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DESIGN AND DEVELOPMENT OF AUTOMATIC CONTROL DEVICE FOR SWITCHING LIGHTING SYSTEM USING ENERGY EFFICIENT PHOTO SENSOR

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Abstract

This paper presents the Design and Construction of an Automatic Control Device for Switching Lighting System using an Efficient Energy Photo Sensor and a Microcontroller Device for efficient energy utilization. Hitherto, the control of home/industrial lights has been done by manual switching. The high number of switching operation of these lighting systems make the manual control inefficient in the present day of scarce energy resources. This work therefore seeks ways to automatically put ON lights when needed, and put them OFF when not needed without any physical human operation. In the design of this work, the entry and exit of persons into an environment is used to control lighting system. The hardware design consists of the entrance, exit and environment lighting sensor unit, Driver/power (opto-coupler) unit, and as well as the control unit and it is designed around a microcontroller which forms the heart of the system. A Light Dependent Resistor (LDR) is used as a sensor, which senses the entry and exit of people to either turn ON or OFF the lights. The LDR is interfaced with the microcontroller through a comparator and a Laser Diode which produces a red beam of light to the LDR. The Drivers and the Power units enable the lighting Systems to be powered from an AC source through a DC control signal. Results from tests carried out both in software simulation and hardware implementation showed that light control can be done effectively within an environment without the intervention of human control with a considerable energy consumption reduction.

***Keywords**: Light Dependent Resistor (LDR), Laser Diode (LD), Entrance/Exit Sensors, Environmental Sensor, Load (Electrical Appliance), Drivers/Power Switch.*

1.0 Introduction

Today as the world is going through modernization, the life of the common man becomes more comfortable with the use of advanced technologies. Homes are migrating to the use of these technologies for almost everything. These smart home systems comprises of different subsystems for lighting control, sound control, temperature control, security control and certain other systems [1]. This work is intended to carry out development of an intelligent home/industrial light control system. The key control unit of this system is microcontroller which is capable of processing enough sensory signals for smart lighting purposes.

Low power consumption systems are cost effective and is an important consideration in the present field of electronics and electrical related technologies [1]. And as such, ideas of designing a new system for homes and industries, that do not consume huge amount of energy and illuminate large areas with the highest intensity is a major source of concern to designers in this field of human endeavor.

The demand for more energy is on the increase and the cost of production of this energy as well, as our society grows also is on the increase. Much demand on the available energy sources as population increases is gradually resulting to serious scarcity of this commodity such that if not properly addressed, may lead to total short down of power systems networks. The cost of energy consumption can be greatly reduced if only there is a proper management of our lighting systems both at home and within the city and work places [2].

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The use of Laser Diodes as an alternative to the existing lighting elements, as well as exploring its controllability for the production of intelligent energy saving lamps that is capable of reducing energy consumption while still giving adequate light to the environment is necessary. The use of conventional incandescent and fluorescent lamp have not helped matter in this case since they need a lot of energy to be powered, wasting most of this energy in form of heat and unwanted light. This system assumes that the location of each user is known via a wireless sensor that is carried by each user and that detects local light intensity [3]. An additional assumption is that there is no obstacle between the whole lighting devices and fixed sensors.
Therefore, the aims are meant to overcome or make up for the human lapses in process control, by providing high reliability control method of our lighting systems, as well as home and industrial appliances [4,5,6]. The work is a simple dark activated electronic switch (circuit) that controls automatically the home lighting Systems according to the ambient level of the environment.

