LS1A causes CR2 to de-energize, stopping the machine. Then, when the operator releases

S1, CR1 turns off, and CR3 turns on. The circuit is now back in it's original state and ready for another cycle. There are some speed limitations to this circuit. First, if the machine cycles so quickly that the cam switch "flies" over the detent in the cam, the machine will cycle endlessly. One possible fix for this problem is to increase the width of the detent in the cam. However, if this fails to solve the problem, a non-mechanical switch mechanism must be used. Normally, the mechanical switch is replaced by an optical interrupter switch and the cam is replaced with a slotted disk. This will be covered in a later chapter. Secondly, if the machine has high inertia, it is possible that it may "coast" through the stop position. In this case, some type of electrically actuated braking system must be added that will quickly stop the machine when the brakes are applied. For our circuit, the brakes could be actuated by a N/C contact on CR2.

3.4.9 Combined Circuit

Figure 3.35 shows a single cycle circuit with the START switch replaced by the two rungs that perform the 2-handed, anti-tie down, and anti-repeat functions. In this circuit, when both palm switches are pressed within 0.5 second of each other, the machine will cycle once and stop, even if both palm switches remain pressed. Afterward, both palm switches must be released and pressed again in order to make the machine cycle again.

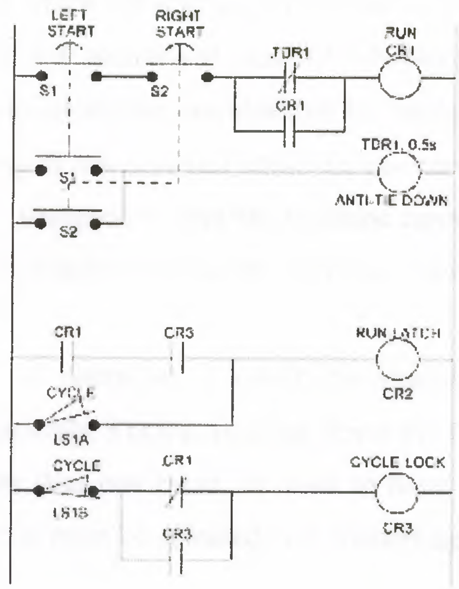


Figure 3.35 2-Handed Anti-tie Down, Anti-repeat Single Cycle Circuit

3.5 Machine Control Terminology

There are some words that are used in machine control systems that have special meanings. For safety purposes, the use of these words is explicit and can have no other meaning. They are generally used when naming control circuits, labeling switch positions on control panels, and describing modes of operation of the machine.

A list of some of the more important of these terms appears below.

ON This is a machine state in which power is applied to the machine and to the machine control circuits. The machine is ready to RUN. This is also sometimes call the STANDBY state.

OFF Electrically, the opposite of ON. Power is removed from the machine and the machine control circuits. In this condition, pressing any switches on the control panel should have no effect.

RUN A state in which the machine is cycling or performing the task for which it is designed. This state can only be started by pressing RUN switches. Don't confuse this state with the ON state. It is possible for a machine to be ON but not RUNNING.

STOP The state in which the machine is ON but not RUNNING. If the machine is RUNNING, pressing the STOP switch will cause RUNNING to cease.

JOG A condition in which the machine can be "nudged" a small amount to allow for the accurate positioning of raw material while the operator is holding the material. The machine controls must be designed so that the machine cannot automatically go from the JOG condition to the RUN condition while the operator is holding the raw material. INCH Same as JOG.

CYCLE A mode of operation in which the machine RUNs for one complete operation and then automatically STOPs. Holding down the CYCLE button will not cause the machine to RUN more than one cycle. In order to have the machine execute another CYCLE, the CYCLE button must be released and pressed again. This mode is sometimes called SINGLE CYCLE.

3.6 Summary

Although this chapter gives the reader a basic understanding of conventional machine controls, it is not intended to be a comprehensive coverage of the subject. Expertise in the area of machine controls can best be achieved by actually practicing the trade under the guidance of experienced machine controls designers. However, an understanding of basic machine controls is the foundation needed to learn the programming language of Programmable Logic Controllers. As we will see in subsequent chapters, the programming language for PLCs is a graphic language that looks very much like machine control electrical diagrams.

CHAPTER FOUR

DISCRETE INPUTS/OUTPUTS

4.1 Introduction

To understand discrete control of a programmable controller the same simple lamp circuit illustrated with forcing will be used. This is only for instructional purposes as a circuit this simple would not require a programmable controller. In this example the lamp is off when the switch is open and on when the switch is closed.

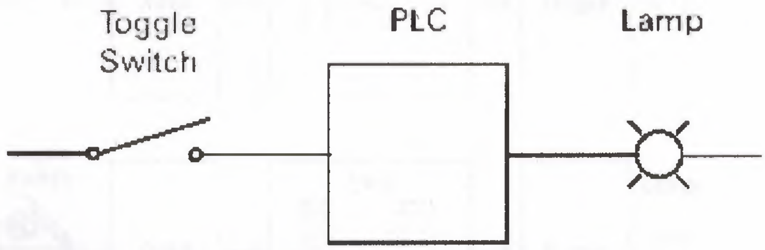


Figure 4.1 Logical Operation of a Lamp using PLC

4.2 Wiring

To accomplish this task, a switch is wired to the input of the PLC and an indicator light is wired to output terminal.

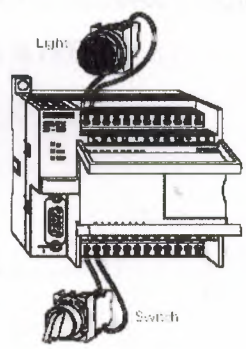


Figure 4.2 Central Processing Unit

The following drawing illustrates the sequence of events. A switch is wired to the input module of the PLC. A lamp is wired to the output module. The program is in the CPU. The CPU scans the inputs. When it finds the switch open I0.0 receives a binary 0. This instructs Q0.0 to send a binary 0 to the output module. The lamp is off. When it finds the switch closed I0.0 receives a binary 1. This instructs Q0.0 to send a binary 1 to the output module, turning on the lamp.

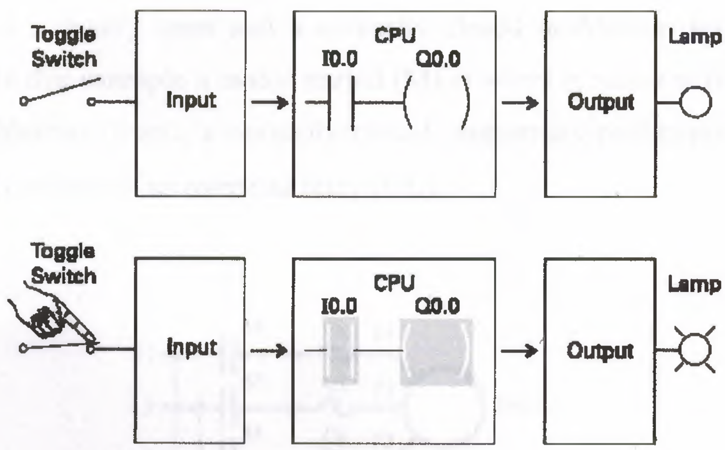
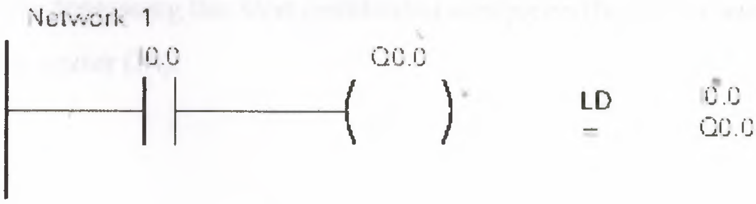


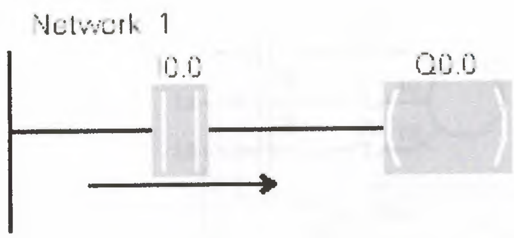
Figure 4.3 Switching fuction of a PLC

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.



