Design and Construction of a Light Dependent Automatic- Off Timer for CD players

BY

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A project submitted in partial fulfillment of the requirements for the award of the bachelors of engineering degree in the Department of Electrical and Computer engineering.

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OCTOBER 2006

DEDICATION

I dedicate this work to my only brother, Onuchenyo Akor Idoko, my parents: Dr. Idoko M. Akor and Mrs. Rebecca O. Akor and my lovely sisters.

You are all wonderful.

ATTESTATION/DECLARATION

I **IDOKO AKOR IDOKO** declare that this work was done by me and has never been presented else where for the award of a degree. I also hereby relinquish the copyright to The Federal University of Technology, Minna.

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ACKNOWLEDGMENT

I wish to acknowledge the following:

First and foremost; My Lord and Saviour Jesus Christ, for His mercies, love and preservation. These are but a striking few of his uncountable wonders in my life. Words and tongues won't suffice to say it all, maybe eternity.

My supervisor, Engr. J.G. Kolo: for his brilliant ideas and corrections.

My dad, Dr. Idoko M. Akor: for his assistance, advice and support. He has truly been a wonderful father. He proved it when he brought out money to provide funds for the purchase of the JAMB form that eventually earned me admission into this school. I can't forget that day. Love you dad.

My mum, Mrs. Rebecca O. Akor: for always being there (*even though not there*) praying for her son. Who else can I call mother? I appreciate your care and love. Words won't be sufficient to express my appreciation. Thanks mum.

My only brother, Onuche (Gee): For his friendship. Though we've had little time together, those we've had will always be cherished. You are my best friend. You may not understand it fully now, but one day you would, and know how much I care.

My sisters: for your love and care. Won't mention names here, but know you all have a special place in my heart. I would try my best and pray God that I lay a good example as a worthy senior brother.

Uncles, aunties, friends and well-wishers: for their positive contributions, concern and impact to my life. May God bless you all.

Finally, I specially acknowledge the Press Unit Family, Fellowship of Christian Students F.U.T. Minna.: for the unique love and fellowship there. Indeed a dynamic house and "a birthplace for me." I would miss you all; keep up with the good work.

ABSTRACT

This project was undertaken to design and construct a device that would be of use to persons who are in the habit of falling asleep while listening to music. The scope of work ranges from the conceptualization of the idea and theories behind the operation of the device to the stage of packaging the design.

The unit provides automatic disconnection of the CD player from the AC mains supply upon the expiration of a pre-set time delay period (50 minutes). The system works by detecting a transition from light to darkness in a room which triggers the device into a time-out mode. During the time delay period, the CD player is connected to the mains supply. Disconnection occurs after the pre-set time delay period elapses.

Tests carried out produced results that fixed efficiency of the overall project work at about 90%. Within considerable limitations, this achievement was deemed acceptable and hence the objective achieved. In recommendation, I would suggest that for the sake of aesthetics, a visual display unit could be incorporated in the design.

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CHAPTER ONE

INTRODUCTION

A switch can simply be defined as a device operated to turn electric current on or off. Switches are therefore very important devices in electrical and electronics circuit design and are hence widely used components today serving as control devices in modern electrical systems and circuits. Switches can also be defined as devices by which a circuit parameter or signal such as electrical current can be either linked to or cut off from another part of a circuit manually or automatically.

This project is simply the design (both theoretical and practical) of a system or device that would operate as a switch that can turn off automatically alternating current (AC) power supply to a CD player after a pre-set time delay period defined during the design stage. A key feature of this device is that its operation is light dependent, that is, the device is activated only when it is powered on in the absence of ambient light or in a sufficiently dark environment making it a light dependent automatic-off timer for CD players.

The light dependent automatic-off timer uses a light dependent resistor (LDR) as its light sensor. It has the following key components:

- A 555 timer integrated circuit (IC) based Schmitt trigger with the light sensor (LDR) at its input.
- A 4060 IC which is a 14 stage binary ripple counter with a built in oscillator
- A normally closed (N/C) relay at the output interface of the device

The above mentioned components give the device its peculiar function. The presence of the LDR makes the device light sensitive and when the room is sufficiently dark, the sensor will have high impedance which will in turn pass a high voltage into the input of the Schmitt trigger. The Schmitt trigger being a logic inverter will pass a low signal to the RESET pin of the 4060 IC activating the timer sub-circuit of the device. After the pre-set time period is over, the device cuts off AC (Alternating Current) power supply from its output interface via the relay action.

1.1 OBJECTIVES

This project involves the design and construction of a packaged circuitry that will eliminate the need to manually turn-off AC power supply to electronics appliances. Hence the major objective of this project is to effectively design and fabricate an electronic device that will be capable of switching off AC power supply automatically from electronic appliances connected to its output interface at night (in dark environments). This device therefore makes it possible for persons to use electronic appliances such as the television set and CD players as they await sleep leisurely late at night.

Furthermore this device finds use not only in homes but as a precautionary and protective interface in industries and offices; serving as a switch to turn off when night falls, AC power supply from electronic appliances left on carelessly or negligently by workers during the day.

1.2 METHODOLOGY

The logical sequence of steps followed in the design and construction of this device is outlined as follows:

1.2.1 Conceptualization

This is the first stage of and marked the beginning of the project work. Here at this stage, the concept or idea underlying the whole project work was developed. Researches particularly aimed at finding out components parts and individual functional blocks that would make up the entire device or system were also carried out.

1.2.2 Design

In the design stage, there would a detailed work on the idea that has been chosen in the first stage. An electrical circuit that would perform the desired function and purpose of the project in mind must be developed and drawn. Every discrete electronic component that would be used must be defined as well as their circuit parameter values. At the end of this stage a circuit diagram must exist showing all discrete components used in the design and a logical assembly of functional blocks that would make seamless operation of the device possible.

1.2.3 Purchase of discrete electronic components

This stage in the methodology sequence is as important as any other as the proper functioning of finished product depends on the accurate purchase of the components detailed in the circuit diagram. Components to be purchased include resistors, capacitors, diodes, step down transformer, relay, transistor, 555 timer IC and the 4060 IC.

Some of the components would be purchased from electronic shops while others could be sourced from scrap electronic boards.

1.2.4 Fabrication

The objective of the stage is simply to develop a hardware duplicate of the electrical circuit diagram. This involves soldering the purchased discrete components in place on a Veroboard ensuring consistency with the drawn circuit diagram. Soldering of components is done after the circuit is tested on a breadboard and its performance deemed satisfactory.

1.2.5 Packaging

What is done in this stage of the methodology is to prepare a compatible casing that will house and protect the delicate soldered circuit hardware. Care must be taken to ensure that the choice of casing will allow for the display of visual electronic components like the light emitting diode (LED) indicators. Hence special slots will be made for LED indicators and the sensor on the external surface of the casing.

1.3 LIMITATIONS AND CONSTRAINTS

The inability of securing discrete electronic components with the exact parameter values arrived at during the theoretical design calculations proves to be a major challenge to be faced during the design and construction of this device. For example a resistance value of 225 kilo-ohms may not be found readily; but a good alternative is to choose the closest value available such as 220 kilo-ohms in this case.

Also the possibility of parameter values of discrete electronic components taking values within their tolerance limit other than the desired value indicated on the component serves as a constraint also to the optimal performance expected e.g. a 220kohm resistor may read 217kohm or 223kohm as actual resistance value when wired into a circuit.

1.4 SCOPE OF WORK

The scope of work for this project work ranges from the point or stage of conceptualization to the final technical report writing of the finished work or project. It involves all the steps outlined earlier in the methodology and spans to the preparation of the written thesis of the project work.