2.0 Related Work

Since the beginning of electrification, switching of electrical devices has been done by means of connecting or disconnecting them from power sources. In recent years, physical connection of a device from its energy source has become less popular. Energy savings are of utmost importance today. The goal is therefore, the reduction of operating prices of home/industrial light with the creation of a system characterized by straight forward installation and low power consumption.
Older methods of controlling of home/industrial electrical devices apply the use of manual switches [7]. In these methods, a manual control switch is set in each of the electrical appliance in a specific area; it was called the first generation of the original version of electrical power control especially in lighting system. The major disadvantage of this system is the exposure of the switches to constant wear and tear.
A network which includes energy measurement nodes and a central server where the nodes read the energy used and wirelessly reports their readings to the central server for processing is presented in [8]. In their work, they designed, built and tested a wireless sensor and actuator network called 'the wireless energy custodian network for monitoring the energy use of alternating current (AC) appliances in a home environment'. The measured energy use of individual appliances can be displayed through a user visual interface. The system allows for inexpensive monitoring of home energy use and illustrates a practical way to control the energy consumption through user interaction. However, this system did not proffer a remedial solution for non-human intervention home energy management. A controlled built system on a wireless platform for the automatic control of house hold electrical appliances which operates mostly on a cable based infrastructure was developed [9]. The complication of the system is that the control of all home appliances is done by means of the ubiquitous infrared and wifi wireless technologies. Some Researchers have also suggested that these Home Control systems be integrated to the whole of the sensory information with security systems connected to all the modules of these systems and to either a telephone line or through LAN, which can also be used with SMS based modules to enhance standard of living [4,9].These Systems are based on existing third party networks with delay and cost overhead, which posed a serious disadvantage in home appliance control and energy management.
A new method of using a light emitting diodes (LED) which uses direct current (DC) electric energy sources as an alternative to the existing lighting elements as well as exploring its controllability for the production of intelligent energy saving lamps that are capable of reducing energy consumption while still giving adequate light to the environment was also implemented [10].

3.0 Design Methodology

The implementation of this control system is based on hardware design and embedded software development. The hardware section comprises of various components that are implemented on a Vero board and connected through physical wiring. The hardware ensures physical signal link between devices in the system that produce the best performance of the whole circuit. The embedded software development creates the internal flow sequence for the home/industrial light system control .It requires a development process to enable the integration of the physical hardware to the desired control algorithm.
This section covers extensively the major components that are used in the circuit design of this work including an indebt analysis of the various units and functions of the part that constitute the design. Design calculations and consideration are all thoroughly treated. The modular approach is used in this work where the overall design was first broken into functional block diagram where each block in the diagram represents a unit of the circuit that carries out a specific function.
In this process, the entrance and exit of persons into and out of an environment is used as a control signal to determine whether artificial lights sources are to be powered or not. The system, is also required to fast track the environmental natural light through feedback to ensure that energy is not wasted in putting on these artificial lights when there is adequate natural light.

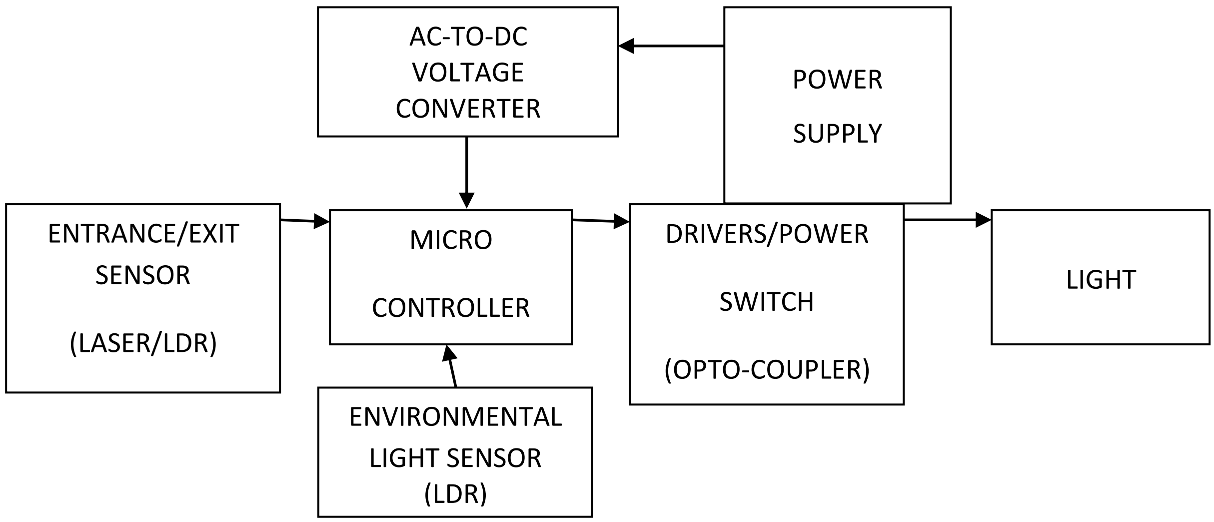

Figure 1: Basic Block Diagram Of Automatic Light Control System

3.1 Hardware Design

The hardware design of this work consists of seven essential units which includes; the entrance/exit sensor unit, AC-to-DC voltage converter unit, power supply unit, Drivers/Power Switch Unit, Light Unit, Environmental Light Sensor unit and the Microcontroller Unit, where the Microcontroller is the heart of the entire circuit as shown in figure 1

3.1.1 Power Supply and Voltage Rectifier Units

This unit provides voltage sources of 12V and 5V to power the system circuit component through the 220/12V AC supply. It consist of a step down transformer, a rectifier, filtering capacitor and voltage regulator.

