Design and Construction of a Remote Controlled Power Supply Unit

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Abstract

The paper presents the design and construction of an infrared remote controlled power supply-switching unit, which is a device that enables the user to operate or control the mains power supplied from approximately 5 to 10 meters away. The remote transmits a beam of light using an infrared light emitting diode; this light is picked and decoded by the receiver unit (Photodiode). The receiver only activates when it receives the beam of light, there are no accidental activations. The system was broken down into simpler functional parts namely: The transmitter stage, the detector (phototransistor) stage, the NAND Schmitt trigger stage, the flip-flop stage and the relay stage. Details of the stages are described in the paper.

Keywords

Transmitter, Infrared, Control, Device, Design

Introduction

With the advancement in technology, new electrical protective devices with various levels of complexity have been designed, and different failures from these systems have been recorded. The design and construction of a reliable cost effective protective device, "the remotely controlled power supply switching unit" is to be used in collaboration with some other forms of protective devices (circuits breakers and fuses). The primary aim of this work is to design a simple cost effective and reliable circuit (protective system), which will aid in-protecting electrical and electronic devices in our homes and offices with ease.

Basically, a remote control operates in the following manner. A button is pressed; this completes a specific connection, which produces a Morse code line signal specific to that button. The transistors amplify the signal and send them to the LED, which translates the signal into infrared light. The sensor on the appliance detects the infrared light and response appropriately to the received signal or command [1].

The aim of this work is to facilitate the protection of electrical and electronic devices from electrical faults in the home, and also to facilitate the control of mains supply to a room from a distance easily. The infrared remote control is made up of a transmitter and a receiver (Photo detector). The transmitter transmits within the frequencies of 30 KHz and 60 KHz having a wavelength of about 950nm.

Today, remote control is a standard feature on some consumer electronic products including VCRs, cable and satellite boxes, digital videodisc players and home audio receivers. The most sophisticated TV sets have remotes with as many as 50 buttons. In year 2000, more than 99 percent of all TV sets and 100 percent of all VCRs and DVD players sold in the United States were equipped with remote control. The average individual these days probably picks up a remote control at least once or twice in an hour. And in most pieces of consumer electronics from recorder to stereo equipment, an infrared remote control is usually always included [10].

System design and implementation

This remote controlled power supply switch has six stages namely: The transmitter stage, the detector (phototransistor) stage, the NAND Schmitt trigger stage, the flip-flop stage and the relay stage. The circuit comprises of a transmitter designed to generate an average frequency from 30 KHz to 60 KHz. [9]. The frequency rate of the output pulse is determined by the values of two resistors "R_1 and R_2" and the timing capacitor "C of the 555 timer [8]. The signal generated by the timer is picked up by the infrared detector unit, which goes low on receiving the signal [2]. The detector unit (photodiode) is set by different values of "R_1" and "C_1"and the values for the resistor "R_1" may be as high as 10Kohms and the capacitor C_1

40μF. This will prevent the photodiode unit from turning on under normal lighting conditions [8]. The output of the photodiode, which is at low level, is then inverted by the NAND Schmitt trigger, (the NAND gate is a NOT -AND, or an inverted AND function)[3]. The NAND gate used for this project is the CB 4093 BCN, the output of the NAND gate (a high) is now fed to into the flip flop which is a D – type of flip flop and it stores the information it receives which is a high (i.e.1), until it receives a contrary command or information which may be a low (i.e.0) when the transmitter button is pressed again [3,5]. The flip-flop receives data or information, which is a single bit and stores it; the data may be a low or high depending on the input. The output of the flip-flop now turns on or triggers the relay, which supplies power to the AC supply line. The flip-flop used for this work is the TC 4013 BP as shown in circuit diagram of Figure 4. The relay acts as a switch and as an isolator in this work because it is used to isolate the main circuit from the AC supply line, and it switches the power supply of a given room ON or OFF as the case may be.

