DESIGN AND CONSTRUCTION OF A MICROCONTROLLER BASED LABORATORY TRAINER

[1]Onyeyili Tochukwu Innocent, [2]David Idakwo Friday, [3]Nworabude Ekene Franklin, [4]Ogu chiedozie Darlington

[1,2,3,4] Department of Electronic/Computer, Faculty of Engineering, Nnamdi Azikiwe University Awka, Anambra State Nigeria.

Abstract: Design and Construction of a Microcontroller Based Laboratory Trainer is the development of a lab trainer kit to serve as an improvise to carry out Lab experiments for students. The knowledge of microcontroller to engineering students is essential hence it will help them in the development of their prototypes for their design projects. This project is designed using both the 8051 and automatic voltage regulator (AVR) family of microcontrollers in a compact laboratory-type electronic trainer. The trainer is capable of carrying out 7 experiments which include; LCD experiments, 7 segment display experiments, traffic light experiments, streetlight experiments, temperature-based experiments, and logic gate experiments. Results of all the experiments show the trainer requirements of involving conventional electronic and classical control systems.

Keywords: Automatic Voltage Regulator (AVR), LCD, Engineering Microcontrollers, Logic gates, laboratory trainer, Seven Segment Display.

INTRODUCTION

The world over the times has made considerable advancement in digital computerization which is employed in households, industries, commercial and educational sectors. It is realized that the ever growing concentration of modern digital devices and electronics system put innovation and strict requirements on the education, particularly in the field of science technology and engineering. [1]. A microcontroller is a small computer on a single integrated circuit, which contains a processor core, memory, and programmable input/output peripherals (Bannatyne & Viot, 1997). A microcontroller is widely used nowadays in almost every application such as printers, remote control, and modern automobile. Because of its usefulness, engineering students find it essential in building design prototypes for their thesis related projects. Microprocessor and Design Projects are important subjects required to complete their course (Hamad, Kassem, Jabr, Bechara, & Khattar, 2006). In these subjects, students are required to learn the concepts of Microprocessor system and its purpose. However, the previous researches use the older version of Programmable Interface Controller (PIC) microcontroller for their laboratory experiments (Hamad et al., 2006), where they need external clock and other components for it to function properly. Hence, previous designs were prone to complications. In the department of electronic & Computer engineering, Nnamdi Azikiwe University, Awka Nigeria, the courses on Microprocessor Systems (ECE 421) and Design Projects (ECE 517/) are two of the important subjects required for ECE students to complete their course. In these subjects, students are required to learn and understand the concepts of a microcontroller and their purpose. These students conduct laboratory activity by taking the electronic components and other devices piece by piece during lab activity. These components are prone to damage or loss, disorganization, and non-systematic laboratory activity. With this scenario, the components and microcontroller modules are easily damaged due to electrostatic discharge brought by humans to the components. For this reason, the proponents decided to develop a trainer module that integrates and organizes various microcontrollers, electronic module, and other devices to limit electrostatic discharge. It allows students to earn self-pace the concepts of hardware programming (Hamad et al., 2006). The main goal of this study was to assist students in prototyping their future projects; enhance user's programming skills in hardware applications, and help the students in understanding the concept presented in the laboratory experiments.

Review of Related Literature

In the past years, extensive research has been done on the design and construction of microcontroller-based trainers, or microcontroller digital training kits as they are sometimes called to facilitate the technological learning process in

tertiary Institutions [6].

These research works developed a Microcontroller Training System for Hands-on Distance and Campus-Based Classes using PIC microcontrollers. The training system was designed with many basic modules such as power supply, input/output switches, keypad, interrupt inputs, LED outputs, LCD display, serial interface, parallel interface, PC communication interface, high power motor driver, sensing, etc. It was also built with the flexibility to accept advanced module connections for future expansions.