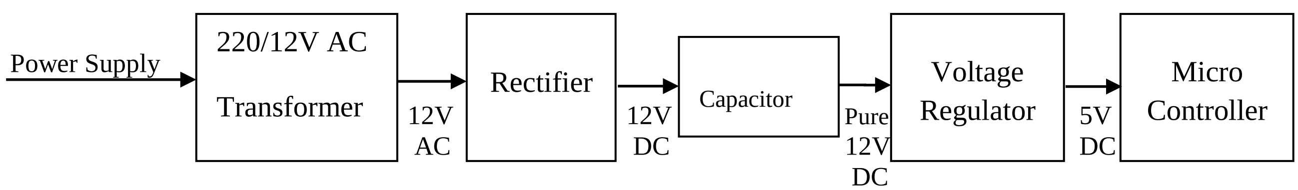

Fig 2: Block Diagram of the Power Supply Unit

3.1.2 Entrance/Exit Sensor Unit

This unit consists of a Light Dependent Resistor (LDR), voltage comparator (OP-Amp) and laser diode. A laser diode and a light dependent resistor (LDR) are employed to detect people direction of movement. This sensor is not intended to sense the availability of electric power supply but to detect the movement of persons into and out of a room or apartment/confined environment.

In this design, the LDR is installed in such a way that it is hidden away from natural sunlight. It is the light from the laser diode that penetrate into the LDR. The design is such that the light from the laser diode activate the LDR. As long as the laser light touches the LDR, its will have a negative resistance i.e. higher brightness decreases the resistance. As the resistance increases with more darkness the voltage becomes higher than the set voltage (5V) causing the output to go High. Under normal condition, when light beam fall on the LDR directly, the resistance at that point becomes very low, making the voltage to be very low, thereby causing the output to be Low (OV).

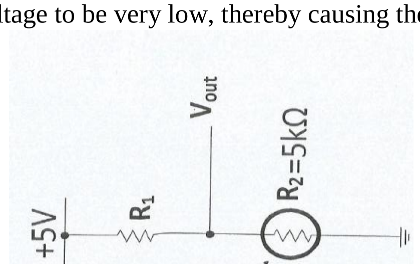

Figure 3: Light Dependent Resistor

From figure 3 and using voltage divider rule

$Vout = \frac{VinR_2}{R1 + R_2}$ ……………………………………………………………………......(1)

Assuming $V_{in} = 5V$, $V_{out} = 3V$, $R_2 = 5K\Omega$ As showed in the circuit above, then,

$R_1 = \frac{VinR_2 - V_{outR_2}}{Vout}$ ………………………………..(2)

$= \frac{5X5}{3} - 5 = 3.3k\Omega$

Therefore, the preferred value of R_1 is $3.3k\Omega \pm 5\%$. Hence, as the resistance of the LDR decreases due to increase in light intensity, the output voltage also decreases.

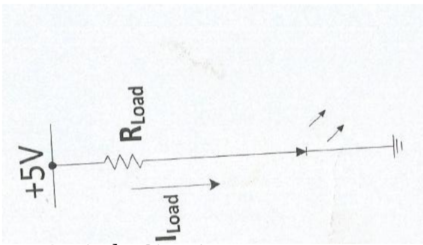

Figure 4:Diode Circuit

From figure 4

$\mathbf{V_{in} = I_{load} R_{load} + V_{out}}$ ……………………………………...(3)

Assuming that $V_{in} = 5V$, $V_{out} = 3.5V$, $R_{load} = 10x10^3A$

Then, $R_{load} = \frac{V_{in} - V_{out}}{I_{load}}$ …………………………………………..………..................(4)

$= \frac{5 - 3.5}{10x10^3} = 150\Omega$

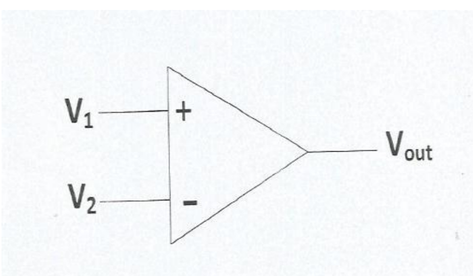

Figure 5: Schematic Diagram Of The Comparator

The comparator consists of an operational amplifier as in figure 5 used as a voltage comparator. A voltage comparator is a device that compares two input voltage (V_1 and V_2) and produces an output (V_{out}) depending on the following situation.

