DESIGN A CONTROLLER TO CONTROL FLUORESCENT LIGHTING AND OTHER ELECTRICAL EQUIPMENT IN A CLASSROOM USING PROGRAMMABLE LOGIC CONTROLLERS

By

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ABSTRAK

Pada masa kini, pengawal Logik Program (PLC) digunakan secara meluas dalam pelbagai aplikasi industri. Dalam projek ini, PLC digunakan untuk mengawal nyala padam dan keterangan pada lampu pendaflor serta peralatan elektrik yang lain dalam sebuah bilik. Masukan kepada PLC termsuklah satu pengesan keterangan cahaya, satu pengesan keadaan projektor dan dua suis yang digunakan untuk menentukan keadaan kecahayaan yang diperlukan oleh pengguna bilik. Projek ini menawarkan pengurusan tenaga yang effisien dengan mengelakkan pembaziran tenaga yang disebabkan kecuaian pengguna. Pengawalan keterangan pada lampu pendaflor bukan sahaja memberikan penjimatan tenaga tetapi juga boleh memperpanjangkan hayat penggunaannya dan memastikan keterangan yang sesuai kepada penguna-pengunanya. Sebuah model bilik kecil telah dipertimbangkan dalam projek ini untuk pengawalan lampu. Pengesan pergerakan pasif infrared telah digunakan untuk mengesan kehadiran orang dalam bilik manakala suis biasa juga dimasukkan dalam projek untuk dioperasi apabila pengesan tidak berfungsi. Selain daripada itu, pengesan keterangan lampu juga diimplimentasikan dengan menggunakan “Light Dependent Resistor” (LDR) untuk mendapatkan tahap luminasi dalam bilik.. Pengesan projektor juga diimplimentasi dengan LDR untuk memberikan kawalan lampu yang sesuai. Keluaran daripada pengesan-pengesan and suis-suis ini akan disambungkan kepada masukan pada PLC and kawalan lampu pendaflor yang bersesuaian akan dihantarkan kepada lampu menerusi ballast and litar kawalan. Untuk mengawal keterangan pada lampu pendaflor, ballast elektronik yang biasa perlu digantikan dengan ballast lampu pendaflor khas. Ballast ini melibatkan teknologi baru dan langkah rekabentuk yang agak compleks dan melibatkan ilmu yang mendalam merekabentuk ballast. Walaupun begitu, dengan menggunakan perisian pereka ballast (BDA), langkah merekabentuk dapat dipermudahkan. Dalam projek ini, ballast lampu pendaflor direlisasikan dengan menggunakan dimming ballast IC IR21592 daripada International Rectifier. Ballast ini direkabentuk untuk lampu pendaflor T8 36W daripada Voltan Masukan 240Vac. Menerusi projek ini kawalan lampu pendaflor dan pengurusan tenaga yang bersesuaian telah dicapai dengan perisian luar dan dalam yang minimum. .

ABSTRACT

Programmable Logic Controllers (PLC) is widely used in almost any industrial applications in our modern world. In this project, the PLC is used to control dimming and ON/OFF control of fluorescent lights as well as other electrical equipments in a typical classroom. Sensors and switches are used as inputs to the PLC to determine the current condition is the classroom. This project offers great energy management control avoiding energy wastage by human carelessness as well as unnecessary over energy usage. Dimming control of fluorescent lights would not only allow energy saving but would also pro-long the life span of the fluorescent lights as well as ensuring a sufficient and comfortable level of light intensity in the classroom for the students. A small classroom model is considered in this project for fluorescent lights control. A Passive Infrared Remote (PIR) Motion Sensor is used as an input sensor to detect the presence or absence of people in the classroom; manual switches are also included in this project for special cases where the motion sensor malfunctions. Apart from that, light intensity sensors are also implemented using light dependent resistors (LDR) to obtain the luminance level of the environment as well as allowing dimming control of the fluorescent lights in the classroom. Besides that, a light sensor is also implemented to detect the projector current status to allow proper lighting control. All these input sensors and switches will serve as input signals to the PLC making proper lighting control possible. Proper lighting controls will be sent through the PLC I/O ports to the hardware devices. For dimming control of fluorescent lamps, the normal ballast must be replaced with dimming ballast. Although dimming ballasts involves rather new technology, tedious and complex design procedures as well as in depth knowledge in ballast design, by using the Ballast Designer software (BDA) its steps are significantly reduced and simplified. The ballast designed in this project is done using the dimming ballast IC IR21592 from International Rectifier. This ballast is designed to suite a single T8 36W fluorescent lamp from a 240Vac input voltage source. This project shows how proper fluorescent lighting control and energy management in a classroom can be derived through a proper interface with minimum software and hardware connections.

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Regards,

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Chapter 1

Introduction

Global warming in relation of the use of energy is a subject that is often debated nowadays. Energy are consumed in almost everywhere in the world from household to industry applications. Energy consumption has grown to become a very part of our everyday lives thus minimizing energy consumption and maximizing energy usage efficiency is very important.

1.0 General Overview

Programmable logic controllers are widely used in many industrial applications. By applying the same concept in this project, with a programmable logic controller as the heart of a simple electrical system in a typical classroom, we can implement higher energy savings by providing automatic on off and dimming control of the fluorescent lighting. Inputs signals would come from sensors and switches where the programmable logic controller would evaluate and send appropriate output signals to either turn on or off the lamps as well as to dim them through a dimming ballast which allow a ramp voltage to be applied to the lamps depending on the luminance level in the room and thus provide higher energy saving and also extends the life span of the lamps. In other words, the fluorescent lamps will be automatically turned on when the presence of people is detected and vice versa. When the measured luminance level is differs from the preset recommended luminance level in the PLC, output signals will be sent to dim the fluorescent lamps to their recommended levels without removing bulbs or turning on/off portions of the lighting. Automatic controlling of fluorescent lamps enables the end user to precisely deliver the correct amount of light when and where it is required. Managing light in this manner will allow a massive reduction in global energy consumption due to lighting.

1.1 Project Objective

The objective of this project is to implement an automatic control system to control fluorescent lights and other electrical equipments in a typical classroom by using a programmable logic controller. The main feature of this project is to provide higher energy savings, greater vision comfort and also to increase the life span of the electrical equipments. Its operation is similar to the smart home concept, where automatic switches and controllers are used to achieve better efficiency and effectiveness of energy delivery. As its title suggest, this control system would be able to turn fluorescent lamps on and off as well as vary the lighting intensity of the fluorescent lamps without any manual switches and dimming control.