These research works developed an Integrated Microcontroller-based Tutoring System for Computer Architecture Laboratory Course. The main component was an 8-bit microcontroller unit (MCU) MC68HC908GP32. The board was designed to support voltage regulation and protection against power inverses and short circuits. It also supported in-circuit simulation/debugging and programming of the microcontroller's flash memory through an RS232 serial link (DB9-A). The configuration mode was enabled through six slide switches (SWPTC0, SW-PTC1, SW-PTC3, SW-IRQ, SW-PTA0, and SW-PTA7) [6].

Literature Gaps

In the reviewed works only, PIC microcontrollers were used thereby reducing the performance of the trainers. This was rectified in the design and construction of this project by implementing two different families of microcontrollers which are the 8051 and the AVR family [7].

MATERIAL AND METHOD

The waterfall prototyping model was used in the implementation of the various units in which each unit is developed separately from other units, at the end of which the whole unit is integrated together to form a whole system. For each unit added to the system, they must be tested before advancing to the next stage. This method makes for ease in troubleshooting each unit separately. After the development of all the units of the laboratory trainer, the various units are integrated, further test carried out to ascertain the system's workability before the final packaging and deployment.

Quite a number of properly laid out steps were followed to achieve this project. Each step is carried out with care knowing that each successive step is dependent on the success of the previous step. These steps are represented in figure 3.1 shown.
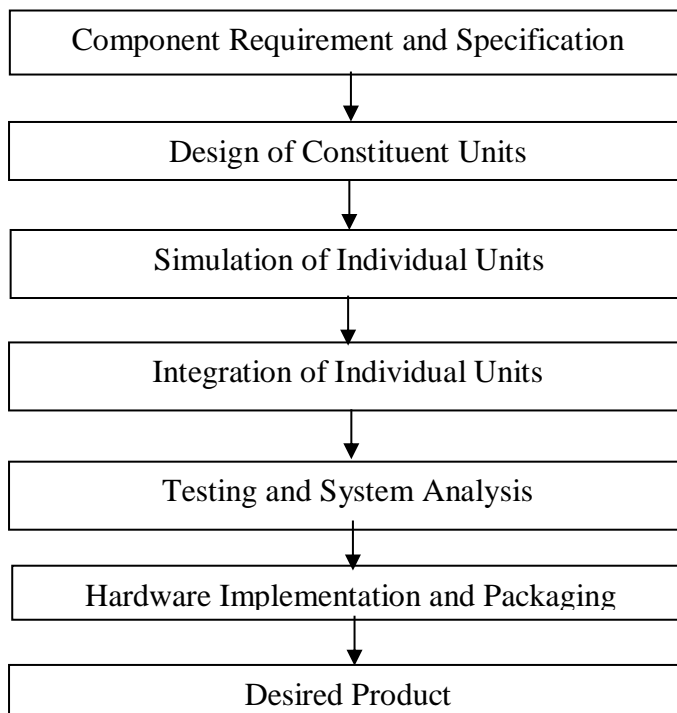
Figure 3.1 Block diagram of process outline

Step 1: Component Requirement and Specification

The hardware and software components required for the complete execution of the project are determined in this stage. The hardware requirements are At89c52 and ATMEGA328p microcontrollers, Light Dependent Resistor (LDR), thermostat, Alternating Current (AC) lamp, DC motor, LEDs, variable resistors, resistors, capacitors, power source, transistors, seven-segment display, DOT matrix display, logic gates, Zener diode, 7805 voltage regulator, LCD display. Software requirements: MIDE-51, Proteus, PETMEG.

