Development of a Light Dependent Automatic- Off Timer for House Holds Electronics

Jonathan Gana KOLO

Department of Electrical and Computer Engineering, Federal University of Technology, Minna, Nigeria.
E-mail: jgkolo@gmail.com

Abstract

This work was undertaken to design and construct a device that would be of use to persons who are in the habit of falling asleep while watching or 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 appliances from the alternating current (AC) mains supply upon the expiration of a pre-set time delay period. 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 appliance e.g. CD (Compact Disk) player is connected to the mains supply. Disconnection occurs after the pre-set time delay period elapses.

Keywords

Automatic; Timer; Switching; Schmitt trigger; Relay; Oscillator.

Introduction

A switch can simply be defined as a device operated to turn electric current ON or OFF. Switches are important devices in electrical and electronics circuit design. They 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 [1].

The major aim of this paper is to effectively design and fabricate an electronic system 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 at night AC power supply from electronic appliances left on carelessly or by workers negligently during the day.

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 electrical appliances.

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

- 555-timer integrated circuit (IC) based Schmitt trigger with the light sensor (LDR) at its input.
- 4060 IC which is a 14 stage binary ripple counter with a built in oscillator
- 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 power supply from its output interface via the relay action. Fig.1 shows the generalized block diagram of the system.

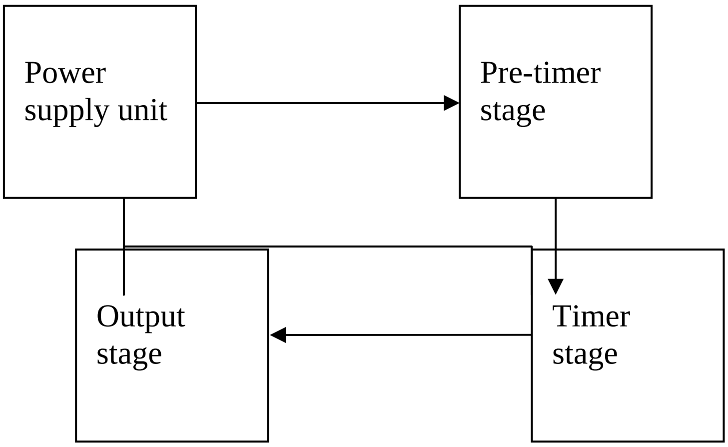

Figure 1. Block diagram of the system

Pre-timer stage

The Schmitt trigger (the pre-timer unit) in Fig.2 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 voltage at the input of the 555 timer-based trigger is controlled by the voltage divider circuit consisting of the LDR (the light sensor) and the parallel combination of two resistors- 47kΩ and 100kΩ. The effective resistance of the parallel combination is given by:

$$\frac{47 \times 100}{47 + 100} = 32K\Omega$$

The LDR is connected directly to the input of the Schmitt trigger. 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, in the range of mega ohms (MΩ). 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 resistance of 32kΩ. 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 in kilo ohms which varies with light intensity.

The expression for the input voltage V_{IN}, at the input of the Schmitt trigger at any given time is: $V_{IN} = \frac{R_{LDR}}{R_{LDR} + 32} \times 12 volts$

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 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-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 $\frac{V_{cc}}{3}$ -required for a low to high logic state switching, and $\frac{2V_{cc}}{3}$ for a high to low logic state switching [2]. For the 12V DC supply, the thresholds are:

$\frac{12}{3} and \frac{2 \times 12}{3}$ this yields 4V and 8V respectively. 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 capacitor connected to pin5 of the 555-timer eliminates noise in the circuit [3-5].

Design Calculations

The major operational component in the timer stage is the 4060IC, which is a 14 stage binary ripple counter with built-in oscillator as shown in Fig. 3. The frequency with which the oscillator oscillates is determined by the value of the resistor, R and capacitor, C connected to pins 9 and 10 of the 4060IC respectively. Hence, the time delay period of the timer unit is pre-set by the value of these two components [2][6][7].

The time delay of the timer unit is activated when the 4060IC 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 [7][8]. Fig 3 is the circuit diagram of the timer unit.

The count LED (Light Emitting Diode) 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. Since the 4060 IC 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 frequency of oscillation determined by the external RC circuit is given by [9-11]:

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

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
3000 seconds (50 mins) was determined.

