DESIGN AND CONSTRUCTION
OF
DUAL BEAM INFRA-RED INTRUSION DETECTOR

BY

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CERTIFICATION

This is to certify this work was carried out by Isaac Abanyi of the Department of Electrical/ Computer Engineering. Federal University of Technology Minna, Niger State.

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EXTERNAL SUPERVISOR DATE

DEDICATION

This masterpiece is fondly dedicated to my loving parents and all my siblings

[signature]
17th Oct. 2003

ACKNOWLEDGEMENT

Foremost, to God

For in Him we live, and move, and have our being

My lovely parents & sibling

Their contributions are enormous

My friends too numerous to mention

For always being there

My class mate

They made the work easier

My sources of information

They've been resourceful.

Especially Ray Mastron &Steve Ramshade

Electronic today international,Feb 1987.

ABSTRACT

A comprehensive and concise report on the design and construction of a dual-beam infrared intrusion detector. The system is distinctively divided into two parts - the transmitter design and the receiver design. The transmitter is a modulated source of infrared energy, sending out dual beams that are highly directional the receiver on the other hand is an infrared energy detector, configured to receive at the transmit frequency bandwidth.

The report is presented in a four chapter thesis .the first chapter presents an introduction the objective and literature review for the design. In the second chapter, the design stages an operation of the various networks, circuit and sub-systems that constitute the entire system is masterly discussed. The third chapter was brief and its focus on the construction testing and installation. These abstract was concluded on the fourth, which also is the last chapter. Recommendation for improvement as well as references and appendices are included here.

TABLE OF CONTENT

1.0 CHAPTER ONE: INTRODUCTION

This dual- beam infrared intrusion detector has an exceptional degree of false-triggering immunity and a useful range of several meters. It can form the basis of a first class domestic or commercial security alarm to deter intruder and or apprehend intruder.

The project comprises two units – an infrared transmitter and an infrared intrusion detector with a relay output. Both prototype units are mains powered with alternative facility for an uninterrupted supply in case of sudden power failure. The receiver unit contains facility for externally disabling the relay for 20 seconds via concealed 'by-pass' switches so that authorized persons can pass through the beams without activating the alarm.

The most unusual feature of my alarm is the use of a dual-beam infrared link. For this prototype, the two beams are spaced two inches apart and both must be broken simultaneously to operate the alarm. The system thus respond only to object greater than the dual beam size and cannot normally be false triggered by the moths or other insects passing through the beams or settling on the transmitter or receiver diodes

1.1 DESIGN OBJECTIVE

The aim and objective of this design that incorporates fascinating features, is to deter and apprehend burglars or intruders in a given area –whether residential or commercial and at all times –day or night by employing modulated source of infrared signal to provide dual and highly directional infrared beams that can be detected only by the receiver at which they are aimed ;thus providing a high degree of capability .The minimum size of the e object to be detected is pre-determined by the spacing of the beam

1.2 LITERATURE REVIEW

Intrusion detectors are system that detect presence of an intruder. If the primary aim is to apprehend intruders a signal transmitted by wire to a near by police station or security office .An infrared intrusion detector system uses an infrared beam projected onto a photoelectric cell either indirectly or by means of mirrors . If an intruder interrupts the inevasible infrared beam, the break is detected ,thus triggering alarm . A wide area can be covered when the beam is deflected by mirrors[7]. Infra red is that invisible portion of the electromagnetic radiation spectrum that extends from wavelength of 0.75 to 1000 micron (one micron is 10^6 metres). These wavelengths are longer than those of visible light but shorter than wavelength commonly used in radio communication.

Sir Fredrick Williams Hershel, the German born British astronomer royal, is credited with the discovery of infra red radiation during the spring of 1800. Hershel referred to this infrared radiation as invisible light and speculated, that its nature was the same as visible light.

Many of the early experiments searched similarities between infra red energy and visible light. In 1847 , Armand Hippolyte Louis Fizeau, and Jean Bernard Leon Foucault of France showed finally that infra red radiation exhibited interference effects in exactly the same way as visible light .it has also been revealed among others things that though, infra red radiation is reflected and refracted just like the visible light[8].

Today infrared find use in: material analysis, thermal imaging, Remote temperature sensing, and communications.

Material analysis: Many complex molecules absorb infrared energy at specific wavelengths. This is characteristic permits rapid identification of material without the use of chemicals and without destroying the material.

Thermal imaging: Infrared scanning instrument (or image-forming cameras) produces thermal picture of their targets. Medical application of this include remote thermal mapping of human body temperature. Areas that exhibit abnormally high or low temperature are readily revealed and analyzed for body malfunctioning or disease. Also infrared microscope permits thermal mapping of very small objects such as transistors or microcircuits. Devices that exhibit localized and excessive high temperature are discarded as defective.

Communications: Modulated sources of infrared energy provide highly directional infrared beams that can be detected only by the receiver at which they are aimed, thus providing a high degree of privacy.

Remote temperature sensing:; Radiation emitted by an object is a unique function of its temperature. The infrared radiometer or pyrometer collects and measures the radiation from a target to determine its temperature. Versions of the infrared radiometer have been used to detect fires, plot ocean surface temperature from air craft, and detect overheated bearings on railroad vehicles as they move at high speed.

Military applications of radiometer are found in heat-seeking missiles, aircraft and missiles trackers, aiming devices for locating vehicles and people in the dark and for gun fire control.

Atomically radiometers track the position of the sun , moon and stars. Long range weather forecasting depends on infrared radiometer surveillance of the earth's cloud coverage from satellites. Radiometers called Horizon sensor detect the thermal discontinuity between the eart6h and space and are used to establish a stable vertical reference for altitude control of a missile.

2.0 CHAPTER TWO SYSTEM DESIGN AND OPERATION

Here, the design and operation of the various stages, networks, and circuit that function together to revolve the dual beam infrared signal transmission and intrusion detection is discussed in detail. Starting from this transmitter therefore, the receiver

2.1.0 LOW FREQUENCY SIGNAL GENERATOR

An a stable signal of alternate period of 1ms and 49ms(to save and optimize transmission power considerably[3]) is generated using an a stable multi vibrator configured by a 555 timer IC with two external resistors and a capacitor to obtain required frequency (20Hertz) of oscillation and duty cycle of 98% [4].

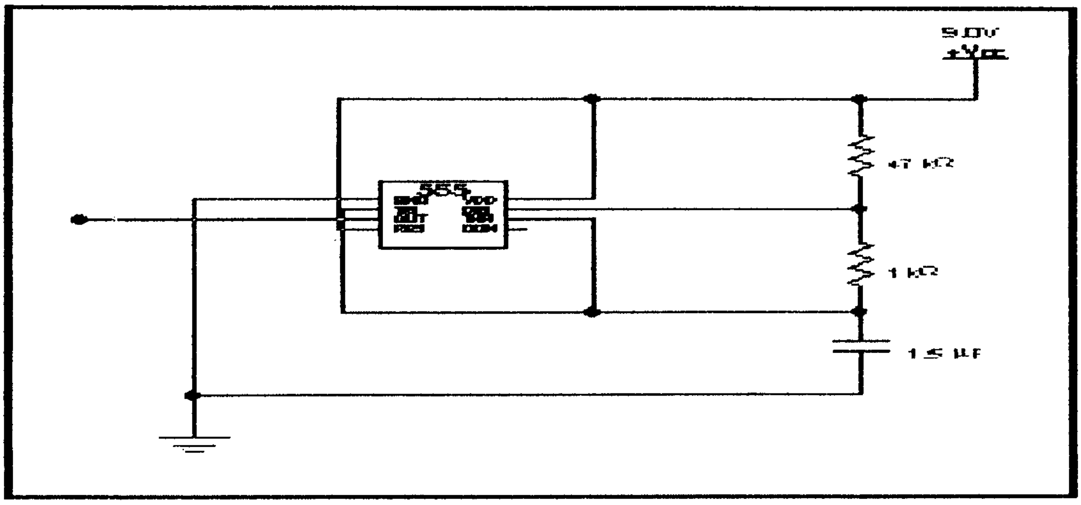


Fig 2.0

From calculation, to the nearest preferred value R1,R2 and C are found to be 47 K ohms,1k ohm 1.5µf [2] NE 555 Timer IC was used [A]

Thus frequency $F = 1.44/((R1+2R2)*C)$

$F = 1.44/((47k+2(1k))*1.5\mu f)$

$F = 19.60Hz$

Duty cycle $D = (R1+R2)*100/(R1+2R2)$

$$D = (47k+1k)*100/(47k+2(1k))$$

$$D = 97.96\%$$

The low frequency astable and alternate signal generated is buffered and inverted and used to gate the high frequency carrier wave generator ON and OFF.

2.1.1 HIGH FREQUENCY CARRIER SIGNAL GENERATOR

For a transmission of weak message, (the time an infra red signal), a high frequency carrier signal is required to modulate the weak signal [3].