Step 2: Design of Constituent Units

This is the second stage that includes the design of the electrical and electronic units of the system. In this stage, the contents of each block are not considered, only what each block must do is considered. This is sometimes referred to as a "black box" design. Each block was considered in more detail, though with a lot more focus on the details of the electrical functions to be provided.
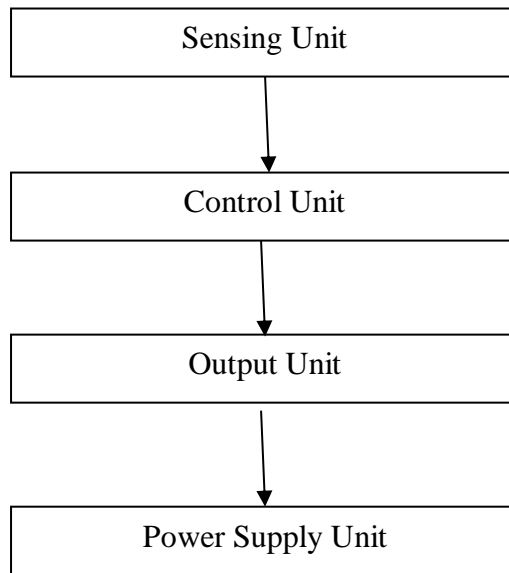
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┌─────────────────────────┐
│      Sensing Unit       │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│      Control Unit       │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│      Output Unit        │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│    Power Supply Unit    │
└─────────────────────────┘
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Figure 3.2 Block diagram for the electronic circuit

Once again, each step is carried out with careful articulation, because the success of each successive step is dependent on the success of the previous step. Having done this, the circuit design proceeded.

Step 3: Simulation of Individual Units

Simulation models a real-life or hypothetical situation on a computer so that it can be studied to examine system performance. This helps to have a preview of what system performance might be like. After developing the circuit diagram, the system was simulated by means of a schematic capture tool called Proteus Virtual System Modeling (VSM). The Proteus design suite offers the ability to simulate and monitor the design model. It is a tool to virtually investigate the behavior of the system under study, changing variables in the simulation leads to predictions to be made about the behavior of the system.

Step 4: Integration of Individual Components

After simulating each constituent part and it functions properly, they are now integrated to form the whole system.

Step 5: Testing:

Performance evaluation is carried out at this stage and necessary modifications were made to meet the objectives of the system. After which the design is then implemented fully.

Step 6: Packaging

The final stage is the packaging of the entire circuitry. Choice of material for the packaging is made based on their ability to withstand the heat generated by the circuit and also suitability for outdoor purposes.

Hardware Design and Analysis

After finalizing the session topics, work began on the hardware design. The initial goal was to design a microcontroller-based laboratory trainer circuit using the 8051 and AVR microcontrollers. Due to the complexity of the project, four microcontrollers (three AT89C52 which are 8051 family, and ATMEGA328p which is an AVR family of microcontrollers) were used in the design of the project thereby sharing most of the experiments to be handled by each of the microcontrollers. This will make for easy understanding. Two microcontrollers would have been used to achieve the same purpose but the four microcontrollers were used to mitigate the complexity and avoid many multiplexing that would have resulted in the breakdown of system.
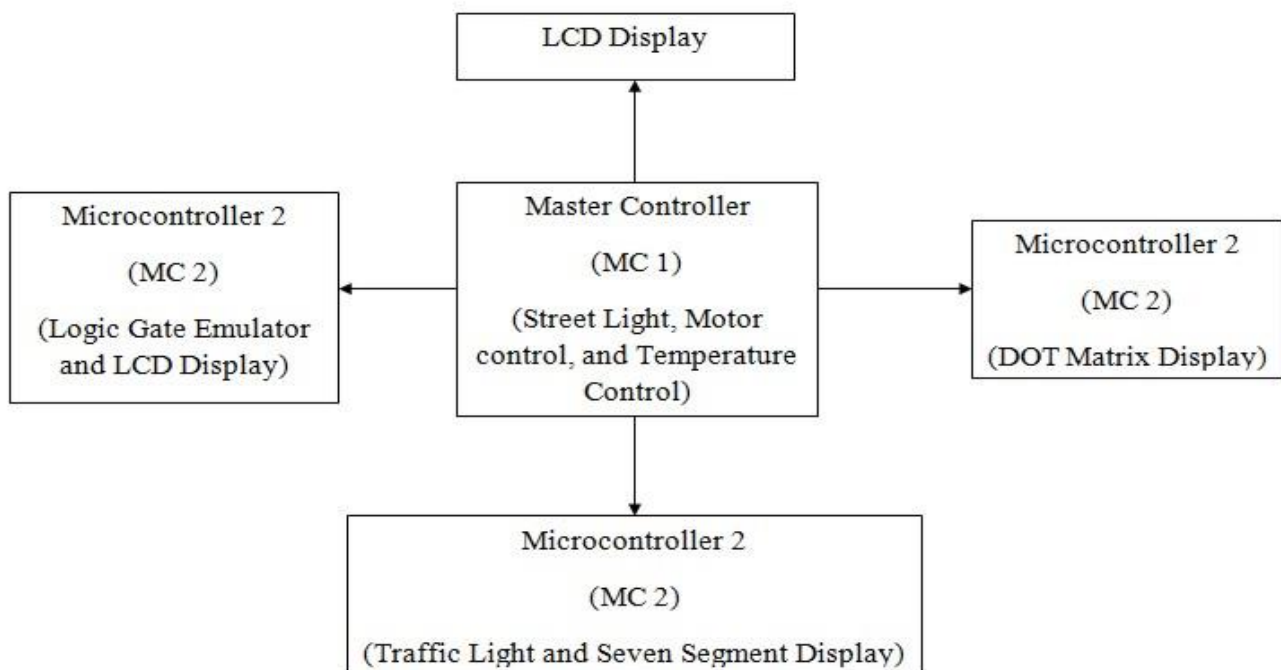