Now, Q14 goes high after 2^{14} clock pulses and since two clock pulses make a cycle (one high and low pulse makes a clock cycle), Q14 goes high after $\frac{2^{14}}{2} = 8192$ cycles of input clock waveform.

Also, a time-delay of 50 minutes is: 50 × 60 = 3000 seconds.

From these values, the frequency with which the oscillator must oscillate to generate the 50 minutes time-delay is: $F = \frac{8192}{3000} \approx 2.73$ cycles/second (Hz)

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

We have: $2.73 = \frac{1}{2.3RC}$ (i.e. equating equations F and F_{OSC}).

Solving yields,

$$RC = (2.3x\ 2.73)^{-1},\ RC \approx 0.15926$$

Now, choosing a resistance value of 440kΩ, we have an accompanying capacitor value of: C = 0.15926÷ 440000 ≈ 0.000000362F or 0.362μF.

Two capacitors 0.033μF and 0.33μF were connected in parallel to realize this capacitance value i.e. $C_{eq} = C_1 + C_2$ = 0.033+ 0.33= 0.363μF 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 = 0.363μF.

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.

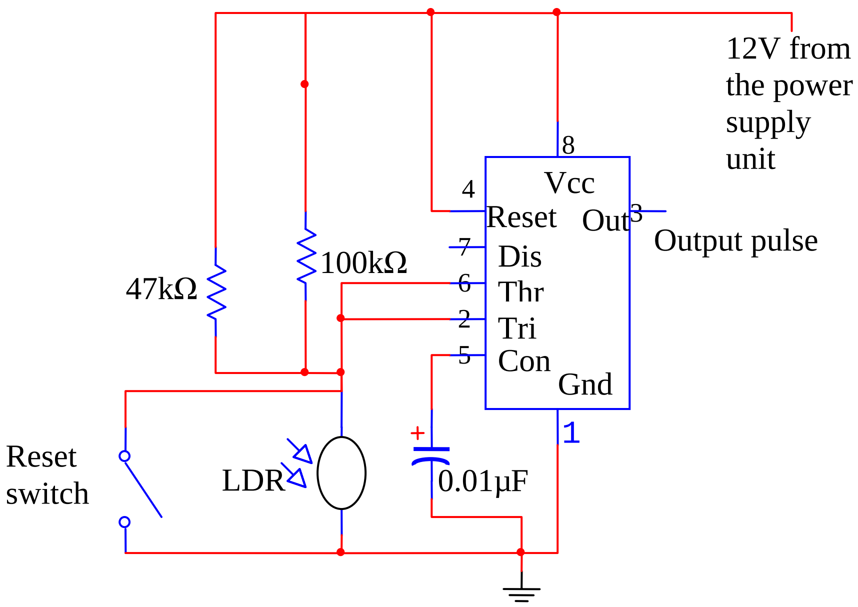

Figure 2. Circuit diagram of the Pre-timer unit

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.

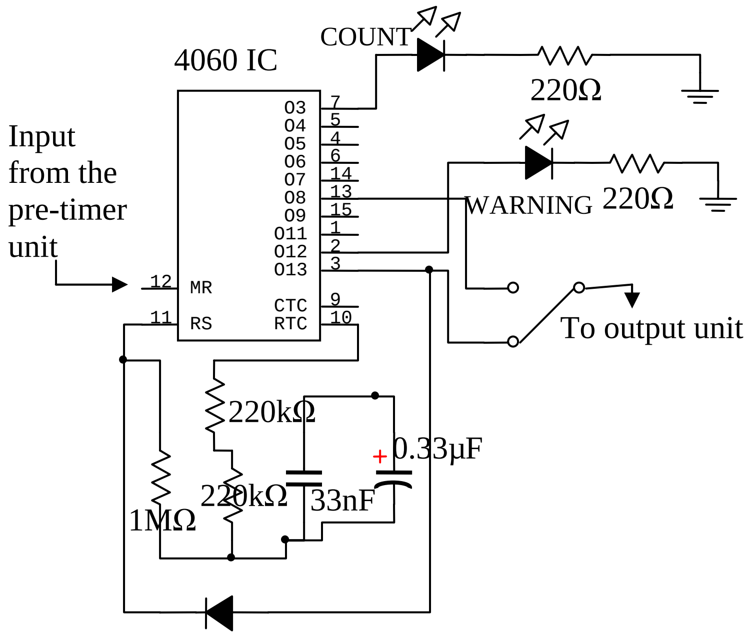

Figure 3. Circuit diagram of the timer unit

This yields- $2.73 = \frac{256}{T_D}$ therefore, $T_D = \frac{256}{2.73} = 93.77s$

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.