Also modulated source of infra red energy provide a highly directional infrared beam that can be detected by the receiver of which that are aimed, thus providing a high degree of privacy [8]

2.1.0 HIGH FREQUENCY SIGNAL GENERATOR

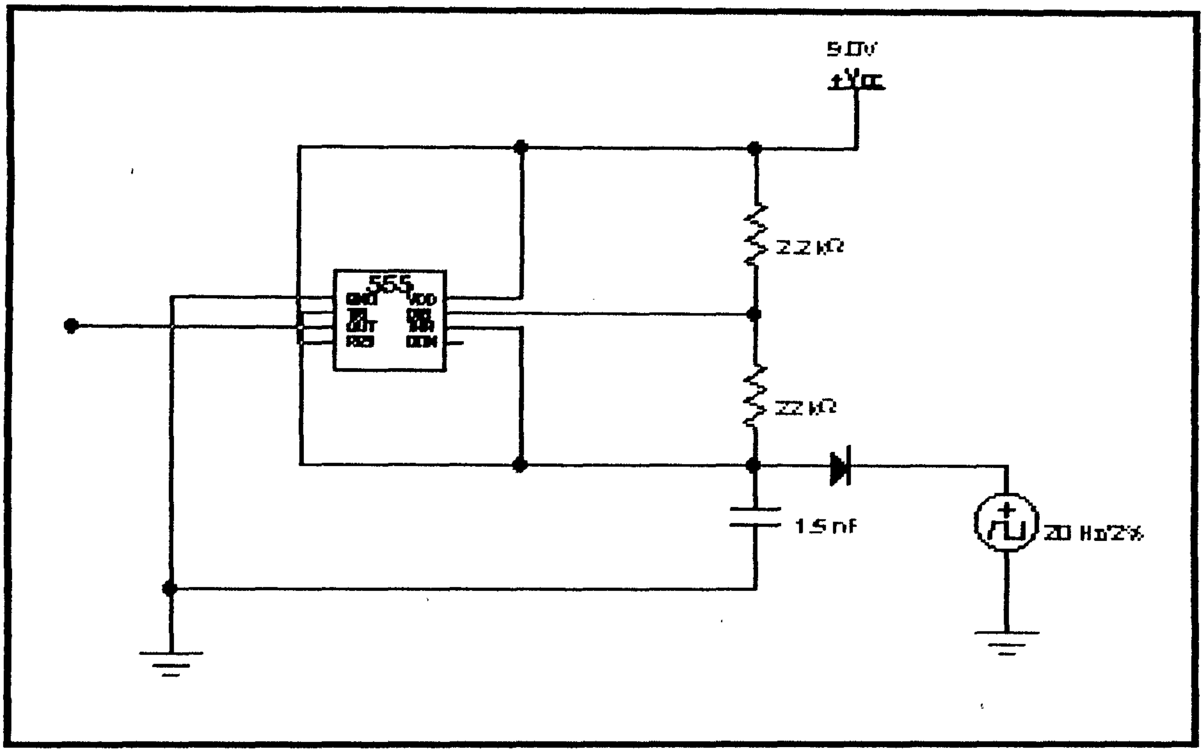


Fig 2.1

As an astable and symmetrically high frequency signal of 20 KHz is generated using a 555timber IC with two external resistors and a capacitor. Also to the nearest preferred value R1 R2 and C were found from calculation to be 2.2k, 22k and 1.5nF respectively [2].

Thus frequency $F = 1.44/((R1+2R2)*C)$

$F = 1.44/((2.2k+2(22k))*1.5nf)$

$F = 20.78$ kHz

Duty cycle $D = (R1+R2)*100/(R1+2R2)$

$D = (2.2k+22k)*100/(2.2k+2(22k))$

$D = 52.4\%$

Again the output signal is buffered and passed in to the next stage.

2.12 INFRA-RED EMITTER DIODE DRIVER STAGE

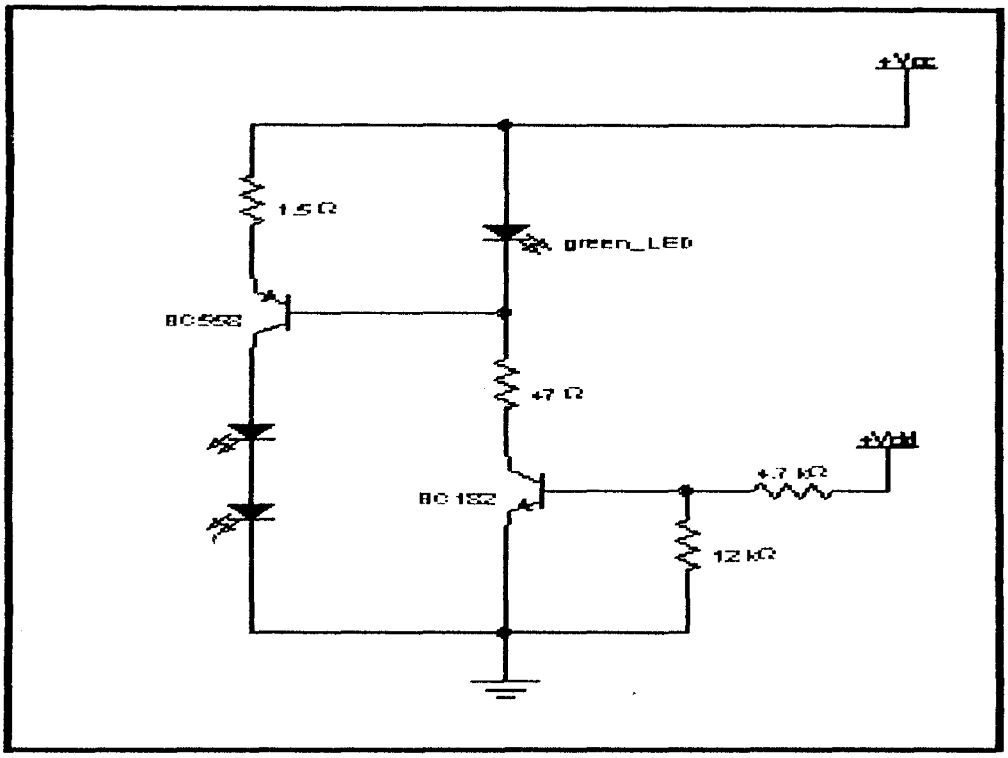


Fig 2.2

In the first stage, output signal from the buffer via a voltage divided sets up a fixed value of base current. This is the base-biasing network usually very useful in digital circuit because they are designed to operate at saturation and cut-off region [2]. This first stage, gates current ON and OFF to the next stage- the base of the next resistor as well as to drive LED 1 to glimmer dimly to indicate correct transmitter operation.Bc 182 is an npn transistor,having □dc =190 [2].

Given Vbb = (12k*Vref/(12k+4.7k))

= 0.718Vref for Vref= 6V and Vbe = 0.7V

= 4.3V

And, Rb = R12k//R4.7k
=3.38k

At saturation,

$Ib = Vbb-Vbe/Rb$

$= 4.3V - 0.7V/3.38k$

$=1.06mA$

$Ic = Ib□dc$

$=201.4\ mA$

At cut-off, Vref = 0 therefore Vb = 0and Ic =0

In the second stage, the collector current of the 1st stage, gets 600mA to constant current generator, T2-Re-LED, On and OFF and thus feed a high energizing current to the two series connected IR transmitter diode.The transistor biasing of the second stage is the emitter-biased infrared emitter driver.

It is very useful when it comes to current amplification because we need circuits whose operating point (Q-point) is immuned to changes in current gain. When a current gain changes from say 50 to 150, the Q-point is Rock solid-shows no movement along the load line. Hence this biasing technique is beta independent [2]. Emitter biasing has other advantages viz exact LED (infrared diode) voltage does not matter also a collector resistor is not required. T2 is an pnp transistor that works as a current source [A].Note:The high current transmitter pulses are derived from the 1000uf storage capacitor provided.

2.1.3 DESIGN OF A 9V POWER SUPPLY

(With battery back-up for uninterrupted supply)

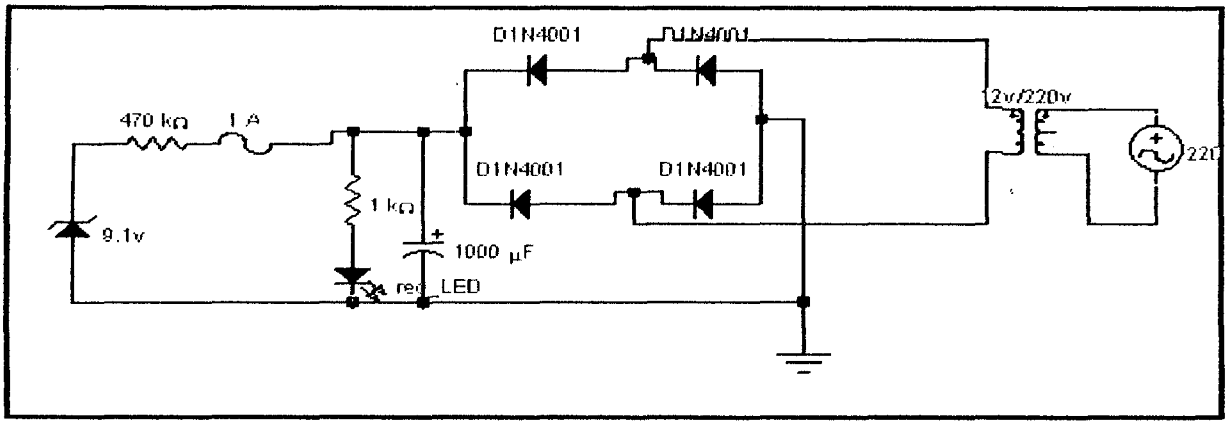


Fig 2.3

A supply built around a high-performance is often the most practical choice in circuit. This prototype employs just that. The ac mains input is connected to a220v/12v step down transformer of current rating 1000mA and passed to the full-wave bridge rectifier network as shown above.