1.2 Project Research

The core unit of this project would be the programmable logic controller (PLC), all input and output hardware devices interfaces with it. There are all kinds of programmable logic controllers available in the market varying from sizes, manufacturers, its functionality and the programming format. Due to the availability of the CQM1H-CPU51 programmable logic controller from OMRON in our school lab, I have chosen to use this PLC. The PLC will be programmed to automatically provide on/off and dimming control of the fluorescent lights depending on the inputs received.

Fluorescent lamps are the most widely used type of indoor lighting. In this project the dimming ballast is designed for T8 36W linear fluorescent lamps. The fluorescent dimmable ballast is designed using the dimming ballast IC from the International Rectifier IR21592 is used. This IC operates to regulate lamp power, set minimum and maximum brightness levels and protect the ballast against conditions such as lamp strike failures, filament failures, low DC bus, thermal overload or lamp failure during normal operations. This dimming ballast IC used externally programmable input such as preheat time and current, ignition-to-dim time, and a complete dimming interface with minimum and maximum settings providing flexibility in designing dimming control for almost any type of fluorescent lamps.

As for the inputs switches and sensors, it includes two manual switches; one for maintenance purposes while the other operates to turn on or off the fluorescent lights when the control system malfunctions. All sensors and switches are mainly implemented using relays as relays provide better performance and ease of circuit constructions. As for the light intensity sensor, the Light Dependent Resistor (LDR) is used to detect the luminance level in the classroom. The projector status sensor will also be implemented using the LDR to detect the projector light when it is turned on, when sufficient the sensor detects light, an input will be directed into the PLC controller indicating that the projector is in use. Lastly, for the occupancy sensor, a Passive Infrared (PIR) sensor is used. Besides using the PIR sensor, there are also other types of motion sensors such as the ultrasonic sensors can also be used.

1.3 Project Overview

Fluorescent lights are the most widely used lighting source all over the world. Although a fluorescent lamp consumes very little energy compared to other electrical equipments, due to the extensive and increased number of usage, it is often a wiser choice to have dimming controls of the lighting to save electricity and maintain a longer lamp life span. In this project, PLC control system implementation is done on a typical classroom to control the fluorescent lights depending on the presence and absence of people as well as the lighting intensity in the room. Human eye responds to dim lights by automatically enlarging the pupil to allow more lights into the eye, making the light appear brighter. Thus, automatic lighting intensity control will allow greater comfort, better vision capabilities and avoid over-strained eyesight problems. The dimming control of the fluorescent lights would depend on inputs such as occupancy sensors, lighting intensity sensors, manual switches and projector status sensor. Programmable logic controllers are widely used in the industrial world and it is used in this project to control dimming ballast and provide ramp voltage to the fluorescent lights and in a typical classroom.

Overall, the automatic lighting system will be able to detect the presence of students and trigger on the lights as well as off the lights when nobody is presence, perform appropriate dimming of the lighting depending on the luminance level of the room and also react to turn off the fluorescent lighting when teaching is done with the projector for better vision. The programmable logic controller will act as the core of the entire system. The overall block diagram of the automatic control system is shown in the figure below. Noticed that there are five inputs and four outputs devices connected to the PLC controller. The light intensity sensor input and the fluorescent light dimming control output are connected to the PLC analog I/O port while all other devices are connected to the PLC Digital I/O ports.

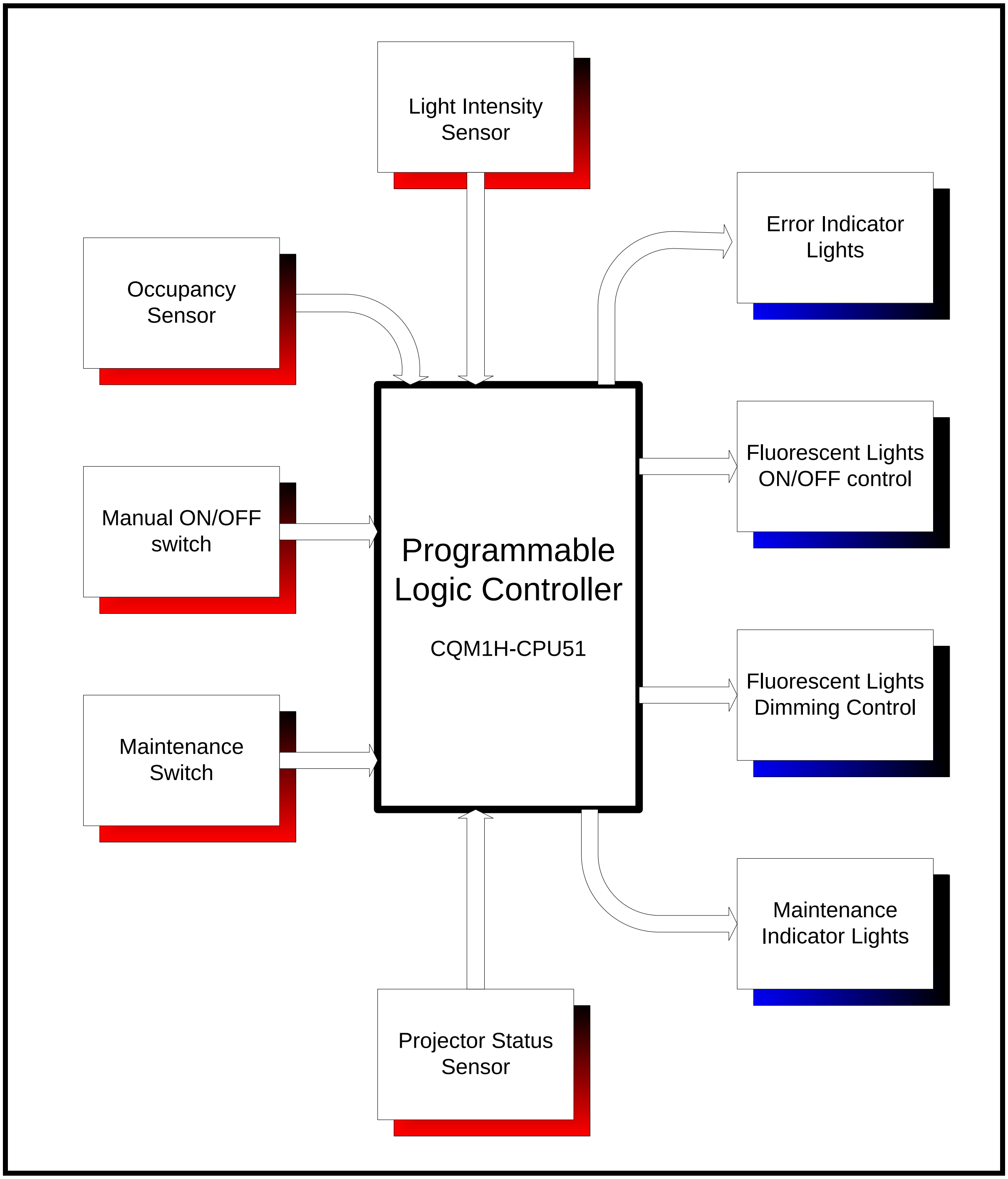


Figure 1.1: Project Overall Block Diagram

- Light Intensity Sensor

The light intensity sensor is realized using a Light Dependent Resistor (LDR) together with a potential divider circuit. This sensor is used to detect the luminance level in the classroom. The output voltage from the sensor will vary depending on the luminance level that is detected. This voltage level will then be directed into the analog input of the PLC controller to be evaluated.