CHAPTER TWO

LITERATURE REVIEW

The light dependent automatic-off timer has its operation based on the availability of Direct Current (DC) power supply just like any other electronic device or appliance. Also, its operation has basic underlying theories and principles, therefore in this chapter I undertake to introduce and explain the fundamental electrical principles and theories behind the operation of the device being designed.

2.1 THEORETICAL BACKGROUND

A good understanding of the build up of all functional sub-units, or individual building blocks that compose the whole system is necessary to grasping the theoretical principles backing the device. Appendix A is a block diagram illustrating the logical flow of signal within the structure of the light dependent automatic-off timer. The diagram also highlights the order of interaction between each functional block and sub-unit.

2.1.1 DC power supply sub-unit

The Power Holding Company of Nigeria (PHCN) is the national body in Nigeria that is responsible for the generation, transmission and distribution of electrical power to consumers across the country. There are basically two forms in which electrical power can be generated, transmitted and distributed: A.C. power and D.C. power.

In Nigeria, electrical power is generated, transmitted and distributed in the A.C. power form. The production of electrical power as A.C. power is more preferable to power production in D.C. power for the following reasons:

1. In power generation it is possible in practice, to construct large high-speed A.C. generators of capacities up to 500MW. On the other hand D.C. generators cannot

be built of ratings higher than 5MW because of commutation trouble. Moreover, since they must operate at low speeds, it necessitates large and heavy machines.

II. A.C. generators are more economical in matter of cost per KWH of electric energy produced as well as in operation.

III. A.C. voltage can be efficiently used and conveniently raised or lowered for economic transmission and distribution of electric power respectively while D.C. power has to be generated at comparatively low voltages by units of relatively low power ratings.[1]

Therefore, it follows that the form of electric power available to consumers is A.C. power. This makes it necessary for the electronics engineer to provide an electronic circuit capable of converting the input A.C. power to D.C. power that is required for the operation of any electronic device.

The process of electric power conversion from A.C to D.C. power or voltage is called rectification. The rectifier is an electronic circuit that can convert A.C. voltage to D.C. voltage [2]. The D.C. supply unit is therefore an electronic sub-unit that has the capability to step down (transform) the voltage to a safe operation level, rectifying the input A.C. voltage and filtering out pulsations in the rectified output D.C. voltage. A step down transformer, bridge rectifier and smoothing capacitor serving as filter are required for this function.

The transformer is a device that operates on the principle of electromagnetic induction to step down or step up voltage level by a fixed ratio [3]. It consists of a magnetic core with a specific number of both primary and secondary coil windings (N_1 and N_2 respectively). Transformers couple source voltages at its primary coil windings to the secondary by means of the magnetic field acting on both coils; hence, a transformer operates by converting electrical energy to magnetic form and then back to electric form[4].

The ratio of voltage transformation of a transformer is given by N_1/N_2 and the expression that gives the transformed output V_2 from an input voltage level of V_1 is: $V_2 = V_1 \times N_2/N_1$. Therefore, for a step down transformer the number of primary coil windings must be greater than that of the secondary [4]. The transformer simply operates to permit the scaling of the A.C. voltage level to the desired level. It connects the A.C. source to the rectifier.

The rectifier is a circuit composing of diodes configured to convert A.C. voltage to a pulsating D.C. voltage. The two basic types are the full wave rectifier and the half wave rectifier. But for basic electronics application, the full wave rectifier is used in preference. A full wave rectifier offers substantial improvement in efficiency over the half wave rectifier as the latter utilizes only half the energy available in the input A.C. waveform [5]. The bridge rectifier is an example of a commonly used full wave rectifier.

It consists of four diodes wired in the above configuration. A diode is an electronic device that only allow for the flow of current in one direction when forward biased by an operating DC voltage. A diode is forward biased when its anode potential is higher than that of the cathode; when this condition is satisfied, the diode will pass electric current through it. The rectification operation of the bridge rectifier is based on this property of the diode. During the positive half-cycle of an input AC voltage, two opposite diodes will conduct while the other two become open circuits as they become reverse biased. Similarly, during the negative half-cycle of the input AC voltage, the reverse of the former occurs leaving the first two diodes open while the other two conduct [6]. With this process, the rectification process occurs during both the positive and negative half cycles of the AC waveform.

Filtering the rectified output of the rectifier becomes necessary due to ripples-that is, the fluctuation about the mean voltage [6]. To solve this problem, the advantage of the energy-storage properties of the capacitor is employed. The capacitor serves as a low pass filter that preserves the DC component of the rectified voltage while fil*tering out components at frequencies at or above twice the AC signal frequency [6].

Hence the DC power supply is a circuit that practical applies rectifier circuits in the conversion of AC power to DC power. It consists of a step down transformer, followed by a bridge rectifier and a filter capacitor followed by a voltage regulator. Fig 2.1 is a circuit diagram of a simple DC power supply.

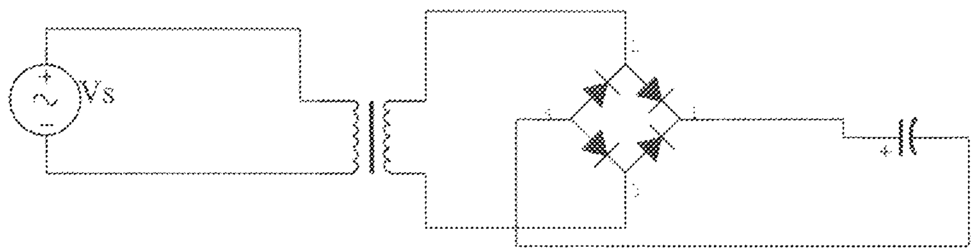

Fig 2.1 circuit diagram of a simple DC power supply

2.1.2 Pre-timer stage

This stage of the system is responsible for generating the signal (electrical pulse) required to trigger the timer stage or sub-circuit when necessary conditions are satisfied. This stage uses a Schmitt trigger configuration using a 555 timer IC with the light sensor (LDR) at its input.

The LDR or light sensor is connected to the Schmitt trigger's input by a voltage divider circuit involving both the sensor and another resistance value. The voltage divider is an electronic circuit that provides different voltage levels for different sections of a circuit from a common voltage supply. The figure below is a simple voltage divider circuit:

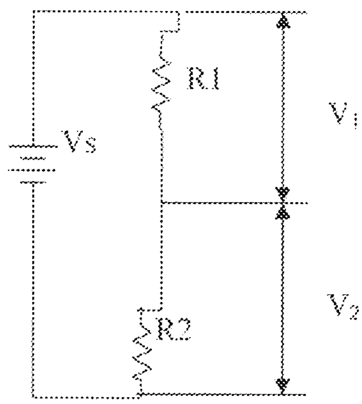

Fig 2.2 simple voltage divider circuit

Let V_1 be the voltage across the R1 resistor and V_2 the voltage across the second resistor: R2. This voltage divider circuit divides the supply voltage, Vs into voltage levels: V_1 and V_2 by the two resistors present. The ratio of division of the supply voltage depends on the value of resistors used in the divider circuit. The value of V_2 is given by the following expression: $V_2 = R2 / (R1+R2) \times Vs$ and similarly, we have: $V1 = R1 / (R1+R2) \times Vs$; it is important to note also that $Vs = V1 + V2$.

The Schmitt trigger is not classified as a Flip Flop but it does exhibit a type of memory characteristics that makes it useful in certain special applications. One of such applications is its use as an inverting buffer [7]. The Schmitt trigger can be configured to function as a standard inverter by using a 555 timer IC with its pins wired as shown by the circuit diagram shown below (Fig2.3).