Working: During the positive input half –cycle, terminal M of the secondary is positive and N is negative., Diode D1 and Diode D3 become

Forward biased (ON) whereas D2 and D4 are reverse biased (OFF). Hence current flow through D1 and D3 producing a drop across RL.

During the negative input half-cycle, secondary terminal N becomes positive and M negative. Now, D2 and D4 are forward biased circuit current flow through RL in the same direction during both half cycles of the ac input supply. Consequently, point A always acts as an anode and point C as cathode.The output voltage across RL is as shown in figure (b).Its frequency is twice that of the supply frequency [2].

For better reliability and uninterruptible supply a good bacck-up system is employed.It uses diodes to pass the higher of the voltages without affecting the lower.A battery back-up like this will keep the system operating none-stop even when there is a mains power failure or battery failure and not both at the same time. The battery does nothing until the power from the mains fail then it takes over without interruption [5].

A 9V BATTERY BACK-UP SYSTEM

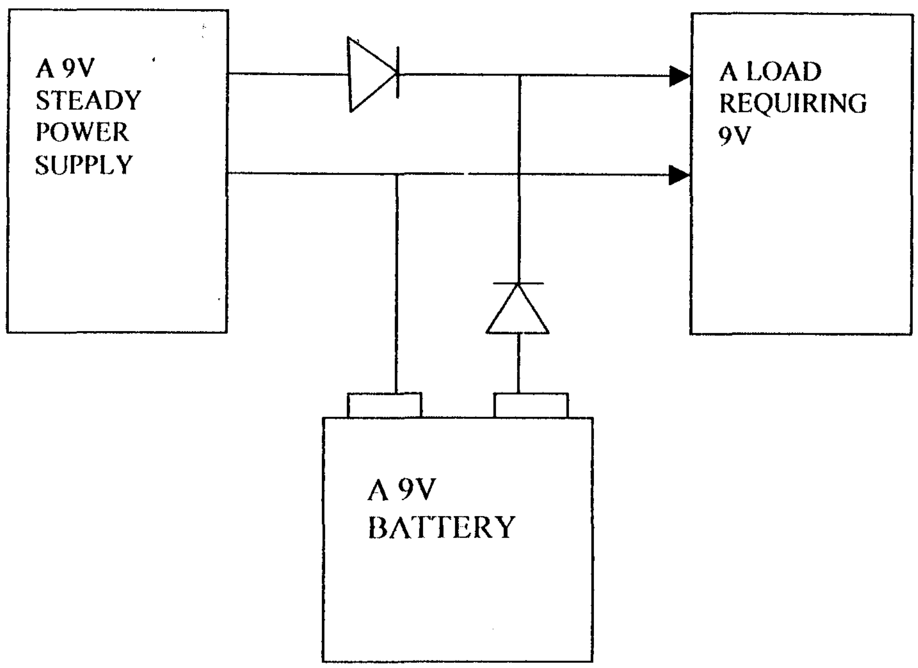


Fig. 2.4

2.2.0 FIRST STAGE RECEIVER AMPLIFIER

The two IR detector diodes are connected in parallel and wired in series with the resistor 100 K so that the detected IR signal is developed across it. The detected signal is fed to the inverting input of the 1st stage receiver amplifier. Signal amplification is achieved using operational amplifier(op-amp).By connecting two external Resistor R1 and R2,we can adjust the voltage gain and band-width of the op-amp to our exact requirement. This prototype project used the most basic op-amp i.e. the inverting amplifier which uses negative feedback to stabilize the overall voltage gain. Half the Vcc supply by design is fed to the non-inverting input. A and because the two input are virtually shorted the inverting input has a quiescent voltage of approximately +0.5Vcc[2].A typical MOSFET amplifier CA3140 [A] with frequency capability of order 20 KHz was used.

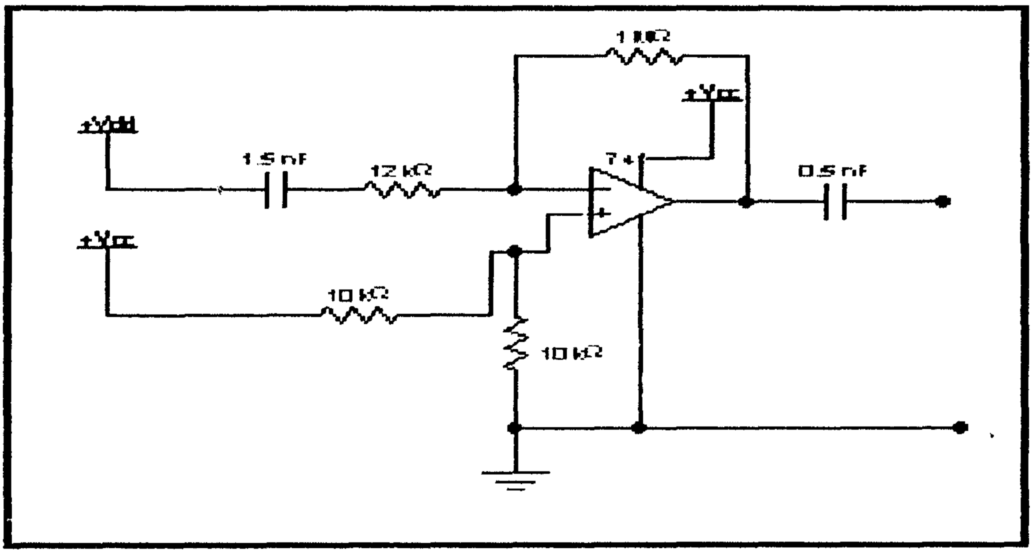


Fig 2.5

In the d:c equivalent circuit, all capacitors are open and they act is a voltage follower that produces a d.c output voltage of 0.5Vcc.Input offsets are minimized because the voltage gain in unity.

In the a.c equivalent circuit, all capacitors are shorted and the circuit is an inverting amplifier with a voltage of -R2/R1

- Avl = -1M/12K

- Av1 =-88.3

2.2.1 SENSITIVITY CONTROL NETWORK

The sensitivity control network is a special design to control the voltage gain derived from the first stage amplification of received signal [1]. Output signal from this first stage amplifier can then be varied from maximum to minimum using sensitivity control potentiometer .Basically, the sensitivity control is used in this prototype to set the system such that the relay/output LED turns on only when both IR bears are broken simultaneously and not just either at a time.

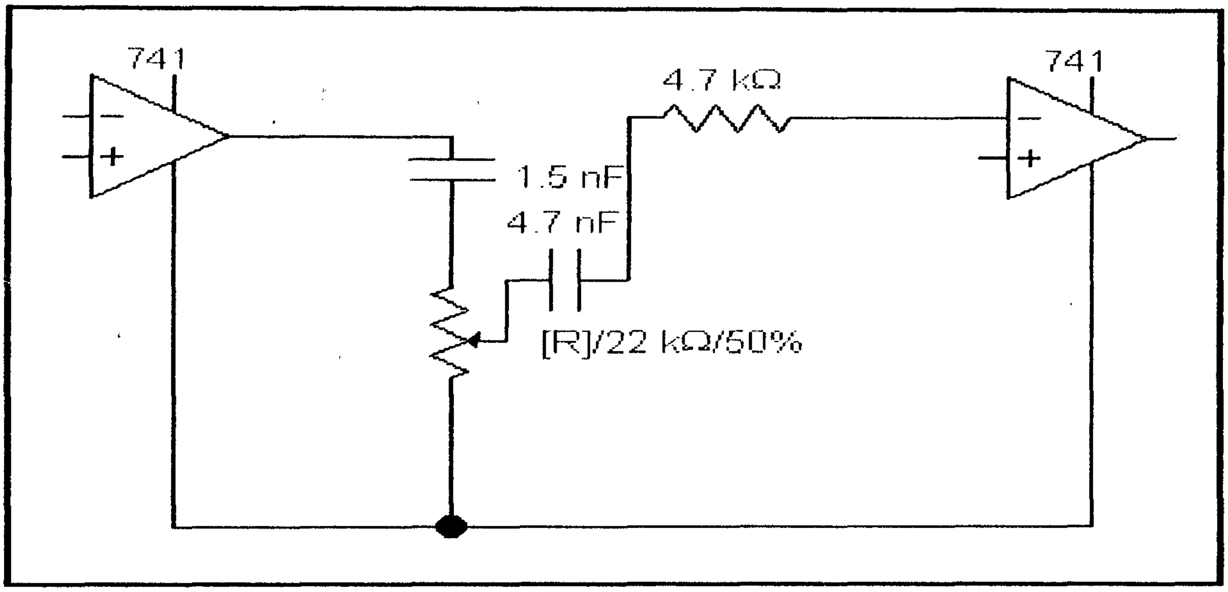


Fig 2.6

2.2.2 SECOND STAGE RECEIVER AMPLIFIER

The output signal from the sensitivity control network is fed to the inverting input of the second stage inverting amplifier by connecting R1and R2 as in the first stage, the voltage gain and bandwidth of the 2^{nd} op-amp is set with the desired value. Both the d.c and the a.c equivalent circuit's operations remain as in the 1^{st} stage above.