Figure 3.3 Block diagram of a microcontroller-based laboratory trainer

Design of the Master Control Unit

The microcontroller used here is the ATmega328p which is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs close to 1MIPS per MHz This empowers the system designer to optimize the device for power consumption versus processing speed. The microcontroller was chosen because of its high performance and low power consumption. The master controller (MC1) controls three experiments which are the temperature control experiment, motor control experiment, and street light experiment. It also has a 20x4 LCD display interfaced to it which is used as the master display which is connected to pin 11 of the microcontroller and displays which experiment is to be selected.

Power Circuit Design

In most electronic products or projects, a power supply for converting mains AC voltage to a regulated DC voltage is essential. For making a power supply, designing each and every component is essential. Here, the design of 5V Power Supply is considered.

The design of any circuit begins with a general block diagram. It helps us to design the sections of the circuit individually and then at the end put them together to have a complete circuit.

The general block diagram for this project is given below. It is very simple. It has the following four main sub-blocks.

1. The Transformer
2. The Rectifier Circuit
3. The Filter
4. The Regulator

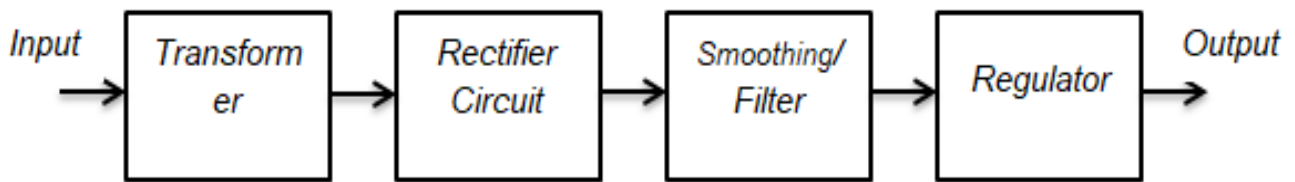Each block is explained in general and then follows the design.