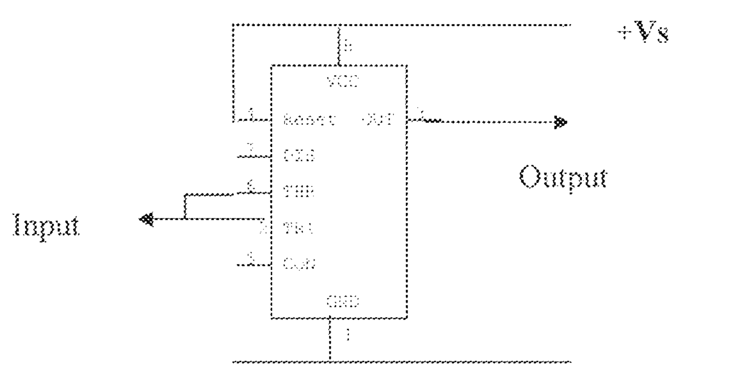

Fig2.3 555 Timer IC based Schmitt trigger

The input pins (pins 2 and 6) are connected to a common or single input source. Pin1 is grounded (connected to the zero volts (0V) supply line), while the reset pin (4) and pin pin8 are connected together to the positive voltage supply terminal. The output corresponding to the input is taken from pin3 the output pin of the timer IC.

In this configuration, the 555 timer IC operates as a Schmitt trigger inverter whose operation is similar to the digital NOT gate function. Fig 2.6 shows the circuit symbol of the NOT gate. The Schmitt trigger is an inverting buffer or NOT gate because the output logic state (high/low) is the inverse of the input state. Its simple operation is based on the following rules:

- Input low (< ⅓Vs) makes output high: +Vs
- Input high(>⅔Vs) makes the output low: 0V [8]

Hence, the Schmitt trigger could serve as a switch, switching between a high and low logic state depending on the voltage level (high or low) that appears at its input.

The buffer circuit's input has a very high impedance (about 1MΩ) so it requires only a few μA, but the output can sink up to 200mA. This enables a high impedance signal source such as an LDR to switch a low impedance output transducer or IC such as the 4060 (14-stage binary ripple counter) IC [8].

2.1.3 Timer stage/sub-circuit

The timing function of the device is provided by the operation of the 4060IC, which is simply a 14-stage binary ripple counter with a built in oscillator. The counter is a sequential logic device that can take one of N possible states, stepping through these states in a sequential fashion. Taking as an example, a 3-bit binary counter would have 2^3=8 possible states and a 14-stage binary counter would have 2^{14}=16,384 possible states similarly. When clocked (enabled by a clock input signal), the counter steps through each possible state as the input clock waveform causes the counter to make a transition for each clock pulse. A string of JK Flip Flops can accomplish or be wired to function as a counter.

The 4060IC is simply a cascade of 14 JK Flip Flops. The analysis of its internal structure reveals an oscillator section and 14 ripple-carry binary counter stages. The oscillator configuration allows the design of either RC (resistor/capacitor) or crystal oscillator circuits. A RESET input is provided which resets the counter to the all-0's state and disables the oscillator. A high level on the RESET line accomplishes the reset function. All counter stages are master-slave Flip Flops [9]. The state of the counter is advanced one step in binary on every negative trailing edge of the clock pulse.

A ripple counter is realized (from a string of Flip Flops) by applying the ENABLE clock pulse to the first Flip Flop stage. The output of this stage would now serve as a clock input to the next stage in the cascade. This goes on till the counter proceeds sequentially through all the states, i.e. from all-0's state to all-1's state. This is how input clock pulse to the first stage ripples through the whole cascade of Flip Flop stages- hence the name ripple carry counter.

Furthermore, the frequency of the input clock pulse is dependent on an external RC network. This feature makes it possible for different clock frequencies to be realized by using different values of R (resistor) and C (capacitor). The time delay period, t is given by: t=2.3RC where 2.3 is a propagation factor due to the carry through all the stages. The values of R and C are in Ohms (Ω) and Farads (μ) respectively. Similarly the expression for frequency of oscillation, F equals 1/t (t^{-1}) which also equals $(2.3RC)^{-1}$

The next diagram (Fig.2.4) shows a single Flip Flop stage in cascade of FF (Flip Flops).

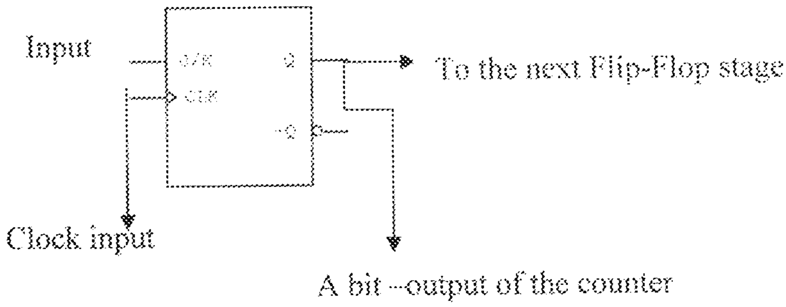

Fig 2.4 single Flip Flop stage

Fig 2.4 shows that the two output pins of the FF are complements of each other i.e. Q and ~Q. Whenever the input logic transits from a high to a low state (1 to 0); the Q output of the FF goes high enabling the next stage while also serving as an output bit of the counter. This means that the first FF stage would output the most significant bit (LSB) of the binary string of outputs of each FF stage in the counter. This also expresses the binary number of the present (a possible) state of the counter. Importantly also the input signal to the FF stage is applied simultaneously to the J and K input pins in the Flip Flop.

Considering a 3- bit binary ripple counter, whose circuit diagram is shown below:

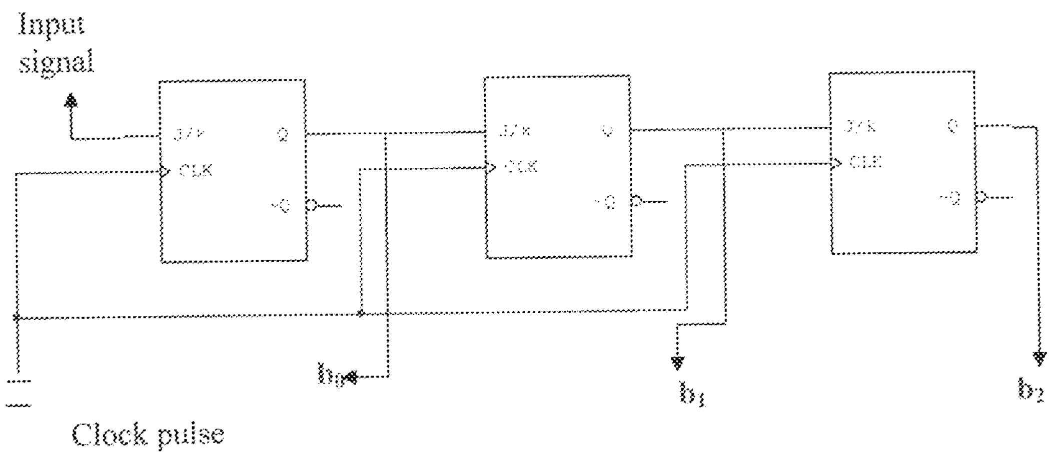

Fig 2.5 3- bit binary ripple counter

The binary logic state of the counter gives the binary number ($b_2b_1b_0$) designation of the present state of the counter. In this case there are eight possible states and the range from 000 binary to 111 binary (state 0, 1, 2, 3, 4, 5, 6 and 7 all in decimal). The counter steps through these eight states sequentially on each trailing edge transition of the input clock signal.