Transmitter

A 9 volts battery powers the transmitter. It consumes little power. A 555 timer shown in Figure 1 was used to generate the signal and it was configured in unstable mode [7,9]. The threshold input pin (6) six was connected to the trigger input pin (2) two. The external components R_1, R_2, and C_1 form the timing network that sets the frequency of oscillation. When the switch S_1 is closed, power is turned ON, and the capacitor "C_1" uncharged, thus the trigger voltage (pin 2) is at 0 volt. This causes the output of the comparator "B" to be HIGH and output of comparator "A" to be LOW, Forcing the output of the latch, and thus the base of Q_1 LOW and keeping the transistor OFF. Now, C_1 begins charging through R_1 and R_2 as seen in Figure 1 when the capacitor voltage reaches $^1/3$ Vcc, comparator B switch to its LOW output state, and when the capacitor voltage reaches $^2/3$Vcc, comparator A switches to it's HIGH output state. This RESETS the latch, causing the base of Q_1 to HIGH, and turns ON the transistor. This sequence creates a discharge path for the capacitor through R_2 and the transistor. The capacitor now begins to discharge, causing comparator A to go LOW. At the point where the capacitor discharges down to $^1/3$ Vcc, comparator B switches HIGH; this SETS the latch, which makes the base Q_1 LOW and turns OFF the transistor. Another charging cycle begins and the entire process repeats. The result is a rectangular wave output whose duty cycle depends on the values of R_1 and R_2. The transmitter circuit is shown in Figure 1.

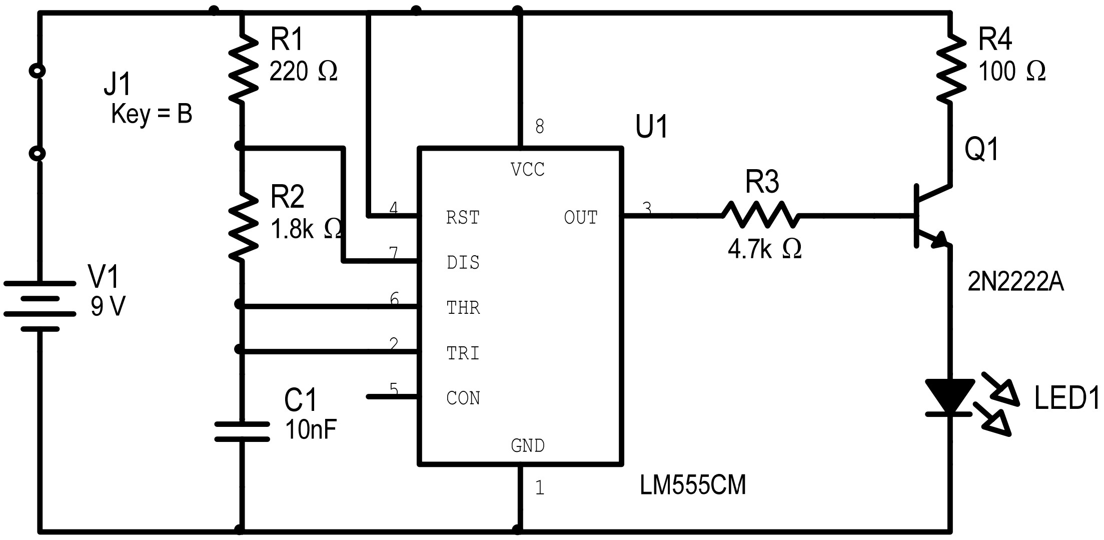

Figure 1. Transmitter circuit

The resistor R_2 was chosen to be one with very high resistance, because a duty cycle approaching a minimum of 50% can only be achieved if $R_2 >> R_1$ so that the charging and discharging times are approximately equal. Therefore, R_2 was chosen to be 1.8kΩ and R_1 to be 220Ω for this project design.

