DESIGN AND CONSTRUCTION OF AN ULTRASONIC INTRUDER DETECTOR

BY

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APPROVAL

I hereby certify that this project was carried out by Master Jiya Sunday of the Department of Electrical and Computer Engineering under my supervision.

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DECLARATION

I do hereby declare that this thesis presented by me under the Supervision of Mr Usman Abraham Usman and presented in partial fulfilment of the requirement for the award of Bachelor of Engineering (B.Eng) Degree has not been presented before either wholly or partially for any other degree elsewhere. Information and data hereby obtained from published or unpublished works of other people have been acknowledged accordingly.

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Jiya Sunday Date

DEDICATION

To God Almighty, and my Late Dad, Mr Paul .N. Jiya

ACKNOWLEDGEMENT

My sincere gratitude goes to God Almighty for his steadfast love, the source of my wisdom and understanding. My gratitude goes to my Supervisor Mr Usman Abraham Usman for his co-operation, assistance and encouragement. I also commend my project mate Mr Ndaeji Andrew Baba for his co-operation and understanding.

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ABSTRACT

The design and construction of ultrasonic intruder detector is described in this project.

The project uses ultrasonic sound, which is generated by using 555 timer. The transmitted signal is then received by another transducer (receiver).

The objective of this project is to detect intrusion; this is achieved when an intruder breaks the reception, thereby setting up an alarm.

The theory, design, circuit analysis, block diagram and circuit diagram with values are provided to give adequate information about the design.

CHAPTER ONE

1.1.0 INTRODUCTION [3]

This project is based on the "DESIGN, CONSTRUCTION AND TESTING OF ULTRASONIC INTRUDER DETECTOR" stating clearly the device is used to detect an intruder coming across it. Using an ultrasound is better than other means used in intrusion detection e.g. infra-red.

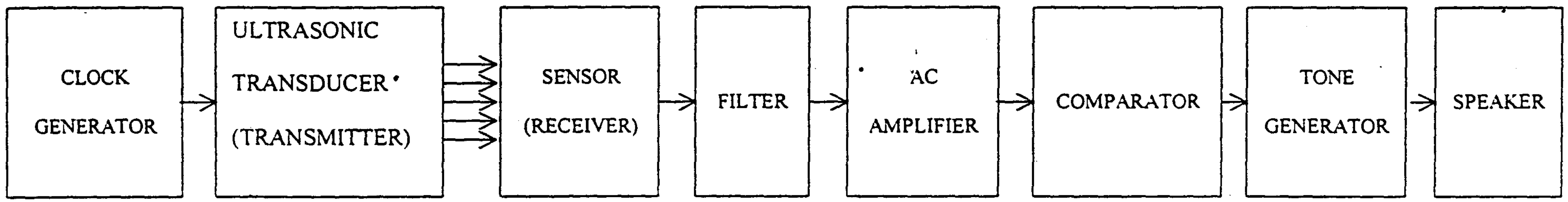
The term ultrasonic refers to the science and technology dealing with acoustic waves (elastic waves or stress waves that is mechanical waves), the frequency of which is higher than the nominal limit of audibility by human ear. It is nominal limit since it is not definable in exact terms, only on some statistical bases because it also depends on sex and age, which varies from person to person. Hence 20,000 hert₃ (cycle per second) is taken as limit of audibility by human ear, sounds having frequencies between 20 hert₃ and 20,000 hert₃ are termed as audible sounds, vibrations above 2000Hz are too fast to be detected by the ear. Hence this project is aimed at generating 40,000Hz ultrasound frequency for its operation. The advantage of using ultrasound is that it is not visible and audible.

The ultrasonic sound generated by an oscillator in this case (a 555 timer is used) is transmitted by a transmitting transducer (in this case Ultrasonic transducer is used} in the form of a beam to the receiver (Utrasonic transducer), the received signal is filtered and amplified.

The device is composed of four functional blocks- the pulse generator, the ultrasonic transmitter, receiver and the alarm circuit. Each block is in itself a simple circuit with few individual components. Fig 1.1 shows the block diagram of the ultrasonic intruder detector.

For intrusion detection, the transmitting transducer sets up a pattern of ultrasonic wave passed in the form of a beam to the receiver. An intruder alters the ultrasonic wave pattern setting on an alarm. In this case an ultrasonic sound precisely 40KHz is sent through the transducer (ultrasonic receiver), the received signal is filtered and amplified, but at intrusion, reception is broken and the alarm is activated or triggered.

After intrusion, while transmission and reception resumes the alarm switch is reset for next action



BLOCK DIAGRAM OF THE ULTRASONIC INTRUDER DETECTOR

Figure 1.1

1.1.1 AIMS AND OBJECTIVES [4]

Nature has been so kind to man by providing a lot of resources at his disposal, which sound, is one of such resources. Therefore in this project we want to explore sound as one of such resources by using ultrasonic sound of precisely 40KHZ. Hence this project is design in such a way that if there is alteration in the reception of the transmitted signal an alarm will be set on, which gives an indication that is intrusion.

1.1.2 APPLICATIONS [7,8]

Apart from using ultrasonic wave for intrusion detection, ultrasonic waves have many practical applications. Ultrasonic waves have many uses industrially, example, testing and inspection of castings and other manufactured objects. In many circumstances ultrasonic method can replace the more hazardous and expensive radiographic techniques of flaw detection and thickness measurement.

One of the earliest uses of sound at ultrasound frequencies was to improve the depth sounding method at the sea. Ultrasonic wave is also used in medical and surgical diagnosis. Others include military application, Electro-Magnetic Distance Measurement (EDM) in surveying fields etc.

These applications can be divided into two major groups: passive and active, passive applications, which can also be called low-power application cause no permanent change in the propagation medium but are used to collect information about the presence of defects, obstacles, targets and so on.

Active applications, which can also be called high-power applications include applications in which ultrasound waves are used as a particular form of energy, active in bringing about some change in the medium of propagation or on the surface of the objects the energy hits. They may improve a technological process or even make a new process possible (e.g., clearing, machining hard materials welding dissimilar materials) etc.

1.2.0 LITERATURE REVIEW [4,6,8,9]

The possibility of making use of ultrasonic beam for practical purpose has over the years developed devices to reproduce ultrasonic waves. These devices are either mechanical or electronics.

As frequency of sound waves goes up and the wavelength goes down, a beam of sound diverges to a smaller extent, is less easily diffracted and is reflected by smaller and smaller objects.

The use of ultrasonic beam for practical purposes dates back to 1880, when the French physicist Pierre curie and his brother discovered that quartz crystal develop small electric charge on the opposite faces when compressed very slightly under high pressure. This phenomenon is known as the direct piezoelectric effect. Pierre curie and his brother also discovered that if a difference in voltage is set up in metal plates held against opposite faces of the quartz crystal, a small compression is induced in the crystal. This phenomenon is known as inverse piezoelectric effect.

The inverse piezoelectric effect can be used to produce ultrasonic waves. If a voltage is applied and removed rapidly, the crystal expands and contract with equal rapidity, which sets up the surrounding medium. Ultrasonic beams can be produce by speeding up the applied-voltage cycle sufficiently.