- Av =-R2/R1
- Av2 =1M/4.7K
- Av2 =-212.76

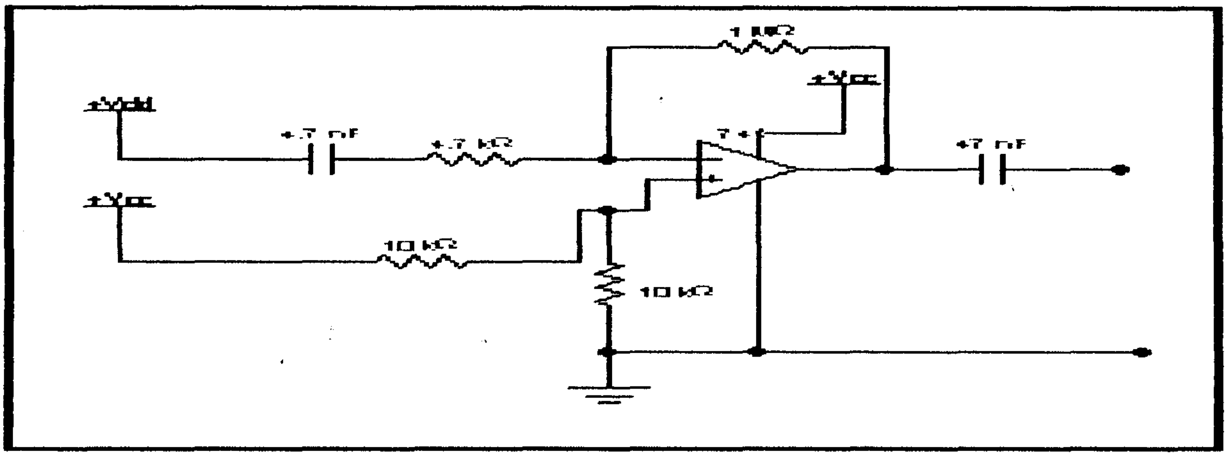


Fig 2.7

Total voltage gain when sensitivity is maximally set and assuming no attenuation is

Av (total) = Av1* Av2

Av (total) =-83 * -212.76

Usually out put gain is measured in decibel.

Gain (decibel) =20 Log (Vout/Vout)

2.2.3 VOLTAGE DOUBLER AND SMOOTHENING CIRCUIT

The amplified output from the second stage receiver amplifier is rectified smoothed and doubled by voltage-doubler network which comprise of the diode D1, D2, and the associated C-R. As shown below, this voltage doublers circuit lets you ground one side of the voltage source[5].

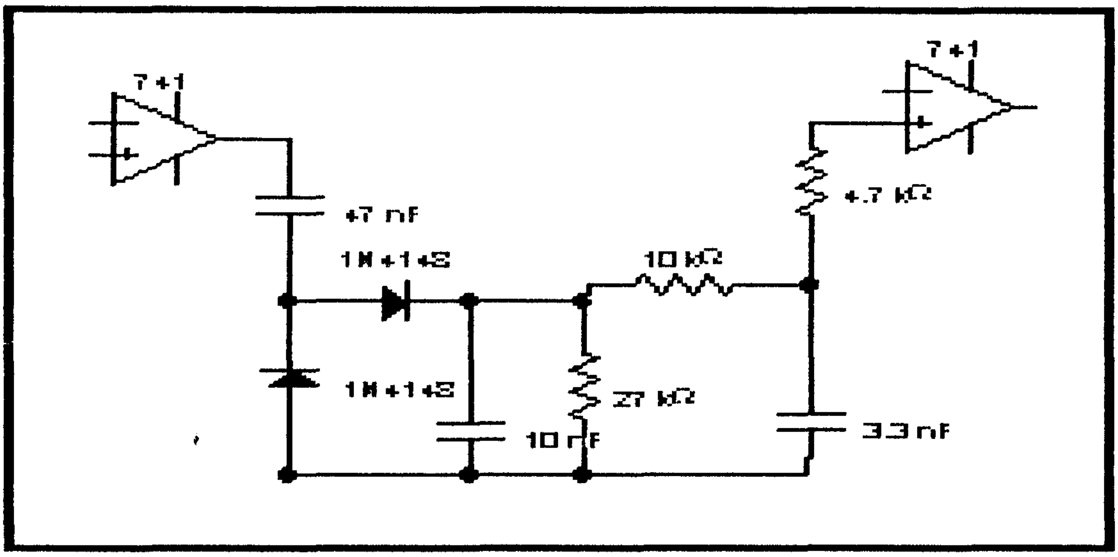


Fig 2.8

2.2.4 COMPARATOR DESIGN STAGE

Monolithic op-amps are inexperience, versatile and reliable. Apart from their use in linear circuits, they can be used for non-linear circuit such as comparators. For the non-zero reference type[2],we can change the threshold voltage as needed by biasing either input.

- From the Vcc via a current limiting Resistor 6.8k and a Zener 5.6V for a stiff input a voltage divider network is connected to set the trip voltage (reference voltage)
- Vref = R2*Vcc/(R1+R2)
- Vref = 10K *Vzener /(10K+47K)
- Vref = 0.98v

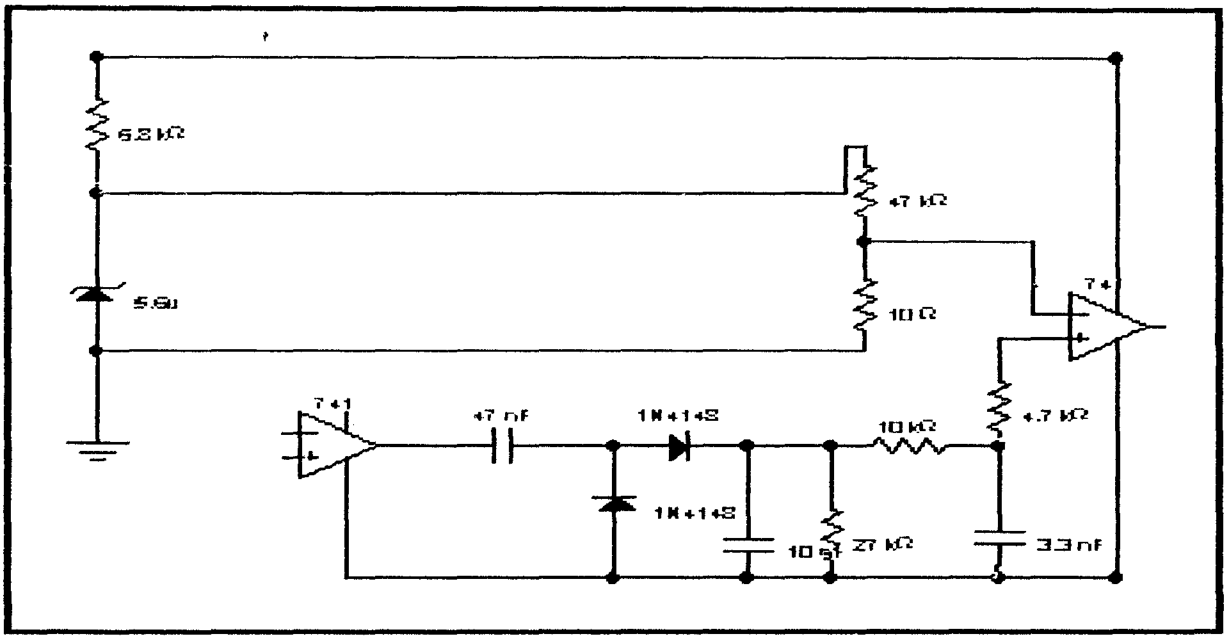


Fig 2.9

A stiff supply of Vref is applied to continuously inverting input of the comparator while the signal from the voltage doubler and smoothening network goes to the non-inverting input. Output voltage from the comparator takes the form of a series of repeatitive positive-going pulses when a strong IR beam signal is present or of a logic 'O' signal when the beam is broken. The output signal is passed to the main receiver unit.