The capacitor alternately charges towards Vo and discharges towards zero according to the input voltage shown in figure 2. Here, the frequency (and therefore period) of the input square wave voltage is exactly such that the capacitor is allowed to fully charge and discharge. The time constant "t," is equivalent to KRC [4].

$$t = KRC \tag{1}$$

Assume that a square wave voltage is applied across an RC circuit. If one were to continually monitor the voltage across the capacitor, the waveform would resemble that of figure 2.

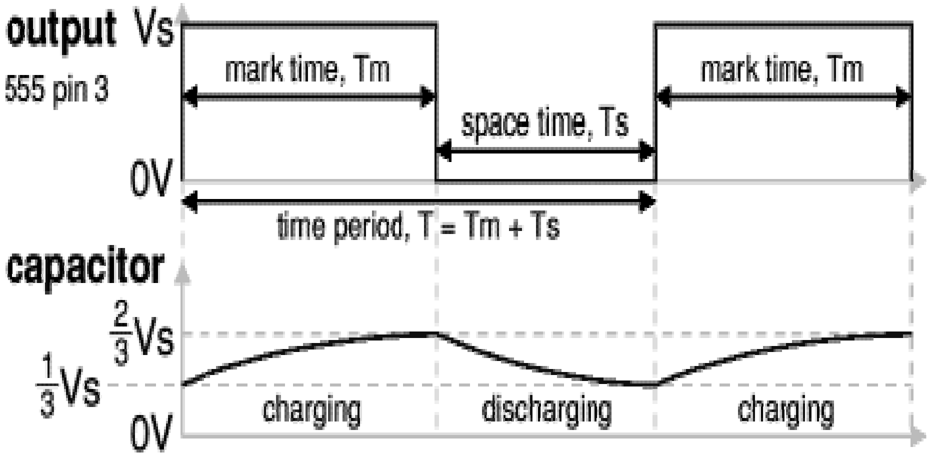

Figure 2. Waveform of an RC circuit

Frequency circuit calculation

Considering equation (1), the time constant t = KRC and from the figure above, it can be deduced that for 1 (one) period of oscillation of the RC circuit the capacitor charges for say T charge seconds and discharges for T discharge seconds. Where R is a resistor, C is a capacitor, and K is a constant (0.693).

From the transmitter circuit in figure 1: $R_1 = 220\Omega$, $R_2 = 1.8k\Omega$ $C = 0.01\mu$ F:

$$T\ charge = 0.693R_TC \quad (2)$$

where R_T is $R_1 + R_2$

Therefore:

$$T\ charge = 0.693(R_1 + R_2)\ C$$
$$T\ charge = 0.693(220 + 1.8k)\ 0.01x10^{-6} = 1399.86 \times 0.01\ x\ 10^{-6} = 14\mu s \quad (3)$$

$$T\ discharge = 0.693R_2C$$
$$T\ discharge = 1.8k \times 0.693\ (0.01 \times 10^{-6}) = 13\mu s \quad (4)$$

Therefore, period of oscillation:

$$T = t\ charge + t\ discharge = 14 + 13 = 27\mu s \quad (5)$$

Frequency of oscillation:

$$F = 1.44/\ (R_1+2R_2)\ C\ =\ 1.44/\ (220+3600) \times 0.01 \times 10^{-6}$$
$$F = 37{,}696.34Hz \approx = 38\ kHz \quad (6)$$

The oscillator in this circuit is a free running non-sinusoidal oscillator.

The receiver

It consists of a photodiode pre-amplifier and a signal processor, which operates at a turned frequency of about 37.9KH$_3$. When the pin 3 of the receiver is powered, R_1 limits the current into the photodiode. The output of the Receiver at pin one (1) as shown in Figure 3 is the voltage drop across the photodiode under normal light. When the photodiode, receivers any signal from the transmitter, the resistance of the photodiode will drop and consequently drop the voltage across it. With a considerable signal received by the receiver of about 30KH$_3$ to 40KH$_3$, the resistance may fall to a negligible value and thus the drop across the photodiode is approximately zero volts, thus making the output of the receiver low. But when no signal is received, the resistance increases and thus the voltage drop across the photodiodes increases.