Also in 1846, James Prescott and later more extensively, George Washington Pierce, investigated the phenomenon that a ferromagnetic bar when it is weakly magnetized but contracts when magnetic saturation is reached, such mechanical (dimensional) changes due to changes in magnetic field are called magnetostrictive effects. When these changes are of linear nature they are known as joule effect, which is of great importance in producing ultrasonic oscillations for commercial applications.

In 1917, after the development of the electron tube, the French physicist Paul langevin succeeded in setting up an electric circuit that produced strong ultrasonic beams. This was during the World War 1, Langevin attempted to use ultrasonic beams to detect submarine under water by sending an ultrasonic pulse methodically out-ward in ever-changing direction (scanning), and when a pulse stricks a submarine it in reflected. The direction from which a returning pulse is reflected is the directions of the submarine. The distance can be estimated by noting the time lapse and the return of the reflected pulse and by knowing the velocity of sound in water.

During the 1920s ultrasound was.put at work in peaceful ways. It was used to measure the depth of the sea bottom. The locations of schoolof fish, hidden reefs or under water portion of icebergs could also be determined using ultrasound.

Following the development of radar during World War 2, ultrasonic techniques Were used in such a wide-ranging fields as the study of mocular properties of materials, detection of flaws in metal ultrasonic cleaning, industrial and dental drills, measuring the thickness of the heart walls in man, and determining the presence of fluid in the sac around the heart. Other attempted early applications were as a means of communication and as light modulators in early experiment with television.

CHAPTER TWO

2.1.0 THEORY AND DESIGN ANALYSIS

INTRODUCTION

Sound can be used in the detection of intrusion. In this project an inaudible sound (ultrasonic) precisely 40KHz frequency is used. For intrusion detection, the transmitting transducer sets up a pattern of ultrasonic wave passed in the form of a pattern of ultrasonic wave passed in the form of a beam to the receiver (transducer) which receives the transmitted signal, the received signal is filtered and amplified.

2.1.1 VELOCITY OF SOUND [3]

Sound waves are longitudinal in character. The experimental determination of the velocity of sound in a medium and its exact agreement with the theoretical value tends further support to the idea that sound waves in a medium are longitunal in character. The amplitude of sound wave, however, decreases as we move away ? sound due to viscosity and heat condition of the medium.

Humidity can have a small effect on the velocity of sound up to about 0.35% at 20^0C. The presence of moisture in air lowers its density and hence increases the velocity of sound through it. The higher the degree of saturation; the greater will be the velocity of sound through it.

The velocity of sound in air is directly proportional to the square root of the absolute temperature. A change of temperature changes the density of air and hence causes a change of the velocity of sound through it.

The mathematical expression is developed as

$$\frac{V_t}{V_o} = \sqrt{\frac{\rho_o}{\rho_t}}$$

Where V_0 and V_t denote the velocities of sound in air at temperature 0^0C and t^0C respectively assuming pressure remains constant.

While ρ_o and ρ_t are densities of air at temperature O^0C and t^0C respectively.

Now if α denotes the coefficient of expansion

$$\rho_o = \rho t\,(1 + \alpha t)$$

$$\frac{V_t}{V_o} = \sqrt{1 + \alpha t} \qquad \text{as } \alpha = \frac{1}{273}$$

$$\frac{V_t}{V_o} = \sqrt{\frac{273 + t}{273}}$$

$$= \sqrt{\frac{T_t}{T_o}}$$

Hence, the velocity of sound in air is directly proportional to the square root of the absolute temperature.

An application where the temperature varies significantly requires compensation to achieve accuracies exceeding a few percent. Exceeding a few percent can do this. This can do by measuring the temperature and adjusting the assumed value for the velocity of sound accordingly. It should be noted that it is the air temperature that is relevant, not the transducer temperature. Alternatively, temperature compensation can be done using a fixed target at a known distance as a reference for calculating distance.

2.1.2 OPERATING FREQUENCY [4]

The operating frequencies of ultrasonic transducers vary from below 8KHz to above 200KHz. The low frequencies are used in long-range, high power applications where absorption of sound in air is reasonable. Sound wave having frequency below 14KHz fails to produce any sensation in the human ear (inaudible). Absorption of sound is not a problem in the higher frequencies. Higher frequency devices produce a narrower beam and higher resolution; therefore they are better suited for shorter-range applications. Acoustic interference from other sources is a problem at higher frequencies. Resolution tends to be proportional to wavelength, but it is also a function of the sophistication of the associated electronics.

The divergence angles of ultrasonic beam also varies with, frequency. Normally the wavelength is relatively long composed to the dimensions of the transducer; therefore ultrasonic energy does not propagate in a well-defined beam like light does but rather in a diffuse cone, it is more intense at the centre and dropping off at the edges.

The most common practice is to quote a 3db include angle, that is, the included angle at which the amplitude to the received signal has dropped to 0.707 of the maximum. The 3db-included angle may be calculated for sensors radiating uniformly across a circular face using the relation

$$\theta = 2\text{arc Sin } \frac{1.6C}{F\pi D}$$

Where

C is the speed of sound

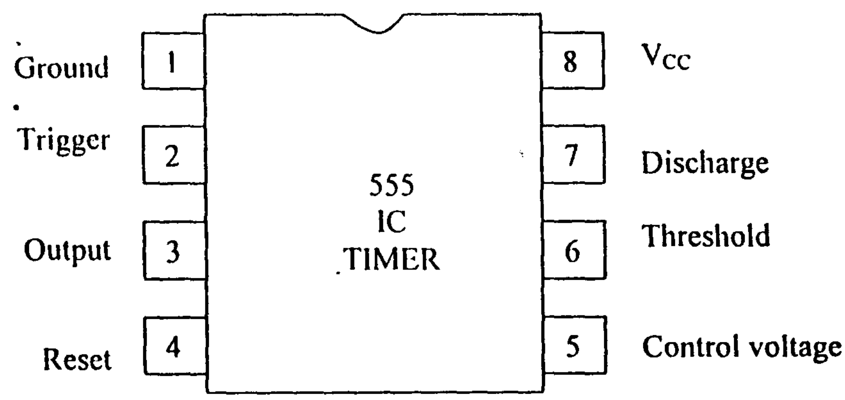
F is the operating frequency

D is the effective diameter of the transducer.

2.2.0 CLOCK GENERATOR ASTABLE MULTIVIBRATOR [2,4]

High frequency astable multivibratiors can be constructed using Schmitt trigger inverters, operational amplifiers, 555-timer IC etc. But for this project a 555-timer integrated circuit timer is used, to generate precisely a 40KHz frequency.

The 555 timer IC is a highly stabled device for generating accurate timer delay or oscillation. The 555 IC timer is available in 2 package styles, 8-pin circular style, To-99 can or 8-pin mini DIP or as 14-pin DIP. The 555 timer can be used with supply voltage in the range of +5V to +18V and drive load up to 200mA. Because of the wide range of supply voltage, the 555 timer is versatile and easy to use in various applications, these applications include oscillator, pulse generators ramp and square wave generator etc. figure 2.1 gives the 8-pin package diagram of a 555 IC timer used in this project.



