DESIGN AND IMPLEMENTATION OF A REAL TIME AUTOMATIC CONTROL SYSTEM TRAINER

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ABSTRACT

Engineering and Technology is a field that requires practical experience for better understanding of its operations and for effective implementation. There is no system without any form of control if a predefined outcome is anticipated; therefore, an in-depth knowledge of control system is a must for every engineer. The indigenous Real Time Automatic Control System Training kit proposed in this work is intended for use in Electrical/Electronic Engineering control laboratory. It comprises of seven modules: the power unit that supplies power to the system; the LCD (Liquid Crystal Display) unit that displays the state of the system at any particular time; the Traffic Light Unit for experiments in traffic light monitoring and control; the Temperature Control Unit for temperature monitoring and control; the Automatic Security Light Unit for trainings in Security light design; the Intruder Detection and Alert Unit for experiments on the design of security management systems using intruder detection system and alarm and the Controller which is the central control unit for the system. There is also an extension for the connection of bread board if the students want to develop other microprocessor based control systems. The microprocessor is detachable so that the student can reprogram the chip to suit his or her application. This system if implemented will greatly enhance engineering training in Nigeria and can also be a great revenue source for the country.

Keywords: Real Time, Automatic, Control, Trainer.

INTRODUCTION

Automatic Control systems are implemented to increase dynamical performance or precision of scientific and industrial equipment. The basic principle of such system is to take into account actual measurements in order to compute appropriate actuations that adjust the operational conditions to meet given requirements (Salzmann et al, 1999). Due to this broad application field and its interdisciplinary nature, Automatic Control is a fundamental subject usually taught in many engineering disciplines, such as electrical, mechanical and chemical engineering. Practical experimentations are made during laboratory sessions where students can try out on real processes the material they learn during the class (Gillet et al, 1994). As a matter of fact, implementing a complete control solution from scratch requires knowledge not only of the matter studied but also of the different technologies needed to interface the real process, such as sensors and actuators, to the computers or hardware used to conduct the experiment. Knowledge of hardware interfacing and real-time programming are also needed to carry out the experiment. Fundamentals of all these aspects should be taught to students in automatic control. Acquisition of measurements and modification of actuations are the usual tasks carried out by automatic control systems.

Students studying engineering in Nigerian universities are faced with the challenges of inadequate exposure to these practical experiences due to the inability of the institutions to provide the needed laboratory equipment especially with the dwindling economy. Some software laboratories exist and are very good but they cannot be compared to physical exposure. There is therefore need for a training kit especially in the field of automation which is the bedrock of modern control engineering. The training kit proposed in this work seeks to solve this problem by providing a mini-laboratory for real time automatic control system.

LITERATURE REVIEW

A Real-Time System (RTS) is defined as a system in which the time where the outputs are produced is significant. The outputs must be produced within specified time bounds referred to as deadlines. The correctness of a RTS depends not only on the logical results produced, but also on the times at which such results were produced. The system may enter an incorrect state if a correct result is produced too early or too late with respect to the specified time bounds or deadlines. Figure 2.4 shows a block diagram representation of an example of a RTS.