Fig 3.31 Block diagram of the power circuit

RESULT AND DISCUSION

Logic Gate Emulator Design

A logic gate is an idealized or physical device implementing a Boolean function; that is, it performs a logical operation on one or more binary inputs and produces a single binary output.
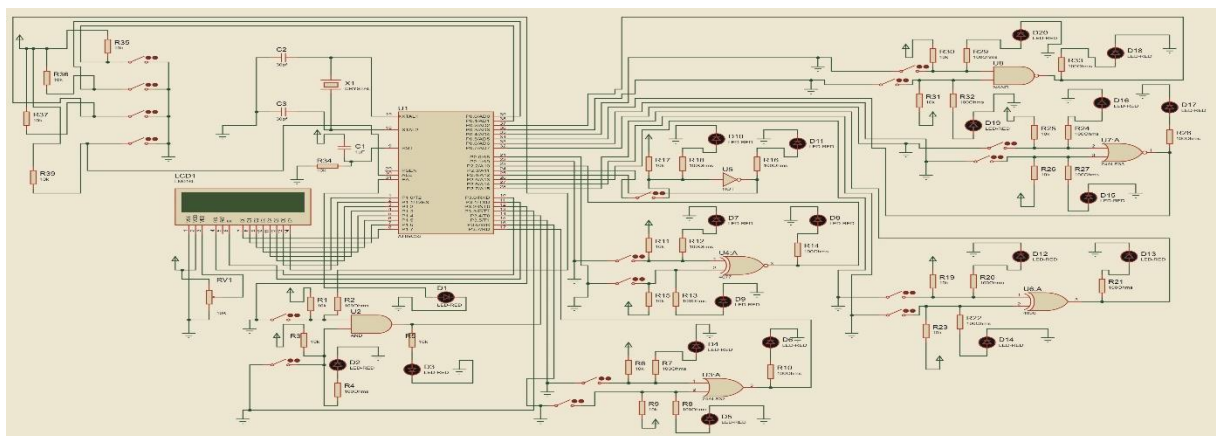

Figure 3.21 Circuit diagram of the MC 4 module

From the circuit diagram in figure 3.21, each logic gate has two switches connected to the input pins of the logic circuit. The switches are used to perform the gate experiment and are still used to select the particular gate to experiment on.
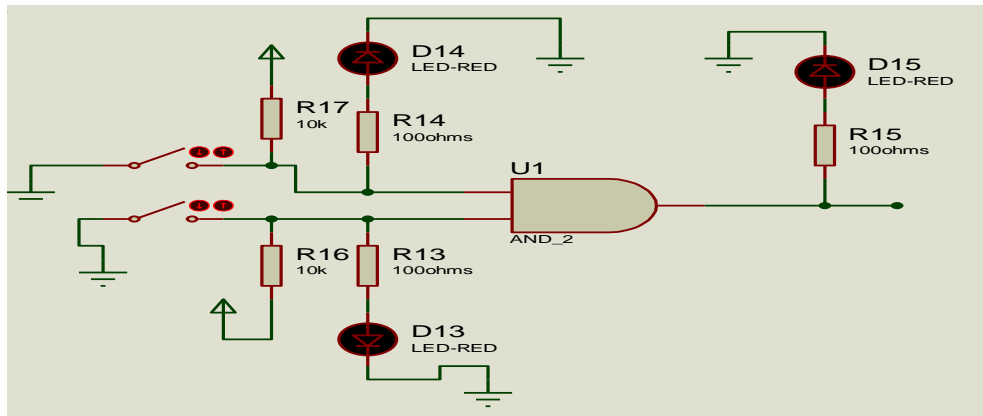
Figure 3.22 Configuration of logic circuits