8 – pin package

figure 2.1 pin – diagram

The basic circuit for astable (free-running) operation of the 555 timer is shown in figure 2.2. The timing circuit consist of RA, RB and C. the trigger (pin 2) and threshold (pin 6) terminals are connected to the timing capacitor, and the discharge terminal (pin 7) is connected to the junction point between the resistors. For the simplest form of astable operation the reset (pin 4) and control (pin5) functions are not used, so pin 4 is connected to Vcc, and pin 5 is by passed to ground with 0.01ΩF capacitor.

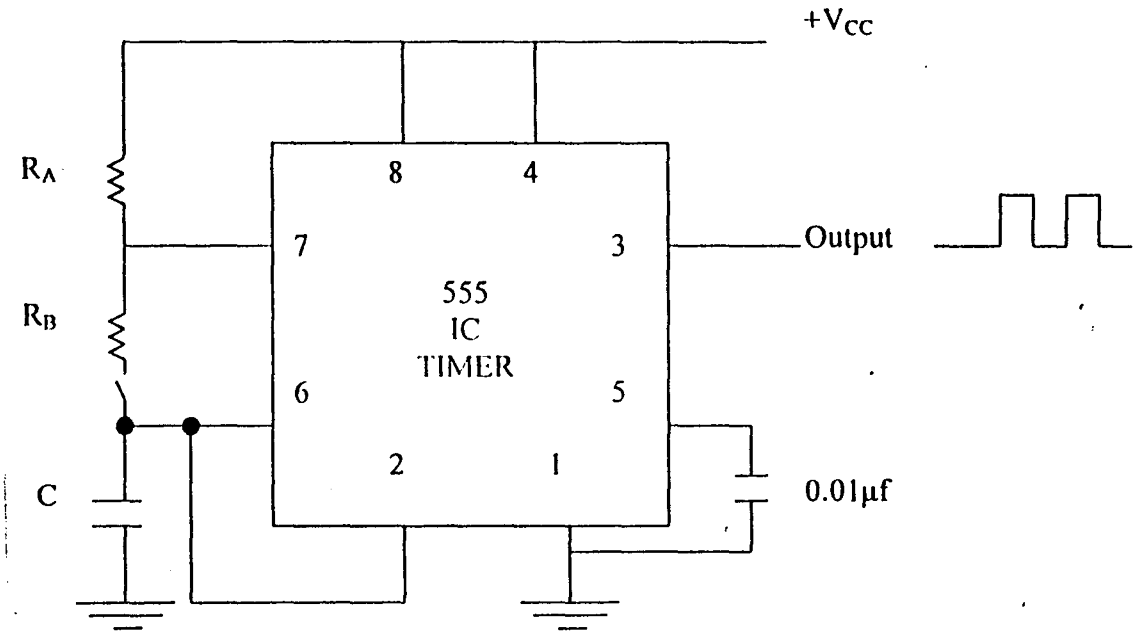


Figure 2.2 Astable Multivibrator Using 555 Timers

For better understanding, the complete diagram of astable multivibrator with detail internal diagram of 555 timer is shown in figure 2.3. The timing resistor is split into two sections RA and RB. Pin 7 of discharging transistor Q1 is connected to the junction of RA and RB. When the power supply Vcc is connected, the external timing capacitor C charges towards Vcc with a time constant (RA + RB) C. During this time, output (pin 3) is high (equals Vcc) as Rest R = 0, sets S = 1 and thus combination makes $\bar{Q}$=^{o}which has unclamped the timing capacitor C.

When the capacitor voltage equal (to be precise is just greater than), (2/3)Vcc the upper comparator triggers the control flip-flop so that $\bar{Q}$ = 1. This, in turn, makes transistor Q1 ON and capacitor C starts discharging towards ground through RB and transistor Q1 with a time constant RBC (neglecting the forward resistance of Q1). Current also flows into transistor Q1 through RA. Resistors RA and RB must be large enough to limit this current and prevent damage to the discharge transistor Q1. The minimum value of RA is approximately equal to Vcc/0.2 where 0.2A is the maximum current through the ON transistor Q1.

During the discharge of the timing capacitor C, as it reaches (to be precise, is just less than) Vcc/3, the lower comparator is triggered and at this stage S = 1, R = 0, which turns $\bar{Q}$ = 0. Now $\bar{Q}$ = 0 unclamps the external timing capacitor C. The capacitor C is thus periodically charged and discharged between (2/3) Vcc and (1/3) Vcc respectively.

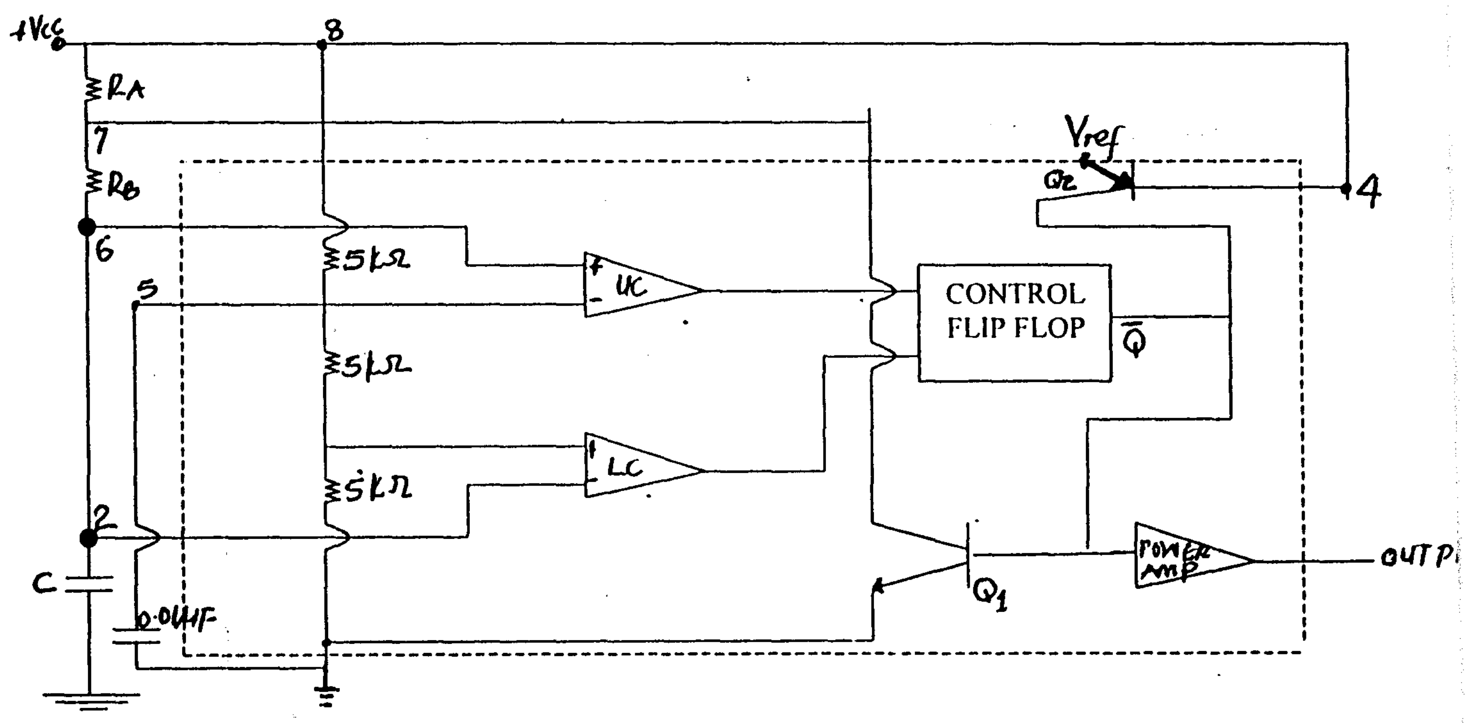
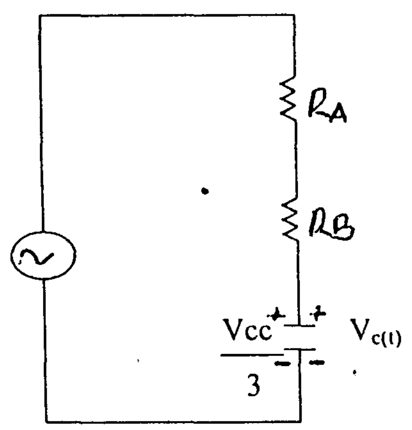