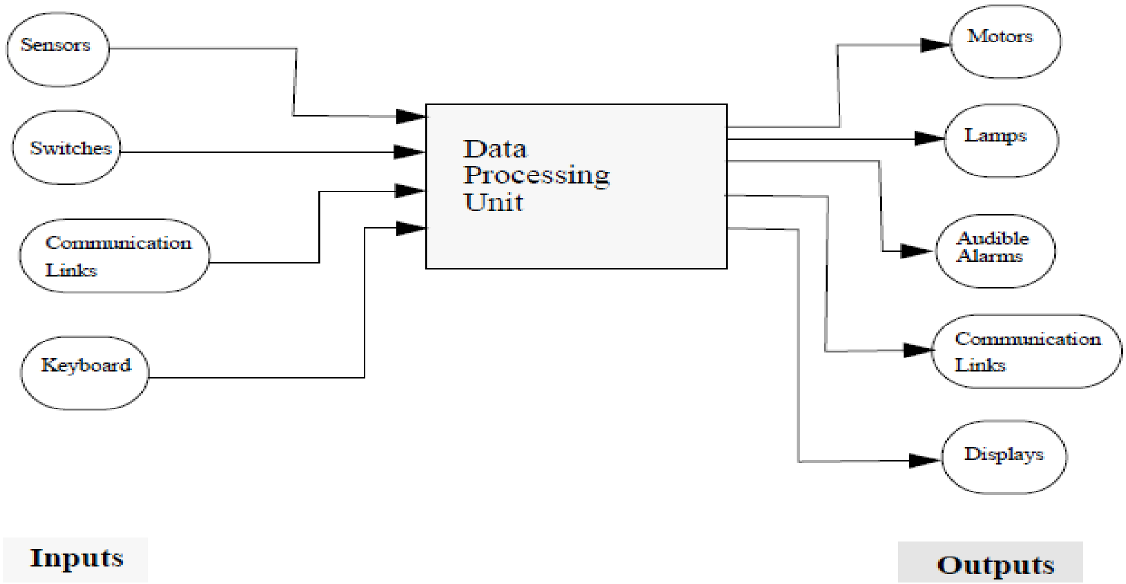

Figure 1: Example of Real Time Control System

Some works have been done in automatic control system trainer. This section is on the review of such works with a view of finding gaps which the proposed wish to fill. Industrial Automatic Control Trainer by Didactic Dolang (Dolang, 2016) is an industrial automatic control trainer, where students can complete experiments relating to electrotechnics, electric drive, PLC, frequency converter, text display, and others. They can digest multiple related technologies in their normal learning and training operations. This realizes educational resources sharing and optimizes the experimental teaching management.

Sprel Ltd (Sprel, 2016) displayed some automatic control system trainers like lab-Volt, the one by Deltronics, Elabo, Bytronics and Leaptronix to mention a few. Zhongyou (2016) talked about Automatic control principle teaching experiment apparatus which is specifically designed for satisfying open automatic control principle experimental teaching with open-structured experiment teaching device, which has the characteristic of favorable performance and open structure, providing a good platform for automatic control principle experimental teaching level.

Finally, the work in (Robert et al, 2006) worked on the use of rapid prototyping tools for automatic control system laboratory. These trainers are good but are imported and very expensive and as such are not readily available in schools. Some of them are very complex and customized

METHODOLOGY

This dissertation used top-down design approach and prototyping methodology in its design and implementation. The design of this project will be done under two headings namely hardware and software design.

Hardware Design

The Real Time Automatic Control System Trainer is made up of seven sub-systems. They are: the power unit, the intruder detection unit, the traffic light control unit, the temperature control unit, the Display unit, the automatic security light unit and the controller. Figure 2 shows the block diagram of the system showing the different units.