If $V_1 > V_2$………… V_{out} = High (1)M If $V_1 > V_2$………… V_{out} = low (0)

If $V_1 > V_2$………… V_{out} will assume its initial state

In this design, If V_2 is the reference voltage while V_1 is the sensor voltage; this reference voltage can be calculated as follows;

Assuming Vin= 5V, $V_{out} = 3V$, $I_z = 10mA$

Consider the circuit above Vin = IzR+V2

$R = \frac{V_{in} - V_z}{I_z}$ ……………………………………………………….…………………. ..(5)

$= \frac{5 - 3}{10x10^{-3}}$, $= 200\Omega$

Therefore, preferred value is $220 \Omega \pm 5\%$. For the variable resistor, a value of about 50Ω can be chosen.

3.1.3 Environmental Sensor Unit

This unit is used to detect availability of natural light to determine when the controlled artificial lights are to be put ON or OFF. It serves as the power control unit of the system and performs its operation automatically.

3.1.4 Drivers/power switch unit

This unit serves two functions: it enables the light which is an AC source to be driven from a DC source that is the signal from the microcontroller to power ON or OFF the light which are using AC signal are controlled through this units. And it also helps to isolate the AC signal from the DC power source of the circuit. While the light system through the Relay uses an AC signal of about 120 to 240V AC, the side of the circuit is actually running on 5V supply AC (which is very small compared to the AC power that is running). Hence, in order to isolate this system, the driver unit employs an opto-coupler which uses light to separates the microcontroller signal from the AC light.

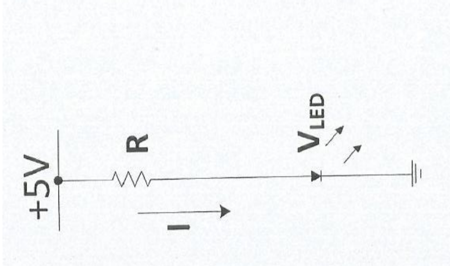

Figure 6: Schematic Diagram of the Opto-Coupler

From figure 6

$$\mathbf{V_{in} = IR + V_{LED}} \quad \text{……………………………………………………..................................} (6)$$

$$\text{Therefore, } R = \frac{V_{in} - V_{LED}}{I} \quad \text{…………………………………………………………………..} (7)$$

Assuming; $\mathbf{V_{in}}$ = 5V. V_{LED} = 2V, I = 20mA then, $R = \frac{5 - 2}{20x10^{-3}} = 150\,\Omega$

But for the purpose of this study 5V and 250Ω resistor was used.

3.1.5 The Control Unit

The microcontroller processing and control unit is the brain of the light control system. It is responsible for signal reading from the peripheral sensor devices, process them into data, store and retrieve data from memory, and carry out the execution of the control software algorithm within the system.

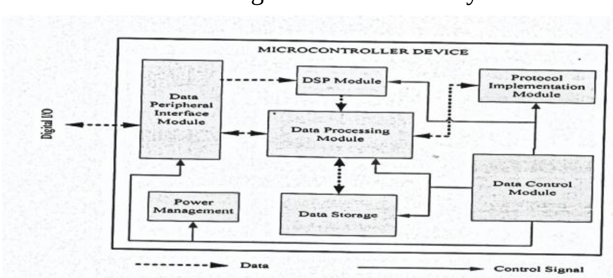

Figure7: Block Diagram of the Control Unit

All these activities are carried out in software codes written and stored in the processing device code memory as firmware.

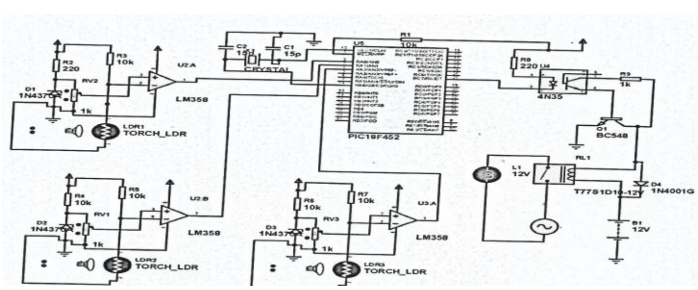

Figure 8: Complete Circuit Diagram of Automatic Light Control System

3.2 Software Design

This involves series of steps or set of activities which are necessary for the development of reliable and maintainable software. It is importance to note that hardware design cannot be used in microcontroller based system without dependable software algorithm. So, the software is one of the major part of the system without which the problem of system break down as a result of inadvertent hardware fault analysis would not be achieved. See fig.9