This design is in such a way that when the both switches are closed, it depicts that the particular logic gate has been selected to experiment on which the experiment now follows. The LED glows when the switch is closed. To determine the amount of current that enters into the LED;
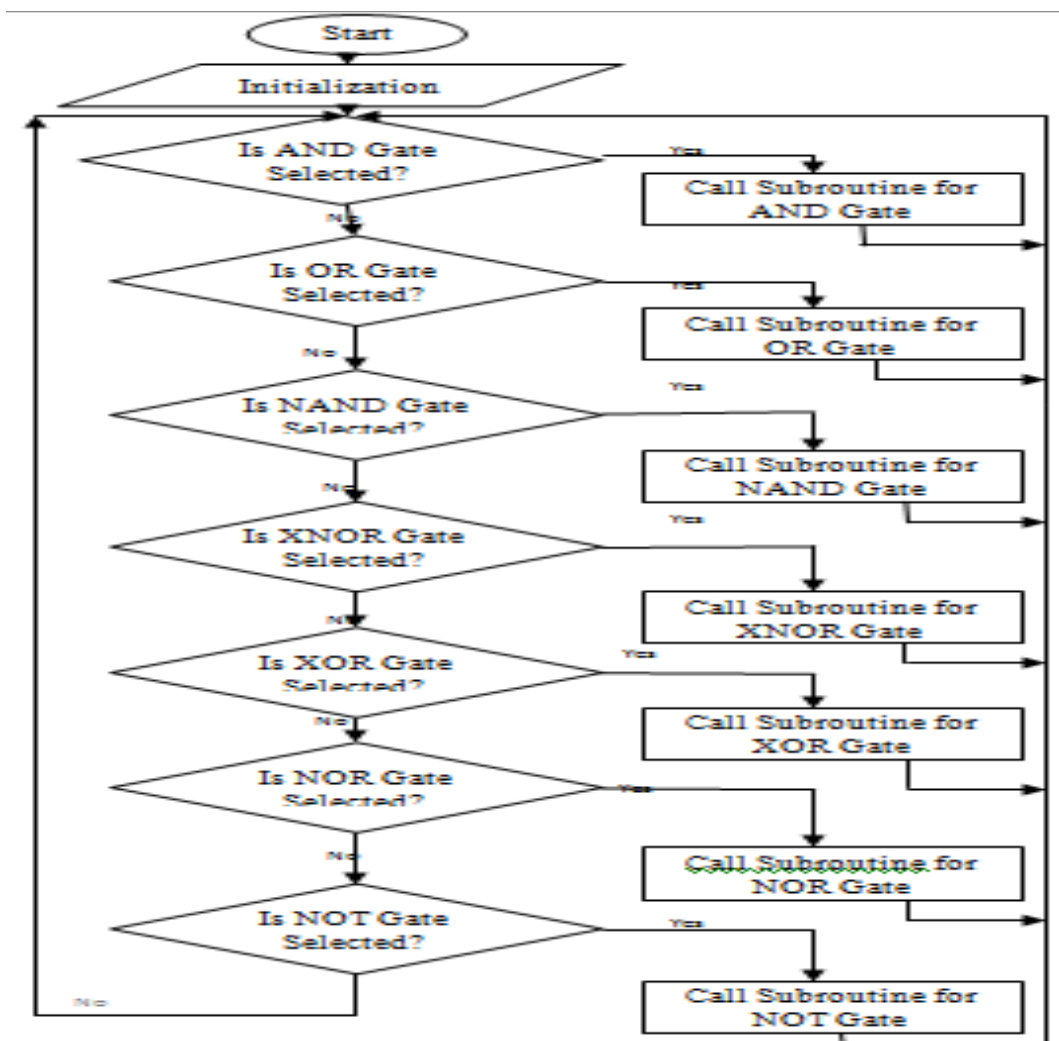

Figure 3.23 Flowchart of logic gate emulator

The LCD is connected directly to the ports of the microcontroller. The LCD already has its own internal configurations.

Seven Segment Display

Seven segment display is an electronic device that consists of seven Light Emitting Diodes (LEDs) arranged in some definite pattern (common cathode or common anode type), which is used to display Hexadecimal numerals (in this case decimal numbers, as input, is BCD i.e., 0-9).

Two types of LED display:

1. Common Cathode Type: In this type of display all cathodes of the seven LEDs are connected together to the ground or –Vcc (hence, common cathode), and the LED displays digits when some 'HIGH' signal is supplied to the individual anodes.