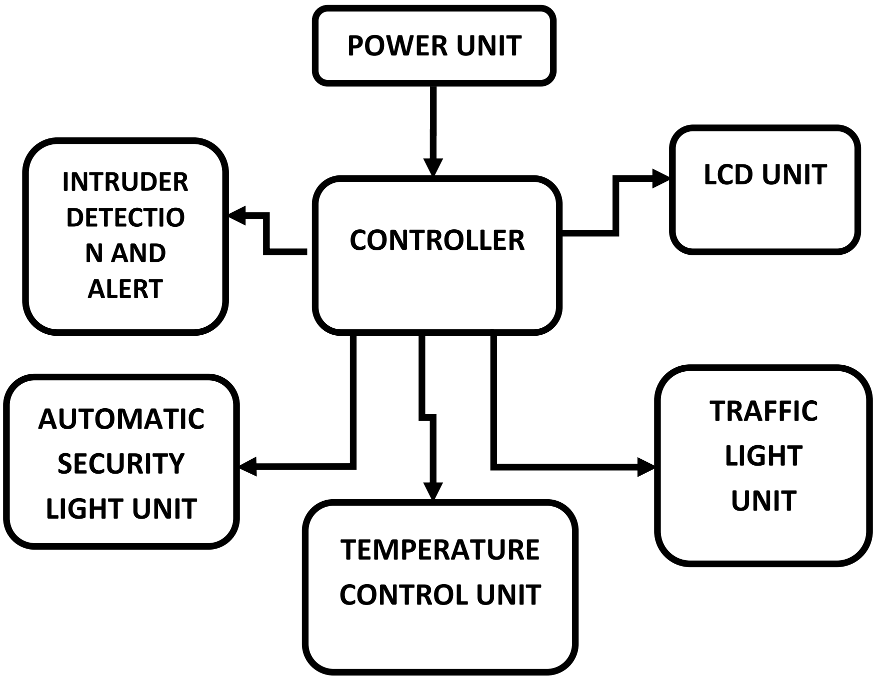

Figure 2: Block diagram of the prototype Real Time Automatic Control System Trainer

The power supply is the source of constant and efficient electric energy needed to power the system. This is supplied by a 5V, 2A power supply adapter through a power jack, and then the output is then further smoothened by a 10uf capacitor. Additionally, it has a LED indicator which helps indicate when the power is available.

Intruder Detection and Alert Unit

This unit is for performing experiments on intruder detection and alert systems. It consists of an infrared module for intruder detection and an arrangement of resistor, transistor, diode, LED and a buzzer for alarm activation. IR LED is used in this circuit to transmit infrared light. Photo diode is used to capture reflected light of IR LED. When an intruder is detected, a signal is sent to the p1.4 of the control unit which interprets it and sends a corresponding signal to the alarm sub unit through the p0.3 of the control unit for necessary action.

Alarm Sub-system Calculation

The system sounds an alarm when an intruder is detected. The alarm unit is connected to the microcontroller and the basic design here is achieved by the use of resistors and transistor. This transistor is configured as a switch. It functions as a switch if it is properly biased. For proper biasing, the base current (C_b) must be ten times smaller than the Collector current (C_c). But

$$I_c = LED\ current\ + buzzer\ current \tag{1}$$

$$LED\ current = \frac{5}{220} = 22.7mA$$

Remember

Buzzer current(BZ) $=$ 5mA

$$I_c = 22.7mA + 5mA = 27.7mA$$

$$R_c = \frac{V_c}{I_c} \tag{2}$$

Since $V_c = 5\text{v}$

Therefore

$$R_c = \frac{25}{27.7\text{mA}}$$

$$R_c = \frac{25 \text{ x } 10^3}{27.7}$$

$$R_c = 0.90\text{k}\Omega$$

Approximately $R_c = 1\text{k}\Omega$

Therefore, for approximately 27.7mA current to flow through the collector, a buzzer with resistance of 780Ω and 220Ω were used at the collector of the transistor.

Hence, considering the base resistor

$$I_c = I_b \beta,$$

$$therefore \qquad I_b = \frac{I_c}{\beta} \tag{3}$$

B > 5 x load current

$$\beta > 5 \times \frac{Loadcurrent}{\text{Max.chip current}}$$

But, load current = 27.7mA, Max. Chip current = 20mA

$$\beta > \frac{5 \times 27.7 \times 10^{-3}}{20 \times 10^{-3}}$$

$$\beta > 6.93$$

Therefore, let β = 7

From equation 2

$$I_b = \frac{27.7 \times 10^{-3}}{7}$$

$$I_b = 3.96\ mA$$

But, $R_b = \dfrac{V_b}{I_b}$

$$V_b = 5\text{v}$$

$$R_b = \frac{5}{3.96\text{x } 10^{-3}}$$

$$R_b = 1.26\ k\Omega$$

Hence a 1K Ω is used to ensure the transistor is driven to saturation.

Automatic Security Light Unit

It performs experiment as regards automatic security light, which comes on at night or when it is dark and goes off during the breaking of the day. This unit is made up of the darkness detection sub-unit (light dependent resistor) and the security light switch. The LDR (Light Dependent Resistor) uses the intensity of the light rays it receives to determine when it is dark.

On detection of darkness (i.e. very low light intensity) by the darkness detector sub unit, a signal is sent to the control unit which interprets it and then activates the security light by biasing the transistor in the security switch sub unit. When the light intensity increases the security lights are automatically switched off.