Finally, the oscillator sub section of the 4060IC enables an engineer to vary the rate at which the counter steps through those states. This depends on the value of resistor, R and capacitor, C chosen as they determine the oscillating frequency of the oscillator and hence frequency of the clock input waveform.

2.1.4 Output interface/stage

This stage simply consists of a transistor amplifier operating in the common emitter mode, a relay (normally closed) and a 3- plug socket which serves as the device interface to the outside world. The transistor is a semiconductor device that has three pins namely the base terminal, the emitter terminal and the collector terminal. It can perform two functions that are fundamental to the design of electronic circuits: amplification and switching.

Put simply, amplification consists of magnifying a signal by transferring energy to it from an external source; whereas a transistor switch is a device for controlling a relatively large current between or voltage across two terminals [10]. The BJT (bipolar junction transistor) will be considered here because it was used in the design of the light dependent automatic-off timer.

Bipolar Junction Transistors are formed by joining three sections of semiconductor materials each with different doping levels. Therefore there are two types of BJTs: PNP and NPN BJTs depending on the doping technique employed.

For the BJT to function as an amplifier, the operating (quiescent) point must fall in the active region of the transistor. There are three basic amplifier circuits namely: the common-emitter amplifier, the common-base amplifier and the common-collector amplifier. In the common-emitter amplifier circuit, the emitter terminal is common to both the input and output sections of the amplifier configuration-hence the name common-emitter. Fig 2.6 is a circuit diagram of a BJT in common-emitter mode.

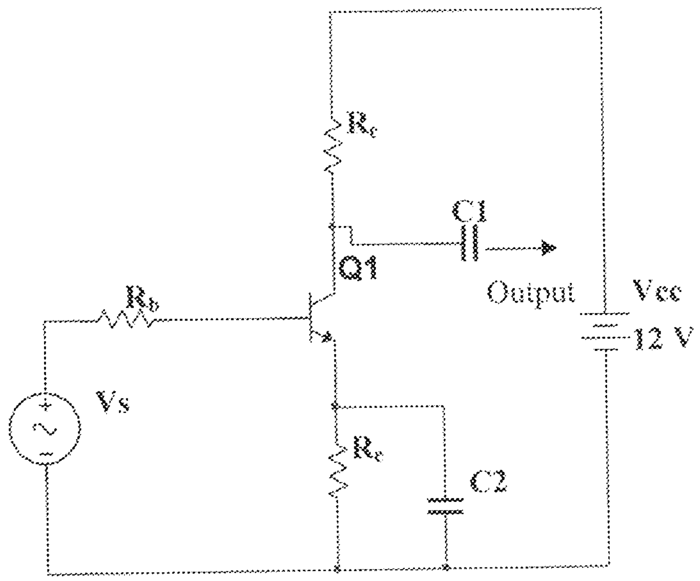

Fig 2.6 circuit diagram of a BJT in common-emitter mode

Vcc is the supply voltage, C2 is the emitter bypass capacitor, and C1 is a blocking capacitor. R_b, R_c, R_e are the base, collector and emitter terminal resistances respectively. The following are equations used in the DC analysis of the common-emitter amplifier:

- $Vcc = IcRc + Vce$
- $Vs = IbRb + Vbe$
- $\beta = Ic/Ib$
- $Ie = Ib + Ic$

Where Ic, Ib, Ie are the collector, base and emitter currents and β is the current amplification factor of the transistor.

The relay is essentially an electromechanical switch that permits the opening and closing of electrical contacts by means of an electromagnetic structure. The working of the relay is as follows; when triggered, an electrical current flows through the relay coil and generates a field in the magnetic structure. The resulting force draws the moveable part of the relay towards the fixed part causing an electrical contact to be made. One striking advantage of the relay is that a relatively low-level current can be used to control its opening and closing of a circuit that can carry large currents [11]. The type of relay used in the foregoing design is the normally closed relay. This relay remains normally closed in an electrical circuit, but when activated it opens, switching off electric current to another section of the system in which it operates or from any device connected to it.

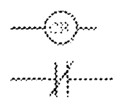

Fig 2.7: Normally closed relay circuit symbol

2.2 HISTORICAL BACKGROUND

A **timer** is a specialized type of clock. A timer can be used to control the sequence of an event or process. Timers can be mechanical, electromechanical, digital, or even software, since most computers have clocks. Early timers used typical clockwork mechanisms, such as an escapement and spring to regulate their speed. Inaccurate, cheap mechanisms use a flat beater that spins against air resistance hence they were basically mechanical timers. More accurate mechanisms resemble small alarm clocks. The chief advantage of these is that they require no battery, and can be stored for long periods of time. The most widely-known application is to control explosives [12].

Later on, still in the early 20th century, electromechanical timers emerged and became widely used, replacing its mechanical ancestor. There were two common types: The thermal type, which has a metal finger made of two metals with different rates of thermal expansion (steel and bronze are common). An electric current flows through this finger, and heats it. One side expands less than the other and an electrical contact on the end of the finger moves away from an electrical switch contact, or makes a contact (both types exist). The most common use of this type is now in the "flasher" units that flash turn signals in automobiles, or sometimes in Christmas lights.

The other type of electromechanical timer (a cam timer) uses a small synchronous AC motor turning a cam against a comb of switch contacts. The AC motor is turned at an accurate rate by the alternating current, which power companies carefully regulate. Gears slow this motor down to the desired rate, and turn the cam. The most common application of this timer now is in washers, driers and dishwashers. This type of timer often has a friction clutch between the gear train and the cam, so that the cam can be turned to reset the time.

Electromechanical timers survive in these applications since they were often combined with electrical relays to create electro-mechanical controllers; also mechanical switch contacts are still less expensive than the semiconductor devices needed to control powerful lights, motors and heaters.

Electromechanical timers reached a high state of development in the 1950s and 60s because of their extensive use in aerospace and weapons systems. Programmable electromechanical timers controlled launch sequence events in early rockets and ballistic missiles [12].

However, in modern times digital timers have become common place since they can achieve higher precision than mechanical timers because they are quartz clocks with special electronics. Integrated circuits have made digital logic so inexpensive that an electronic digital timer is now less expensive than many mechanical and electromechanical timers. Individual timers are implemented as a simple single-chip computer system, similar to a watch.

Moreover, in recent times, most timers are now implemented in software. Modern controllers use a programmable logic controller rather than a box full of electromechanical parts. The logic is usually designed as if it were relays, using a special computer language called ladder logic. In PLCs, timers are usually simulated by the software built into the controller. Each timer is just an entry in a table maintained by the software.

Embedded systems often use a hardware timer to implement a list of software timers. Basically, the hardware timer is set to expire at the time of the next software timer of a list of software timers. The hardware timer's interrupt software handles the house-keeping of notifying the rest of the software, finding the next software timer to expire, and resetting the hardware timer to the next software timer's expiration [12].

2.3 LIMITATIONS

The inability of securing discrete electronic components with the exact (precision) parameter values arrived at during the theoretical design calculations is the major limitation faced during the design and construction of this device. For example a resistance value of 225 kilo-ohms may not be found readily; but a good alternative is to choose the closest value available such as 220 kilo-ohms in this case.

Also the possibility of parameter values of discrete electronic components taking values within their tolerance limit other than the desired value indicated on the component serves as a constraint also to the optimal performance expected e.g. a 220kohm resistor may read 217kohm or 223kohm as actual resistance value when wired into a circuit.

In comparison with other timer devices, this device has provided the timer circuit with its own DC power supply source eliminating the problem presented by the use of dry cell batteries. Timers that use suitable batteries to drive both the timer and its output device require that the designer adopt a well thought-out power management strategy or the operational life between charges may become unacceptably short [13].