Figure 2.3 Functional diagram of astable multtivibrator Using 555 timer

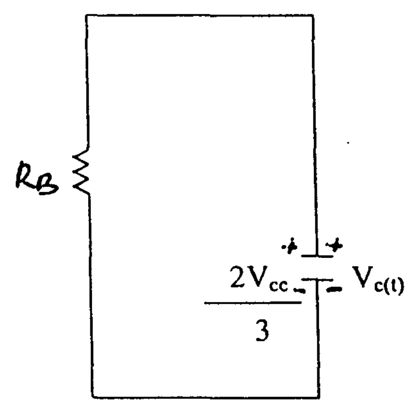
The timing portion of the circuit is shown in figure 2.4 and the associated waveforms are shown in figure 2.5

The model for the timing circuit during the output high state is shown in figure 2.4 (a). This circuit is a first-order circuit with a d.c source and an initial capacitor voltage. Thus, the capacitor voltage Vc (t) has initial value $V_c(0^+) = Vcc/3$. The capacitor charges towards Vcc (although switching action prevents it from reaching that level), so Vc (α) = Vcc.

The equivalent circuit during the output low state is shown in figure 2.4 (b). The action of the discharge terminal has removed the effects of RA and Vcc from the timing circuit. The timing circuit now consists of a capacitor initially charged to (2/3) Vcc in parallel with a resistance RB. The capacitor will now start to decrease exponentially as shown in fig 2.5 (b)



(a) Output High state



(b) Output low state

Figure 2.4 Equivalent circuits of timing portion of 555 astable circuit.

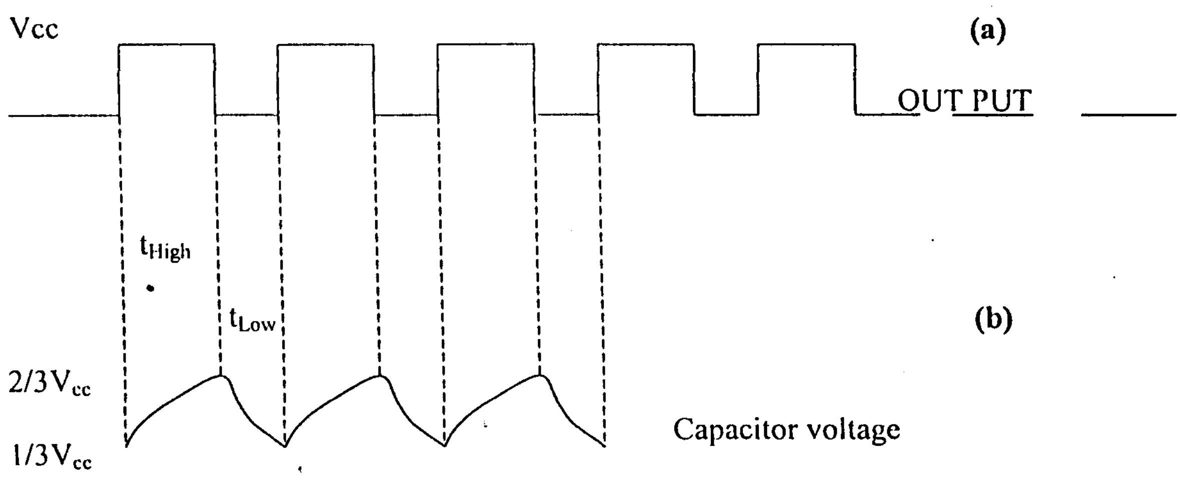


Figure 2.5 Waveform in 555 astable circuit.

(a) Timing sequence waveform

(b) Capacitor voltage waveform

The length of time that the output remains HIGH is the time for the capacitor to charge from (1/3) Vcc to (2/3) Vcc.

Mathematical expressions for the period and frequency will now be developed. The capacitor voltage for a low pass RC circuit subjected to a step input of Vcc Volt is given by

$$Vc = Vcc\ (1-e^{-t/RC})$$

The time t_1 taken by the circuit to charge from 0 to (2/3) Vcc is

$$(2/3)\ Vcc = Vcc\ (1-e^{-t1/RC})$$

$$t = 1.09RC$$

and the time t_2 to charge from 0 to (1/3)Vcc is

$$(1/3)Vcc = Vcc\ (1-e^{-t2/RC})$$

$$t_2 = 0.405RC$$

So the time to charge from (1/3)Vcc to (2/3)Vcc is

$t_{HIGH} = t_1 - t_2$

$t_{HIGH} = 1.09RC - 0.405RC$

So for the given circuit

$t_{HIGH} = 0.69\,(R_A+R_B)\,C$

The output is low while the capacitor discharges from (2/3) Vcc to (1/3) Vcc and voltage across the capacitor is given by

$(1/3)\,Vcc = (2/3)\,Vcc\,e^{-t/RC}$

Solving, we get

$t = 0.69RC$

So for the given circuit,

$t_{LOW} = 0.69RC$

But R_A and R_B are in charge path, but only R_B is in discharge path. Therefore the total time,

$T = t_{HIGH} + t_{LOW}$

or $T = 0.69\,(R_A + 2R_B)$

therefore

$$F = \frac{1}{T}$$

$$F = \frac{1.45}{(R_A + 2R_B)\,C}$$

2.2.1 ELECTRICAL CHARACTERISTICS OF ULTRASONIC TRANSDUCER [4,10]

To accomplish the measurement of any variable, an instrumentation system has to be used. These intrumentation systems are composed of transducers. A transducer is an 'energy conversion device' and it requires energy transformation into the device before the variable of interest can be detected. The variable must be accompanied by an additional quantity such that the combination of the two provides energy to be transferred into the sensing transducer. This energy is then converted into another form of energy as require by a signal conditioning transducer and a read-out transducer such that the input signal can be presented and approximately interpreted at the output of the measuring system.

A transducer can be defined broadly, as a device capable of being actuated by an energizing input from one or more transmission media and in turn generating a related signal tone or more transmission systems. The energy transmitted by these systems may be electrical, mechanical or acoustical.