3.2.1 **Simulation**

The system as designed in section 3.1 was first built in Proteus simulation environment with the exception of the power supply. This is due to the fact that the simulation environment already assumes the behavioral characteristics of each of the components within the environment. A plus 5V supply is therefore not necessary during any logical simulation. The simulated version of the system was run and used to correct all logical errors before the physical implementation was carried out. This process largely reduces implementation cost and time by avoiding physical wiring that could have been repeated over time. The simulated version of the system can be found in figure 10

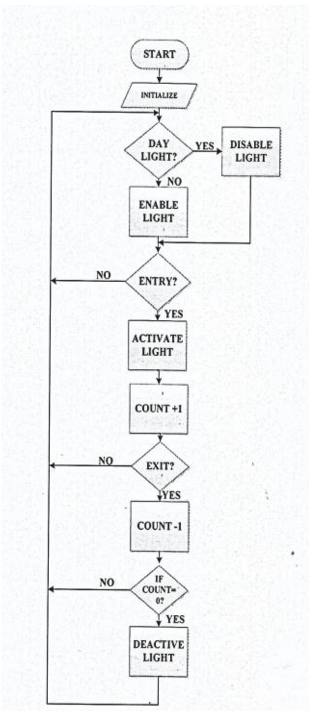

Figure 9: Microcontroller Development Flow Chart

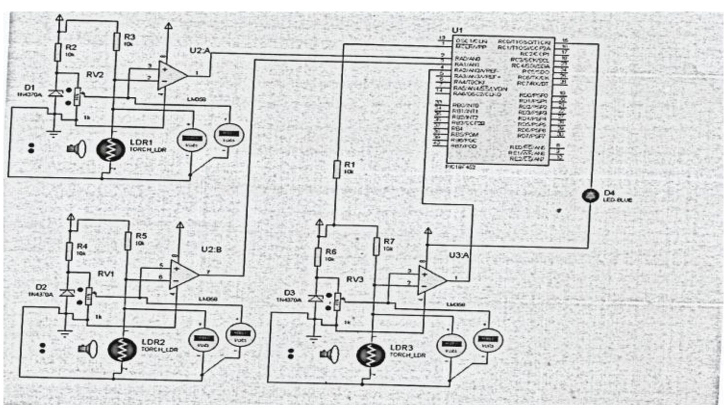

Fig. 10: Complete Circuit Designed on Proteus

4.0 Implementation

The implementation of the various systems blocks and their respective circuits were done with the different physical components that made up each circuits part. First, the entire circuit was implemented using a software simulation tool (PROTEUS ISIS) and simulated to ensure that all parts are performing as described in the system's algorithm, and secondly on a Vero Board and then on a Wooden Walk Way used as a prototyped of the proposed system.

4.1 Software Implementation

In order to implement the algorithm design of figure 9, a C language with integrated environment (Mikro C PRO) which comes with a C compiler enables the codes to be compiler into a hex file. The hex file was then transferred into the microcontroller with the aid of a programmer device (PICKIT 2 PROGRAMMER) as showed in figure 11 below.

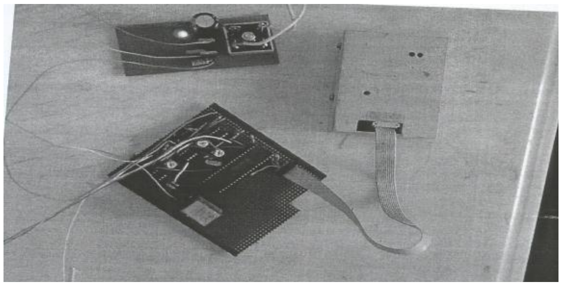

Figure 11: PICKIT 2 Programmer

4.2 Hardware Implementation

The hardware component of the system design was implemented on a Vero Board. The type used has bored parallel holes with copper coating across the length and breadth of the board. Some precautionary measures were put in place to ensure that electrical signal lines do not get short circuited with one another during connection and soldering of the components on the Vero Board.

4.2.1 Implementation of the Exit Sensor Unit

In order to implement the circuit design of an LM358 IC, two comparators were used through an 8 pin IC socket. The IC was properly soldered and placed on the board and the connections with respect to the circuit design of figure 8 were made as shown in figure 12 .