2.2.5 DELAY CONTROL NETWORK

The delay control network is another special design aimed at controlling the delay time for the relay /LED to be turned ON when an intrusion, occur [1]. This special network can allow some lapse after the intrusion, before triggering the relay/LED which in reality may be used to lock an electrically operated gate or may be used to shoot a rubber bullet at the suspected intruded or alert a house-keeper of the presence of an intruder .This design is done using a delay control potentiometer, which is used to vary the response time to a break.

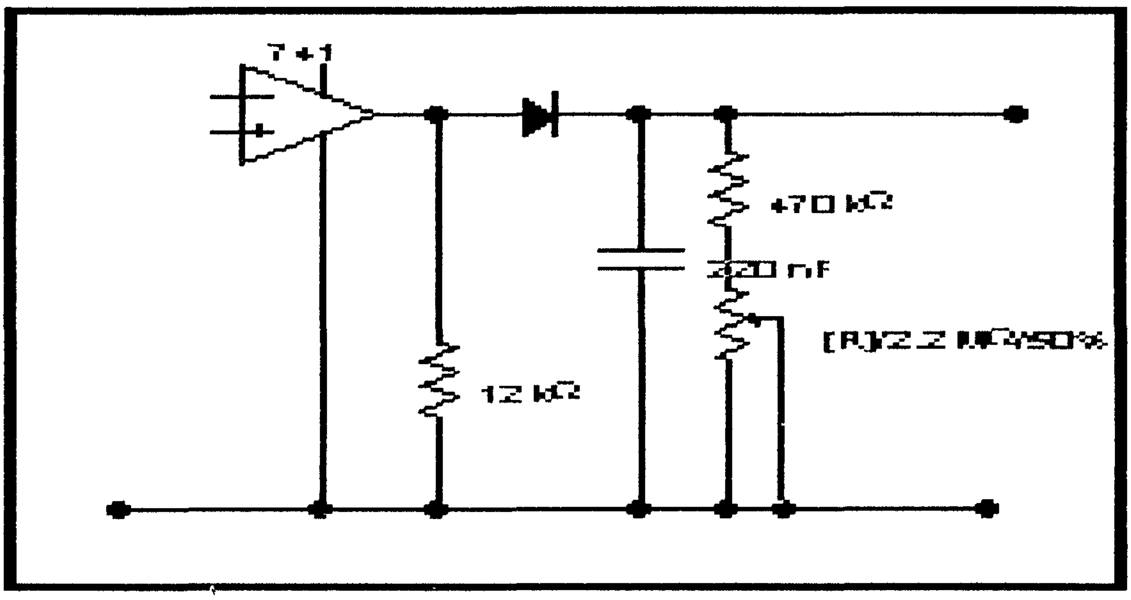


Fig 2.10

OUTPUT CONTROL LOGIC CIRCUIT

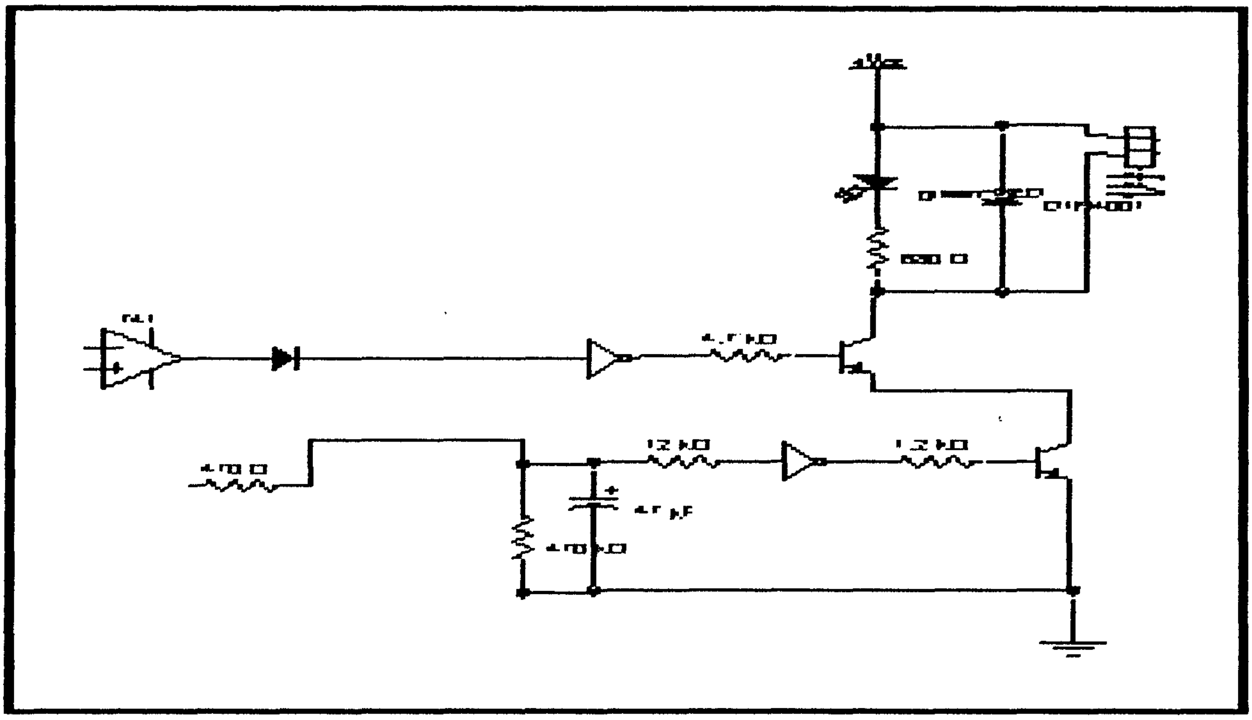


Fig 2.11

For a simple understanding of the operation in this output control logic circuit, assume that the emitter of transistor Q1 is shorted directly to ground. The output signal from the Delay control network detected is fed to an inverter [A] which feeds the base of transistor T1 via base resistor 4.7k We have assumed Q1 emitter shorted directly to ground, in practice, however, the connection to ground is made via Q2 collector. For a normal operation, a low input is fed to the inverter to obtain a high which goes via base resistor 1.2k to Q2 and drive it to saturation [2], to act as an effective short circuit, so that our initial assumption is obtained.(Q1 and Q2 are basic 2N2222, npn transistor used for switching [A].

2.2.6 A 20 SECOND DISABLING NETWORK

Another special feature incorporated into this prototype project, is a facility to disable the relay circuit momentarily to allow an authorized person to pass through the IR beams without activating the alarm. Via some concealed switches either or Pb 1 or Pb 2, Q2 can be cut-off at any time, thereby disabling the relay circuit.

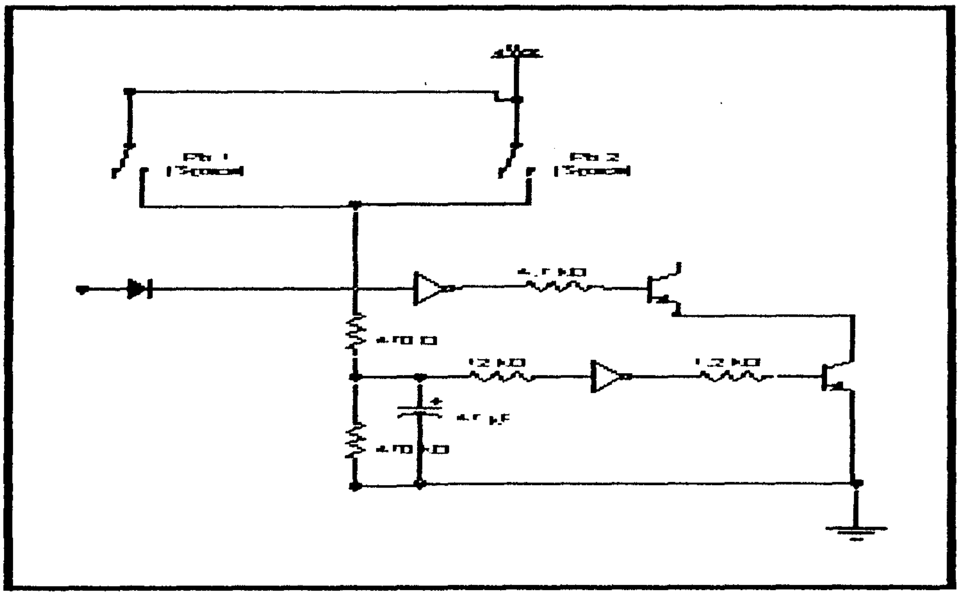


Fig 2.12

By operating either of the switches, the 47uF Tantalum capacitor charges rapidly via the 470R and cut-off the Q2 base drive via the inverter. The base drive is only restored roughly 20seconds after the release of the closed switch to allow the charges leak away through 470k resistor.