Temperature Control Unit

This unit allows one to perform an experiment that has to do with temperature monitoring and device control. This unit is made up of LM35, resistor, LED and an Analog to Digital Converter (ADC). The output of LM35 gives analog reading which is converted from Analog to Digital through the ADC and its output fed into the port 3 of the control unit, LED is used to indicate when the temperature limit (in this case 29^{o}C) is exceeded, while all its activities are displayed on the central Liquid Crystal Display. The output voltage from theLM35 is linearly proportional to the measured temperature. The network of resistors and zener diodes seen in the ADC configuration supply 1.28V to the $V_{ref/2}$ pin of ADC0804 as its reference voltage as shown in fig.3.5. This is the voltage by which the step size of the ADC0804 will be set to 10mV. LM35 output voltage varies by 10mV per °C change in temperature. Hence both the LM35 and ADC0804 are now working at 10mV change. So for a range of 0 to 100^{o}C, LM35 outputs 10mV per ^{o}C and ADC0804 processes 0V to 1V.The state of the module and the ambient temperature as sensed by the LM35. The system sends a signal to the actuator triggering a predefined action when the redefined maximum temperature is exceeded. In this work the maximum temperature is 29^{o}C and the actuator puts on an LED. In real life application it can be to put on a cooling system if it is an industry it can be a cooling system or it can be a fan in the home.

Traffic Light Control Unit

The traffic light control unit allows one to perform an experiment that has to do with traffic light demonstration, but this is limited to T-junction. For the purpose of the demonstration nine LEDs were used. The LEDs are configured as common Anode, while the cathodes of the individual LEDs were interfaced to the port 2 of the control unit.

Limiting resistor for all led used in this work

From database, LED allowable current is taking as 23mA, and 5v across it.

But $R = \mathrm{V}/\mathrm{I}$

$$R = 5/23\text{x } 10^{-3}$$

R =217Ω

But for this work, **220Ω** Resistor was used since it is readily available in the market.

Liquid Cristal Display (LCD) Unit

This unit is responsible for displaying all the activities of the system, making it user friendly. HD 44780 based LCDs are most commonly used.

The Control Unit

This unit does the entire processing of all the input signals to the system and as well as take the necessary action in response to the input (s). It consists of four control buttons and an Atmel microcontroller (AT89C52). A 10uf/16V capacitor and 10KΩ resistor was connected to pin 9 to complete the reset of the microcontroller. To perform traffic light experiment the control button T.L is pressed, to perform security light experiment S.L control button should be pressed, on performing temperature experiment TEM control button should be pressed and to perform experiment regarding intruder alert then T.A control button should be pressed.
The circuit diagram for the system is shown in figure 3.

