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Design and Implementation of a Configurable Programmable Logic Controller Using Microchip PIC

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***Abstract*: Automation has a very important place in industries nowadays. The micro controllers play a major role in designing automated devices. A Programmable Logic Controller (PLC) is a device that is ruggedized to be used in industrial environments and is used as the main computing device in industrial automation. But PLC generally have closed architecture so that user cannot add extra configurations to them easily. So, here we go for a Configurable "Programmable Logic Controller Using Microchip PIC". This system is proposed in such a way that it performs the same functionality as that of the industrial PLC, with the same standards using a low-cost micro controller. Moreover, this system will have a PLC open architecture. This enables the user to re-program the PLC and can be used to support their functionality. For an example application here we implement it to measure the temperature of a boiler field.**

***Keywords*: Analog, Automation, Programmable Logic Controller, Controller, Digital, Inputs, PIC, Outputs, Relay.**

1. Introduction

Since ages automation has played an important role in the lives of people. Humans has always wanted to make their tasks easier and hence to make their lives simpler. Repeating the same tasks in the same pattern has never been the interest of people. People wanted something that could do these regular tasks on its own without their supervision. As far as the industries are concerned, they preferred less human power, high efficiency and high consistency in the products.

Reasons for automation include higher working speed, capability in processing data and less human power. Further, worker's concentration, energy, working speed etc. will affect the quality of the products produced. The products quality varied depending on who has produced it and their mental and physical health. Thus, a solution to all these problems concluded into the need and objective of automation.

Any machine or system that could do the repetitive tasks without any human intervention making the lives and tasks of human easier is said to be an automatic system. The development of automation systems dates to ancient era through the invention of oil lamps and water clocks. Later, the invention of machines like steam engines led the development of automation into the era of industrial automation. Automation expanded into other branches like power plant, transportation and manufacturing.

Before all else, robotization frameworks depended on electro-mechanical frameworks comprising of transfers and contactors. After 1970s, another item has been utilized with the assistance of advancements in semi-conductor innovation, called Programmable Logic Controller (PLC), which has gigantic impact and widespread use in mechanical creation.

An ideal PLC is a gadget, which comprises of a CPU, input what's more, yield interfaces, memory, programming gadget, and client program. Most PLC gadgets moreover have association parts for specialized techniques such as Controller Area Network (CAN), Modbus, ProfNet, and Ethernet.

Yet, the issue with mechanical PLC is that it has a closed architecture, thus client won't have the benefit to empower extra setups due which supplanting the PLC to help their usefulness will be required.

Here, we go for a "Programmable Logic Controller Using Microchip PIC". This framework is proposed so that it plays out a similar usefulness as that of the modern PLC, with similar measures utilizing a minimal effort small scale microcontroller. In addition, this framework will have a PLC open architecture. This empowers the client to re-program the PLC and can be utilized to help their usefulness. For a model to depict the usefulness and multiple purposes of the open architecture PLC three applications has been presented.

2. Literature Review

There are a lot of books published and studies done regarding the PLC's. The basic properties of PLCs, their advantages over conventional relays and contactors, the method to program these PLCs are explained and they give us a good knowledge to get familiar with PLC systems and their programming methods [1]. PLCs can be gainfully utilized in a wide range of territories other than the business. PLCs using PIC controller has been

previously built, varying in their features, types and the number of inputs and outputs and their extension capabilities [2]. Commercially available PLCs are used to monitor boiler temperature [3]. There are resources available that explain the use of PLCs in conveyor belt system control [4]. Water level control systems also utilize PLCs to control the level of water and automatically on/off the pump whenever the water level reaches a specific level [5]. Material handling processes [6] use PLCs to pick and place the materials, palettize and depalletize the goods. General use of PLCs in automation [7] have been explained in many studies they all give a knowledge to find the current problems in industries and a way to rectify them.

Here, in this project we have implemented a PLC board using a PIC controller at a low cost with an open architecture.