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.



LD I0.0
= Q0.0

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).

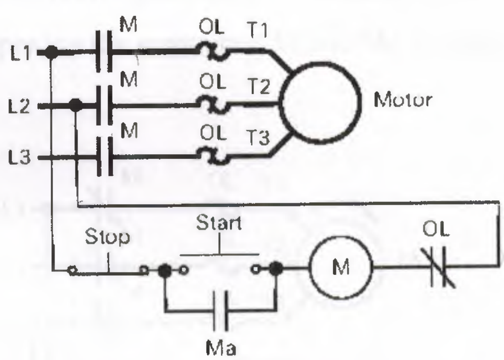


Figure 4.4 Off-Mode of a Motor

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

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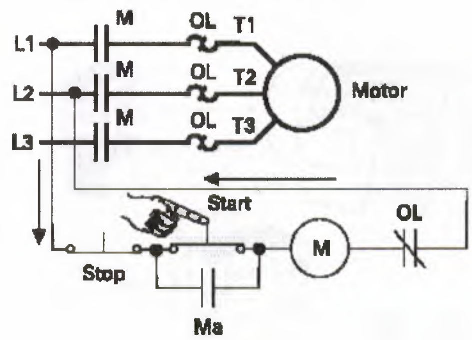


Figure 4.5 Start-Up Mode of a Motor

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.

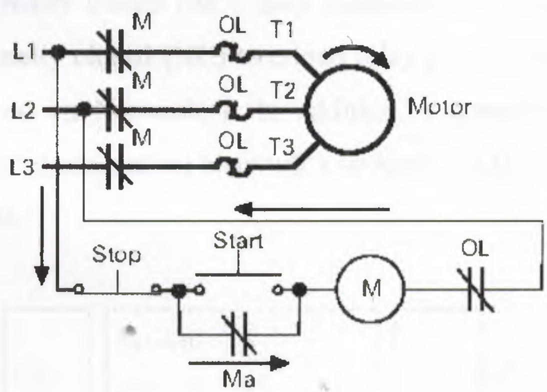


Figure 4.6 On-Mode of a Motor

This control task can also be accomplished with a PLC.

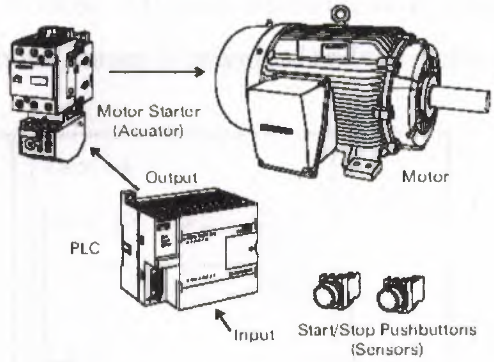


Figure 4.7 Equipments Of PLC

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.

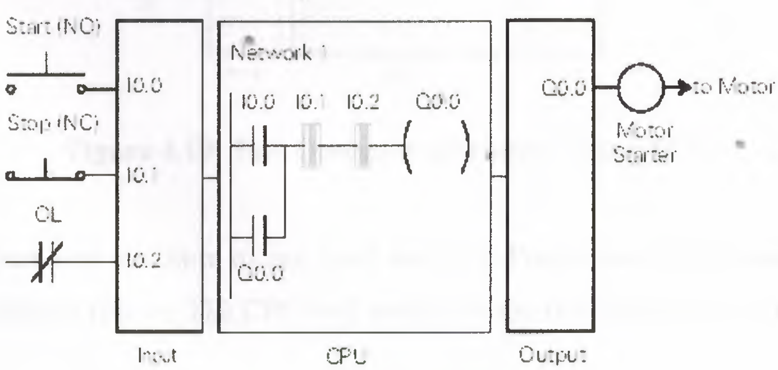


Figure 4.8 Input/Output Diagram of a PLC Circuit

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.

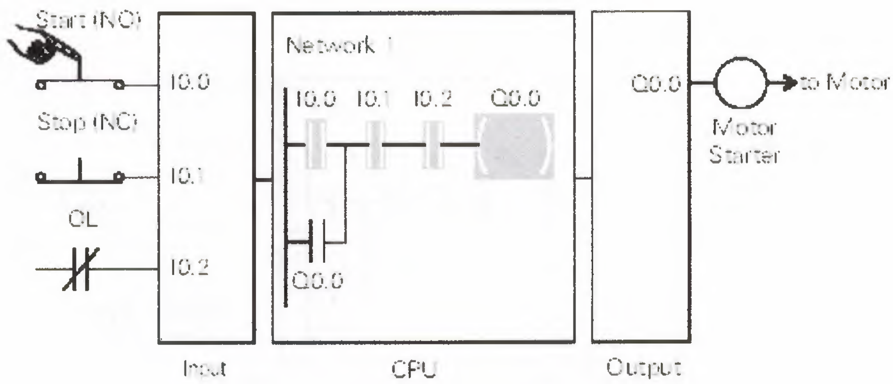


Figure 4.9 Start Operation of a Motor Using PLC

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.

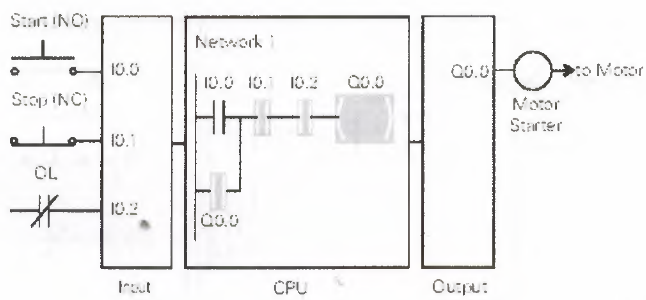


Figure 4.10 Stop Operation of a Motor Using PLC

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.

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.

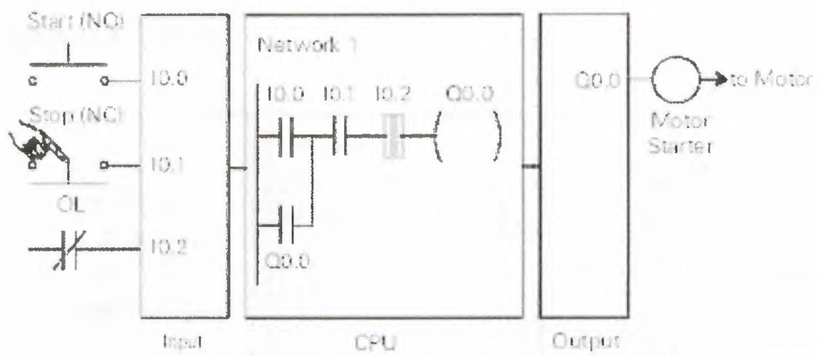


Figure 4.11 Reset Operation of a Motor Using PLC

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.