- Maintenance Switch

This manual switch is serve to be turn on when maintenance or upgrade work are to be carried out. When this switch is turned on, the main power supply will be cut off regardless of all other inputs.

- Manual On/Off Switch

This switch is turned on when there is error in the occupancy sensor in detecting the presence of someone in the room. When the occupancy sensor malfunctions, the fluorescent lights can be turned on/off through this switch.

- Occupancy Sensor

Occupancy sensors are also known as motion sensors. The type of occupancy sensor used in this project is the Passive Infrared Sensor. When someone is presence in the room, the sensor will be able to detect it and send an output signal to the PLC controller. This sensor works through detecting the motion of heat producing bodies.

- Projector Status Sensor

This sensor circuit is used to detect if the projector is in use. If the projector is in use an output signal to the PLC controller. The projector status sensor used in this projector is build by using a Light dependent Resistor (LDR); this sensor will detect the on/off condition of the projector through the amount of lights that hits it as the projector emits light when it is turned on. The sensitivity of the sensor can also be adjusted depending on the user needs.

- Error Indicator Light

The error indication light will be turn on when the occupancy malfunctions. This happens when the fluorescent lights does not automatically turned on when someone is in the room. When this light flashes the user will know that the occupancy is not functioning.

- Maintenance Indicator Light

The maintenance indicator light shows that the system is under maintenance. In cases where the switch is not turn off when maintenance work is completed, this light will serve to inform the user to turn the maintenance switch off.

- Fluorescent Lights On/Off Control

Fluorescent Lights On/Off Control is implemented using a relay circuitry. The fluorescent lights will be turn on/off depending on the input signal received from the PLC controller. This control is often use when someone enters or leave the room.

- Fluorescent Lights Dimming Control

Fluorescent lights dimming control is realized by building fluorescent lights dimming ballast. This circuit is possible by using a dimming ballast IC from International Rectifier, IR21592. This ballast has externally programmable features making it suitable for almost any types of lighting loads. In this project the dimming ballast is designed for a T8 36W fluorescent tube light.

The figure 1.2 below shows the overview of the dimming control design. This process is continuous and involves analog input and outputs. Both the input to the PLC controller from the light intensity sensor and output from the PLC control unit to the dimming ballast will vary from 0 to 5V depending on the luminance level in the surrounding.

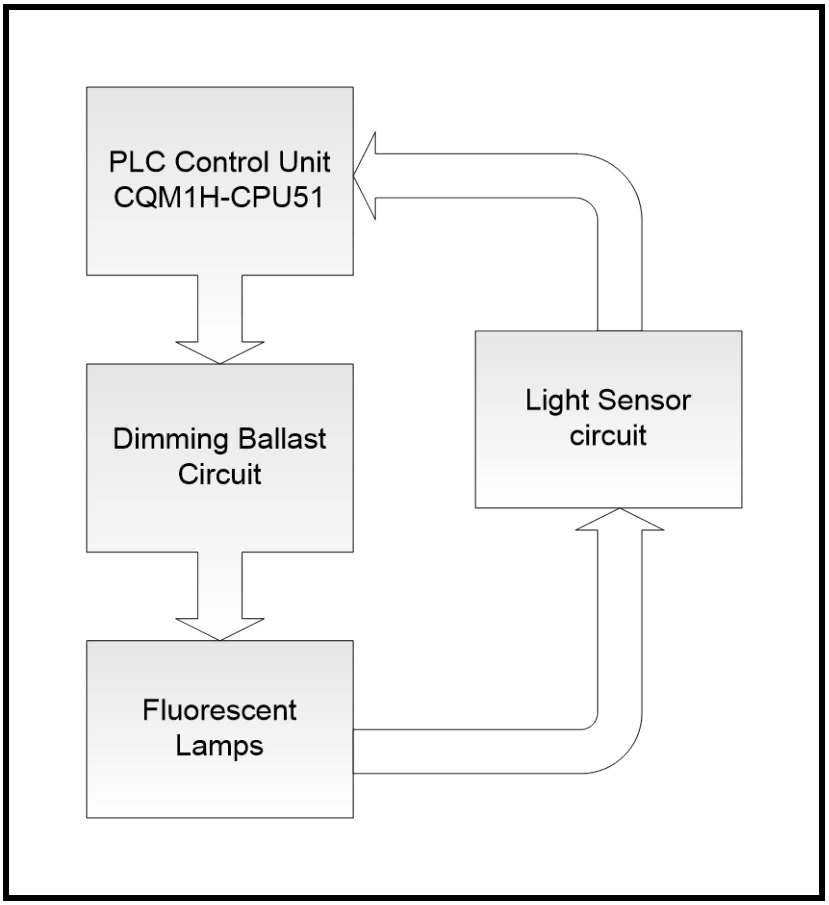


Figure 1.2: Fluorescent Lamps Dimming Control Block Diagram

Figure 1.3 shows the overall fluorescent on/off control design. The conditions that have to be met and the outputs of each condition are shown. It is noticed that there are few conditions to be met before the fluorescent light turned on. Similar to the dimming control design, although this process only involves digital control, the program flow will also be continuous. The PLC controller will scan through each input devices after each cycle to update the current changes. Although delay and sequence exist, due to the short delay and high speed scanning the user will feel the output almost instantly.