Ultrasonic transducers are those ones that convert electrical energy to acoustic energy (compatible with this intended application). For this project the following were considered while selecting the transducer.

(1) Sensitivity: - chosen to allow sufficient output

(2) Operating frequency: - chosen to maintain range requirement and good resolution.

(3) Frequency response and resonal frequency: - flat over the entire desired range.

(4) Environmental compatibility: - Temperature range, corrosive fluids pressure, shocks, interaction, size and mounting restrictions.

(5) Minimum sensitivity: - To expected stimulus, other than the measured.

(6) Usage and ruggedness: - Ruggedness, both of mechanical and electrical intensities versus size and weight etc.

Used in this project is high sensitivity ultrasonic transmitter and receiver designed for sending and receiving ultrasonic sound in the form of continuous or pulse wave through the air at 40KHz.

The characteristics of the ultrasonic transducer used in this project one outlined below: -

	SCG-40IT Transmitter	SCM-40IR Receiver
Sensitivity	106dB	-65dB
Resonant frequency	40±1KHz	40±1KHz
Pulse rise time	2msec	0.5msec
Maximum input voltage	20Vrms	______
Impedance	500Ω	30KΩ
Operating Temperature	-20^{0}C to +60^{0}C	-20^{0}C to +60^{0}C
Capacitance	1100PF	1100PF

The operating distance and the direction angle are 5meters and 30^0 respectively.

2.2.2 TRANSMITER CIRCUIT

The output of the 555 timer goes into the ultrasonic transmitter (transducer). The transducer convert the electrical signal generated by the 555 timer into sound wave. In this project a 40KHz ultrasonic transmitter was used, which is readily available in the electronics market.

2.2.3 THE RECEIVER CIRCUIT

The receiver circuit consists of the ultrasonic sensor (receiver), a filter, an ac amplifier, a comparator, a tone generator and the alarm.

2.2.4 FILTER [2,5,1]

A filter is defined as any circuit that produces a prescribed frequency response characteristic, of which the most common objective is to pass certain frequencies while rejecting others. Some circuits classified as filters have objectives other than frequency respond criteria. The most commonly used filters are: -

Low Pass Filter (LPF)

High Pass Filter (HPF)

Band Pas Filter (BPF)

Band Reject Filter (BRF)

Frequency response of some commonly used filters are shown in figure 2.6.

Filters are simply made by the use passive components, such as resistors, capacitors and inductors. This filters work well at high frequencies, i.e. radio frequencies. However the only problem with inductors as circuit element is that, they frequently leave much to be desired. They are often bulky and expensive, and they depart from ideal by being "lossy" that is, by having significant series resistance,

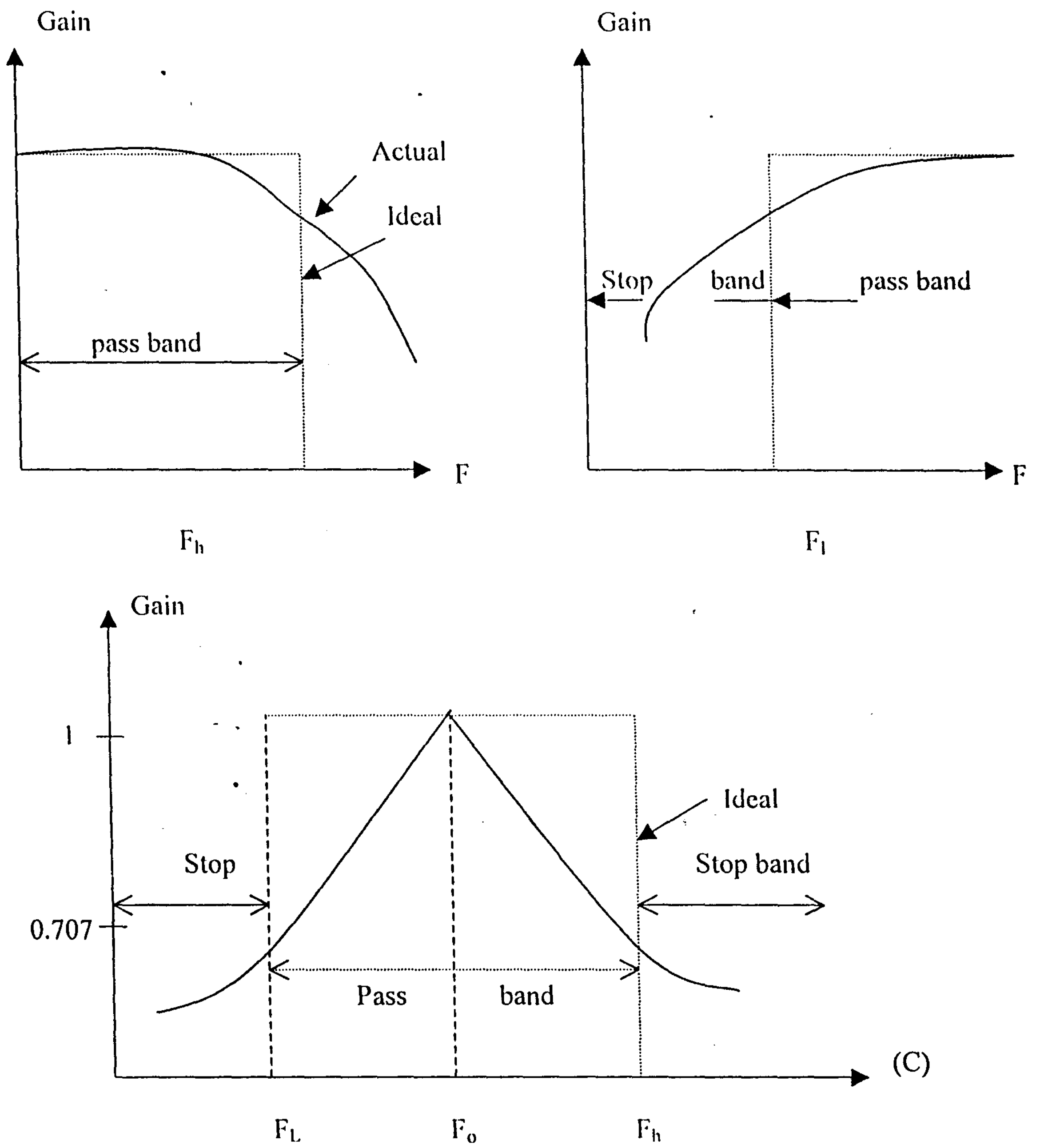


Figure 2.6 Frequency response of some commoly used filter (a) Low-pass (b) High-pass (c) Band pass.

.... Ideal response

——— Practical filter response

as well as other "pathologies", such as non-linearity, distributed winding capacitance, and susceptibility to magnetic pickup of interference. What is needed is a way to make inductor-less filter with characteristics of ideal RLC filter. By using op-amps as part of the filter design, it is possible to synthesize any RLC filter characteristic without using inductors. Such inductors less filters are known as active filters. Op-amps offer high input impedance and low output impedance. This improves the load drive-determining network. Large value of resistors can be used because of the high value of input impedance which reduces the size and cost of the capacitor required in the design.