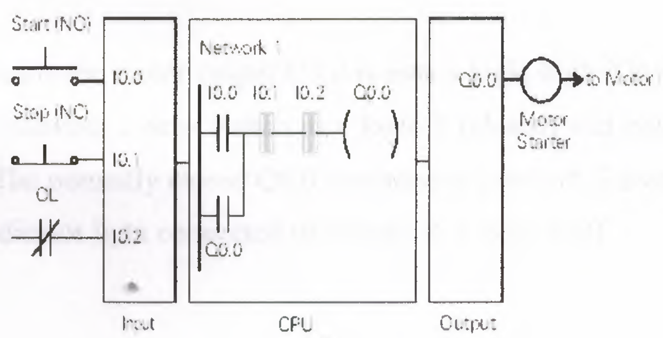


Figure 4.12 Operation of a Motor Using PLC

4.3 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 Q0.1 on Network 3 lights are closed and the STOP indicator light, connected to output Q0.2 is on.

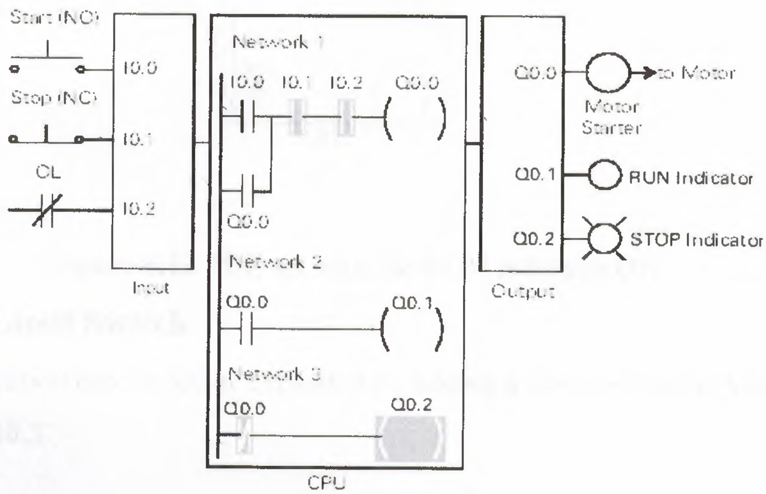


Figure 4.13 PLC set with the STOP Indicator ON

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.

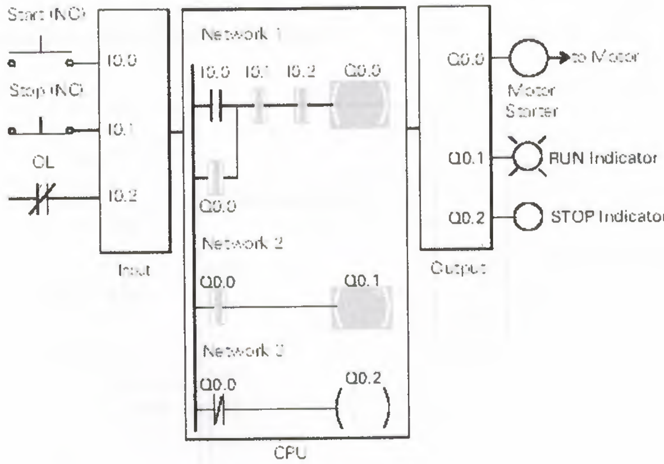


Figure 4.13 PLC set with the RUN Indicator ON

4.4 Adding a Limit Switch

The application can be futher expanded by adding a limit switch with normally open contacts to input I0.3.

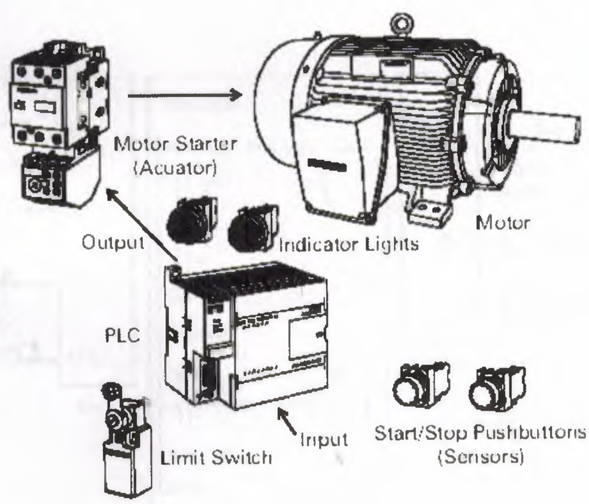


Figure 4.14 Hardware set of PLC set

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 switchís 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.

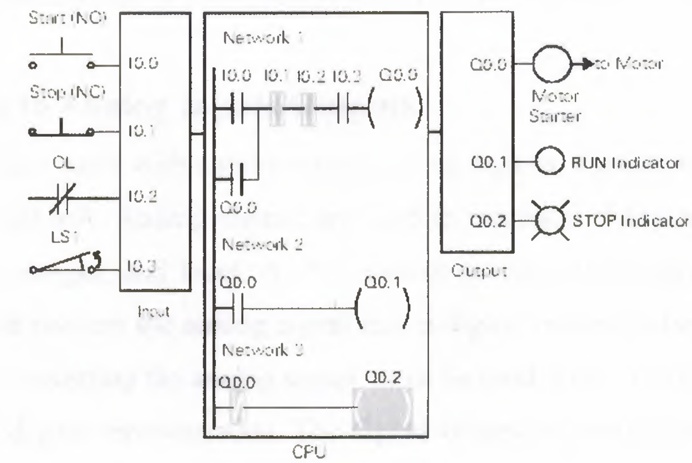


Figure 4.15 PLC set with the Limit Switch

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.

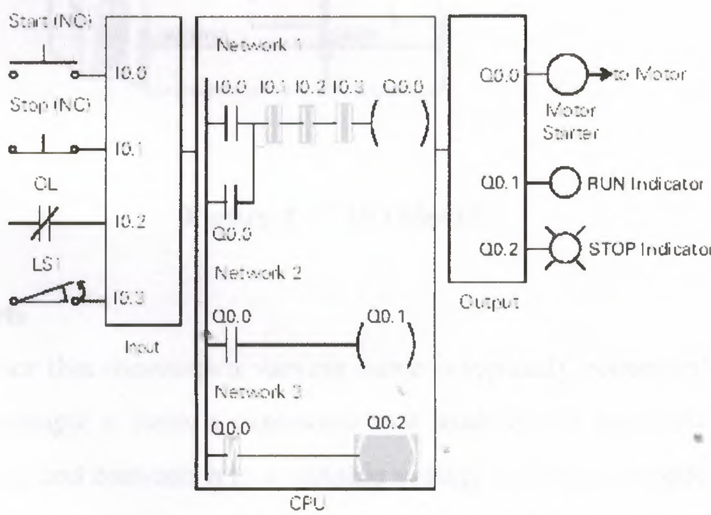


Figure 4.16 Additional Start/Stop Pushbuttons of PLC

The PLC program can be expanded to accomodate many commercial and industrial applications. Additional Start/Stop Pushbuttons and indicator lights can be added for remote operation, or control of a second motor starter and motor. Overtravel limit switches can be added along with proximity switches for sensing object position. The applications are only limited by the number of I/Os and amount of memory available on the PLC.