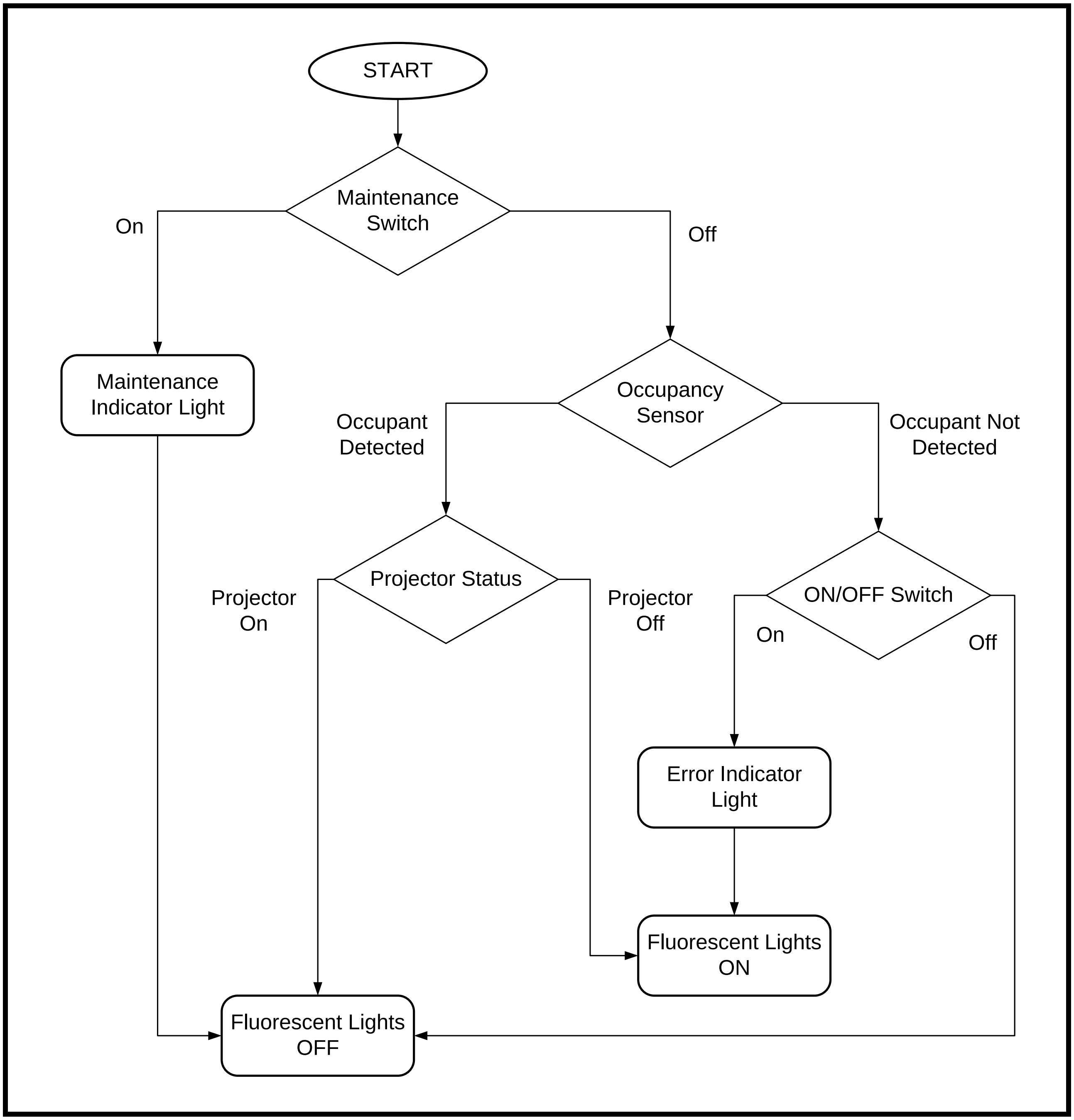


Figure 1.3: Fluorescent Lamps On/Off Control Block Diagram

1.4 Project Development Process

There are mainly 6 stages in the project development process. This process is very important when carrying out projects, as a well-planned project will determine the success rate of the project. By completing projects systematically we can eliminate error and discrepancies. The six main stages in the project development process are:

- Project Requirement and Specification
- Project Analysis
- Project Design
- Project Coding
- Project Implementation
- Project Testing and Validation

1.4.1 Project Requirement and Specification

This first stage in carrying out a project would be to collect the information, determine the requirement and specification and the approach that will be used as well as to learn the necessary programming languages or hardware characteristic involved. This stage is often time consuming and very important in determining the success of the project. In this stage, I have learned the basic hardware and software of the programmable logic controller, the characteristics and function of the dimming ballast circuitry as well as the basic operation of fluorescent lights.

1.4.2 Project Analysis

After the project requirement and specification is determined. The approach taken in carrying out the project has to be analyzed to ensure the compatibility and availability of all the software and hardware devices that are involved. The designing of dimming ballast using the dimming ballast IC and its compatibility with fluorescent lamps, the digital and analog input and output function and its compatibility with the input and output sensors and switches are analyze.

1.4.3 Project Design

The design stage can be divided into two parts, the software design and hardware design. The software design involves determining the main functions and all possible conditions as well as and program flow needed to meet the objectives of the project. The hardware design will then involve all circuit design for the hardware components to meet the specification and requirement of the project. As the project design is done base on theoretical knowledge, in most cases implementation of the design will involve several discrepancy, thus a detailed project design must be done.

1.4.4 Project Coding

After designing the program flow of the project how it should operate and the conditions involved. I started to program the programmable logic controller. This stage will includes writing the software needed and testing it through simulation techniques. The type of program coding used in this project to program the Programmable Logic Controller is the ladder logic diagram.

1.4.5 Project Implementation

After designing and coding the project, next we would have to implement all the hardware components involved. The hardware components are implemented according to the circuit designed earlier and are build using vero boards. Hardware implementation involves two main parts, the input devices and the output devices. The input circuit design involves two manual switches and three sensors while the output circuit design includes two light indicators, one dimming ballast and a on/off control switch.

1.4.6 Project Testing and Validation

This is the final stage of the project development process, and must be given great attention, as it will determine the functionality and success of the project. This stage includes integration between hardware components and software and continuous testing to ensure the system is free from defects. The project testing and validation is done according to modules and results are obtained to verify if the project meet its objective and specification. The root cause of each error that occurs must be determined and defects must be fixed immediately using appropriate solutions.

1.5 Report Guideline

Chapter 1

The objective of the project, its scope, overview as well as the approach taken to carry out the project and a report guideline is shown here.

Chapter 2

The Programmable Logic Controller CQM1H-CPU51 is discussed over here. Both hardware connections and software programming technique is point out here. However the main focus would be on the hardware parts and software programming functions involved in completing this project

Chapter 3

The basic construction of fluorescent lamps, available fluorescent lamp types and its advantages as well as weaknesses is discussed here. Fluorescent Dimmable ballast concept and methods are also introduced here.