3. Methodology

The digital I/O of the PLC have single pole double throw switch at each pin. The pole is connected to the digital pin of the controller and one throw is connected to the input circuitry and the other throw is connected to the output circuitry. So, the digital pin of the plc can be either switched as input or output based on the requirement. After selecting parts to build the PLC, the schematic for the overall circuitry is built and each I/O section, Relay section and analog input section are simulated for correct operation. After simulating the PLC operation and obtaining the desired results, the PCB layout preparation is commenced. The parts are placed, routed and the Gerber file is extracted for fabrication process. The PCB is finally fabricated, and the components are placed, soldered and the PLC is tested for basic operations. Now the PLC is involved to be used in real life applications. Three real life applications are built using this PLC. Each application requires different number of inputs and outputs. So, this PLC can be switched to the desired I/O configuration and used.

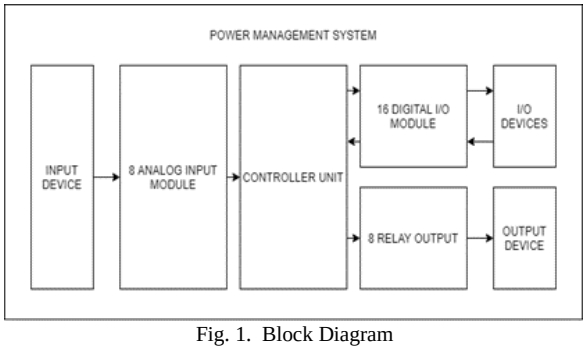

Fig. 1. Block Diagram

4. Selection of Components

A. PIC16F887

It is an 8-bit microcontroller that acts as the central processing unit of the PLC. It is in DIP-40 package. It has a program size of 14KB and data EEPROM of 256 bytes. It has a wide operating voltage of 2.2-5 volts and the operating temperature range of -40 to 125°c makes it suitable for heavy industrial applications. It has 14 channel of analog inputs and total GPIO count of 35. It also has one UART, 1 SPI and 1 i2c communication peripherals and so many sensors and modules with different communication protocols can be interfaced to the microcontroller.

B. PC817

This is an optocoupler that we use to isolate the inputs and outputs from the controller pins. It separates the high voltage side of the outputs or inputs from the low voltage side of the controller so that the noise and spikes on the output side will not affect the controller or any other digital circuitry. The input side has an IR led which emits light when input signal is provided. This signal will fall on the base of phototransistor which is at the output side. This will make the transistor to work as a closed switch. When the input side is not energized, the output will act as an open circuit. The input led has a forward voltage of 1.25v. The collector-emitter voltage is 80v. The maximum collector current is 50ma. The switching frequency is 80khz maximum and the package is 4-pin DIP.

C. IRF9530

This is a p-channel MOSFET that is used as the transistor output side of the PLC. This transistor acts as a current sourcing switch or a high side switch i.e. the switching process is done between the positive voltage side and the load connected. The other end of the load is directly connected to the ground. This MOSFET has a drain to source voltage of 100v and maximum gate source voltage of 20v. The drain current is 12A maximum. The operating temperature is 175°c. So, the MOSFET can carry a maximum drain current of 2A, so that its temperature is lesser than its maximum operating temperature. To carry more current, heat sink of appropriate size should be connected to the MOSFET.

D. ULN2803

It is an 8 transistor Darlington array. It is an 18 pin DIP package. When the high signal is given to the input side of the array, the corresponding output side will be connected to the ground. This array is used when a high current load is to be driven by a small signal such as a microcontroller output signal. The maximum collector-emitter voltage of each transistor is 50v. The maximum collector current of each transistor is 500ma. The base-emitter voltage of each transistor is 30v maximum. Using a single package of this IC will reduce the usage of separate transistors and so, the complexity of the circuitry and the footprint of the PCB can be significantly reduced.

E. G3MB-202P-5VDC

It is a solid-state relay that is used to switch high voltage loads. Solid state relays have many advantages over electromagnetic relays. They contain no moving internal parts and so they will not get wear off over time. Also, electromagnetic relays switch due to magnetization of coils. So, the magnetic fields may interfere with the load side or switching

circuitry. But in solid state relays, the switching process occurs through light. They are like high voltage optocouplers and so no interference problems occur in them. They can be used for high speed switching and have an internal zero crossing circuit. This solid-state relay has a load voltage range of 75-264VAC at 50/60Hz and has a current capacity of 2A. The input switching side works on 5vdc with a maximum forward current of 50mA. It has a built-in input resistor and a built-in snubber circuit is present to absorb the voltage spikes and so the relay can be prevented from damage while switching inductive loads.

