Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (2): 235-238

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The Design and Construction of an Infrared Activated Security System at 9 Khz Frequency

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Abstract
This paper reports the design and construction of a security system. The system will produce sound of a barking dog at audible frequency of 9 KHz. The design procedure and principle of operation of the various modules as presented in this work are based on the locally available electronic components

Keywords: infrared, transmitter, receiver, frequency, multivibrator, stable, monostable, voltage

INTRODUCTION

The opto-electronically controlled security system is to automatically detect the presence of unauthorized person(s) entering or leaving a given area and to notify the security personnel accordingly. In notifying the security personnel, a sound of a barking dog is produced by the system since it has been designed to operate at audible frequency of a barking dog. The system is therefore a dog in disguise. The system has many advantages over other security systems where the presence of intruders is detected by photocells. The cell has inherent inefficiency in that it is either shadow or light operated which the intruder can bypass. Opto-electronically controlled security system incorporates infrared emitting diode at the transmitter end and phototransistor at the receiver end. The design, construction and testing of this work was done in the Department of Physics, Federal University of Technology, Akure. The design of the work as presented in this report has been based on the locally available electronic components in Nigeria such as infrared transmitter and receiver, transistors, resistors, capacitors, 555 timer etc.

Technical Design and Operation of Various Modules

The block diagram of the work is presented in Fig 1. It consists of infrared transmitter, infrared receiver and other circuitry. The design procedure and selection of the components for the various units are hereby presented.

The Infrared Transmitter is the unit that generates the infrared light via infrared emitting diode (IR emitter). The transmitter uses the 555 timer configured in the astable mode as shown in Fig 2. The astable multivibrator is also called free running multivibrator and generates a continuous digital signal or train of pulses whose period is given as [Anyanwu et al., 1987]

$$T = C_1 (R_1 + 2R_2) \ln 2 \quad (1)$$

The frequency F of the output pulses is also given by

$$F = \frac{1}{T} \quad (2)$$

In this work, the frequency of operation has been taken as 9.0 KHz, which is within the range of audible frequency of a barking dog. The pulse therefore has a period of 0.11 *mS.* C_1 is a capacitor and must have a low valued capacitance as to avoid unnecessary charging and discharging [Horowit and Winfield, 1997; Lehman, 1997]. The value chosen is 1.0 *nF*. According to the design, R_2 is to be approximately twice that of R_1 [Horowit and Winfield, 1997]. Using Eq. (1), their calculated values are R_1 = 82 KΩ and R_2 = 39 KΩ

The output of the astable multivibrator at pin 3 is connected to a constant-current source transistor, TR_1. This then provides the infrared transmitting diode, D_3 with a current, which pulsates in rhythm with the output signal of the astable multivibrator. The circuit diagram of the infrared receiver in this work is presented in Fig 3. The transistor, TR_2 is the phototransistor and it senses the infrared signal emitted by the transmitter. The transistors TR_2 and TR_3 formed a cascaded amplifier, which then amplified the detected signal and ensures that the output signal from the unit is in phase with the incoming pulsating infrared light. The output voltage from TR_3 can be measured using [Maddock and Ca cut, 1988]

$$V_0 = \left(1 + \frac{R_8}{R_9}\right)\left(\frac{R_1 R_3}{R_2 R_4}\right) \quad (3)$$

Equation (2) gives V_0 = 1.33 V, which is reasonably comparable to the measured value of 1.46(5) V with 9.77 % difference. This difference may be due to the components tolerance. This output goes to the input of a non-inverting amplifier, A_1. This is to achieve more amplification of the signal. The output signal of

A_1 is an alternating signal with high frequency. This then passes through half-wave voltage doublers to rectifier it and double the voltage of the signal.

The comparator A_2 is meant to generate the triggering pulse for the time delay. When the non-inverting voltage is larger than the inverting voltage, the comparator produces a high output voltage equal to the supply voltage. When the non-inverting input is less than the inverting input, the comparator produces a low output voltage. As long as the receiver receives the pulsating infrared, the output of the comparator remains high. When a person breaks the pulse stream by passing between the transmitter and the receiver, the output from the receiver goes low and hence triggers the time delay using a negative edge trigger.
The time delay and clock pulse circuits used in this work are shown in Fig 4. This determines the time delay operation of the system. A 555 IC has been configured as a one shot multivibrator or in a monostable mode. This produces a single pulse by using the external components C_7 and R_{15}. The circuit triggers when a negative going pulse (this is obtained when an intruder breaks the transmission of infrared light) is sensed through pin 2. The pulse duration time T is given by [Maddock and Ca cut, 1988**;** Day et al., 1976]

$$T = 1.1\ R_1C_1 \tag{4}$$

The values of external components are C_7 = 1.0 μF and R_{15} = 100Ω. These have been chosen to ensure that the frequency of 9.0 KHz is maintained.