4.5 Introduction to Analog Inputs/Outputs

PLCs must also work with continuous or analog signals. Typical analog signals are 0 - 10 VDC or 4 - 20 mA. Analog signals are used to represent changing values such as speed, temperature, weight, and level. A PLC cannot process these signals in an analog form. The PLC must convert the analog signal into a digital representation. An expansion module, capable of converting the analog signal, must be used. The S7-200 converts analog values into a 12-bit digital representation. The digital values are transferred to the PLC for use in register or word locations.

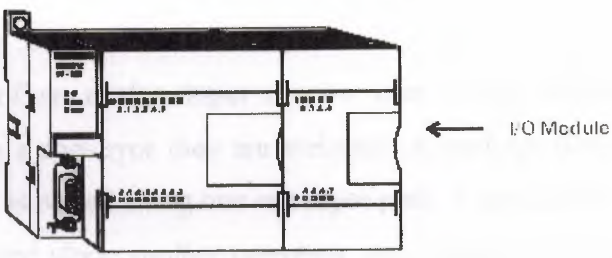


Figure 4.17 I/O Module

4.5.1 Analog Inputs

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 outputs 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.

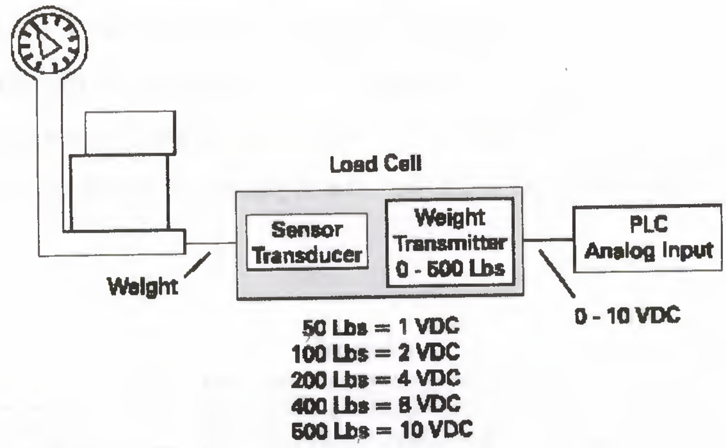


Figure 4.18 An example of analog input to the PLC

Application example:

An example of an analog input can be seen in the following illustration. As packages move along a 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.

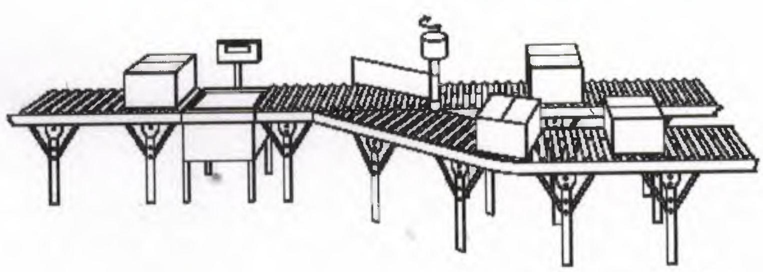


Figure 4.19 Another example of analog input to the PLC

4.5.2 Analog Outputs

Analog outputs are used in applications requiring control capability of field devices which respond to continuous voltage or current levels. Analog outputs may be used as a variable reference for control valves, chart recorders, electric motor drives, analog meters, and pressure transducers. Like analog inputs, analog outputs are generally connected to a controlling device through a transducer. The transducer takes the voltage signal and, depending on the requirement, amplifies, reduces, or changes it into another signal which controls the device. In the following example a 0 - 10 VDC signal controls a 0 - 500 Lbs. scale analog meter.

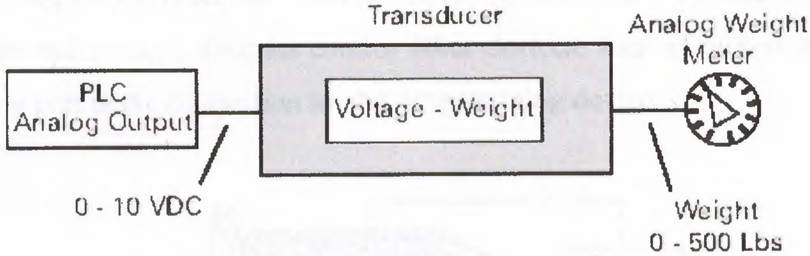


Figure 4.20 One another example of analog input to the PLC

CHAPTER FIVE

S7-200 MICRO PLCs

5.1 Introduction

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.

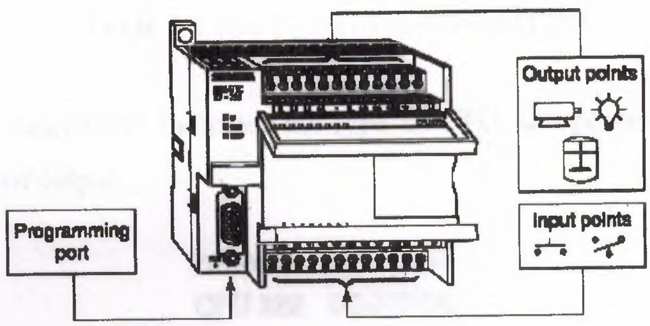


Figure 5.1 S7-200 Micro PLC

5.2 S7-200 Models

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

Model Description	Power Supply	Input Types	Output Types
221 DC/DC/DC 221 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	6 DC Inputs 6 DC Inputs	4 DC Outputs 4 Relay Outputs
222 DC/DC/DC 222 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 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 VAC 47-63 Hz	14 DC Inputs 14 DC Inputs	10 DC Outputs 10 Relay Outputs
226 DC/DC/DC 226 AC/DC/Relay	20.4-28.8 VDC 85-264 VAC 47-63 Hz	24 DC Inputs 24 DC Inputs	16 DC Outputs 15 Relay Outputs

Table 5.1 The Types of the S7-200 CPU

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

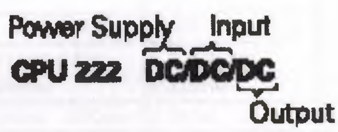


Figure 5.2 Description

5.3 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.