F. Resistor Network

A resistor network is an array of resistors combined in a single package with various combinations. They have bussed type, decade resistor, voltage divider, isolated resistors and many other types. The bussed type resistors are used in this PLC. A 9-pin SIP package 2.2k ohm resistor network is used to pull-up the IRF9530 MOSFET and 9 pin SIP package 10k ohm resistor networks are used to pull down the microcontroller GPIO pins. Each resistor network has a maximum power dissipation of 1.13 watts, and it is ensured that the power dissipation at full scale operation does not exceed this value.

G. XL4015

The components on board have varying power requirements like 12v, 5v and 3.3v. Since the primary power supply of the PLC is 12v, there is a need for step down converters to convert the 12v into 5v and 3.3v. For this purpose, XL4015 is used. It is a DC to DC converter that works based on PWM and has a fixed frequency of 180khz. It can provide output current up to 5a. They have internal current limiting capability, thermal shutdown and short circuit protection function. The output voltage can be regulated by a potentiometer and they have an efficiency of 96%. They are used to provide suitable power to the components on board. Two XL4015 modules are used to provide 5v and 3.3v to the components in the PLC.

H. BSS138 Bidirectional Logic Level Converter

The GPIO output voltage of PIC16F887 is 5v and many modules have an input logic level voltage of 3.3v. Providing 5v to a 3.3v device will damage it. So, the PLC has an on-board bidirectional level converter that can convert 5v to 3.3v and vice versa. This is a four-channel converter meaning four GPIO pins can be level shifted simultaneously.

5. Design of the PLC

The individual components are tested for their functionalities and the final PLC circuit is designed and simulated. Then the PCB is designed and fabricated. When the user decides the application, the number of inputs and outputs are determined. The switches are positioned according to the number of the number of inputs and outputs. The PIC controller is programmed using LDmicro or Mplab. Then the controller is placed in the ZIF socket and locked. The input and output devices are connected, the system is powered, and the programmed process is initiated.