Output stage

The output 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 in fig.4 [12]. The base 220Ω resistance of the BJT generates the base bias current when Q14 pin of the 4060IC goes high. The collector current then flows in the BJT causing 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 [8][13].

The contacts of the relay once operated opens, creating an open circuit between the CD player and the AC mains supply.

Performance evaluation

From the results displayed in table 2 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: $\frac{4.52}{50}\times 100 \approx 9.00\%$ and the discrepancy between the actual frequency of operation and the expected frequency of operation is 2.99 - 2.73 = 0.26; hence, we have $\frac{0.26}{2.73}\times 100 \approx 9.52\%$. Therefore, after the evaluation of the designed system, an overall efficiency of about 90% was attained.

Table 1. Table of device state illustration

LDR	Reset Pin	Count LED
Light	High	OFF
Dark	Low	Blinks

Table 2. 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

Conclusion

A light dependent automatic-off timer was designed and constructed.

The system designed is a unique timer whose timing control is dependent on light intensity.

Issue 12, January-June 2008
p. 129-138

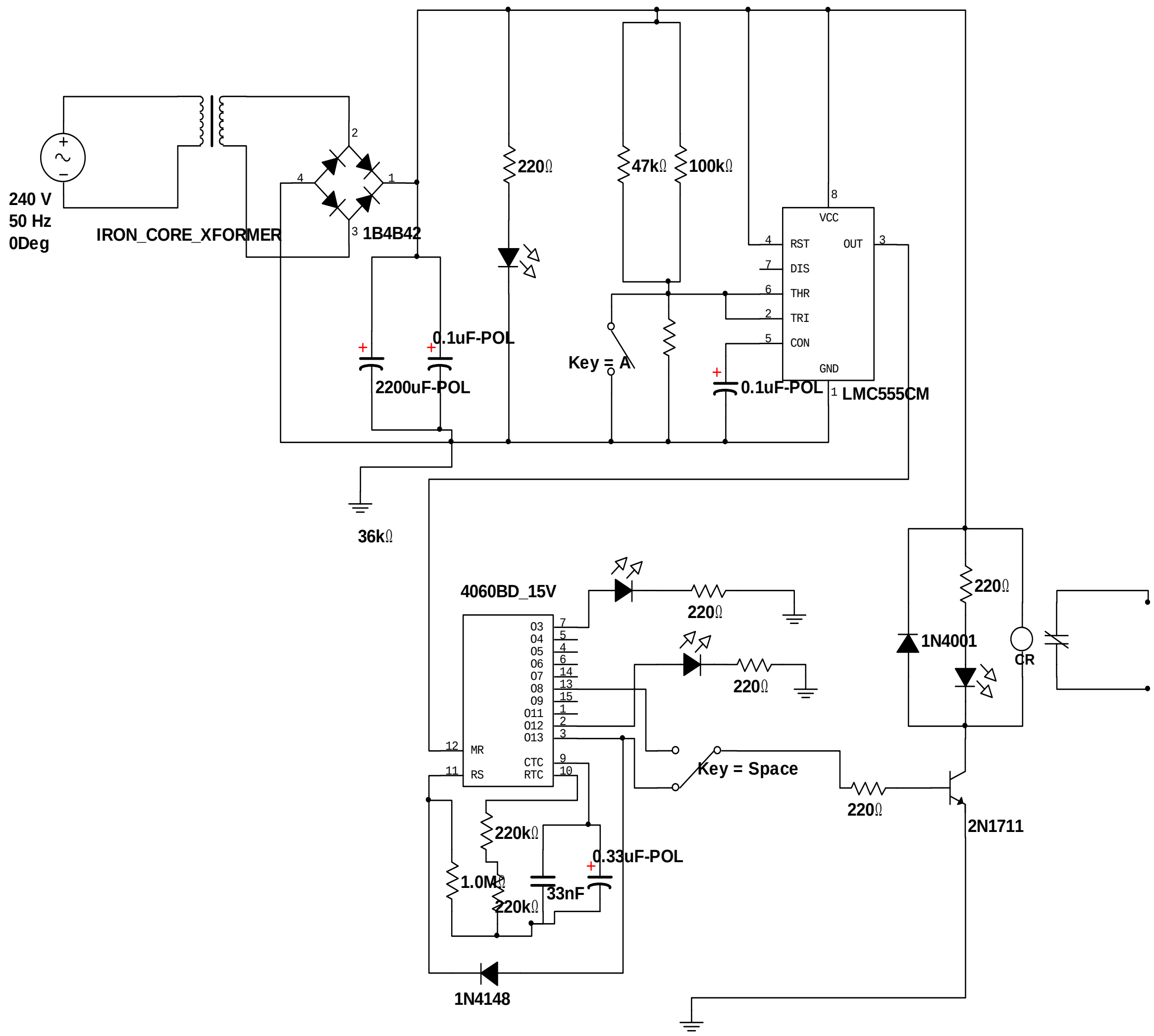

Figure 4. Overall functional circuit diagram of the device

It was primarily designed to aid users who habitually listen to 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 tests carried out, an accuracy of about 90% was achieved. This achievement is deemed satisfactory and significant when limitations like components values variations within the tolerance limits are considered carefully.

The device could be applied to not just CD players but common household electronic appliances like the Television set.

References

1. Rizzoni G., *Principles and application of electrical engineering*, 3rd Ed. McGraw-Hill companies, U.S.A., 2000.