Feature	CPU 221	CPU 222	CPU 224	CPU 226
Memory				
Program	4 kbytes	4 kbytes	8 kbytes	8 kbytes
User Data	2 kbytes	2 kbytes	5 kbytes	5 kbytes
Memory Type	EEPROM	EEPROM	EEPROM	EEPROM
Memory Cartridge	EEPROM	EEPROM	EEPROM	EEPROM
Data Backup	50 Hours	50 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
Maximum Number of Expansion Modules	None	2	7	7
Max Digital I/O with Expansion	6 In/4 Out	40 In/38 Out	94 In/74 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
Instructions				
Boolean Execution Speed	0.37 μs/Inst.	0.37 μs/Inst.	0.37 μs/Inst.	0.37 μs/Inst.
Internal Relays	256	256	256	256
Counters	256	256	256	256
Timers	256	256	256	256
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 (30 KHz)	4 (30 KHz)	6 (30 KHz)	6 (30 KHz)
Analog Adjustments	1	1	2	2
Pulse Outputs	2 (20 KHz DC)	2 (20 KHz DC)	2 (20 KHz DC)	2 (20 KHz DC)
Communication Interrupts	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)
Hardware Input Interrupts	4	4	4	4
Real Time Clock	Yes (Cartridge)	Yes (Cartridge)	Yes (Built In)	Yes (Built In)
Password Protection	Yes	Yes	Yes	Yes
Communications				
Number of Ports	1 (RS 485)	1 (RS 485)	1 (RS 485)	2 (RS 485)
Protocols Supported Port 0	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)

Table 5.2 Features of the S7-200 CPU

5.4 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.

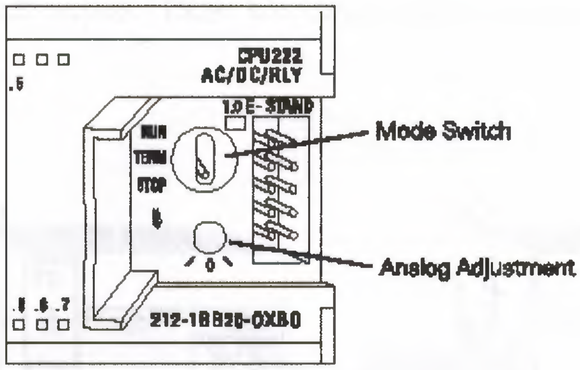


Figure 5.3 Analog Adjustment and Mode Switch

5.5 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.

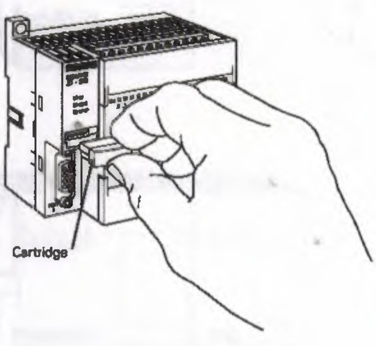


Figure 5.4 Optional Cartridge

5.6 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.

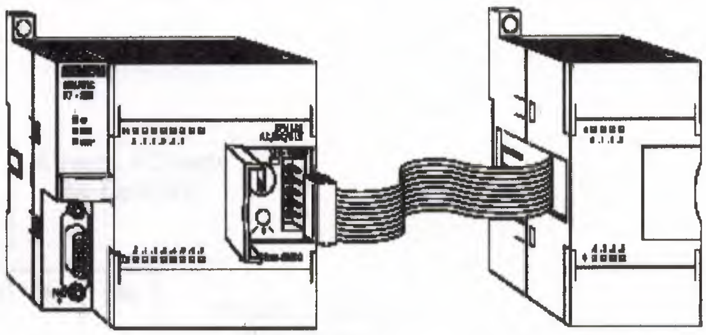


Figure 5.5 Expansion Modules

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

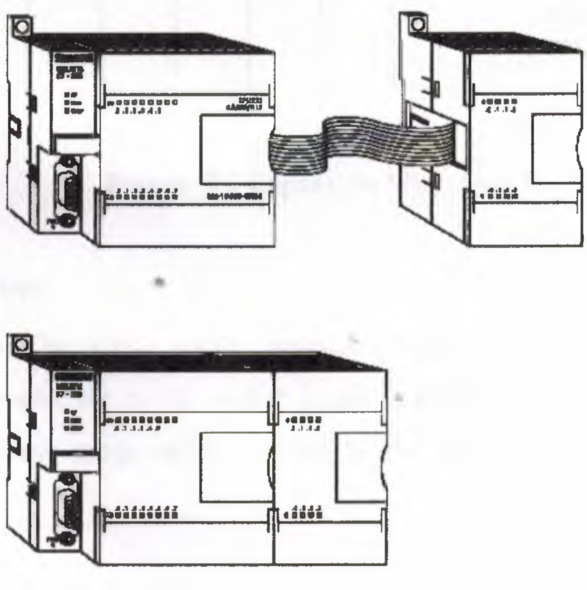


Figure 5.6 Ribbon Connector

5.7 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 comes with 24 digital inputs and 16 digital outputs. The 226 will accept up to 7 expansion modules.

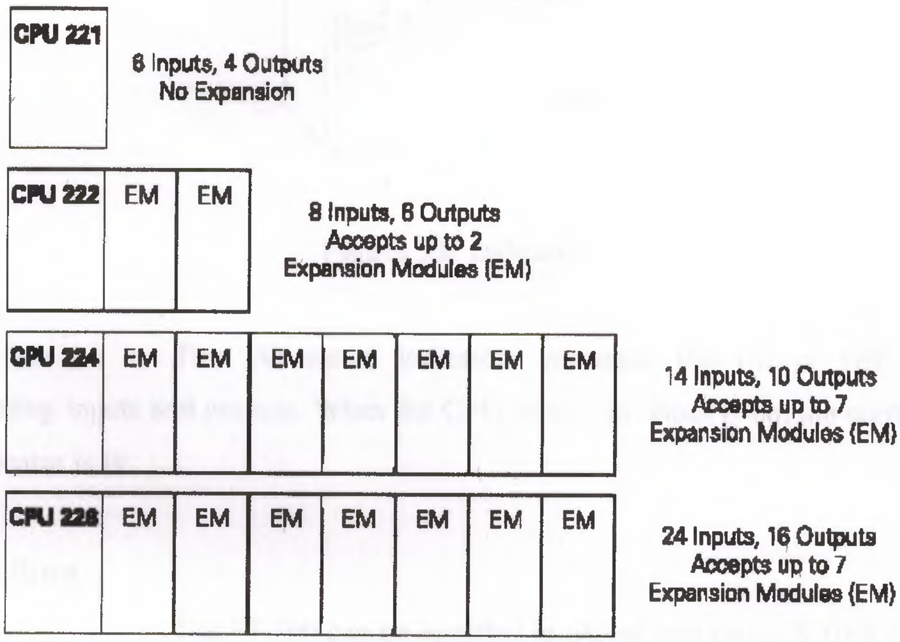


Figure 5.7 Expansion Modules

5.8 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.

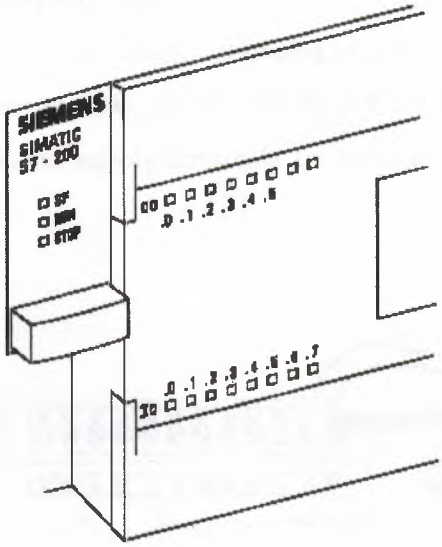


Figure 5.8 Indicator

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.

5.9 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.