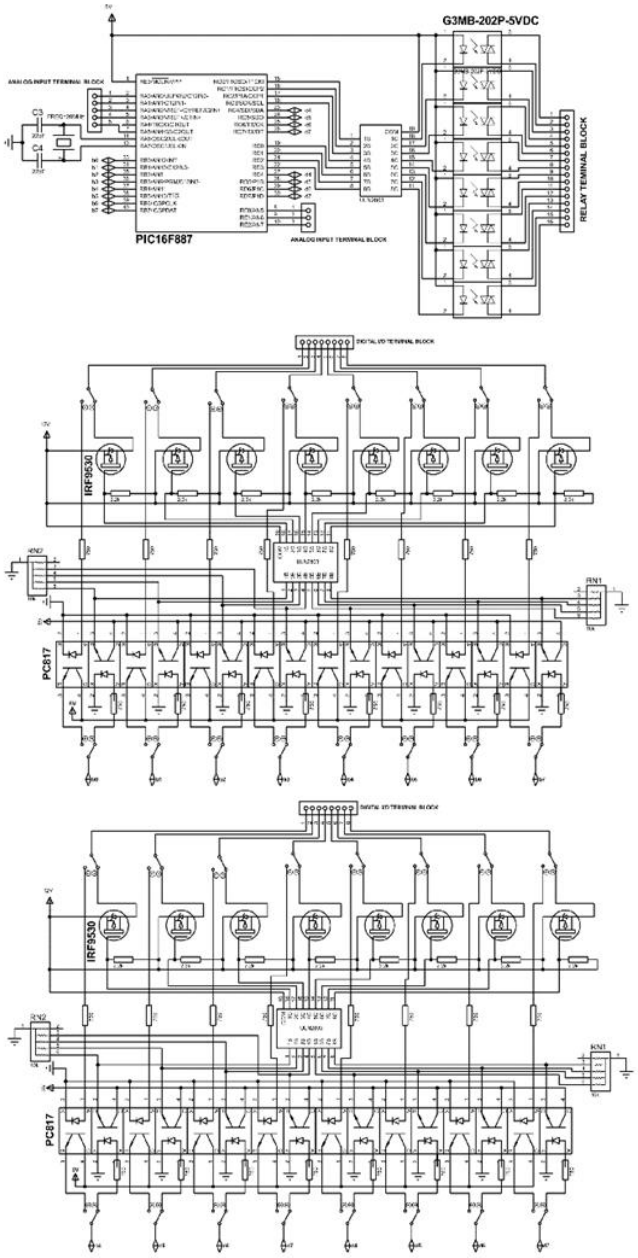

Fig. 2. Circuit Diagram

6. Result and Discussion

A. Result

PLC has been created using PIC as the core controller that makes the PLC an open architecture PLC. The user can now use the PLC for multiple purposes by reprogramming and so does not have the need to replace the existing PLC for each new application. The PLC created using PIC has also maintained all the industrial standards at a lower cost.

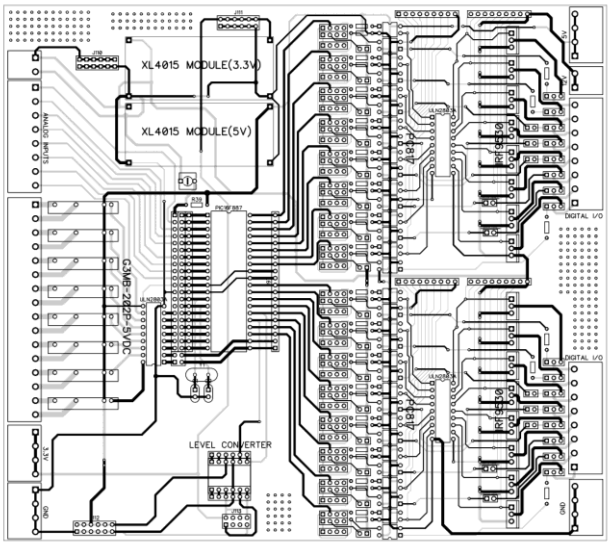

Fig. 3. PCB Layout

B. Merits

- *Open Architecture:* Many external components can be connected and disconnected and the available protocol-based connections in the core controller can be utilized when required.
- *Variable i/o pins:* the i/o can be reconfigured based on the user needs depending on the application.
- *Reprogrammable:* based on the application, the PLC can be reprogrammed and hence be used for multiple purposes.
- *Low cost:* the PLC using PIC has a much lower cost than the available industrial PLC and so is affordable to all.

C. Applications

The multiple purposes of the PLC using PIC has been tested and demonstrated through three different real time applications. Based on the application, the PLC was reprogrammed. The three applications are as follows.

1) Traffic Light Control System

In this application, the all the digital pins in the PLC are configured as output. A four-way traffic light controlling system is built with the countdown timing display. When the system is switched on, the signals in north-south (NS) lane and south-north (SN) lane will be red for 40 seconds. The signals on east-west (EW) lane and west-east (WE) lane will be green. The countdown timer will count from 60 to 21. For the next 20 seconds, the NS and SN signals will be yellow, and the EW and WE signals will remain green. The countdown display will count from 20 to 1. For the next 60 seconds this process will occur interchangeably. This cycle will repeat indefinitely.