2.2.7 DESIGN OF 12V SUPPLY FOR RECEIVER CIRCUIT

(with provision for an uninterrupted supply)

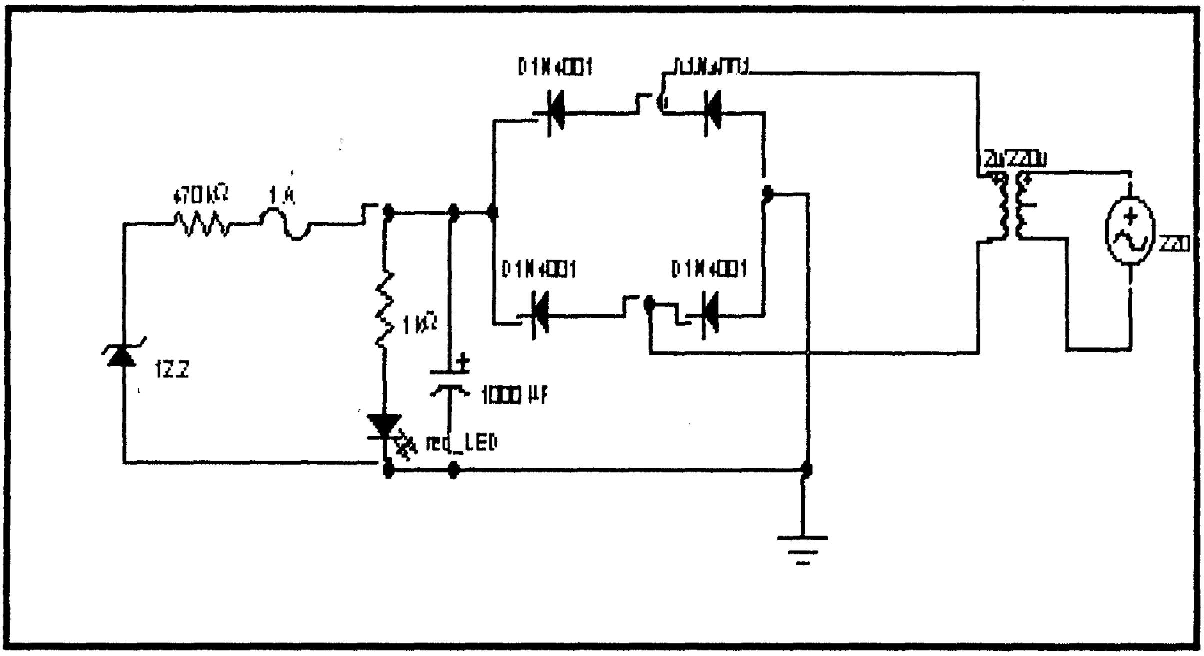


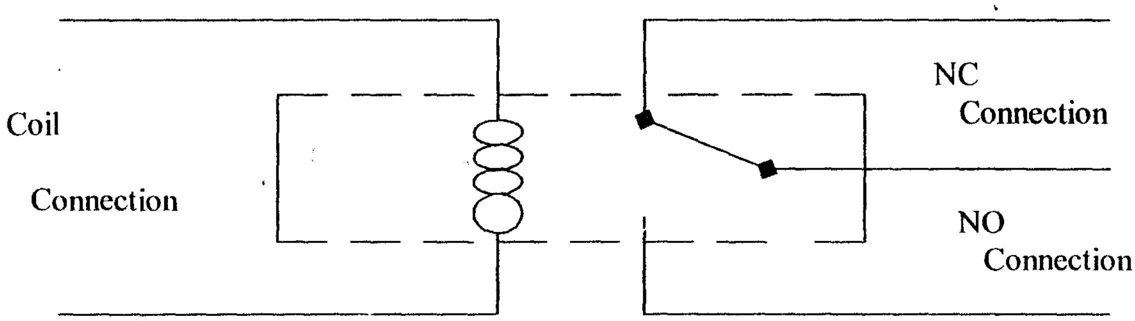
Fig 2.13

A supply built around a high-performance is often the most practical choice in circuit. This prototype employs just that. The ac mains input is connected to a 220/12v step-down transformer of current rating 1000mA,and passed to the full-wave bridge rectifier network as shown below. Its working is similar to the transmitter supply.

2.8.0 RELAYS

Many electronic circuits are operated by electrical switches. A relay is a simple electrical switch which contain an electromagnet. Like an ideal relay race the runner nds over the baton so that the next runner can start. In electrical relays a flow of current in one circuit can be made to switch ON (or OFF in some cases) a flow of current in another circuit.