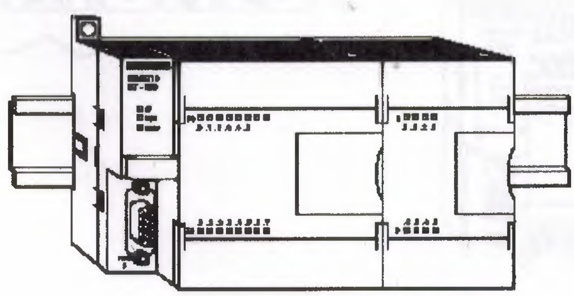


Figure 5.9 Simens S7-200

5.10 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. The power supply terminals are located on the far right side of the top terminal strip.

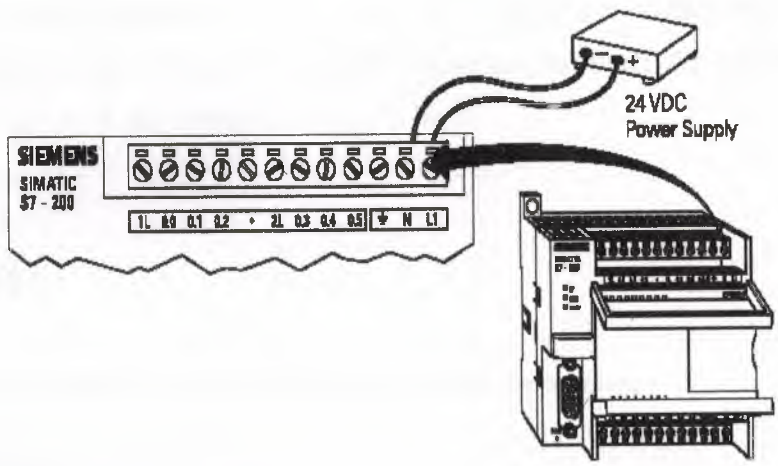


Figure 5.10 External Power Supply

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

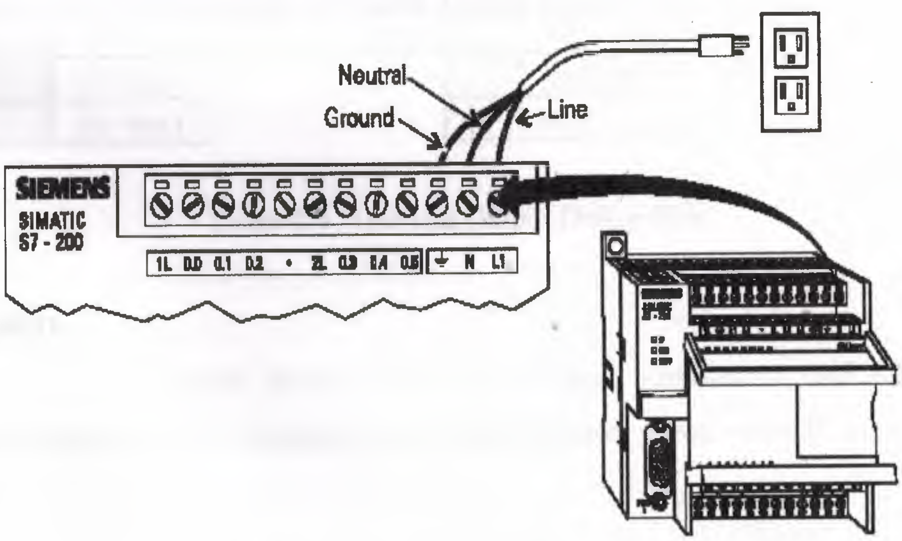


Figure 5.11 VAC Power Supply

5.11 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.

I0.0	1st Input	I1.0	9th Input	Q0.0	1st Output	Q1.0	9th Output
I0.1	2nd Input	I1.1	10th Input	Q0.1	2nd Output	Q1.1	10th Output
I0.2	3rd Input	I1.2	11th Input	Q0.2	3rd Output		
I0.3	4th Input	I1.3	12th Input	Q0.3	4th Output		
I0.4	5th Input	I1.4	13th Input	Q0.4	5th Output		
I0.5	6th Input	I1.5	14th Input	Q0.5	6th Output		
I0.6	7th Input			Q0.6	7th Output		
I0.7	8th Input			Q0.7	8th Output		

Table 5.3 Input and Output Designation

5.12 Inputs

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

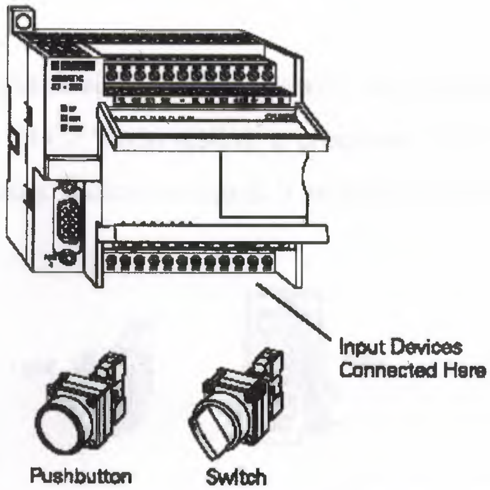


Figure 5.12 S7-200 Inputs

5.13 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. For example, 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.

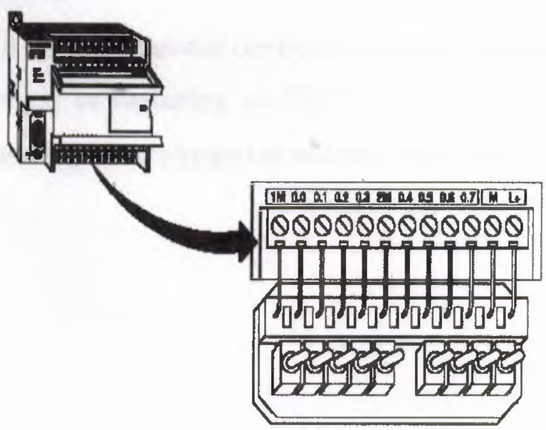


Figure 5.13 Input Simulator

5.14 Outputs

Output devices, such as relays, are connected to the terminal strip under the top cover of the PLC. When testing a program, it is not necessary to connect output devices. The LED status indicators signal if an output is active.

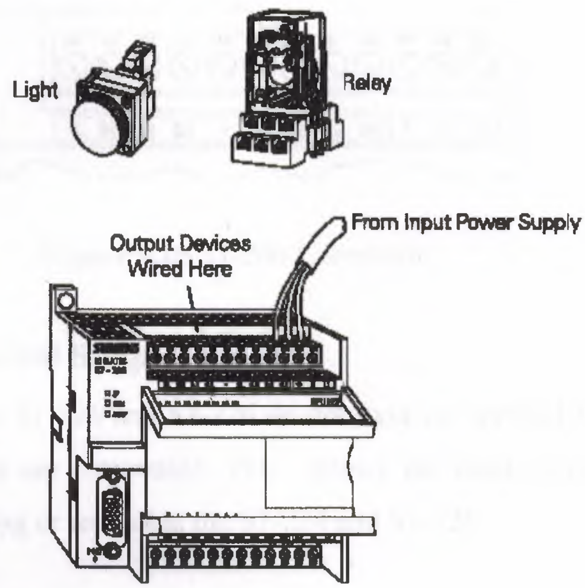


Figure 5.14 Output Devices

5.15 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.