Chapter 4

Overall project circuit connections, installations and its operation are explained here.

Chapter 5

The dimming ballast IC used in the Dimming Ballast Design, IR21592 is discussed here. The basic function of the dimming ballast and the respective design steps involved are explained here. The designed dimming ballast circuitry together with simulation results is included here.

Chapter 6

All hardware circuit design in this project is discuss here. All circuit used are explained.

Chapter 7

Software Design the basic program flow and programming ladder diagram is explained.

Chapter 8

The conclusions of the project and future recommendations are discussed.

Chapter 2

Programmable Logic Controllers

2.0 Overview

Control engineering has evolved over time. In the past humans were the main methods for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer.

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

2.1 Main components

Similar to other Programmable Logic Controllers the CQM1H-CPU51 PLC consists of a Central Processing Unit (CPU) containing an application program and Input and Output Interface modules, which is directly connected to the fixed I/O devices. The program controls the PLC so that when an input device turns ON, the appropriate response is made. The response normally involves turning ON an output signal to some sort of output devices. However in analog I/O cases, there may be few steps of voltage levels for the input as well as the output.

- **Central Processing Unit (CPU)**

  The CPU is a microprocessor that co-ordinates of the activities of the PLC system. It executes the program, processes I/O signals & communicates with external devices.

- **Memory**

  There are various types of memory unit. It is the area that holds the operating system and user memory. The operating system is actually a system software that co-ordinates the PLC. Ladder program, timer and counter values are stored in the user memory. Depending on the user's need, various types of memory are available for choice:

  i. **Read Only Memory (ROM)**

     ROM is a non-volatile memory that can be programmed only once. It is therefore unsuitable. It is least popular as compared with others memory type.

  ii. **Random Access Memory (RAM)**

     RAM is commonly used memory type for storing the user program and data. The data in the volatile RAM would normally be lost if the power source is removed. However, backing up the RAM with a battery solves this problem.

  iii. **Erasable Programmable Read Only Memory (EPROM)**

     EPROM holds data permanently just like ROM. It does not require battery backup. However, exposing it to ultraviolet light can erase its content. A prom writer is required to reprogram the memory.

  iv. **Electrically Erasable Programmable Read Only Memory (EEPROM)**

     EEPROM combines the access flexibility of RAM and the non-volatility of EPROM in one. Its contents can be erased and reprogrammed electrically, however, to a limit number of times.

- **Scan time**

  The process of reading the input, executing the program and updating the output is known as scan. The scan time is normally a continuous and sequential process of reading the status of inputs, evaluating the control logic and updating outputs. Scan time specification indicates how fast the controller can react to the field inputs and correctly solve the control logic.

- **Factors influencing Scan Time**

  The time required to make a single scan (scan time) varies from 0.1 ms to tens of ms depending on its CPU processing speed and the length of the user program. The user of remote I/O subsystems increases the scan time as a result of having to transmit the I/O updates to remote subsystem. Monitoring of the control program also adds overhead time to the scan, as the controller's CPU has to send the status of coils and contacts to the CRT or other monitoring devices.

- **The CQM1H-CPU51, Central Processing Unit Overview**

CPU Units can be broadly divided into two groups: Models that support Inner Boards and the Controller Link Unit, and models that do not. CPU Units also vary in their program capacities, I/O capacities, memory capacities, and the presence of an RS-232C port. The CQM1H-CPU51 has CPU Units that support the Controller Link Unit and also the Inner boards, 512 I/O capacities, 7.2K program capacity and supports the RS-232 port.

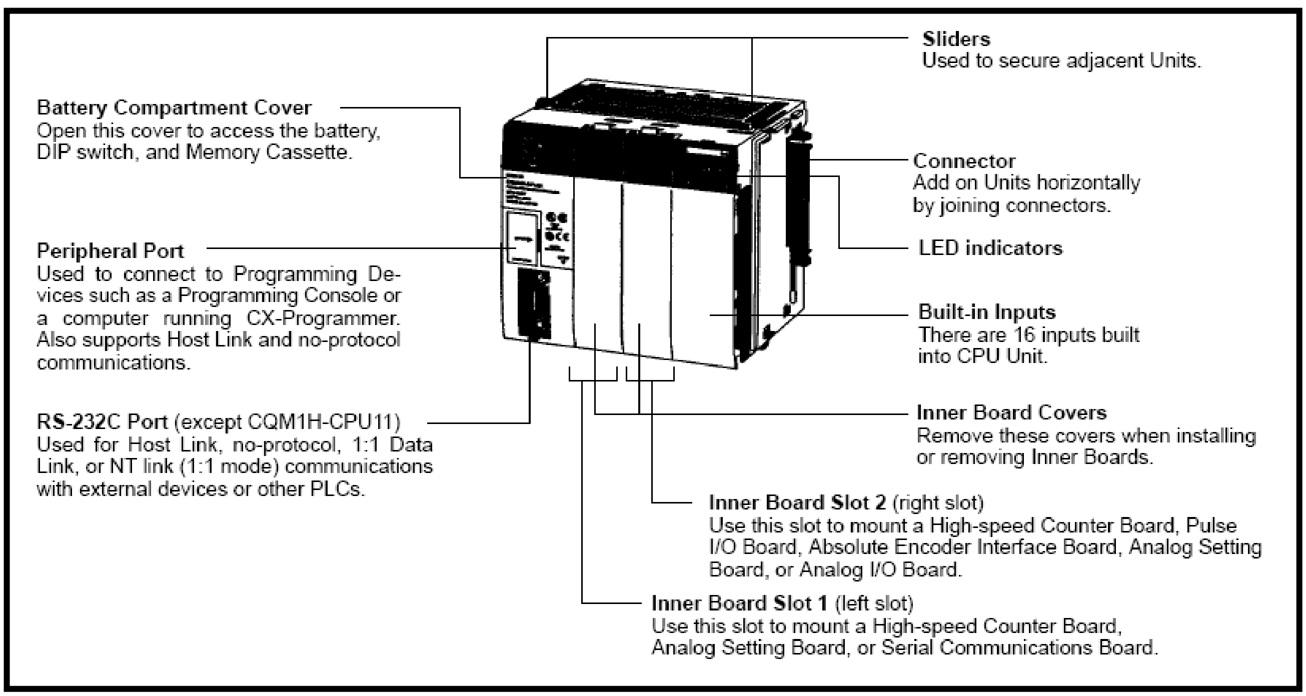


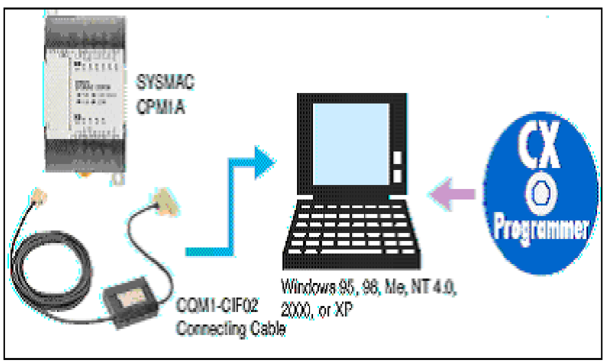
Figure 2.1: Central Processing Unit Overview