In this project it is required that the received signal must be filtered from other interfering signals nearby the frequency, therefore an RC filter is used. To be precise, for this project a RC Band pass filter is used. It is a filter that allows a certain band of frequencies to pass through and attenuates all other frequencies below and above the pass band. This pass band is known as the bandwidth of the filter. The frequency of this filter is shown in fig 2.6 (c).

2.2.5 AC AMPLIFIER [2]

Operational amplifier configurations are the inverting and the non-inverting configurations. The inverting amplifier is the most widely used of all op-amp circuits, the output voltage Vo is fed back to the inverting input terminal through a feedback resistor. Input signal Vi is applied to the inverting terminal and the non-inverting terminal of op-amp is grounded. For non-inverting amplifier the signal is applied to the non-inverting input terminal and the circuit amplifies without inverting the input signal.

These inverting and non-inverting op-amps respond to both ac and dc signals. If an ac frequency respond of an op-amp is to be required or if an ac input signal is superimposed with dc levels, it becomes necessary to block the dc component. This is usually done by using an AC amplifier with a coupling capacitor. In a nutshell Ac amplifiers are of inverting and non-inverting type. For this project an inverting AC amplifier is used to amplify are received signal.

Figure 2.7 shows the circuit diagram of an inverting AC amplifier.

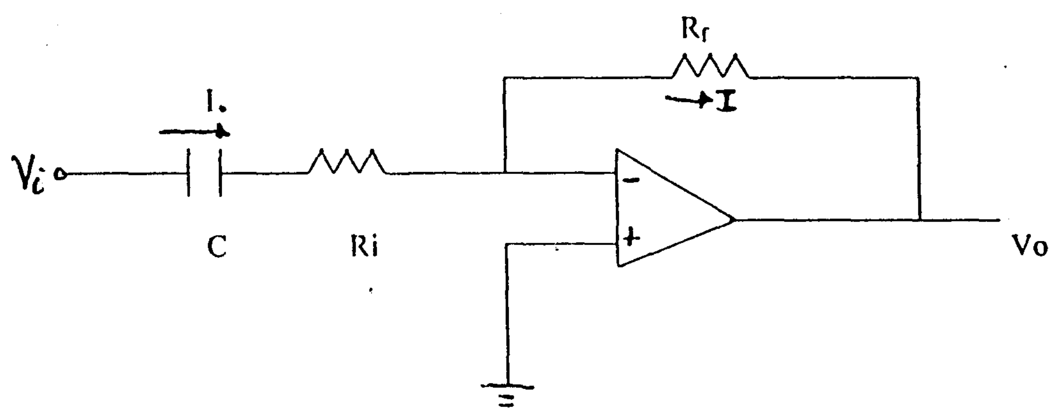


Figure 2.7 Inverting AC amplifiers.

The capacitor C blocks the dc component of the input and together with the Resistor R_1 sets the lower 3dB frequency of the amplifier.

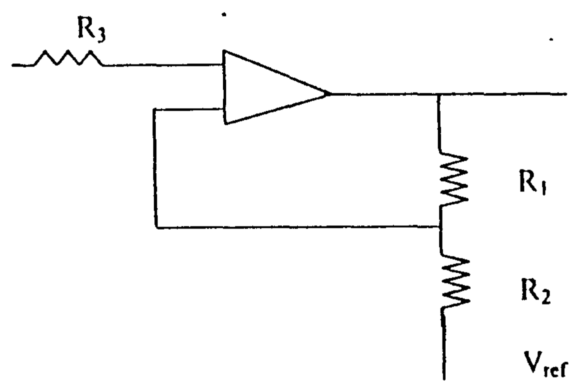


Figure 2.8 An inverting Schmitt trigger

The hysteresis width is the difference between these low threshold voltages i.e. $V_{UT} - V_{LT}$

These threshold voltages are calculated as follows. Suppose the output V0 = +Vsat. The voltage at (+) input terminal will be

$$Vref + \frac{R_2}{R_1+R_2} (V_{sat} - V_{ref}) = V_{UT} \text{..........(C)}$$

This voltage is called upper threshold voltage V_{UT}. As long as Vi is less than V_{UT}, the output V_0 remains constant at + V_{sat}. When Vi is just greater than V_{UT}, the output regenerative switches to $-V_{sat}$ and remains at this level as long as $Vi>V_{UT}$ as shown in figure 2.9 (a).

For V_0 = - V_{sat}, the voltage at the (+) input terminal is

$$V_{ref} - \frac{R_2}{R_1+R_2} (V_{sat} + V_{ref}) = V_{LT} \text{----------(d)}$$

This voltage is referred to as lower threshold voltage V_{LT}. The input voltage Vi must become lesser than V_{LT} in order to cause V_0 to switch from $-V_{sat}$ to $+V_{sat}$. A regenerative transition take place as shown in fig 2.9 (b) and the output V0 returns from -V_{sat} to +V_{sat} almost instantaneously while the complete transfer characteristics are shown in figure 2.9 (C)

Therefore hysteresis width V_H can be written as

$$V_H = V_{UT} - V_{LT} = \frac{2R_2V_{sat}}{R_1+R_2} \text{----------(e)}$$

Since node "a" is at ground, the output voltage V_0 is given by,

$$V_0 = -IR_f = -\frac{Vi}{R1+1/sc} Rf \text{--(a)}$$

Therefore

$$A_{CL} = \frac{V_0}{V_i} = -\frac{R_f}{R_1}\frac{S}{S+1/R_1C} \text{--(b)}$$

But the lower 3dB frequency is,

$$F_L = \frac{1}{2\pi R_1 C}$$

In the mid-band range of frequencies, capacitor C behaves as a short ciruit and therefore equation (b) becomes

$$A_{CL} = -\frac{R_f}{R_1}$$

2.2.6 COMPARATOR [1,2]

One of the applications of op-amps is using them as comparators. A comparator is an op-amp circuit, which compares a signal applied at one input of an op-amp with a known reference voltage at the other input. There are two types of comparator: -

Non-inverting comparator

Inverting comparator

However for this project an inverting comparator was used as a regenerative comparator (Schmitt trigger).

Figure 2.8 shows such a regenerative comparator. The circuit is also known as the Schmitt trigger. The input voltage is applied to the inverting (-) input terminal and feed back voltage to the non-inverting (+) input terminal. The input voltage Vi triggers the output V_0 every time it is outside certain voltage level. These voltage levels are called upper threshold (V_{UT}) and lower threshold (V_{LT}).

Because of the hysteresis, the circuit triggers at a higher voltage for increasing signals than for decreasing ones. If peak-to-peak input signal Vi were smaller than VH then the Schmitt trigger circuit, having responded at a threshold voltage by a transition in one direction would never reset itself, that is, once the output has jumped to, say, $+V_{sat}$ it would remain at this level and never return to $-V_{sat}$. It may be seen from equation (e) that hysteresis width V_H is independent of V_{ref}. The resistor R_3 in fig 2.8 is chosen equal to $R_1//R_2$ to compensate for the input bias current.