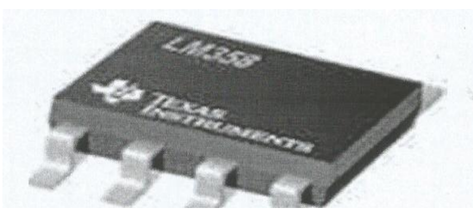

Figure 12:LM358 Integrated Circuit

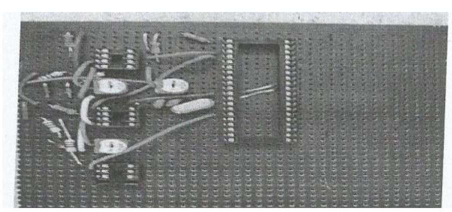

Figure 13: Implemented Circuit Of The Control System

Power was supplied to the board after disconnection from the 5V supply and the comparators operation as designed were tested to ensure that the output goes LOW whenever the LDR senses darkness which indicates the passage of a person or otherwise remain HIGH.

In order to provide a laser beam to the LDR, a laser diode was power through a 220Ω resistor, which help to limit the flow of current to the laser in order to avoid burning out, from the +5V supply. This produces a laser beam that travels a long distance and used in conjunction with the LDR as a passage sensor.

4.2.2 Implementation of the Drivers/Power Switch Unit

This unit bridge the gap between the controlling device (Microcontroller) and the controlled device (Load). While the microcontroller gives a DC signal to switch the load, the load on the other hand requires an AC signal of about 120 to 240V to be switched ON. Therefore, this unit systematically inverts the DC signal from the microcontroller to an AC signal via a latching relay circuit to power the load.

4.2.3 Implementation of the Microcontroller Unit

In order to implement this unit, first a 40 pin IC socket that holds the microcontroller was soldered on a Vero board. Pin 11 and 32 were connected together as the positive supply (5V), 12 and 31 as the ground and the oscillator was connected between pin 13 and 14 with 15μF ceramic capacitor connected with each to ground. To enable the microcontroller to function properly as specified by the manufacturer, a 10kΩ resistor was connected between the 5V supply voltage and the master clear (pin 1) of the microcontroller as shown in figure 13.

4.3 The Constructed System

The system circuit components was first connected on a vero board and was attached with screw and nails at various points to a constructed wooden Walk Way with entrance and exit parts at both ends to allow the movement of persons in and out of the sensed environment. The Entrance and Exit Sensors are connected at strategic points on the Walk Way to detect how many persons enter or leave the sensed environment.

Assuming the sensed environment has multiple Entrance and Exit points, the system, first take note of the total number of persons in that environment and then continue to count the number of persons remaining at every point in time when they begin to exit. At the last count of the person that is to exit, the system automatically passes a control signal through the control unit to switch off all the lights whenever the environment becomes empty of persons. In this process, energy consumption in terms of wastage is drastically reduced to the barest minimum.

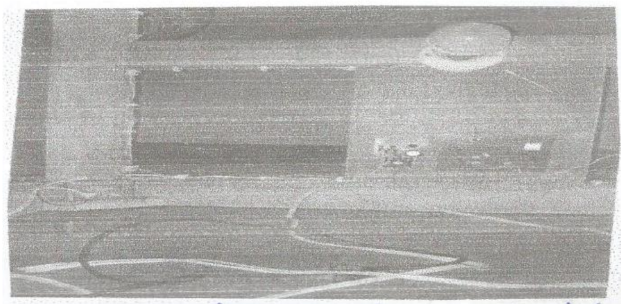

Fig. 14: Constructed System/Prototype

5.0 Results

The aims and objectives of this system design were greatly achieved, because the constructed system was able to switch off light when not in use or needed by using an efficient Energy Photo Sensors, which converts the movement of persons in and out of an environment into an electrical signal which perform the operation through a Relay.

This system does not only greatly reduce Energy wastage to the barest minimum but also the cost of procuring greater number of switching equipment.

6.0 Conclusion

The main purpose that culminated this research work has also been achieved, since the LDR sensor was also able to detect the entry and exit of people and the natural light from the environment. The microcontroller used was able to interpret information for control purposes.

This device can be used at Homes, Offices, Industries, Studio, Cinema Centres, Hospitals, Shops, Schools etc. where multiple switching operations are required. It is cost effective and can be made cheaply from low-cost locally available materials.

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