When compared to the common time-delay timers available today, the light dependent automatic-off timer has a greater sensitivity as it employs a Schmitt trigger to generate the timer ENABLE pulse. Also its versatility is another great advantage it presents to users as it function or operation can be applied to not just CD players but common place electronic appliances like T.V. sets, Personal Computers and so on.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

As detailed in the previous chapter, the light dependent automatic-off timer for CD players comprises of four basic units. This chapter presents a modular analysis of the design of the device.

3.1 DC POWER SUPPLY UNIT

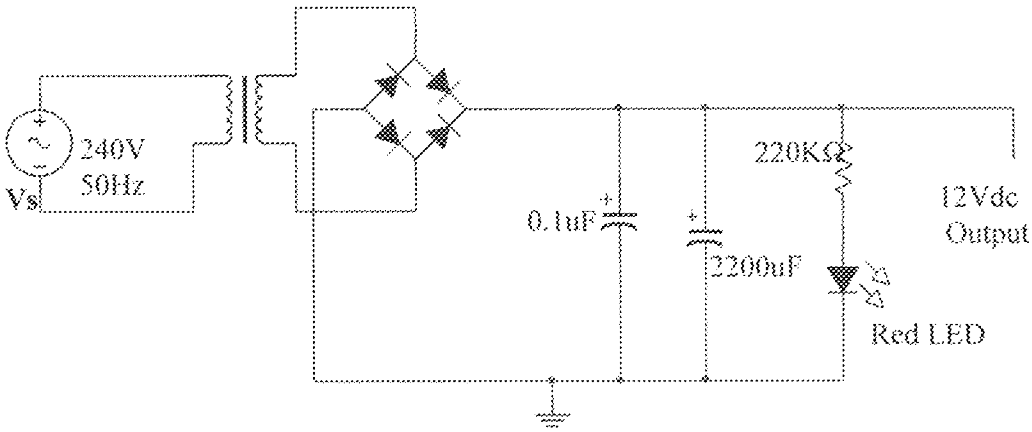

Fig 3.1: Circuit diagram of the DC power supply unit

The transformer steps down the input voltage (which is supply from the PHCN mains) from 230V AC to 12V, the to the desired voltage level necessary for the operation of the device. The secondary current and voltage of the transformer are 300mA and 12V respectively. Therefore the turns- ratio is evaluated as:

Np/Ns= Vac/Vs=240/12

=20:1

=20

The transformed voltage level now passes through the bridge rectifier and consequently through the capacitive filter.

The two capacitors being connected in parallel have an effective capacitance of: 2200 + 0.1 = 2200.1uF this high value of capacitance is chosen because the capacitance reactance must be minimal so that the capacitors can serve as an effective short circuit, sinking AC component of the rectified output to the ground while blocking the desired DC component from the ground.

$$\text{Capacitive reactance, } Xc = \frac{1}{2\pi fc}$$

Substituting actual values into the expression yields:

$Xc = (2x50x\ \pi x2200.1)^{-1}$

$\approx 1.447\Omega$

Lower values of impedance could be achieved by using higher values of capacitance but a trade-off must be made between the capacitor discharge time and the reactance value. This is necessary because a high value of capacitance gives a greater discharge time which is undesirable.

A 1W 220Ω was chosen to limit the current through the power on LED. Power dissipated by the resistor is given by:

$$P = \frac{V^2}{R} = \frac{12^2}{220} \approx 0.655W$$

Care was taken during design to ensure that the power rating of the resistor would not be exceeded when the resistor is connected in the circuit. The purpose of the LED indicator is to indicate whether the device is powered on or not.

3.2 PRE-TIMER UNIT

The purpose of this stage is to generate the triggering pulse that will enable or activate the timer section when the room is sufficiently dark. A 555 timer based Schmitt trigger with a voltage divider circuit at its input was employed. The circuit diagram for this unit is shown below.

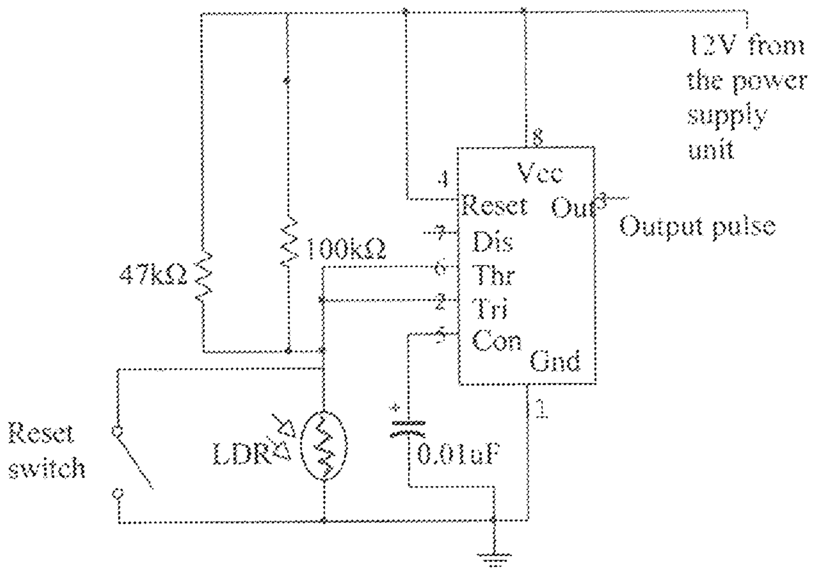

Fig3.2: Circuit diagram of the Pre-timer unit

The Schmitt trigger is a logic state inverter which switches a high logic state at its input to a low logic state at its output and vice versa. The input at the input of the 555 timer based trigger is controlled by the voltage divider circuit consisting of the LDR (the light sensor) and two resistors- 47kΩ and 100kΩ in a parallel combination. Therefore the effective resistance is given by: $\frac{47x100}{100+47} = \frac{4700}{147} \approx 32k\Omega$

The LDR has a light dependent resistance characteristic with its resistance increasing with decreasing light intensity. In dark environments, the resistance of the light sensor is very large and in the range of mega ohms (MΩ). The LDR is connected directly at the input of the Schmitt trigger, hence in the dark; the LDR divides a greater percentage of the voltage because of its large value of resistance when compared to the effective 32k resistance. The voltage division offered by the resistors and the LDR is in the following ratio:

$$\frac{R_{LDR}}{R_{LDR}+32}$$

Where R_{LDR} = the resistance of the LDR which varies with light intensity and the expression for the input voltage V_{IN}, at the input of the Schmitt trigger at any given time is:

$$V_{IN} = \frac{R_{LDR}}{R_{LDR}+32} \times 12\text{volts} \ [14]$$

From the above expression it is obvious that the logic state (high or low voltage) at the input depends directly on the value of R_{LDR}. There are two possible cases: in presence of ambient light and the absence of ambient light.

In the first case, the value of R_{LDR} would be very low because of the presence of ambient light and hence the 32kΩ equivalent resistance would divide a greater proportion of the 12V voltage signal as the resistance of the LDR is very small and negligible when compared to the 32kΩ resistance. Therefore a low voltage will appear at the input of the Schmitt trigger.

In the second case, the value of R_{LDR} would be very large since there is an absence of ambient light. As a result, a greater percentage of the 12volts is divided across the LDR presenting a high voltage input at the input of the Schmitt trigger. An effective resistance value of 32kΩ was chosen in preference over the 100kΩ and 32kΩ resistance values to ensure that the device had great sensitivity to the transition from light to darkness and vice versa.