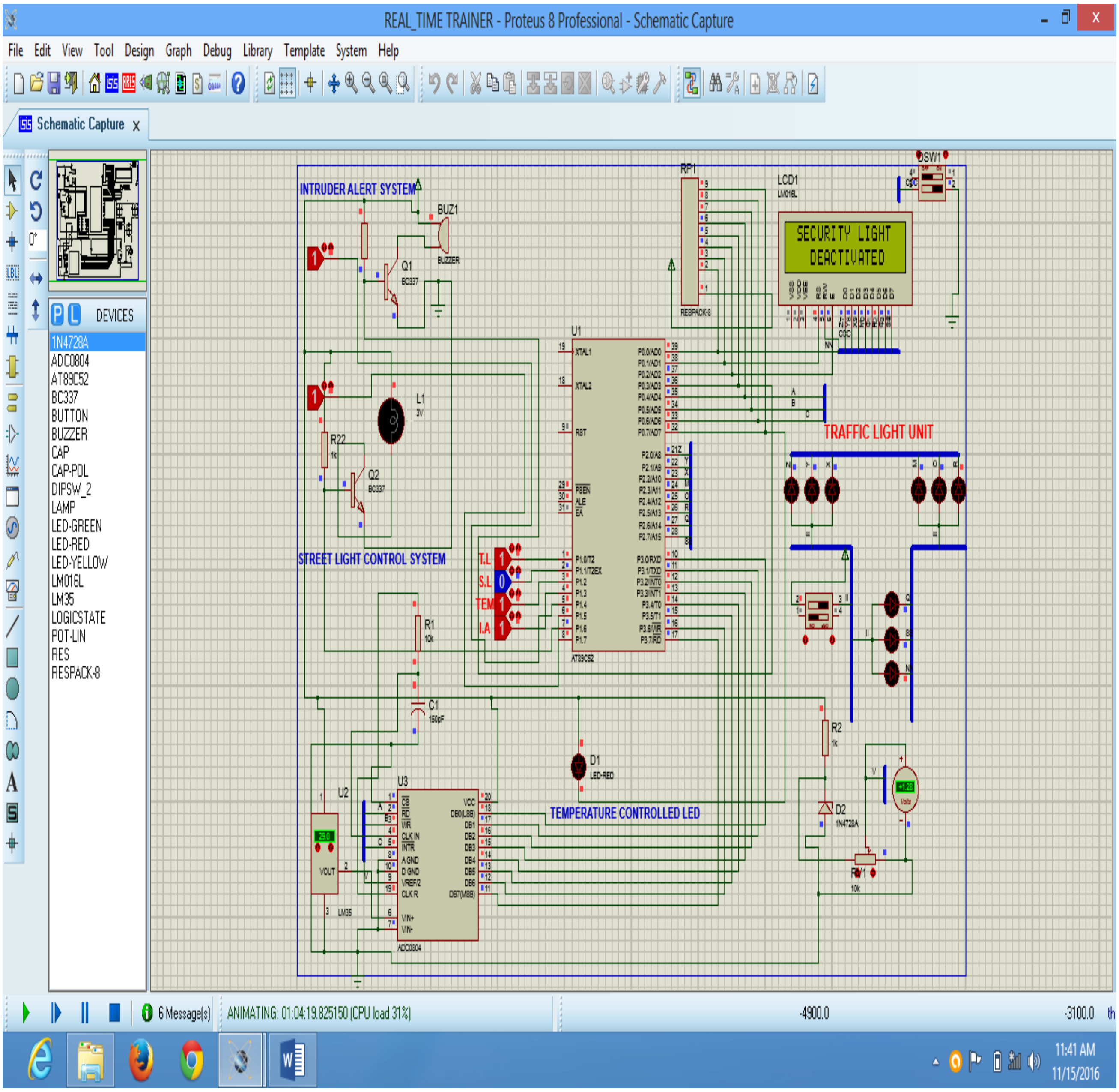

Figure 3: The complete circuit diagram of the Real Time Automatic Control System Trainer

The Software Design

The software design involves the design of the flowchart for the AT89C52 control program. Software has become the most critical element in the design and implementation of a computer based system of whatever size. Because of the critical nature of software, structured

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programming and top-down software development methodologies are usually used by many microprocessor system application designers.

In structured programming, each software component is first described in terms of a few fairly abstract statements, and then they are iteratively refined until they could be expressed in the algorithm. The application program, that is, the set of instructions directing the microprocessor's execution of a specific task must first be developed and then loaded into the memory unit. The flow chart for the software program is presented in the figure 4