The clock pulse circuit also uses 555 IC in an astable mode. This has been design to generate continuous pulses. The output of the clock pulse is determined by the input signal at pin 4, which comes from the time delay circuit. As long as the signal at pin 4 is high, train of pulses is generated at the pin 3 of the clock pulse circuit, the period of which is determined by R_{16}, R_{17}, C_9 and C_{10}.

The pulses generated by the pulse generator are meant to drive the monostable relaxation oscillator for the time delay of 60 seconds. This triggers the oscillator to start barking at the audible frequency of a dog. To maintain this time delay, the values of components that made the clock pulse generator are R_{16} = 22KΩ, R_{17} = 122KΩ, C_9 = C_{10} = 10 *μF*. The circuit adopted to oscillate at this time delay is presented in Fig 5. This generates the output signal whose frequency depends on the charging of capacitors C_{11} and C_{12}. The pulse frequency from the oscillator that controls the output frequency of the voltage-controlled oscillator (VCO) is given by

$$F = \frac{1}{7R_{18}(C_{11} + C_{12})} \tag{5}$$

The Voltage Control Oscillator (VCO) circuit provides varying output signal typically of square waveform whose frequency can be adjusted by a dc voltage [Lehman, 1999; Jones and Scott, 1993]. The Voltage Control Amplifier (VCA) ensures that the single pulse generated by the VCO can only get to the band pass circuit when the switch S_1 is closed. The circuit diagram of Fig 6 presents the VCO and VCA that have been used in this work. Potentiometer, P_1 determines the highest frequency that can be generated at the final output while P_2 is to set how we want the audible tone to decay. Their values are 1MΩ and 50KΩ respectively. It should be noted that comparators A_1 to A_4 are TL084 IC.

This circuit of band pass filter used in this work (Fig 7) permits the signal of desired frequencies to pass. The bandwidth of this type is the difference between the upper and lower frequencies. In this case the lower frequency F_L is 20 Hz while the upper frequency F_H is 200 KHz since the audio frequencies of a barking dog is between this range. The bandwidth of the filter and the center frequency F_0 are related by the Q factor, which is defined by [Maddock and Ca cut, 1988; Day et al., 1976]

$$Q = \frac{F_0}{F_H - F_L} \tag{6}$$

For typical audio filters, the values of the capacitors are between 0.01 and 0.1 *μF*. In this work, C_{18} = C_{19} = C = 10 *nF*. The values of other components that made up the band pass filter have been calculated using Eqs. 7 – 9 with gain, G taken as 0.4 [Maddock and Ca cut, 1988].

$$R_{27} = \frac{2Q}{2\pi F_0 GC} \tag{7}$$

$$R_{28} + P_3 = \frac{Q}{(2Q^2 - G)2\pi F_0} \tag{8}$$

$$R_{29} = \frac{2Q}{2\pi F_0 C} \tag{9}$$

The output signal from the band pass is of low amplitude and must therefore be amplified before getting to the speaker. Two power amplifiers IC LM 386 have been used. They have been cascaded to enhance the efficiency of their operation. The arrangement of the components is presented in Fig 8. The unit that supplies necessary dc voltage to various units of the project is presented in Fig 9. C_{25} – C_{28} are smoothing capacitors to filter the ripples from the rectified voltage and to give a better approximation to the dc voltage. The voltage regulators that have been used in this unit are 7809 and 7909 to supply +Vcc and –Vcc respectively, to the appropriate unit of the project as required. The diodes D_9 and D_{10} are protecting diodes, which are meant to protect the power supply against short circuit.

CONSTRUCTION AND TESTING

It should be noted that in drawing the circuit diagrams, an electronic workbench, which is a computer-drawing package has been employed. For effective and reliable operation the transmitter and the receiver are not to be more than 2 m apart.

SUMMARY AND CONCLUSION

This paper has reported the design procedure and construction of a security system. This has been designed to operate at an audible frequency of 9 KHz. This work would offer assistance to our security personnel on guard to have a thorough monitoring and control over the area of their operation.