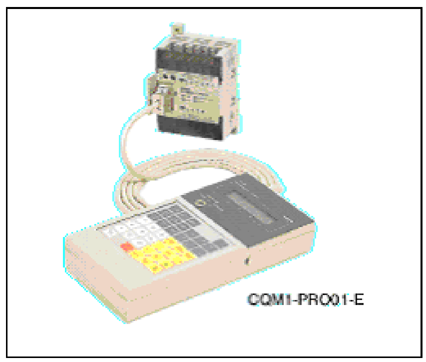
2.2 Programming Devices

The CQM1H-CPU51 PLC can communicate with various devices, such as personal computer, printer, bar code reader and so on. For this project, the PLC will be interfaced with a personal computer to allow programming. In other cases a Programming Console can also be connected and used to program the PLC.

Programming devices

- Serve as an interface between user and PLC.
- Consist of display (LCD/LED) and keyboard (Numeric and some function key).
- Provide display basically meant for monitoring and checking.
- Allow inputting of instructions to program PLC.
- Once PLC have been programmed, these devices can be removed from PLC.
- Type of programming devices: (a) Cx-Programmer (b) Programming Console





(a) Cx-Programmer (b) Programming Console

Figure 2.2 Programming Device

In this project the Cx-programmer software will be used instead of the programming console. The Cx programmer Ver. 5.0 is used to interface with the PLC through a personal computer. This software eases the user in designing and programming the overall system. The Cx-programmer software can be programmed using the ladder logic diagram or structured text (ST). ST language is an advanced language for industrial control. The ladder logic diagram will be used in this project to further simplify the programming process.

2.3 Input and Output Assignment List

The Input and outputs PLC is recognized by PLC by assigning numbers to them according to the I/O Assignment List in table 2.1 below:

Name	Channel	Bit Number							
Input Relays	000	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
	001	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
	↓								
	015	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
Output Relay	100	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
	101	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
	↓								
	115	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15

Table 2.1: I/O Assignment list

<u>Note:</u> Although we have 512 I/O bits (32 channels), only 8 channel (128 bits) can be used as I/O bits. Bits not used for I/O can be used as work bits.

Name	Channel	Bit Number							
Internal Relay	016 – 095	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
	116 – 195	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
	216 – 219	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15
	224 – 229	00	01	02	03	04	05	06	07
		08	09	10	11	12	13	14	15

Table2.2: Internal relay assignment list

<u>Note:</u> Internal relays do not have any specific function, and they can be freely used within the program.

Advantage – save output bits.

Name	Channel	Bit Number	Function
Special Function Relay	254	00	1 – minute clock pulse
		01	0.02 – second clock pulse
	255	00	0.1 – second clock pulse
		01	0.2 – second clock pulse
		02	1.0 – second clock pulses

Table 2.3: Special function relay assignment list

Note: The special function relay has its specific function and cannot be used as work bit in PLC programming.

Name	Size	Assignment List	Comments
Timer/Counter	512	T/C 000 – T/C 511	Timer and counter cannot share the same number.
Temporary Relay	8	TR 0 to TR 7	Used to temporarily store ON/OFF status at program branches.

Table 2.4: Timer, counter and temporary relay assignment list

Note:

- Operand

  The name (from I/O Assignment List) given to input, output, timer, counter, internal delay and so on.

- Instruction

  State that what the operand in the PLC is program do.

- Address

  The position in the memory of the PLC where an operand and instruction take place.

The Input and Output Assignment List above is used in programming the digital inputs and outputs of the system. The PLC will know the position of the input connected by recognizing the port through this Input and Output Assignment List. Any Input or Output port can be use freely within its noted function listed above.

2.4 PLC design flow chart

Flow chart below shows the systematic steps that are used to do PLC design.