CIRCUIT SYMBOL FOR A SPDT RELAY

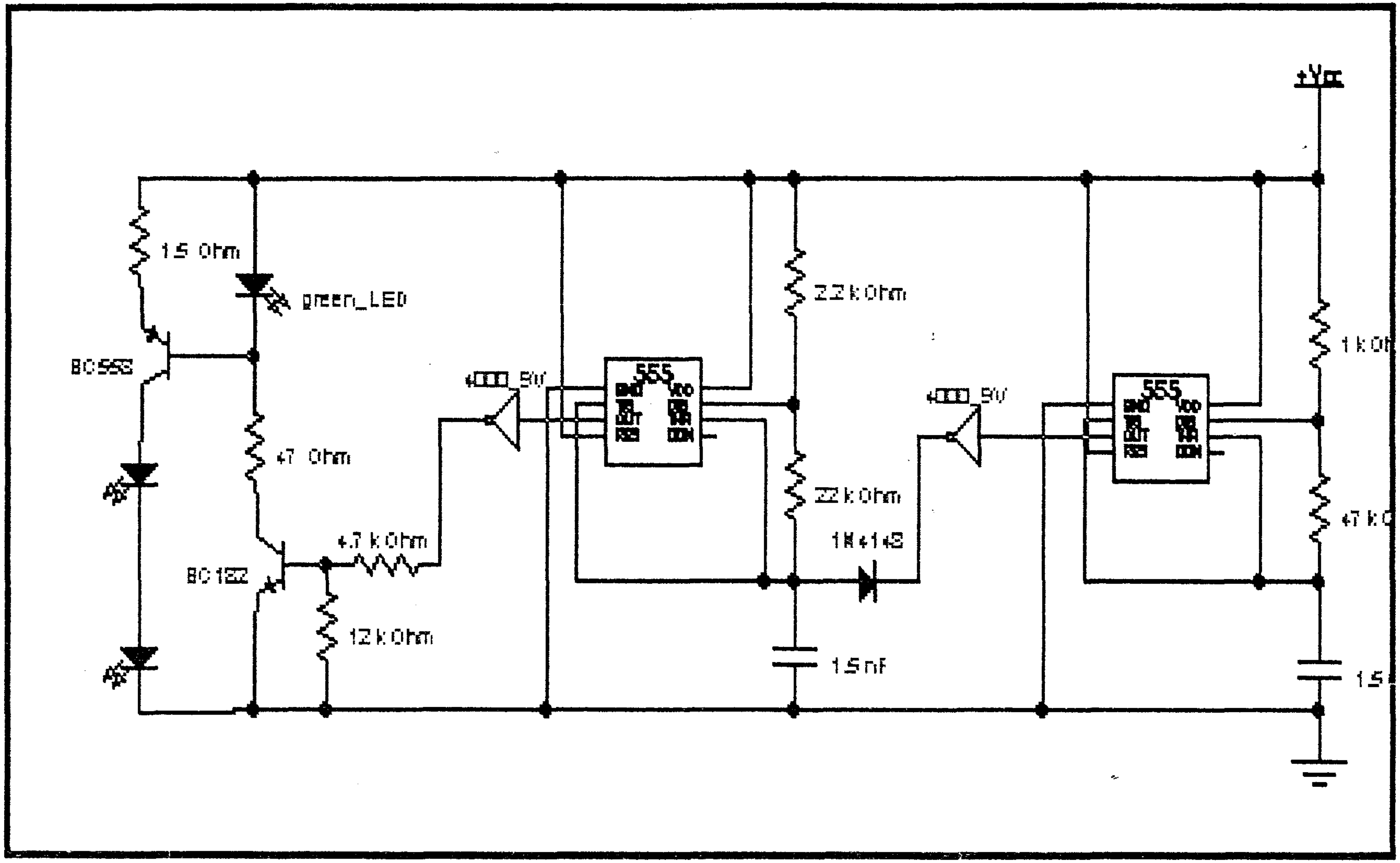


NC connection implies normally closed contact

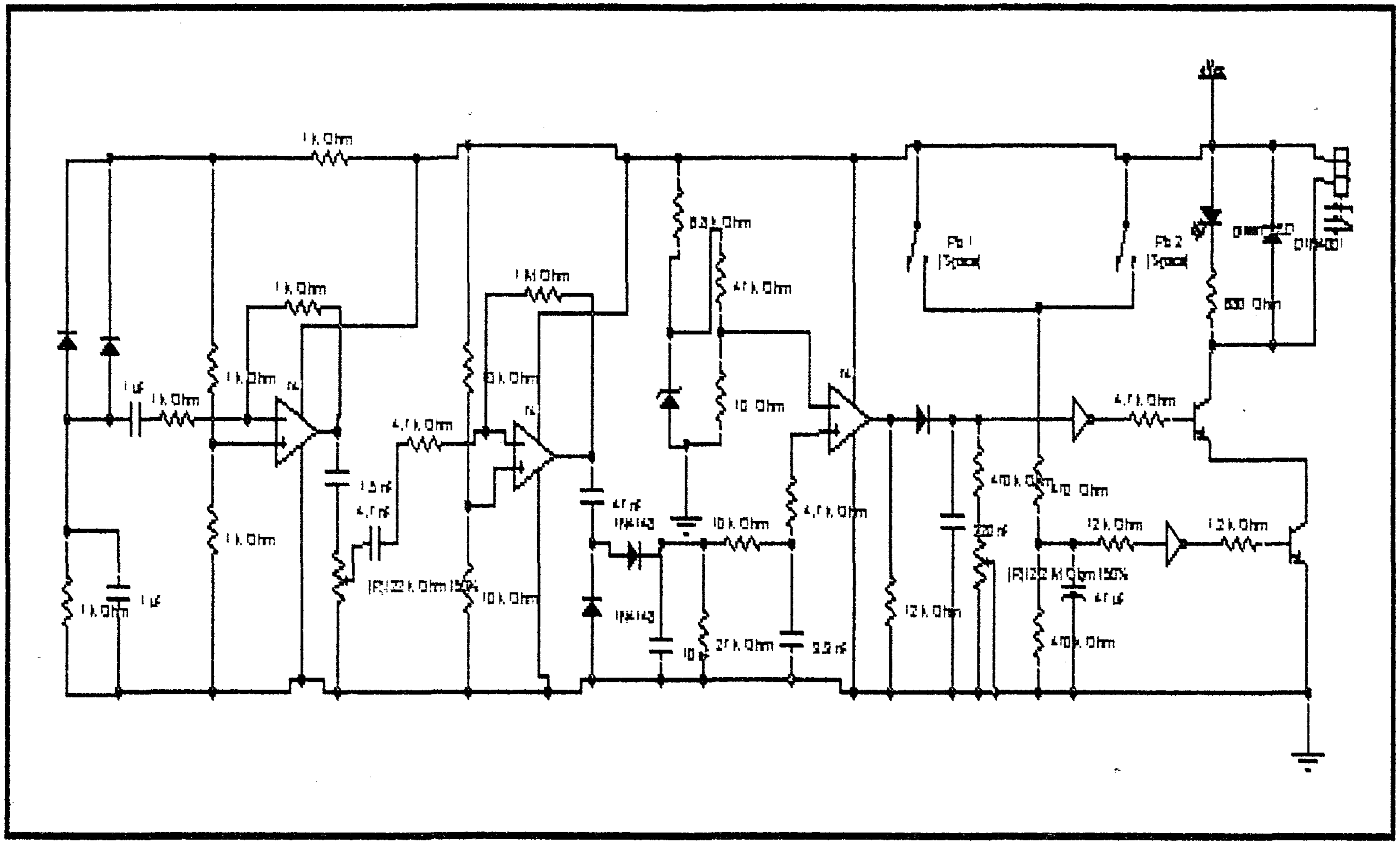
NO connection implies normally open contact

SPDT means single pole double throw

TRANSMITTER CIRCUIT



RECEIVER CIRCUIT



3.0 CHAPTER 3: CONSTRUCTION AND TESTING

This project comprises of two units-the infrared transmitter and an infrared receiver with a relay output. Their construction and testing are discussed below.

"3.1 TRANSMITTER STAGE

For the transmitter construction, two circuit board (CB) are used for the prototype,one for the mains powered supply and the other for the actual transmitter circuit.The usual precautions were taken over components polarity when assembling the board.In mounting the three- IC's sockets were used.

All necessary inter-connections were made, with special care to ensure that the two infrared LEDs and LED were fitted with the correct polarity.To indicate correct transmitter action LED1 glimmers dimly.The completed unit is fitted in a suitable metal case (6.5''x4''x3 '')with two IR LEDs pointing out from the box front.The LED spacing determines the minimum object size that can be detected by the system,two inches was used in this prototype unit.

3.2 RECEIVER STAGE

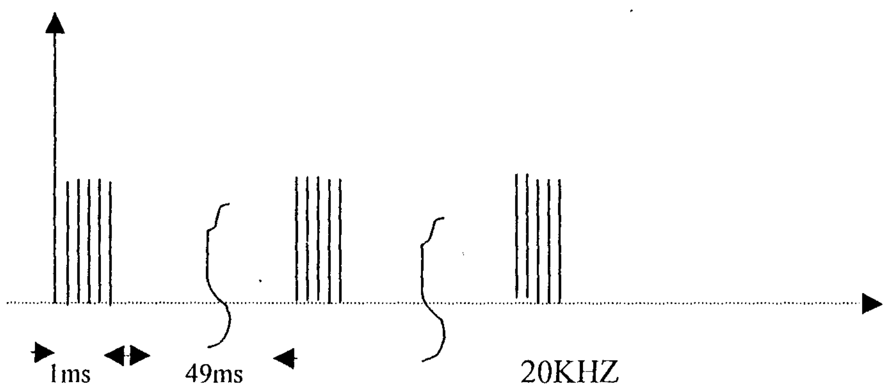
The receiver unit makes use of two circuit boards, one for the power unit and another for the preamplifier and the mains receiver unit. Much care was taken in the construction and linking of the CB.

On completion of the construction, the unit is fitted into a suitable case with same size as transmitted casing,.All the necessary interconnection was made with special care to ensure that the two IRDs are connected with correct polarity.The connections between the IRDs and the circuit board was kept as short as possible to avoid unwanted pick-up.The IRDs are mounted on the front of the case,with the same spacing used for the transmitter IR LEDs.

3.3 TESTING

Using an Oscilloscope the output waveform generated across the two infra red LED was measured as shown below.

Transmitted output waveform



The IR transmitter beam signal comprise 1ms burst of 20kHz pulse,repeated at 50ms interval.Peak IR diode currents of 60mA is generated but because of the wide markm/space ratio 1:50 6mA.This current can be prevailed by either a battery or a mains-derived supply.

To test system's operation, set delay control (Dc) and sensitivity control (Sc) to mid-values.Now space the transmitter and receiver a metre of two apart,roughly facing one another and 1st turn ON the receiver.The relay and LED1 should turn ON indicating that no IR signal is being received.

Now turn ON the tansmitter and check that the relay and LED1 turns OFF. Adjust Dc until relay chatter starts and accompanied by flashing of LED1,and then turn again till chatter/flashing ceases.This point marks the minimum delay setting of the system .Repair delay can be increased beyond the minimum established values if so required.

To set sensitivity control, Sc,block one of the IR Ds and adjust Sc until relay/LED1 turns off. Ensure that relay/LED1 turns ON only when both IR beams are broken simultaneously.

3.4 INSTALLATION

System installation is simple. Merely space the transmitter and receiver to the required distance apart (up to several metres) roughly pointed toward each other and adjust sensitivity control Sc until the required switch action is obtained.

4.0 CHAPTER 4: PRECAUTIONS TAKEN IN CONSTRUCTION

Constructing your own circuits can be satisfying- provided the work at first timeFault-tracing and finding can be terribly tedious and exhausting. Some useful tips taken to get my circuit done correctly at first time include

(1)The use of Breadboard sometimes called the plug board, project boards or test board to make temporary circuits.

On the bread board, faults are easy to trace and correct.The board is also useful to test the circuit to make sure all the components are working properly.Then, the circuit can be made up permanently on the strip.

(2)The Strip boards (S.b) also called the vero boards are useful for making permanent circuits. The board is made of stiff insulating material.Rows of holes in the boards are joined on one side by copper strips.Component legs are soldered permanently onto the strips.Using strip board need two key skills.

(a) Planning on paper (this is optional).It is quite essential before you make real connections on the board.Mark each line with tiny circles to represent the holes along each strip or photo-copy a strip board.Now study the circuit diagram.Then draw the component on the plan so they are connected together correctly.This process is quite tedious and time consuming but it saves lots of time that would otherwise be spent in miserable fault-tracing.

(b)Soldering the component legs onto the copper strips entail carefulness and concentration. The use of sucker to suck up molten solder makes the strip board clean and tidy for resoldering when it is done wrongly.

4.1 RECOMMENDATION

A lot of thought and reasoning has been masterly put to realize this prototype project. There is yet a large room for improvement in the distance to be covered and this can be achieved by the use of mirrors to deflect the beams.

Also with an operational amplifier adopted for very high frequency-hundreds of KiloHz,a carrier frequency much higher that 20kHz can be used and a wider distance can then be covered.

Also if power optimization is not to be strictly considered the low frequency signal generator with astable signal and alternate periods of 1ms and 49ms can be omitted.

4.2 CONCLUSION

Hitting one's target can be gratifying and meeting ones aim and objective can be fulfilling. With this design, any given area of a few metres, with an ambient temperature can be secured from burglars and unwanted intruders. The use of siren, horn or buzzer can be used to deter them instantly or a signal message can be used to send to the security post or police station close by, to apprehend them or get an electrically operated gate/door closed-up at them within a prearranged time.

Also with the design, the relay-circuit can be disabled for a minimum time of 205 to allow authorized passers by. All of these working for 24hrs every day none stop. System's design aimed at effective cost optimization.i.e.high efficiency at low cost, stability, durability and maintenability.