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APPENDIX

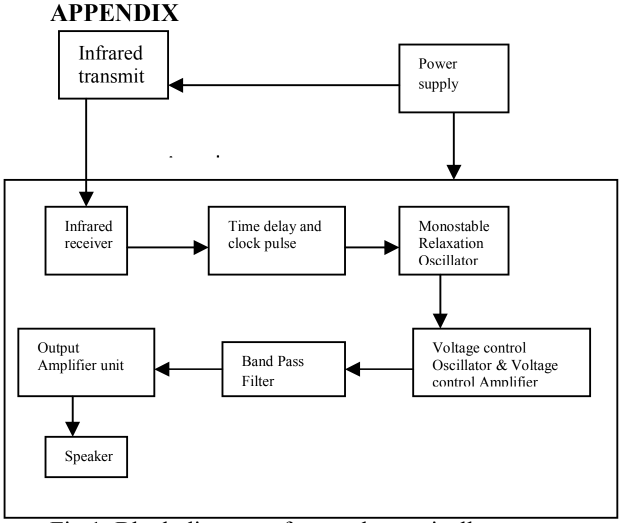

Fig 1: Block diagram of opto-electronically controlled security system

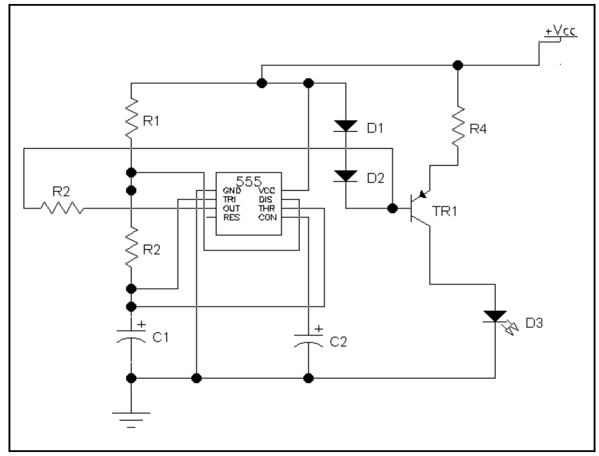

Fig 2: Circuit diagram of the infrared transmitter

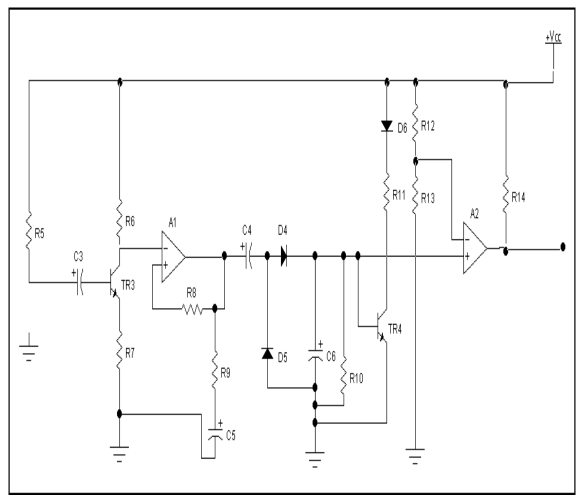

Fig 3: Circuit diagram of the infrared receiver

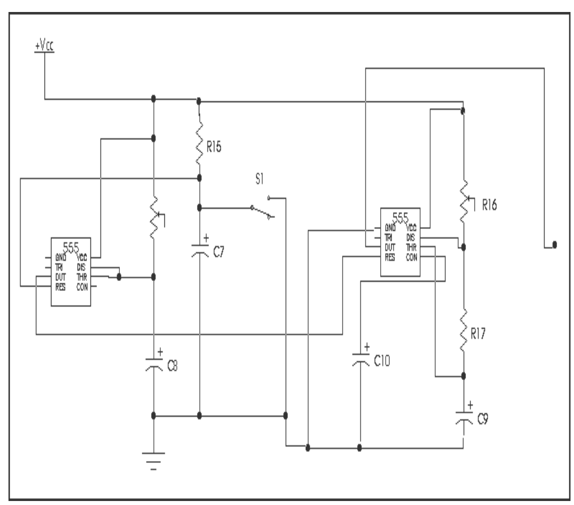

Fig 4: The time delay and Clock pulse generator circuits used in this work