The Schmitt trigger is used to provide a clean switching of the time delay circuit (timer unit) on or off since the resistance of the LDR shows a gradual increase in encroaching darkness and similarly also, a gradual decrease in resistance as light intensity increases (in the presence of ambient light). The change in resistance of the LDR is conditioned to generate an oscillation free output with a 555 timer IC based Schmitt trigger which provides the enable/ disable control needed to switch the timer unit on(in the dark) or off(in bright light).

The switching threshold for the inverter (Schmitt trigger) is fixed at Vcc/3- required for a low to high logic state switching and 2Vcc/3 for a high to low logic state switching. For the 12V DC supply, the thresholds are:

$12\div3$; and $(2\times12)\div3$, which yields-

4V and 8V

Hence, whenever the voltage across the LDR is less than 4V the Schmitt trigger would place a high (12V) logic state at pin 3 of the 555 timer (Timer unit disable condition) and when the input voltage exceeds 8V, a low logic state (0V) at the output of the trigger (Timer unit enable condition).

Summarily, V_{IN} would be less than 4V in the presence of light and V_{IN} would be between 8V and 12V in dark environments. The 0.01uF employed to connect pin5 of the 555 timer to the electrical ground serves the purpose of eliminating electrical noise in the circuit.

Table 3.1 shows the pins and the respective labels of a 555 timer IC.

Table3.1

PIN	LABEL/ STATUS
1	Ground
2	Trigger Input
3	Output

4	Reset
5	Control
6	Threshold Input
7	Discharge
8	voltage supply pin

For the 555 timer IC to serve as a Schmitt trigger in a circuit its inputs are tied together to form a single input pin; connecting both reset pin and the supply pin to the power supply leaving pin 7 unused. Output is taken from pin 3 and pin1 is grounded; pin 5 is also grounded through a capacitor.

3.3 TIMER UNIT

The major operational component in this stage is the 4060IC, which is a 14 stage binary ripple counter with a built-in oscillator. The frequency with which the oscillator oscillates is determined by the value of the resistor, R and capacitor, C connected to pins 9and 10 of the 4060IC respectively [15, 16]. Hence, the time delay period of the timer unit is pre-set by the value of these two components.

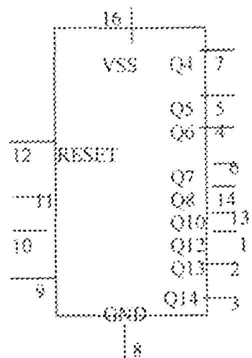

Fig3.3: CD4060IC
showing pin labels

Table3.2: Table showing pins of the 4060IC and their functions

PIN	LABEL	PIN	LABEL
1	Q12	9	Capacitor, C
2	Q13	10	Resistor, R
3	Q14	11	Clock Input
4	Q6	12	Reset
5	Q5	13	Q9
6	Q7	14	Q8
7	Q4	15	Q10
8	Ground	16	Voltage Supply

The time delay or timer unit is activated when the IC detects a low signal or pulse at the reset pin, pin12. A high signal on pin12 would simply reset the IC, disabling the on-chip oscillator. Fig 3.4 is the circuit diagram of the timer unit.

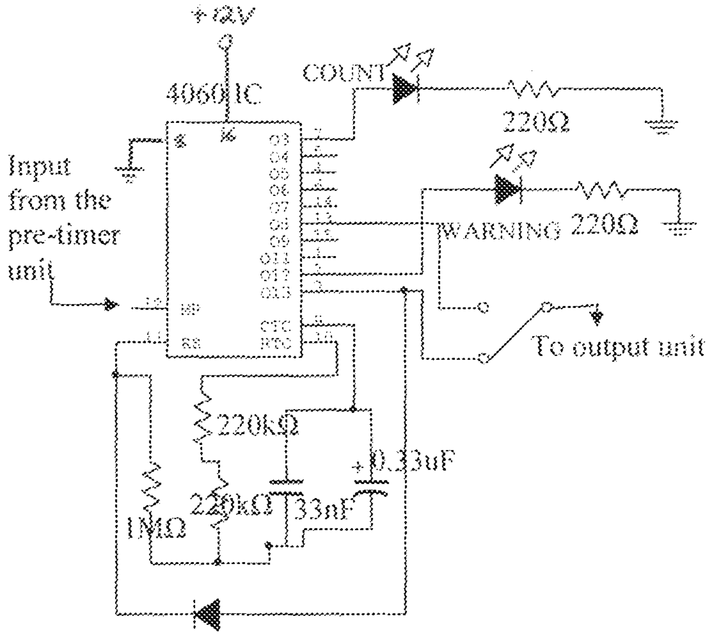

Fig3.4: Circuit diagram of the timer unit

The count LED blinks with the frequency of oscillation, showing that the counter has been activated. The count LED is off when there is a high logic state at the reset pin showing that the counter is disabled or that timer is off. The table below summarizes the description given above.

Table3.3: Table of device state illustration

LDR	Reset Pin	Count LED
Light	High	OFF
Dark	Low	Blinks

Since the IC4060 is a counter that consists of 14 Flip Flop stages, it can be used to generate larger time delay periods than is possible with the 555 timer operating in the monostable mode. The RC component connected between pins 9and 10 determines the frequency of operation of the on-chip oscillator, which, consequently sets the time-delay period of the counter [17].

The frequency of oscillation determined by the external RC circuit is given by:

$$F_{OSC} = \frac{1}{2.3RC}$$

To generate a time-delay period of 50 minutes, the values of the external resistor, R and capacitor, C necessary to set the Q14 output pin of the IC high after a delay of 3000seconds (50mins) was determined.

Now, Q14 goes high after 2^{14} clock pulses and since two clock pulses make a cycle (1high and low pulse makes a clock cycle), Q14 goes high after

$\frac{2^{14}}{2} = \frac{16,384}{2} = 8,192$ cycles of input clock waveform. Also, a time-delay of 50 minutes is

$= 50 \times 60 = 3000$seconds.

From these values, the frequency with which the oscillator must oscillate to generate the 50 minutes time-delay is:

$F = 8,192 \div 3000 \approx 2.73$ cycles/second (Hz)

In evaluating the RC component that will generate an oscillating frequency of 2.73Hz,

We have: $2.73 = \frac{1}{2.3RC}$ (equating equations F and F_{OSC}), solving yields

$RC = (2.3 \times 2.73)^{-1}$

$RC \approx 0.15926$

Now, choosing a resistance value of 440kΩ, we have an accompanying capacitor value of:

$C = 0.15926 \div 440000 \approx 0.000000362F$ or 0.362uF.

Two capacitors-0.033uF and 0.33uF were connected in parallel to realize this capacitance value i.e. Ceq = C1 + C2 = 0.033+ 0.33= 0.363uF and two series resistors of 220kΩ resistance each supplied the 440kΩ resistance.

Summarily, RC components required to generate a 50 minutes time-delay is:

R = 440kΩ and C = 0.363uF

It is important to note also that to prevent the oscillator from rolling over; the positive rising edge of Q14 is detected and fed back to the oscillator through the clock input, pin11. The 1mΩ resistor and signal diode are employed to achieve the feedback loop.

Also, for a test mode of operation, the Q9 output was taken and a switch employed to switch between the Q9 and Q14 output pins. This makes it possible for the user to switch between the "test" and "operate" modes of the device.

Similarly, Q9 goes high after 2^9 clock pulses. Therefore, Q9 goes high after 512 ÷ 2 clock cycles, i.e. 256 cycles. In evaluating the time-delay expected with the oscillator oscillating at 2.73Hz we have:

$F = \frac{256}{T_D}$ where T_D is the time-delay in seconds and F the frequency of oscillation.