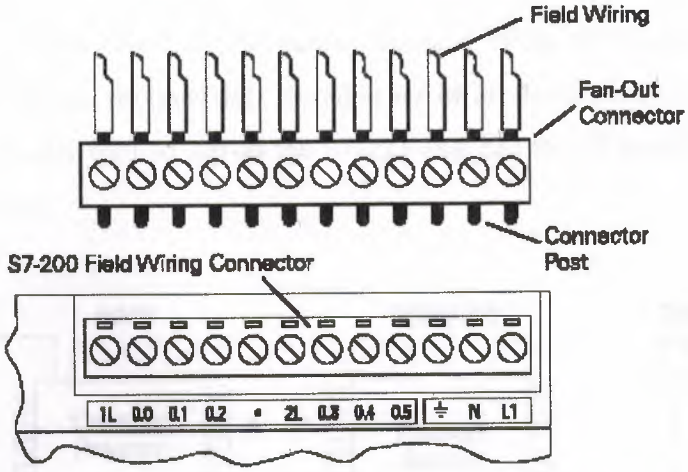


Figure 5.15 S7-200 Connector

5.16 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.

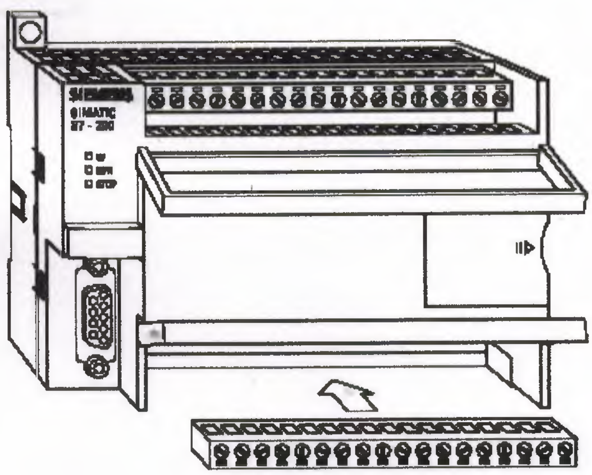


Figure 5.16 Removable Terminal Strip

5.17 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 72 hours.

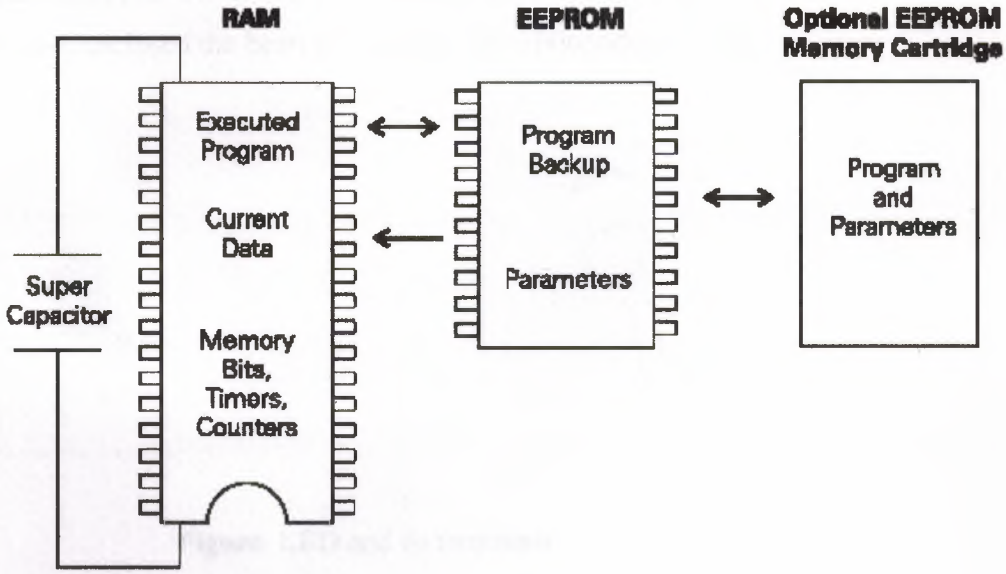


Figure 5.17 Super Capacitor

CHAPTER SIX

EQUIPMENT OF PROJECT

6.1 What is Inside an LED?

LED's are special diodes that emit light when connected in a circuit. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not. A clear (or often colored) epoxy case enclosed the heart of an LED, the semiconductor chip.

Figure LED and its terminals

The two wires extending below the LED epoxy enclosure, or the "bulb" indicate how the LED should be connected into a circuit. The negative side of an LED lead is indicated in two ways: 1) by the flat side of the bulb, and 2) by the shorter of the two wires extending from the LED. The negative lead should be connected to the negative terminal of a battery. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 milliamperes. Voltages and currents substantially above these values can melt a LED chip.The most important part of a light emitting diode (LED) is the semiconductor chip located in the center of the bulb as shown at the right. The chip has two regions separated by a junction. The p region is dominated by positive electric charges, and the n region is dominated by negative electric charges. The junction acts as a barrier to the flow of electrons between the p and the n regions. Only when sufficient voltage is applied to the semi-conductor chip, can the current flow, and the electrons cross the junction into the p region.

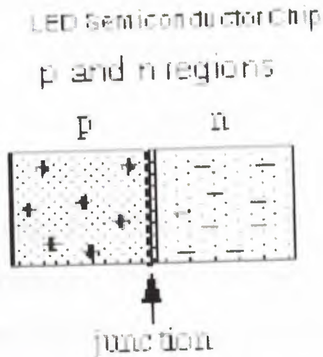


Figure Electronic structure of LED

In the absence of a large enough electric potential difference (voltage) across the LED leads, the junction presents an electric potential barrier to the flow of electrons.

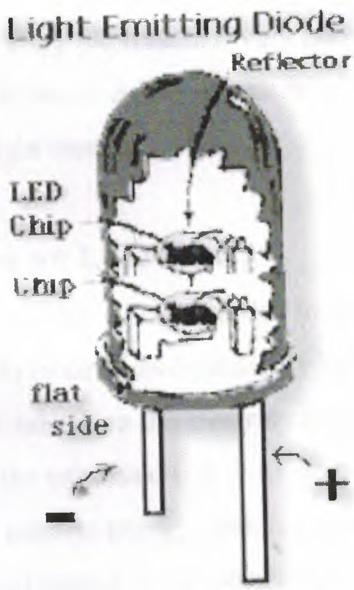


Figure LED internal structure

6.2 What Causes the LED to Emit Light and What Determines the Color of the Light?

When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the junction between the p and n regions. In the p region thereare many more positive than negative charges. In the n region the electrons are more numerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the n region have sufficient energy to move across the junction into the p region. Once in the p region the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the p region, the two charges "re-combine". Each time an electron recombines with a positive charge, electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colors are made of different semi-conductor materials, and require different energies to light them.