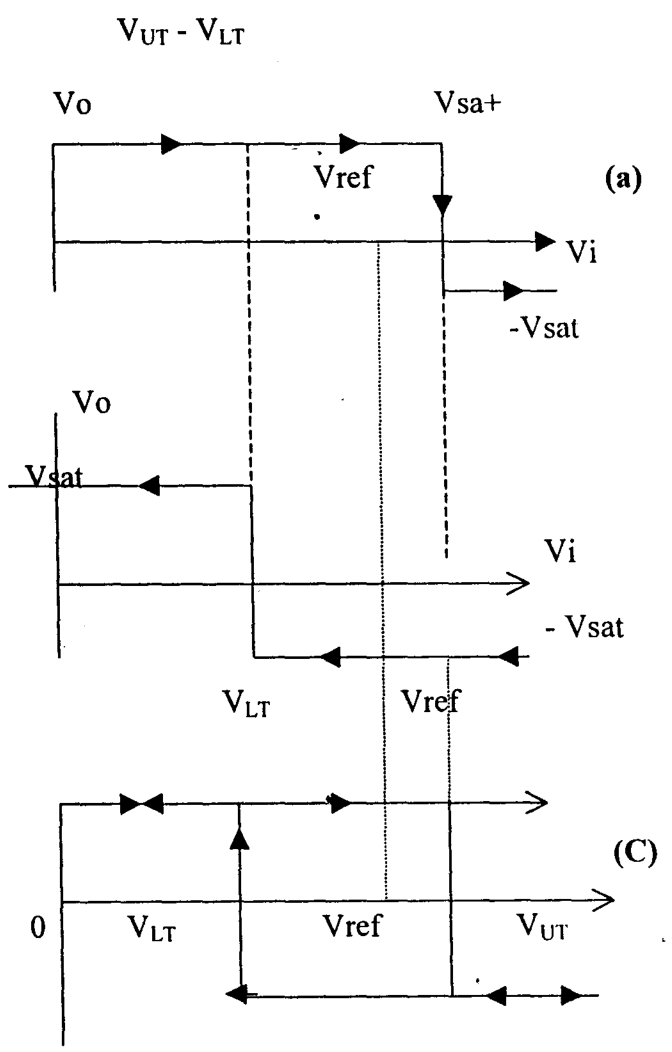


FIG 2.9 (a) Transfer characteristic for Vi increasing (b) transfer characteristic for Vi decreasing (c) Composite input-output curve.

2.2.7 CALCULATIONS

2.2.8 CALCULATION FOR THE 555 TIMER

A 40KHz frequency is needed for this project. The formular to calculate for frequency is given as

$$F = \frac{1}{T} = \frac{1.45}{(RA + 2RB)\,C}$$

RA and RB are large enough to limit the current that will flow through the discharge transistor in the 555 timer in order not to damage it.

The minimum value of RA is approximately equal to Vcc/0.2, where 0.2A is the maximum current through the on transistor.

But Vcc = 9V

Minimum value of RA = 9/0.2 = 45Ω

Taking RA = 150Ω

$$F = \frac{1.45}{C\,(150 + 2RB)}$$

Taking C = 0.01μF.

$$40{,}000 = \frac{1.45}{0.01 \times 10^{-6}\,(150 + 2RB)}$$

$$40{,}000 = \frac{1.45}{(1.5 \times 10^{-6} + 2\times 10^{-8}\,RB)}$$

$$40{,}000\,(1.5 \times 10^{-6} + 2\times 10^{-8}\,RB) = 1.45$$

$$6 \times 10^{-2} + 8 \times 10^{-4}\,RB = 1.45$$

$$8 \times 10^{-4}RB = 1.45 - 6 \times 10^{-2}$$

$$8 \times 10^{-4}RB = 1.39$$

$$RB = \frac{1.39}{}$$

$$8 \times 10^{-4}$$

$RB = 1737.5$

$RB \approx 1738\Omega$

2.2.9: CALCULATION FOR SIGNAL COMPARATOR

Let the gain of Amplifier be high

The minimum voltage to trigger the Schmitt trigger is given by

$$\frac{V_o \Phi R7}{\Phi R7 + R6} + \frac{VCC \Phi R7}{R7 + R8} + V_{fd} \text{ of rectifier}$$

A germanium diode is used to provide approximately 0.2V

Φ Is a ratio got by turning variable resistor clockwise or anticlockwise.

The allowable angle is 240^0

$\Phi = \frac{\theta}{240}$ for linear variable resistors ....0 = the angle

Vcc

Vo = Vcc ______ Thresholds

Vo = 0 ______ Trigger

oV

$$\frac{V_{Trigger} + V_{Threshold}}{2} = \frac{Vcc}{2}$$

$R_7 = R_8 = 10K\Omega$

O < input impedence < ∞

IM μ < really input impedence < 2μf for 358/741/324.

The thevenin voltage is not affected by the op-amp's impedence. To keep errors of loading within 5% - 10%

$$\text{Trigger voltage} = \frac{Vcc\,(R7//R6)}{R6//R7 + R8} + \frac{(R8//R7)Vo}{R8//R7 + Ro}$$

$$V_{trigger} = \frac{9\,(10 \times 10^3 // R6)}{(10 \times 10^3) //R6) + 10 \times 10^3}$$

Voltage greater than or equal to $V_{trigger}$ + 0.2V should be provided by the transmission.

Let $V_{trigger}$ be 1 volt

Peak value of amplifier should not drop below 1.2V if not the alarm will ring.

$$1 = \frac{\left(\frac{10 \times 10^3\,R6}{10 \times 10^3 + R6}\right) 9}{\frac{10 \times 10^3\,R6}{10 \times 10^3 + R6} + 10 \times 10^3\,(10 \times 10^3 + R6)}$$

$$(10 \times 10^3 R6) + (10 \times 10^3) \times (10 \times 10^3) + 10 \times 10^3 R6 = 9 \times 10 \times 10^3 R6$$

$$10 \times 10^3 R6\,(1-9+1) = (-110 \times 10^3)^2$$

$$7 \times 10 \times 10^3 R6 = (10 \times 10^3)^2$$

$$70 \times 10^3 R6 = 100 \times 10^6$$

$$R6 = \frac{(100 \times 10^6)}{70 \times 10^3}$$

$$R6 = 14285\Omega$$

$$R6 \approx 1.5K\Omega$$

For threshold voltages the reset switch can handle that efficiently.

FOR HALF WAVE RECTIFICATION

$$\frac{V_M}{\pi} = Vdc + 0.2$$

$$V_M = \pi Vdc + 0.2\pi$$

$$= (1 + 0.2)\pi$$

$$V_P = 3.769 \text{ Volts}$$

$$V_{peak} - peak = 2VP = 7.539 \approx 7.54V$$

i.e. $\frac{7.54}{9} = 0.8377.$

about 83.78%

AC amplifier gain, $AV = \frac{83.7\% \ Vcc}{1.8V} = 4.1889$

Where 1.8V is the output voltage of the ultrasonic receiver

2.3.1: CALCULATION FOR TONE GENERATOR

$t_1 = 0.6\ 93\ (R_9 + R_{11})\ C_4$

$= 0.693\ (1x10^6 + 4.7k)\ 0.022\mu F$

$=696257.1 \times 0.022x\ 10^{-6}$

$= 0.0153176$

$= 15.318mSec$

$t2 = 0.693(R11)\ C_4$

$= 0.693\ (4.7K)\ 0.022 \times 10^{-6}$

$= 0.000071656$

$= 0.07166mSec$

$T = t1 + t2$

$= 0.693\ (R_9 + 2R_{11})\ C_4$

$= 0.693\ (1x\ 10^6 + 2(4.7K))\ 0.022x\ 10^{-6}$

$= 0.693\ (1009400)\ 0.002\ x\ 10^{-6}$

$= 0.015389$

$= 15.389mSec$

$$\text{Duty ratio} = \frac{R_{10}}{R_{10} + 2R_{11}} \times 100\%$$

$$= \frac{4.7k}{4.7k + 2\,(4.7k)} \times 100$$

$$= \frac{4.7k}{14.1k} \times 100$$

$$= 33.3\ \%$$

Frequency of oscillation is given as

$$F = \frac{1}{T} = \frac{1.45}{(R_{10} + 2R_{11})C_4} = \frac{1.45}{14.1K\ \ x\ 0.022\ x\ 10^{-6}}$$