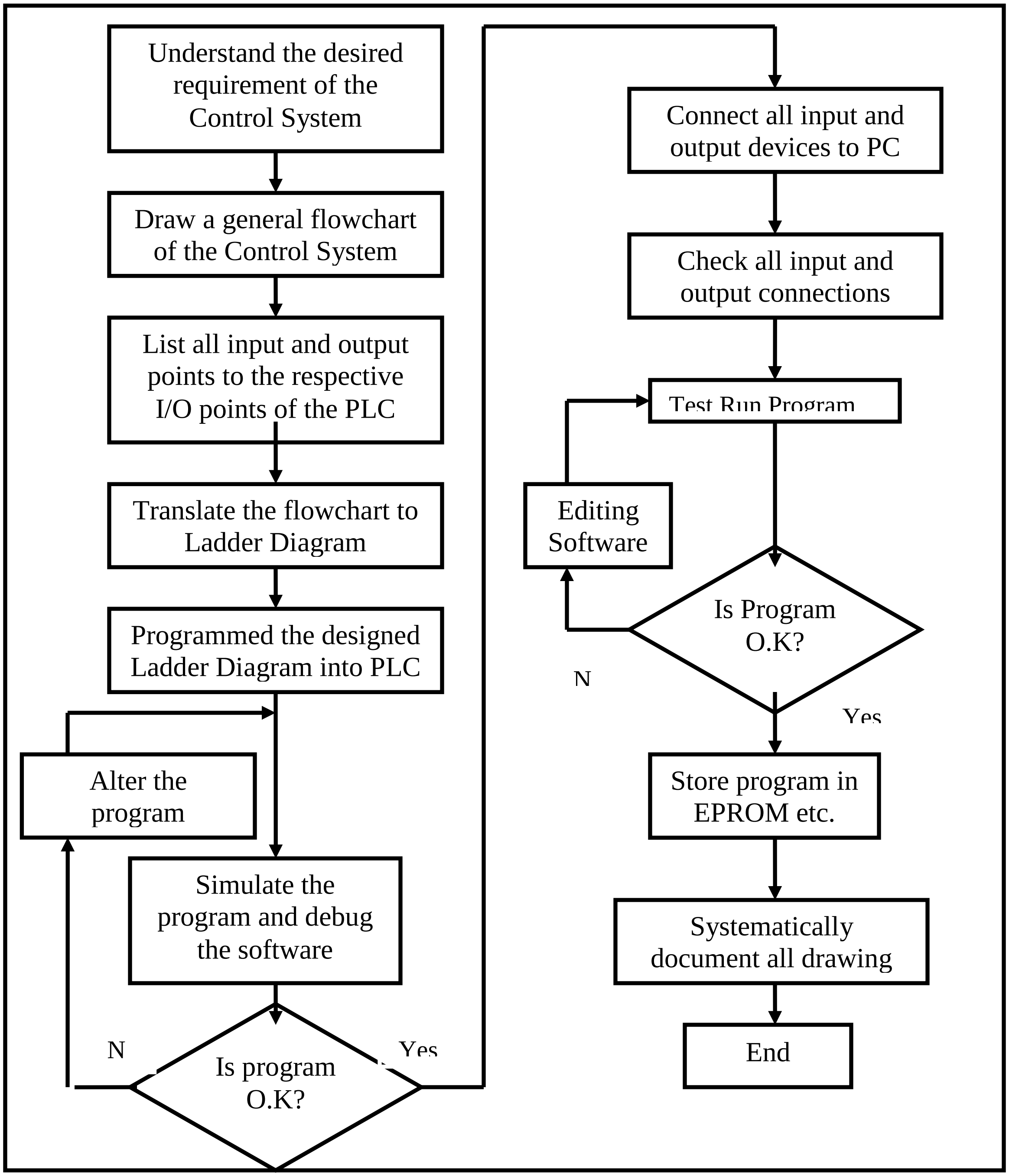


Figure 2.3: Approach used in programming controller design

2.5 The PLC Programming Concept

- On programming

a) The number of contacts for inputs/outputs, internal relays, timer and counters is not limited. However, simple circuit with fewer contacts will ensure the operation run more efficiency.
b) The number of contacts connected in series and parallel is not limited.
c) An output coil cannot be connected to the bus line on the left side. If the coil is required, a normally ON contact is placed between the coil and the bus line.
d) No contact should be connected on the right side of the output coil but on the left side when necessary.
e) Only one output coil is assignable. If two or more coils must be activated at the same time, the contacts of the coil have to activate the other coils.

- Programming Sequence

a) Programming must start from the leftmost circuit to the rightmost circuit.
b) Programming for counter or shift register having two or more inputs should be made in the specified sequence.
c) Data for timer or counter should be entered when creating program for coils.

- Program Comment

Every relay coil as well as input should be given comment. Therefore whoever read the program can understand it easier.

2.6 PLC Operation

A PLC works by continually scanning a program. We can think of this scan cycle as consisting of 3 important steps.

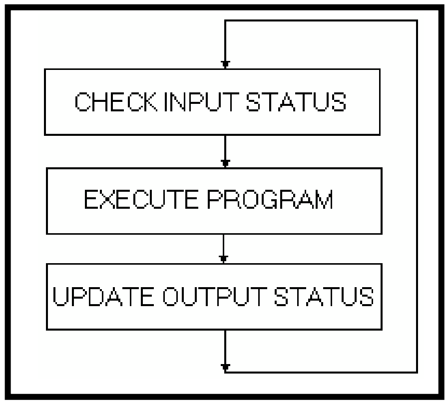


Figure 2.4:PLC Scan Cycle

Step 1-CHECK INPUT STATUS

- First the PLC takes a look at each input to determine if it is on or off. In other words, is the sensor connected to the first input on? How about the second input? It records this data into its memory to be used during the next step.

Step 2-EXECUTE PROGRAM

- Next the PLC executes your program one instruction at a time. Maybe your program said that if the first input was on then it should turn on the first output. Since it already knows which inputs are on/off from the previous step it will be able to decide whether the first output should be turned on based on the state of the first input. It will store the execution results for use later during the next step.

Step 3-UPDATE OUTPUT STATUS

- Finally the PLC updates the status of the outputs. It updates the outputs based on which inputs were on during the first step and the results of executing your program during the second step. Based on the example in step 2 it would now turn on the first output because the first input was on and your program said to turn on the first output when this condition is true.

After the third step the PLC goes back to step one and repeats the steps continuously. One scan time is defined as the time it takes to execute the 3 steps listed above.

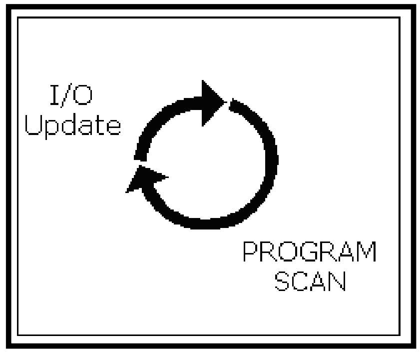


Figure 2.5: One scan time

2.7 Ladder Diagram

There are several languages designed for user communication with a PLC, among which ladder diagram is the most popular. In this project the Ladder diagram will be used to program the PLC. Ladder diagram consists of one vertical line found on the left hand side, and lines which branch off to the right. Line on the left is called a "bus bar", and lines that branch off to the right are instruction lines. Conditions, which lead to instructions positioned at the right edge of a diagram, are stored along instruction lines. Logical combination of these conditions determines when and in what way instruction on the right will execute. Basic elements of a relay diagram are shown below:

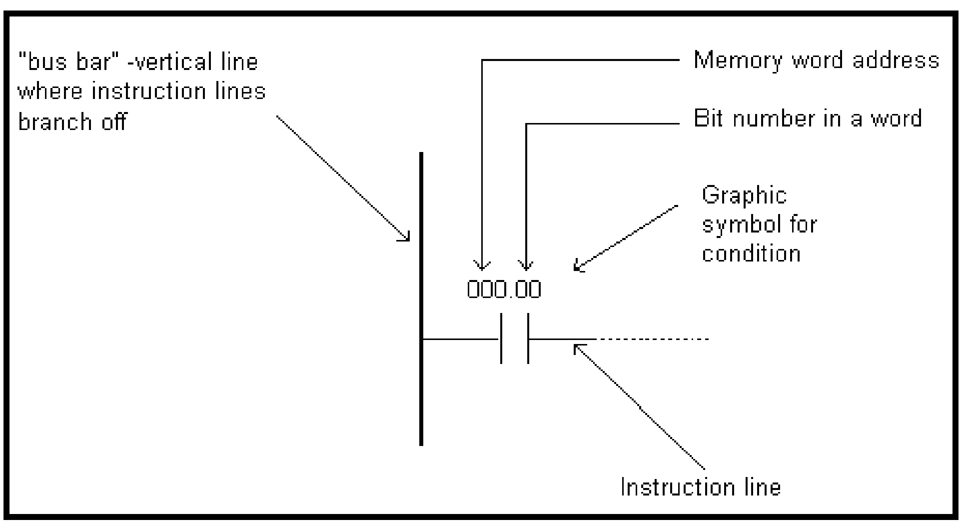


Figure 2.6: Basic elements of a relay diagram

Most instructions require at least one operand, and often more than one. Operand can be some memory location, one memory location bit, or some numeric value -number. In the example above, operand is bit 0 of memory location IR000. In a case when we wish to proclaim a constant as an operand, designation # is used beneath the numeric writing (for a compiler to know it is a constant and not an address.) Based on figure 2.7, one should note that a ladder diagram consists of two basic parts: left section also called condition, and a right section, which has instructions. When a condition is fulfilled, the instruction will then be executed. [1]

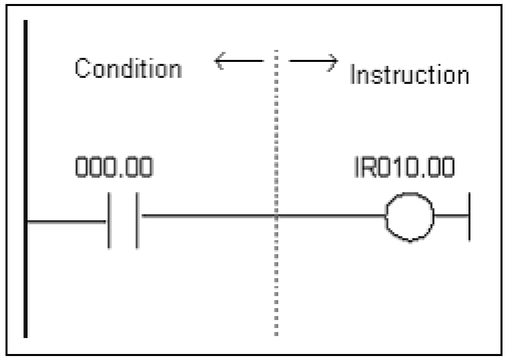
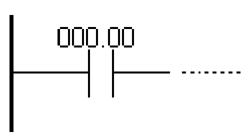
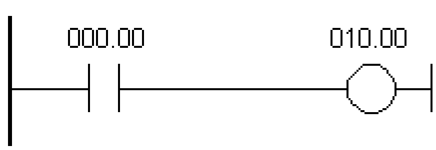


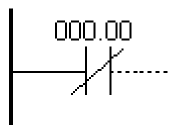
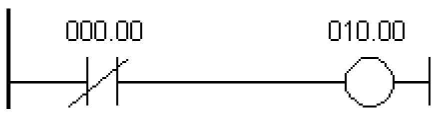
Figure 2.7: Condition and instruction in relay diagram

2.7.1 Basic Instructions

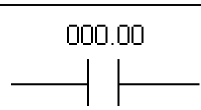
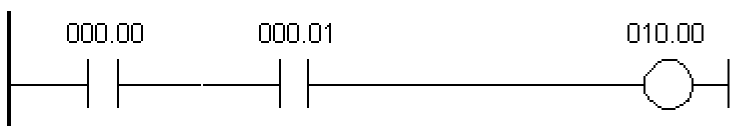
- **LOAD**

Description	First condition that any logical block in the ladder diagram starts with, corresponds to LOAD or LOAD NOT instructions. Both of these instructions require one line in mnemonic code. On the right of these instructions any executive instruction may be used.
Ladder symbol	
Example	 Pressing the button on the input “00” in the word IR000 activates the relay “00” on the output of PLC controller. Conditional instruction doesn’t have be from input memory area; it can be any bit from other memory areas, i.e. SR area as in the following example.

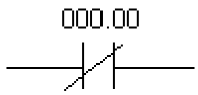
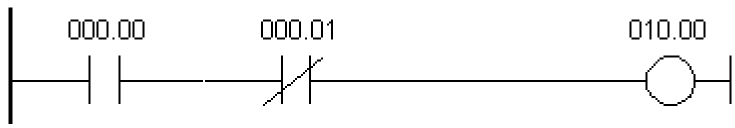
- **LOAD NOT**

Description	First condition that any logical block in the ladder diagram starts with, corresponds to LOAD or LOAD NOT instructions. Both of these instructions require one line in mnemonic code. On the right of these instructions any executive instruction may be used.
Ladder symbol	
Example	 Input “00” in the word IR000 activates the relay “00” on the output of PLC controller. Conditional instruction can be any bit from other memory areas, i.e. SR area as in the following example.

- **AND**

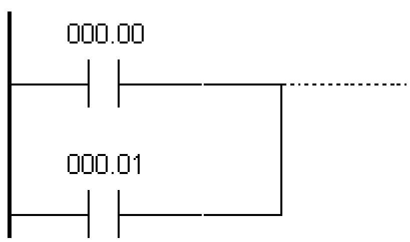
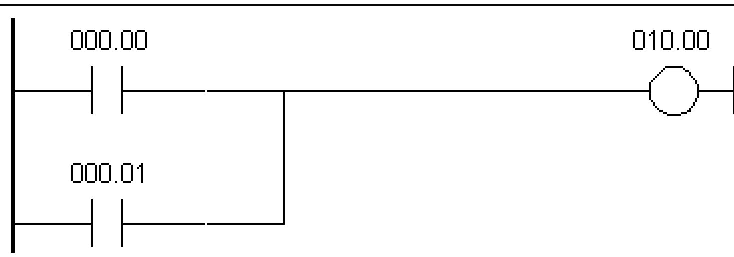
Description	When two are linked serially in one instruction line, first of them corresponds to instructions LOAD or LOAD NOT, while the other represents instructions AND or AND NOT.
Ladder symbol	
Example	 After the LOAD instruction on ‘00’ input, AND instruction is linked to input ‘01’. Instruction on the right will be executed only when both of the conditions from the line are fulfilled, i.e. when both inputs ‘00’ and ‘01’ are in the ON state.

- **AND NOT**

<table>
<tr><td>Description</td><td>When two or more conditions are linked serially in one instruction line, first of them corresponds to instruction LOAD or LOAD NOT, while the other represents instruction AND or AND NOT.</td></tr>
<tr><td>Ladder symbol</td><td>
</td></tr>
<tr><td>Example</td><td>

Instruction on the right will be executed only when both of the conditions from the line are fulfilled, i.e. when input ‘00’ is in ON state and input ‘01’ is in OFF state.</td></tr>
</table>

- **OR**

<table>
<tr><td>Description</td><td>When two or more conditions coexist on separate, parallel lines, the first condition corresponds to LOAD or LOAD NOT instructions, while others correspond to OR or OR NOT instructions.</td></tr>
<tr><td>Ladder symbol</td><td>
</td></tr>
<tr><td>Example</td><td>

Inputs ‘00’ and ‘01’ are in OR relation with the output ‘00’. One of the inputs with ON state is sufficient to activate the output ‘00’.</td></tr>
</table>