2. Common Anode Type: In this type of display all the anodes of the seven LEDs are connected to a battery or +Vcc and the LED displays digits when some 'LOW' signal is supplied to the individual cathodes.
But, a seven-segment display does not work by directly supplying voltage to different segments of LEDs. First, our decimal number is changed to its BCD equivalent signal then BCD to seven-segment decoder converts that signal to the form which is fed to seven segment display.

This BCD to seven segment decoders has four input lines (A, B, C, and D) and 7 output lines (a, b, c, d, e, f, and g), this output is given to a seven-segment LED display which displays the decimal number depending upon inputs. The 74HC245 Integrated Circuit (IC) was used in this case.

The **74HC245 is an 8-bit transceiver IC** with 3-state output. Meaning it has two sets of pins (A0-A7 and B0-B7), in which each set has 8 pins. Out of these two sets one set can be used as input and the other set can be used as output. Since the IC is a transceiver IC, Data can flow from input bus to output bus and also from output bus to input bus, by simply toggling the Direction pin (DIR) pin as required. It also has a decent output current of 35mA and hence can be used to drive nominal loads. It is also possible to use this IC for establishing communication protocol buses (SPI, IIC, etc) between two different Microcontroller Unit/Microprocessor Unit (MCU/MPU) with different operating voltages since the IC has a high-speed buffer.

The output current of the microcontroller is used to switch the seven-segment display.
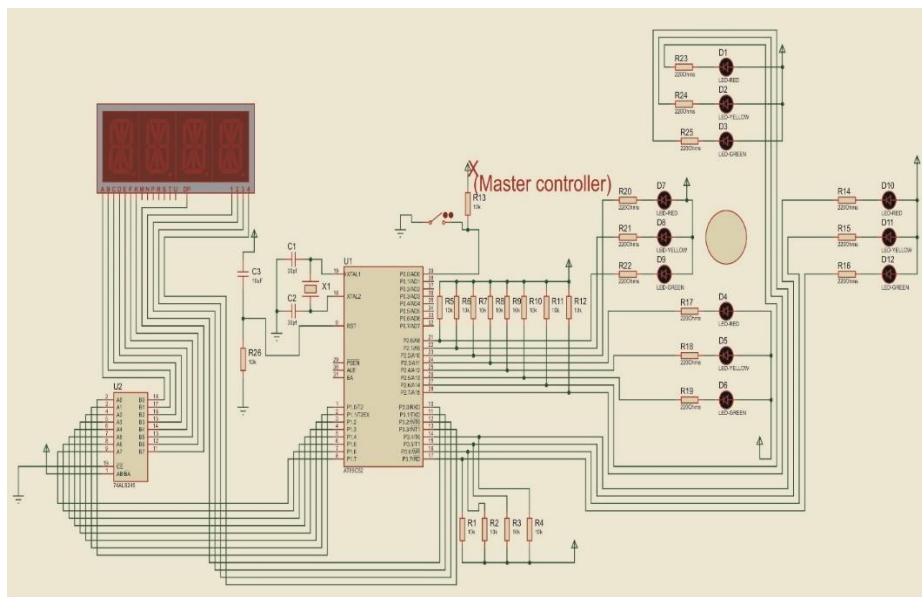