4.3: REFERENCE:

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4.4: APPENDICES

[A] Data Sheets

[B] Graphs

[C] Formulae

DATA SHEETS

Diode	1N4001	1N4148
Description :	general purpose rect (Si)	fast sw diode (Si)
Peak Reverse Voltage PRV max V	600	100 (BRV)
Ave Rect Forward Current Io (max)	1A	200mA
Forward Current Repetitive peak IFRM (max)	_	450mA
Reverse recovery time trr	_	4ns
Forward voltage drop (max) Vf	0.8 at 1A	1.0V at 10mA

Operational Amplifier	CA3140
Type:	MOSFET

Manufacturer : RC – GE/RCA
No per package: 1,2 also available
Trim:*
Ext comp:-
Min gain: 1
Total supply voltage (min) V: 4
(max) V : 44
supply current (max) mA: 6
voltage offset (typ) mV: 2
(max)mV: 5
drift (typ) □V/°c: 6
(max) □V/°c: -
Current Bias (max) nA: 0.04
Offset (max) nA: 0.02
en@ 1kHz (typ) nV/ $\sqrt{Hz}$: 40
Slew rate (typ)V/□s: 7
Ft (typ) MHz: 3.7
CMMR (min) dB:70
PSRR (min)dB: 76
Gain (min) dB: 86
Max output current mA:+10, -1
Max diff'l input V: 8

Transistor	2N2222	BC182L	BC558
Description /Application	NPN-Si AF/RF Amp	NPN-Si AF/RF Amp	PNP-Si Preamp Driver
Collector to base Volts (BVcbo)	75	75	80
Collector to emitter Volt (BVc	40	40	80
Base to emitter Volt (BVebo)	6	6	5
Max collector current Ic Amps	0.8	0.6	1
Max Device Diss Pd watts	0.5(TA=25°c)	0.5(TA=25°c)	0.6(TA=25°c)
Freq in MHz ft	300	300	200
Current gain hFE	200(typ)	200(typ)	180(typ)
Package: Case Fig No	T0-18 T2	T0-92 T16	T0-92 T16

GRAPH

Comparator with non –zero references

In application where a threshold voltage different from zero is preferred, by biasing either input, we can change a threshold voltage as needed.

Vref =
R2*Vcc/(R1+R2)

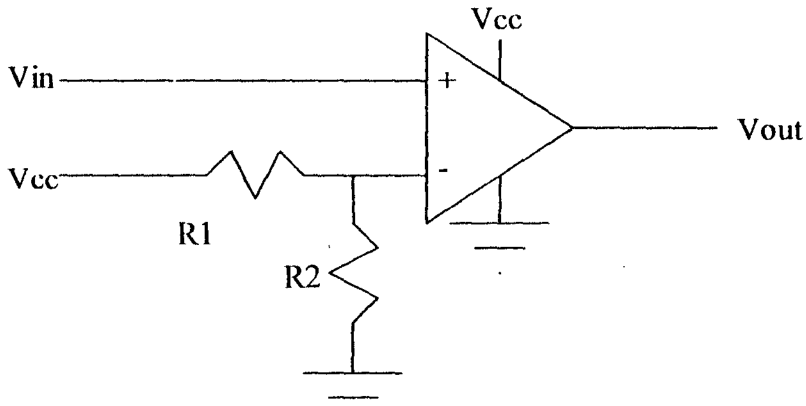

Fig. A

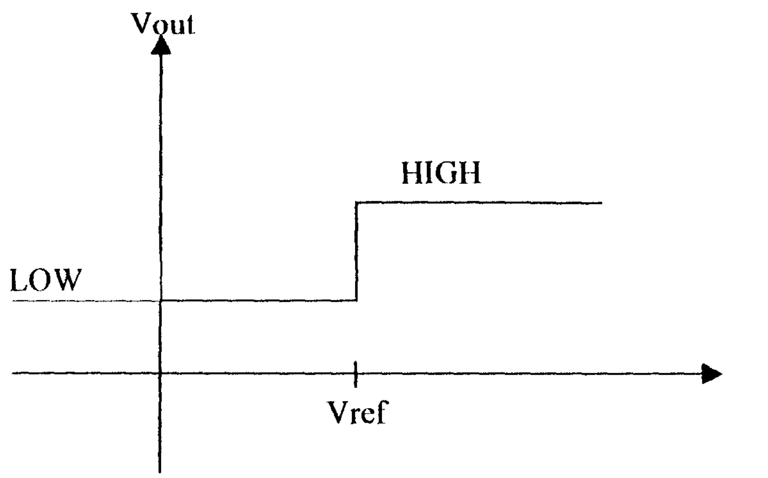

Fig. B

OUTPUT WAVEFORM FOR ASTABLE OPERATION OF 555 TIMER IC

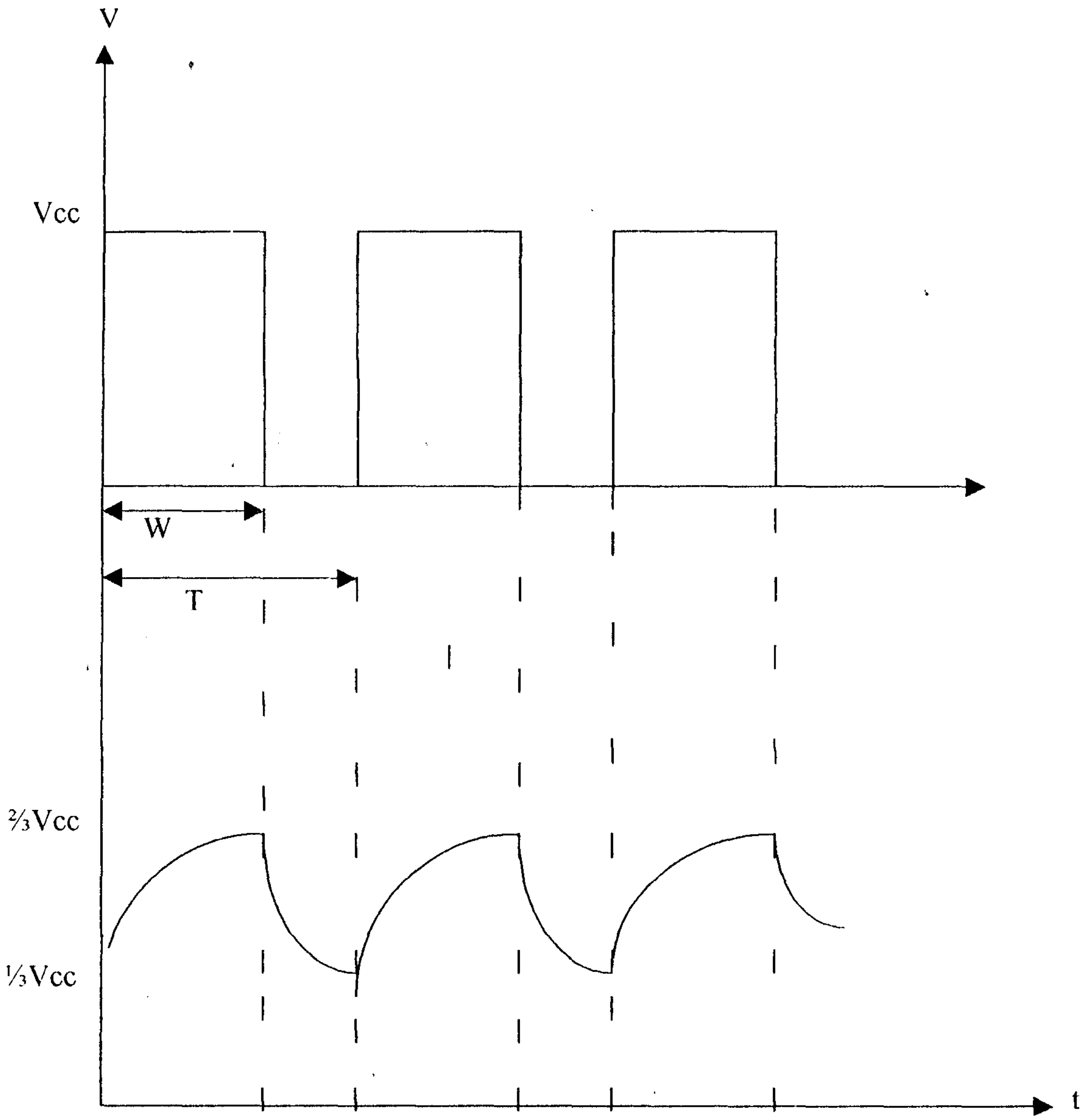

Fig. C

FORMULAE

For an astable multivibrator,

Pulse width, W=0.693*(R1+R2)*C

Period , T=0.693*(R1+2R2)*C

Frequency, F=1.44/(R1+2R2)*C

Duty cycle, D=(R1+R2)/(R1+2R2)

Beta dc,□dc=Ic/Ib

Ic=□dc*Ib

Ib=(Vbb-Vbe)/Rb