2. Ronald J. T., Neal S. W., *Digital Systems: principles and application*, 7th Ed. Von Hoffman press Inc.U.S.A, 1998.
3. *555 timer tutorials* [online]. Available at: http://www.electroniclab.com, 2002.
4. Sacco Company, *Tutorial on how 555 timers work* [online]. Available at: http://www.555timer.com, 2001.
5. Emagbetere J.O., Akeze A.C., Edeko F.O., *Improving Home and Office Security-The Footmat Intruder Alarm System With Restricted Access*, Journal Of Electrical and Electronic Engineering, vol. 10. No. 1, Benin-city, January 2006, p 35-41.
6. Datasheet Search System [online]; ©2003-2006 Alldatasheet.com. Available at: http://www.alldatasheet.com/.
7. Mahmud S. A., Abubakar S. M., Genesis A. A., *Development of a Simple Sound Activated Burglar Alarm System*, Leonardo Journal of Sciences, 2006, 9, p. 97-102 [online]. Available at http://www.ljs.academicdirect.org/A09/097_102.pdf
8. Ahmed M. S., Mohammed A. S., Onimole T. G., Attah P. O., *Design and construction of a remote Controlled fan regulator*, Leonardo Electronic Journal of Practices and
9. Technologies, 2006, 9, p. 55-62 [online]. Available at: http://www.lejpt.academicdirect.org/A09/055_062.pdf
10. [9] Theraja B.L., Theraja A.K., *A textbook of electrical technology*, 21st Ed., S. Chand and Company, New Delhi, India, 1999.
11. [10] Forrest M. Mims III, *Engineer's Mini Notebook*, Volume I. Timer, Op Amp & Optoelectronic Circuits & Projects, 1st Ed., Master Publishing, 1986.
12. [11] Horowitz P., Hill W., *The art of Electronics*, 2nd Ed., Cambridge University Press, U.S.A., 1995.
13. Amos S.W., James M. *Principles of transistor circuit: Introduction to the Design of Amplifiers, Receivers and Digital Circuits*, 6th Ed., Hartnolls Ltd., 1981.
14. Mahmud S. A., Murtala B. Z. A., Kolo J.G., *Design and Construction of a Remote Controlled Power Supply Unit*, Leonardo Journal of Sciences, 2007, 11, p. 41-50 [online]. Available at: http://www.ljs.academicdirect.org/A11/041_050.pdf