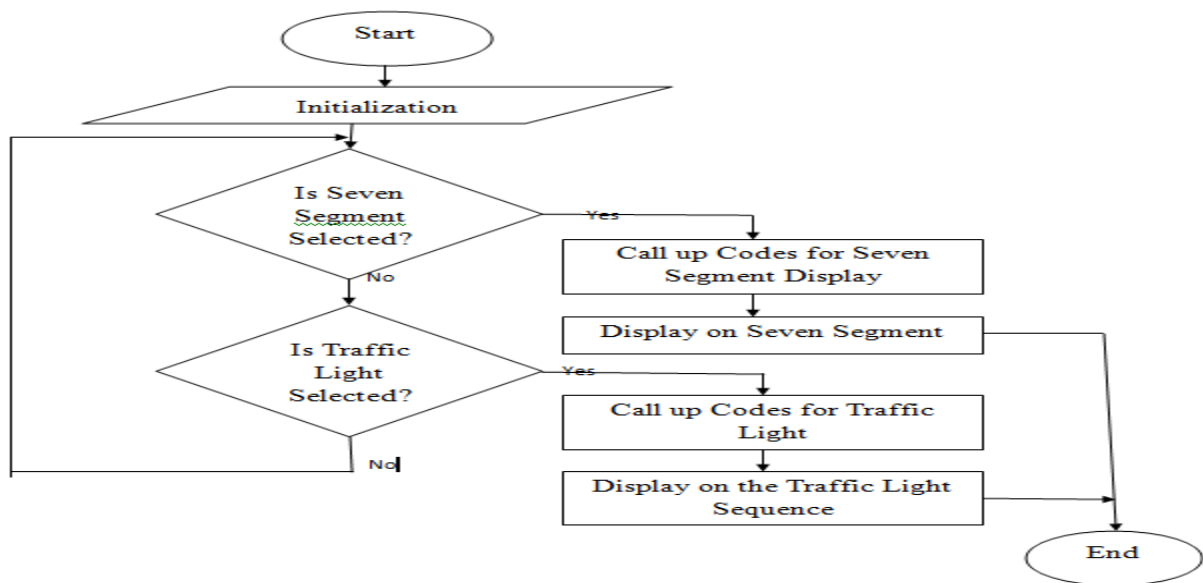**Figure 3.18 Circuit diagram of microcontroller**

Figure 3.19 Flowchart of MC3 module

Design of Microcontroller Module Four

This module handles the logic gate emulator and LCD experiments. The type of microcontroller used here is the AT89C52 which is a family of 8051 microcontrollers.

Prototype

The system implementation of this project employs the prototyping technique. There are three approaches to prototyping namely:

1. Throw away / Rapid prototyping
2. incremental

Each approach has strengths and weaknesses. The decision to go with one approach over the other may be determined by the requirements of the prototype.

Below is a summary of each approach;

1. **Rapid prototyping:** Here the prototype is discharged or thrown away after a small part of the system is developed and evaluated.

2. **Incremental:** The incremental approach can be likened to 'building blocks', incrementing each time a new component is integrated based on an overall design solution. When all the components are in place, the solution is complete. An advantage of this method is that the client has the opportunity to test the developed components and their functionality. They also have opportunities to provide feedback while other components are still in development, and can thus influence the outcome of further development.

Construction of the Microcontroller-Based Laboratory Trainer

This stage is the most technical aspect of the work. This project's design and construction is divided into four sections, which are as follows; the Direct current (DC) supply battery charging, frequency generator, relay switching driving and amplifying, voltage transformation section.

The construction stage is the physical integration of these sections to form one system unit.

Testing

From the analysis of the sections mentioned in materials and methods, all the components were tested and coupled carefully to give the best result. Simulations were also carried out to ascertain the performance of the system and also different forms of tests were carried out to ensure that the system works as its expected.

Three (3) types of tests were performed on the system namely:

a. Unit testing
b. Integrated testing
c. System testing

Packaging

Several factors led to the type of packaging being adopted which includes mechanical damage protection, moisture protection, portability, cost and even convenience. The packaging was carried out using a plastic adapter box. The size was to suit the rectangular form of the overall circuit. The upper section of the packaging was cut off to provide ease of access to the laboratory trainer board. The power supply port was also made accessible to the user through a perfect matching hole placed by the side. Screws were then used to secure the circuit board to the base of the Perspex case to ensure the external ports are firm.

CONCLUSION

The evaluated results from the respondents on the created trainer boards show that it helped the students learn the concepts presented in the laboratory experiments. The results on the assessment of the respondents' confidence in applying the knowledge that they have learned in using 8051 and AVR microcontrollers or other kinds of microcontrollers further ascertains that the created laboratory experiments and trainer boards are helpful in teaching the students programming and interfacing microcontrollers.
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