This yields- 2.73 = 256/ T_D therefore, T_D = 256 ÷ 2.73 = 93.77s

T_D = 1.56 minutes. This is the time-delay for the test mode of operation of the device. The test mode was incorporated is the design in order to provide a much smaller time-delay period specifically for test purposes and to predict the operation of the device in the "operate" mode.

The warning LED indicator is used to indicate when the Q13, the penultimate Flip Flop stage goes high, warning the user that the device would soon operate. This output pin was chosen for the "warning" indication as it glows when the Q13 pin goes high. The

LED indicator would remain ON till the high to low transition on the pin, which will trigger the Q14 output and cause the device to operate, switching off the CD player.

3.4 OUTPUT UNIT

This stage consists of a BJT transistor, two 220Ω resistors, One LED (load-off) indicator, a free wheeling diode and a normally closed relay connected as shown by the circuit diagram below.

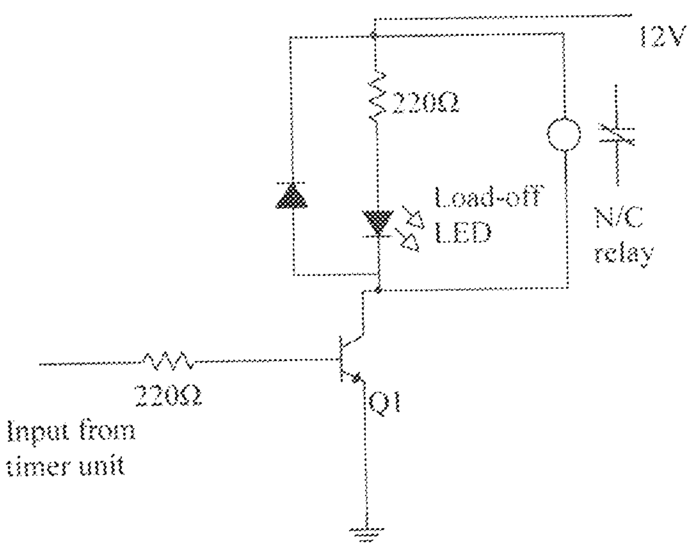

Fig3.5: Circuit diagram of the output unit

The base 220Ω resistance of the BJT generates the base bias current when Q14 pin of the 4060IC goes high. This generates a voltage between the collector and the emitter terminals of the BJT. The collector current flowing in the BJT due to the collector voltage causes the load-off LED indicator to glow and the relay to operate. The free wheeling diode protects against the back e.m.f. from the inductive coils of the relay. The load-off LED indicator glows when the device has operated; cutting off power supply to the CD player.

The purpose of the BJT is to amplify the output signal of the 4060IC to a level sufficient to operate the relay. The contacts of the relay once operated opens, creating an open circuit between the CD player and the AC mains supply. A 3-pin socket serves as the output interface between the internal circuitry of the light dependent automatic-off timer and the CD player power cable.

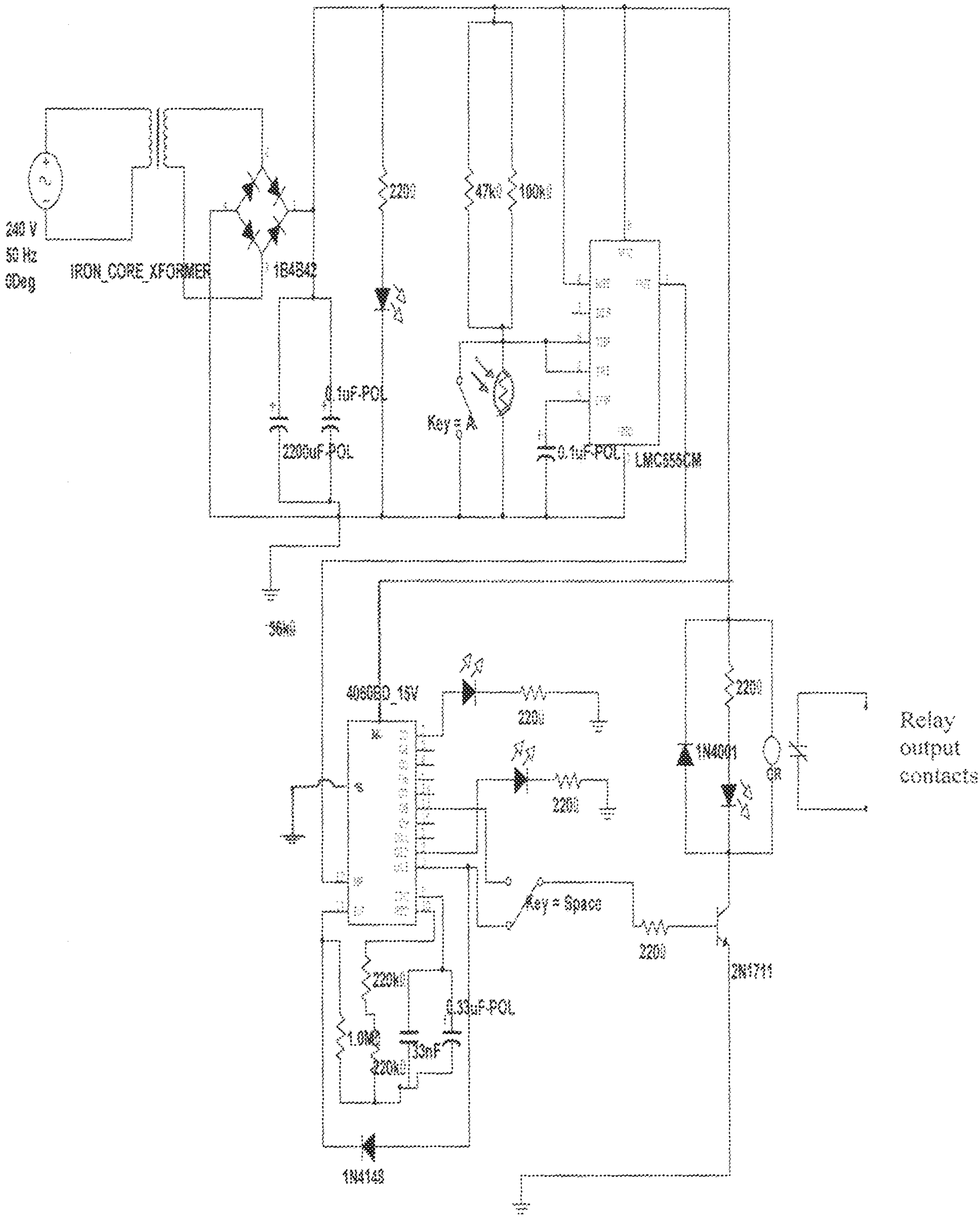

Fig 3.6: overall functional circuit diagram of the device

CHAPTER FOUR

TEST, RESULTS AND DISCUSSION

Testing is carried out primarily to see if the actual performance of any newly constructed device matches its expected performance. This makes it possible for the designer to estimate the accuracy of the fabricated device. Likewise also, the testing of the automatic-off light dependent timer for CD players was necessary for the simple reason stated above. The performance of the device in terms of its efficiency is reflected by the margin of variation between the operational time-delay and the pre-set time-delay (50 minutes) set during design.

4.1 TEST

A test mode of operation was provided during the design of the device solely for test purposes. This "test" mode offered a smaller time-delay period of about 1.5 minutes, providing also, a simple means of securing test results that would be useful in predicting the actual operation of the device in the "operate" mode.

A simple digital stopwatch and a digital multimeter were among the test tools required for the testing of the device. In order to test, the device was simply powered on and its operation mode was set to the test mode. With the LDR was covered to simulate a dark environment, the associated time-delay period was recorded by means of the stopwatch. The multimeter was used to read the frequency of oscillation and the value read was noted. This process was also repeated for the operate mode.