6.3 How Much Energy Does an LED Emit?

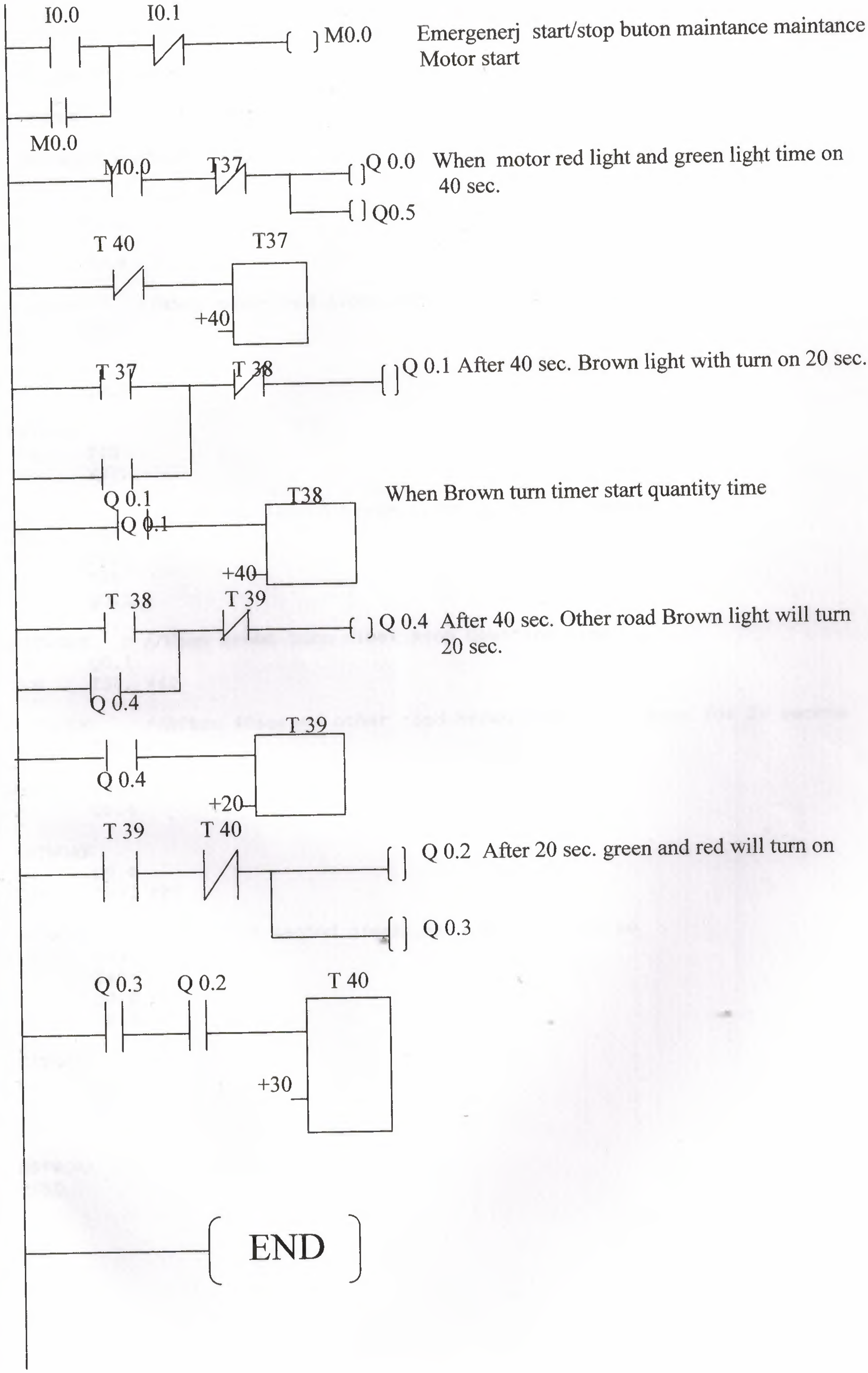
The electric energy is proportional to the voltage needed to cause electrons to flow across the p-n junction. The different colored LED's emit predominantly light of a single color. The energy (E) of the light emitted by an LED is related to the electric charge (q) of an electron and the voltage (V) required to light the LED by the expression: $E = qV$ Joules. This expression simply says that the voltage is proportional to the electric energy, and is a general statement which applies to any circuit, as well as to LED's. The constant q is the electric charge of a single electron, -1.6 x 10-19 Coulomb.

6.4 Finding the Energy from the Voltage

Suppose you measured the voltage across the leads of an LED, and you wished to find the corresponding energy required to light the LED. Let us say that you have a red LED, and the voltage measured between the leads of is 1.71 Volts. So the Energy required to light the LED is $E = qV$ or $E = -1.6 \times 10\text{-}19$ (1.71) Joule, since a Coulomb-Volt is a Joule. Multiplication of these numbers then gives E = 2.74 x 10-19 Joule.

6.5 Resistor

The resistor is one of the most diverse and easiest of all the electrical components be found in the average radio or TV set. This is because it has been around for many years and plays such a vital role that it will continue to in many new shapes and sizes to come. Today there are many different resistors in circulation, all of which will be explained shortly but for now lets go over some of the most important details. The resistor is a component that has one purpose and that is to resist current and voltage by means of combining conductive material with a nonconductive one to form a substance that allows electrons to flow through its self but not as efficiently as a typical wire. The unit of measuring how much the resistor will oppose current is measured in ohms and to determine the outcome of the resistor we would use mathematical formulas known as ohms law. There are three main types of resistors. These are low power resistors, high power resistors and variable resistors.


I0.0
I0.1
M0.0
Emergenerj start/stop buton maintance maintance
Motor start
M0.0
M0.0
T37
Q 0.0
Q0.5
When motor red light and green light time on
40 sec.
T 40
T37
+40
T 37
T 38
Q 0.1
After 40 sec. Brown light with turn on 20 sec.
Q 0.1
Q 0.1
T38
+40
When Brown turn timer start quantity time
T 38
T 39
Q 0.4
After 40 sec. Other road Brown light will turn
20 sec.
Q 0.4
T 39
Q 0.4
+20
T 39
T 40
Q 0.2
After 20 sec. green and red will turn on
Q 0.3
Q 0.3
Q 0.2
T 40
+30
END

```
//
//PROGRAM TITLE COMMENTS
//
//Press F1 for help and example program
//
NETWORK     //Emergenerj start/stop buton maintanece motor start
//
//NETWORK COMMENTS
//
LD      I0.0
O       M0.0
AN      I0.1
=       M0.0

NETWORK     //When motor red light and green light timer 40 second
LD      M0.0
AN      T37
=       Q0.0
=       Q0.5

NETWORK
LDN     T40
TON     T37, +100

NETWORK     //After 40 second brown light on for 40 second
LD      T37
O       I0.1
AN      T38
=       Q0.1

NETWORK     //When brown turn timer stop counting time
LD      Q0.1
TON     T38, +40

NETWORK     //After 40second other road brown light will turn for 20 second
LD      T38
O       Q0.4
AN      T39
=       Q0.4

NETWORK
LD      Q0.4
TON     T39, +20

NETWORK     //After 20 second green and red will turn on
LD      T39
AN      T40
=       Q0.2
=       Q0.3

NETWORK
LD      Q0.3
A       Q0.2
TON     T40, +30

NETWORK
MEND
```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CONCLUSİON

The aim of project was to present a practical using PLC. PLC is used for automating the industrial and process control systems. İn project task was to control a traffic light system using PLC and arrangement of traffic light turning on and turning off process according to desired time. First of lights and road structure was simulated by using hardware components after that accurate ladder program was down loaded on PLC by using ladder programming and then all hardware was connected to the PLC in order to determine the accuracy of program.

Consequently it was observed that control processes either in industry or in usual life can be easily controlled and conviencely modified while controlled with PLC.

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