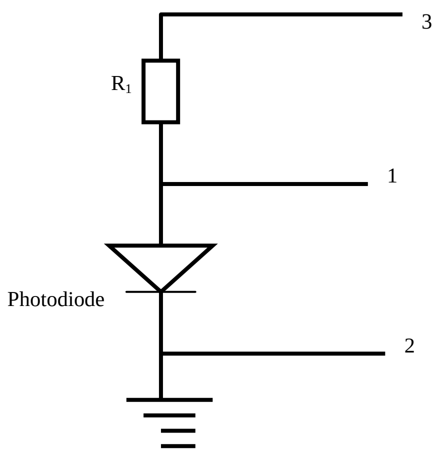

Figure 3. Receiver circuit

The buffer circuit

C9014 [6] transistor or emitter follower is used as buffer as shown in the circuit diagram Figure 4; the output terminal is the emitter, which follows the input (the base), less one-diode drops. For this circuit, the Vin was at the positive 0.6 volt, so that the output will remain at ground level. An emitter follower has current gain; therefore it is used to increase the driving current of the relay, even though it has no voltage gain. The circuit requires less power from the signal source to drive a load, and much power if the signal source were to drive the load directly.

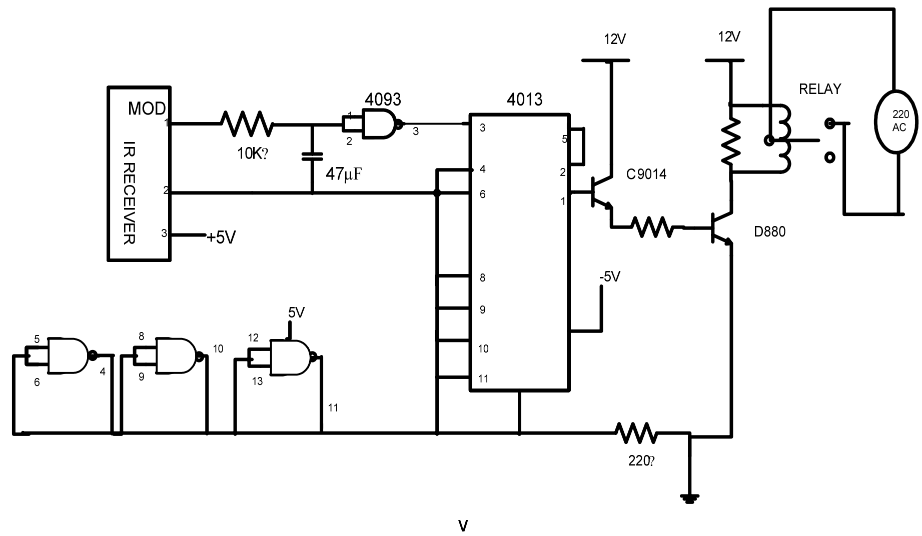

Figure 4. Circuit diagram of an infrared remote control unit

Power / regulator

The power supply used in this design is a linear power supply type, which comprises of a step down transformer, filter capacitors, rectifier and voltage regulators. The two regulators were used to give the various voltage levels. The power supply circuit diagram is shown in Figure 5.