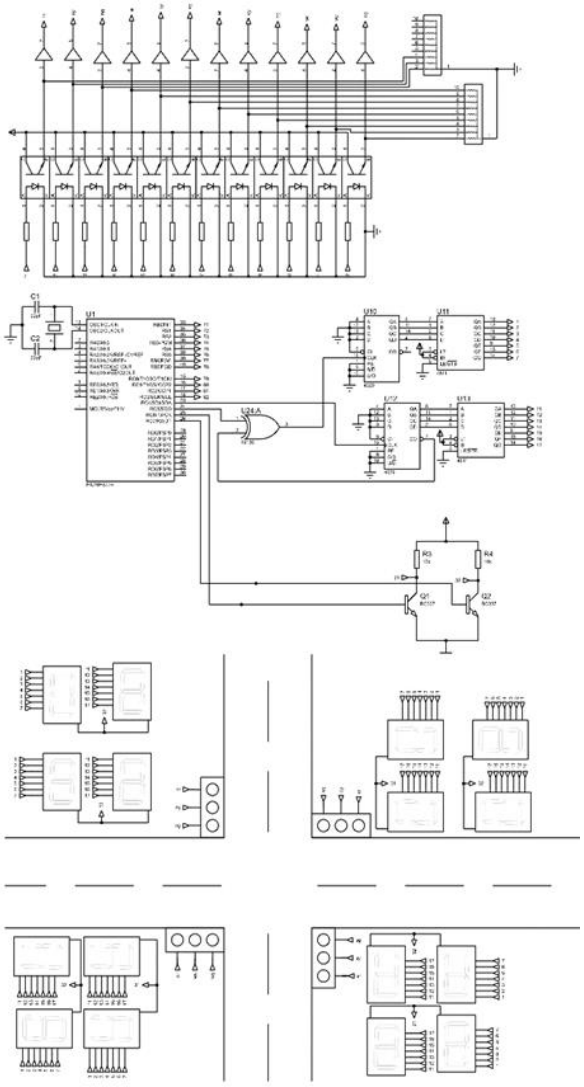

Fig. 4. Traffic Light Control System

2) Boiler Temperature Controlling System

In this application, one input and one relay configuration are used. The temperature in the boiler is provided by a heater. When the temperature reaches a certain value, the relay will be activated, and the heater will be turned off. When the temperature reduces to a certain value, the relay will be deactivated, and the heater will be turned on.

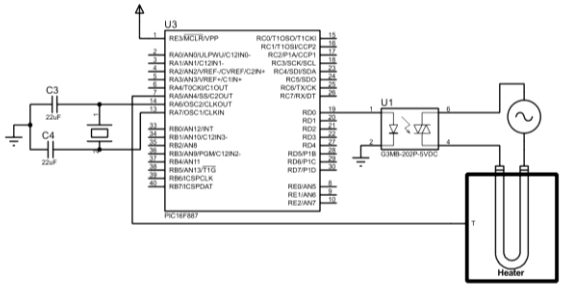

Fig. 5. Boiler Temperature Ling System

3) Bottle Filling System

In this application, there are two inputs and two outputs. When a bottle enters the conveyor belt, it moves forward and the is positioned under the filling nozzle. The position is sensed by a proximity sensor. It gives signal to the controller and it stops the conveyor belt motor. The filling pump will be turned on and the liquid flows through the filling nozzle to the bottle. The filled level of the bottle is sensed by a photo detecting sensor. This sensor gives signal to the controller and in turn, the controller stops the filling pump and the conveyor belt motor. The bottle in position is moved and the next bottle enters the conveyor belt, and this cycle continues.

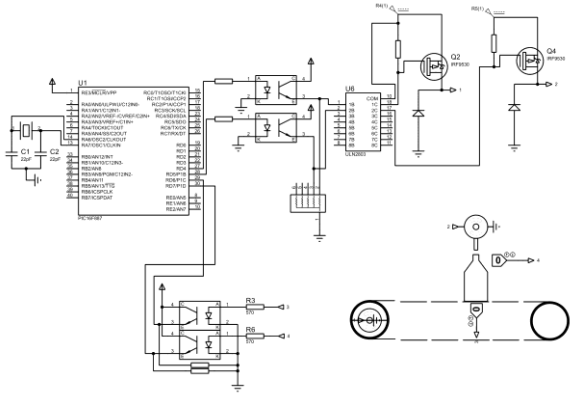

Fig. 6. Bottle Filling System

7. Conclusion

Regularly utilized costly industrial items have considerably more capacity that a portion of their highlights are utilized occasionally. Right now, low cost PLC utilizing PIC microcontroller is structured and actualized. It is meant to produce a fundamental PLC model which can without much of a stretch be changed as per the requirements of explicit procedures. The only requirement is that the user must know to program.

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