4.1.1 Results

Results gotten during the test exercise were tabulated as follows:

Table 4.1: Table of results

Mode of Operation	Actual time-delay	Expected time-delay	Discrepancy
Test	1.27 minutes	1.56 minutes	0.29
Operate	45.48 minutes	50 minutes	4.52

Frequency value read from the oscillator: 2.99 Hz; expected value of frequency: 2.73Hz

4.2 DISCUSSION OF RESULTS

From the results displayed in table 4.1 we see that a little discrepancy occurs between the actual time-delay period in operation and the expected time-delay period. In percentage value, this can be expressed as: discrepancy/expected value × 100.

Considering the results, we have: $\frac{4.52}{50} x \frac{100}{1} \approx 9.00\%$ and the discrepancy between the actual frequency of operation and the expected frequency of operation as 2.99-2.73 = 0.26; hence, similarly, we have: $\frac{0.26}{2.73} x \frac{100}{1} \approx 9.52\%$. Therefore, in the construction of the device from the design, an overall efficiency of about 90% was attained.

4.3 SHORTCOMINGS AND POSSIBLE REMEDIES

The discrepancy observed during the testing of the device presented little surprise as it was anticipated, though within a particular tolerance range. This is so because a few unavoidable limitations were encountered in the course of the project work.

Two prominent shortcomings experienced were the inability to procure precision components and the very erratic nature of AC mains supply from PHCN. The only remedy available in an application where a higher accuracy is needed involves incorporating a voltage regulator into the DC power supply unit as well as procuring precision components since exact circuit parameters yield exact results.

CHAPTER FIVE

CONCLUSION

5.1 SUMMARY

Timers are a very important part of many electronic and digital circuits today as timing based control is the basic function of many modern control sub-systems and systems. More so, timers are also commonly employed to initiate an action or trigger an operation after a set time delay elapses. There is no limit to the versatility this family of electronic devices offer modern engineering design.

The device constructed is actually unique timer whose timing control is dependent on light intensity. This is because, the light dependent automatic-off timer is primarily designed to aid users who habitually listen music late in the night, by providing a safe automatic means to switching off CD players in a case where the user falls asleep suddenly.

Furthermore, from the results presented in the preceding chapter, an accuracy of about 90% was achieved. This achievement is deemed satisfactory and significant when limitations faced and the objectives of the project are considered carefully.

Conclusively, since the objective of the design is met and the fabricated design works normally as expected with accuracy within the tolerance range, this project work/experience is considered successful, rewarding and fulfilling.

5.2 RECOMMENDATION

The operation of this device could be applied to not just CD players but common household electronic appliances like the Television. Where a higher accuracy is required, a voltage regulator could be incorporated in the power supply unit and also a digital display unit, which I deemed optional, in the light of my primary objective.

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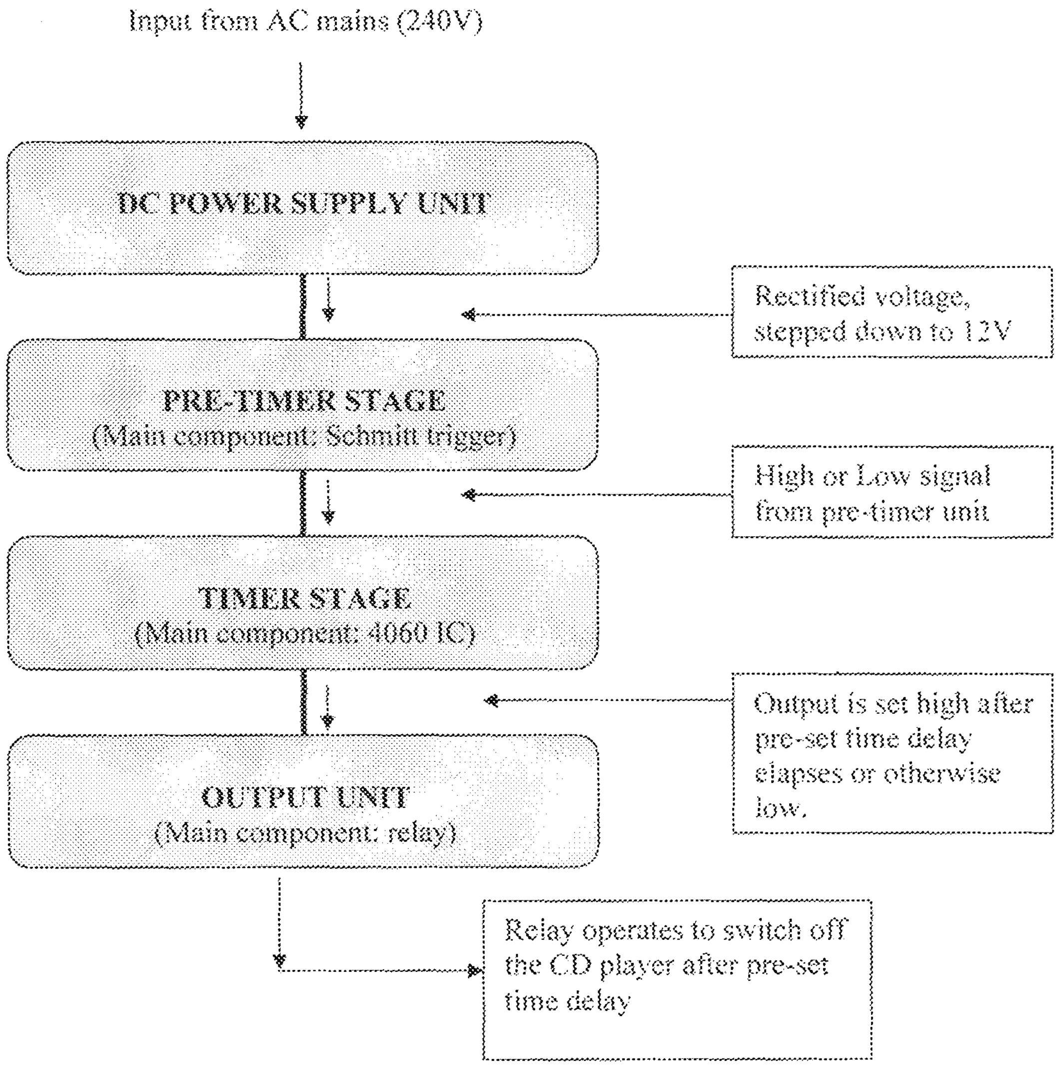
APPENDIX A

BLOCK DIAGRAM OF THE SYSTEM



Key:

- Downward arrows show the direction of logic and signal flow.
- Text boxes highlight the state of signal between the blocks.

APPENDIX B

LIST OF COMPONENTS USED IN THE PROJECT WORK

COMPONENT TYPE QUANTITY

Resistors

220Ω……………………………………………………………………5

220kΩ……………………………………………………………………2

100kΩ……………………………………………………………………1

47kΩ……………………………………………………………………1

LDR……………………………………………………………………1

1MΩ……………………………………………………………………1

Capacitors

2200uF (25V)……………………………………………………………1

0.1uF and 0.01uF…………………………………………………1 each

0.33uF……………………………………………………………………1

0.033uF…………………………………………………………………1

Diodes

IN4001……………………………………………………………………5

IN4148……………………………………………………………………1

LEDs……………………………………………………………………4

SC1815GR Transistor……………………………………………………1

Double pole double throw switches……………………………………2

Relay……………………………………………………………………1

Transformer (12V 0.3A)…………………………………………………1

3 pin socket……………………………………………………………1