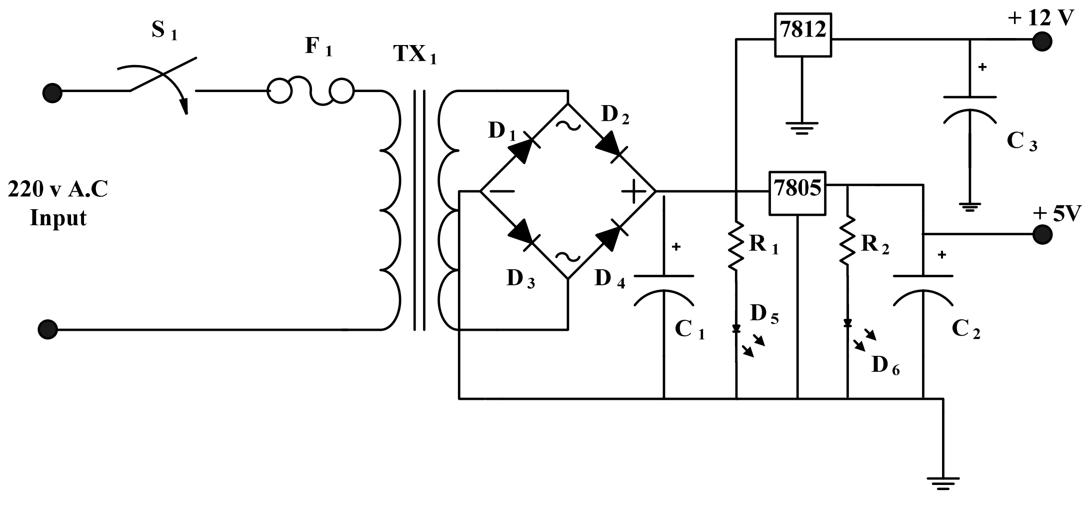

Figure 5. Power supply unit

The turn's ratio of a transformer in a D.C power supply can be selected to either increase or decrease the 220V ac input. With most electronic equipment, a supply voltage of less than 220V is required, and therefore, a step down transformer is used. The secondary output voltage (Vs} from the transformer can be calculated as [2].

$$Vs = (Ns \times Vp)/ Np \tag{7}$$

where:

- Vs = Secondary voltage of transformer;
- Ns = Secondary windings of transformer;
- Np = Primary windings of transformer;
- Vp = Primary winding of transformer.

Construction

The designed Remote Controlled Power Supply Unit was first of all divided into three functional blocks and each block was then simulated on electronics workbench. Each block worked to specification. Thereafter, the construction was done on Vero board in accordance with the designed circuits as illustrated Figure 1, Figure 4 and Figure 5.

Testing

At various stages of the project, it was tested using multimeter to ensure its working ability. The multimeter was used to measure continuity, resistance, voltage, current and the working condition of transistors and diodes, during the project construction. The multimeter was also used to measure the different voltage levels of the power supply unit. The charging time (T on) was calculated to be a little higher than the discharging (T off), because from the design the RC network was adjusted so that a minimum duty cycle of 50% could be achieved, so that the charge and discharge time will be approximately equal. During the test, a percentage error of about 0.001 was recorded, which is still within experimental error.

In testing the transmitter, an AM radio receiver was brought near it. The reception of the radio receiver was interfered with by the transmitter, proving that the transmitter is working. The theory behind this is that infrared circuits cause interference noise whenever they are brought near radio receiver in AM band.

It was also obvious that each time a button is pressed on the remote control, the supply was triggered either ON or OFF.

Conclusion

The transmitter transmits signals to the receiver from a distance of 5m and above when functioning at its best. It was observed that the transmitting distance depends on the strength of the battery because it was observed that when the battery went low, the transmitter had to be brought closer to the receiver before the receiver picks the signal, but reverse is the case with a stronger batteries. Another factor that determines the frequency of transmission was discovered to be the values of the resistor and capacitor used at the transmitter stage. The AC was connected to the relay output, and it performed its normal operation of switching either “on” or “off”, whenever the transmitter button was pressed. The project was not only able to switch the mains power supply unit but, it could also be use to control (switch) the lighting unit of a room, and also to control any electronic or electrical device connected to its output.

Recommendation

Though the main objective of this project was achieved, the following can be made to improve on the performance and rating. A digital display may be included so as to show the voltage level coming into a given room. An automatic regulator unit could be included so that it regulates the incoming voltage or switch off an abnormal voltage. A solid-state relay (opto coupler) and other digital integrated circuits could be used to increase the rate of switching. Incorporating a unique sound alarm unit, that will come ON once there is an unusual voltage. On a final note, to improve the performance of the device, the output of the device should be regulated to properly handle variations in the power supply line.

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