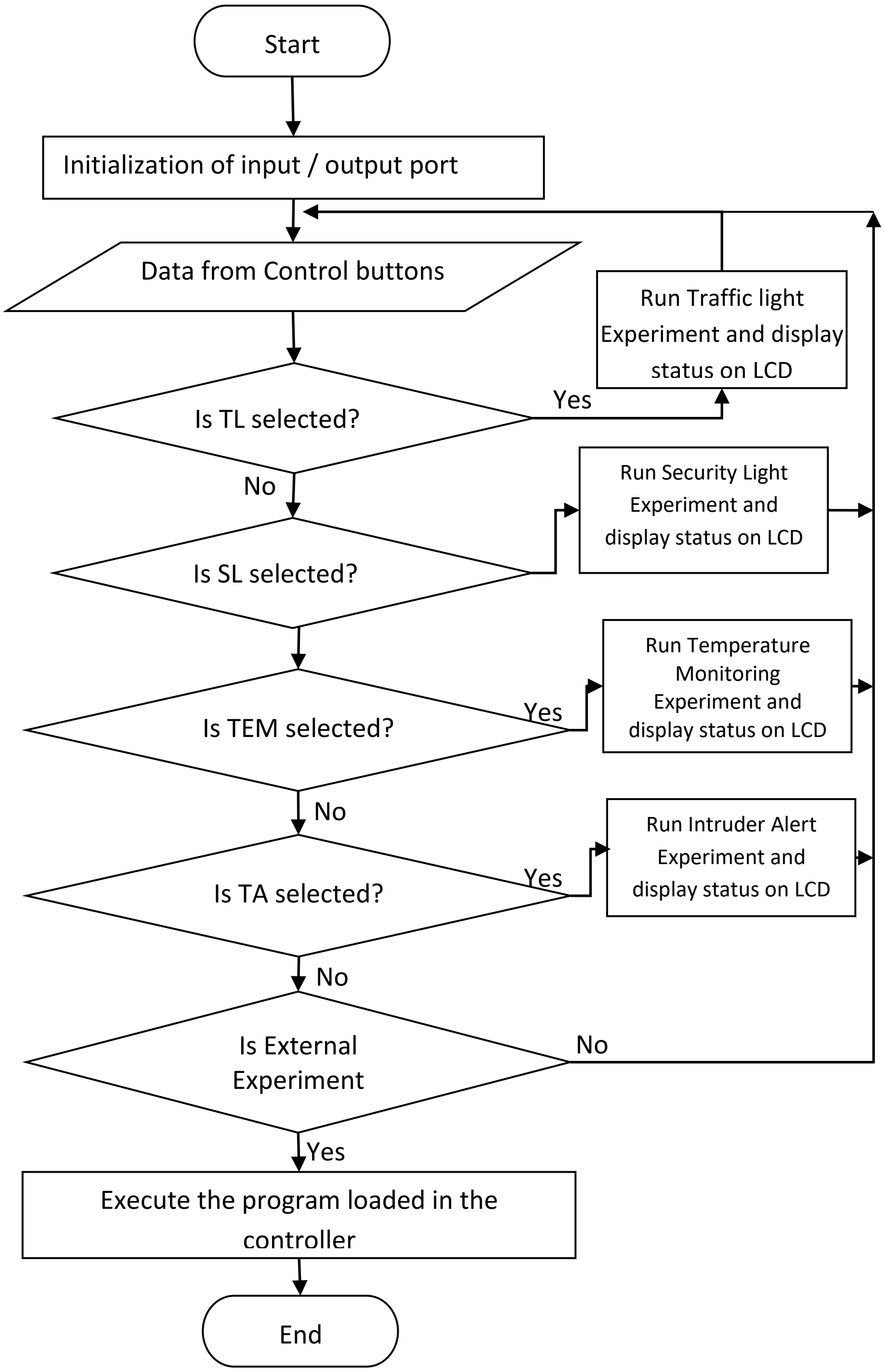

Figure 4: Flowchart for the system

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RESULTS

This section involves the integration of the different components of the design to achieve a complete working device. The complete circuit diagram was tested on a bread board, patterned and etched on a printed circuit board. The components were mounted following the design as shown in figure 4. The system functions in such a way that any student performing an experiment will select the module he or she wants to work on by pressing the button for that experiment. To perform traffic light, experiment the control button T.L is pressed, to perform security light experiment S.L control button should be pressed, on performing temperature experiment TEM control button should be pressed and to perform experiment regarding intruder alert then T.A control button should be pressed. There is also an expansion slot for students that wish to perform other microcontroller based experiments that are not part of the original design.

CONCLUSIONS

The Real Time Automatic Control System Trainer designed in this work comes as a solution to the challenges being faced by engineering students in Nigeria by providing a training kit for practical understanding of the theoretical knowledge taught in class. It is a very good tool for electrical and electronic engineering students in that it provides the platform for them to experience a practical approach to the learning of Real Time Automatic Control System. The system is also economical in that it houses minimum of four different experiments in automatic control covering both industrial and home automation and can be extended to other microcontroller based automatic control system experiments through the expansion slots connected to the controller. The use of this system in school laboratories will greatly enhance the training of engineering students in these fields.

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