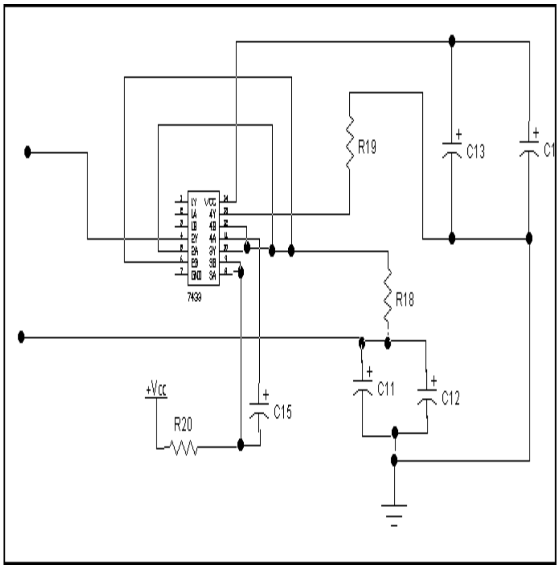

Fig 5: The circuit of Monostable Relaxation Oscillator

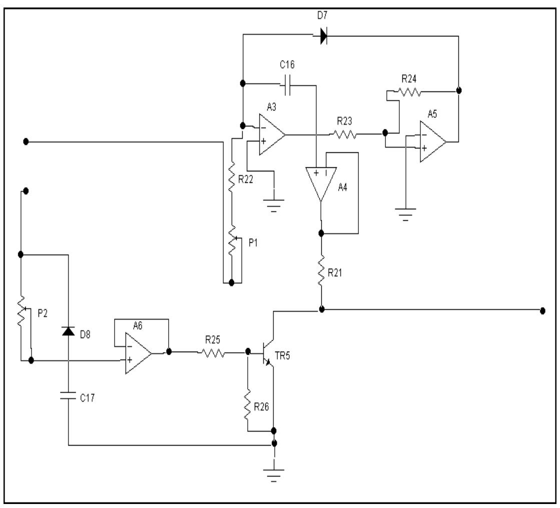

Fig 6: Circuit diagram consisting the VCO and VCA

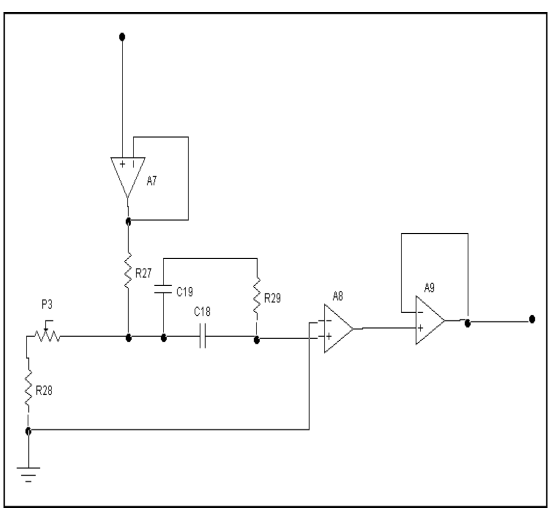

Fig 7: Circuit diagram of the band pass filter

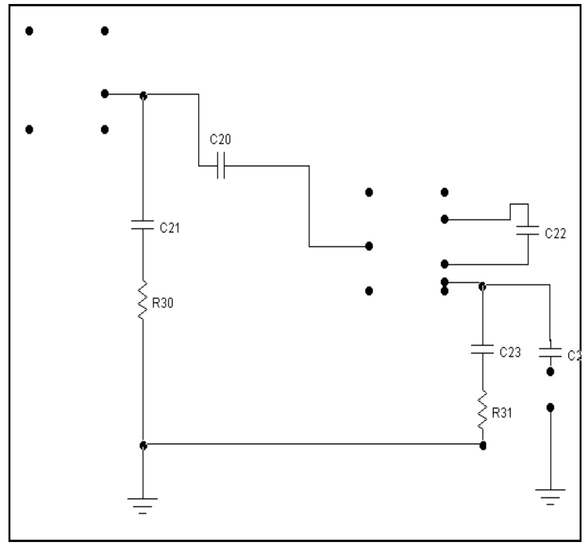

Fig 8: The output power amplifier circuitry

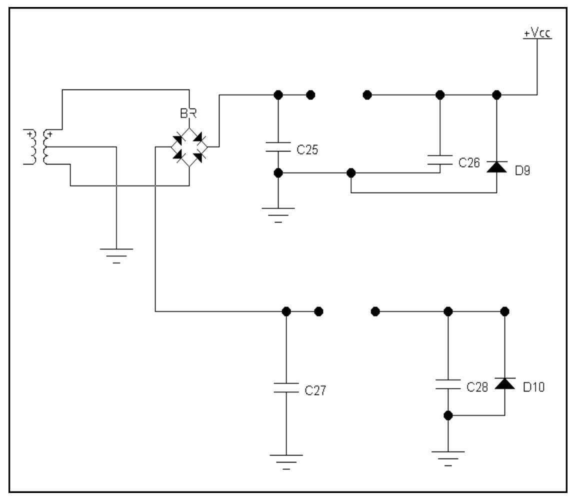

Fig 9: The circuit diagram of the power supply