$$= 4674.4HZ$$

$$= 4.674HZ$$

2.3.2. CALCULATION FOR FILTER

If a.c. amplifier gain = 4.1889

The iput impedence of the amplifier is given as

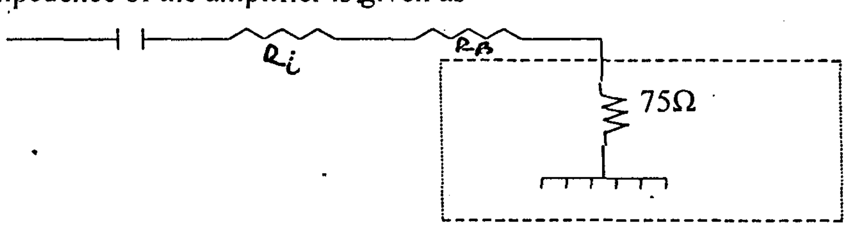


Fig 2.9(a)

$$Zin = \frac{1}{Sci} + Ri + RB + 75\Omega$$

But $4.1889 = \frac{RB}{R_i}$

$$Zin = \frac{1}{Sci} + Ri + 4.189Ri + 75 \leq 1M\Omega$$

$$\frac{1}{s} = \frac{1}{jw} = \frac{1}{2\pi f} = \frac{1}{2 \times \frac{22}{7} \times 40 \times 10^3} = 3.9788\mu sec/rad.$$

If C1 is 0.1μf the Zc1 = 39.7jΩ.

Which quite low for the ultrasonic frequency diagram (a)

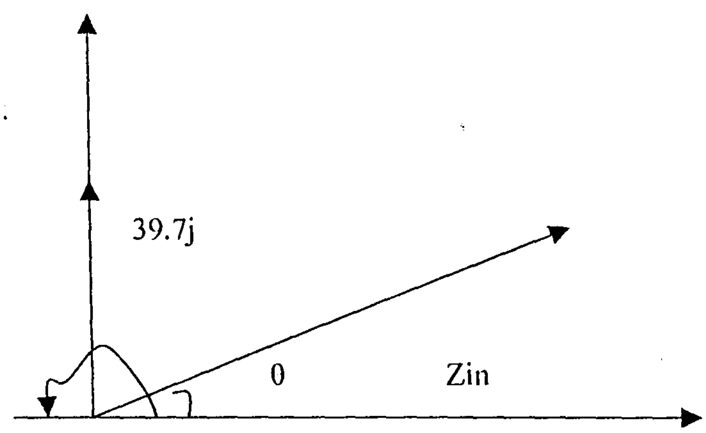


Fig 2.9(b)

$$\theta = \tan^{-1}\left(\frac{39.7}{Ri + 4.189Ri + 75}\right)$$ → phase shift

$Ri + 4.189Ri + 75 >> 39.7\Omega$

If $4.189Ri = 5k\Omega$

Then $Ri = 5 \times 10$

$$4.189$$

$$Ri = 1193.6$$

$$Ri \approx 1.2K\Omega$$

But $4.189 = \frac{RB}{Ri}$

$$4.189 = \frac{RB}{1.2k}$$

$$RB = 4.189 \text{ X } 1.2K\Omega$$

$$RB = 5.0268$$

$$RB \approx 5k\Omega$$

$$0 = \tan^{-1}\left(\frac{39.7}{1.2k + 5k + 75}\right)$$

$$0 = \tan^{-1} 0.006327$$

$$0 = 0.362^0$$

Amplifier input impedence

From the diagram (a) above

$$\tan \theta \ \frac{Zin}{6275}$$

$$0.362^0 = \frac{Zin}{6275}$$

$$Zin = 0.362^0 \text{ x } 6275$$

$$Zin = (2271.6 - 39.7j)\Omega$$

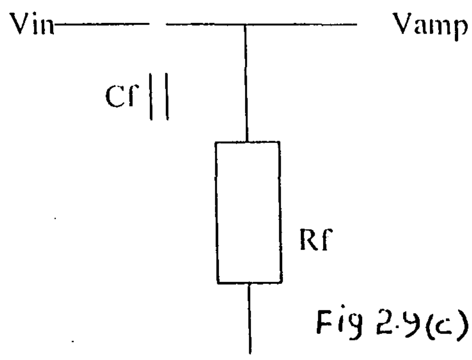


Fig 2.9(c)

But $\frac{Vamp}{Vin} + \frac{Rf}{1/Scf + Rf}$ but this is on no loading

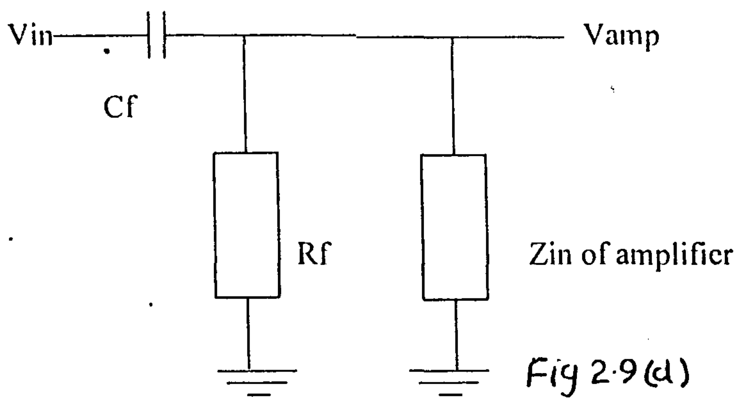


Fig 2.9(d)

$$\frac{Vamp}{Vin} = \frac{Rf /\!/ Zin}{1/Scf + (Rf /\!/ Zin)} = \frac{K_1}{1/Scf + K_1}$$

As S $\longrightarrow \infty$ Transfer function = 1

As S $\longrightarrow$ 0 Transfer function = 0

Dc has S = 0 ==> Dc cannot pass.

Noise of band width (B.W) 20KHZ

S = $2\pi f$

S = 2π X 20 x 103

$= 125663.7$ rad/sec.

New Transfer function = 0.707 T.F at dimishing point

$$\text{New T.zF} = \frac{\text{T.F}}{2}$$

$$\Delta \text{T.F} \; \frac{1}{2} \text{T.F}$$

$$\text{if T.F} \Longrightarrow 0.707 = \frac{\left(\dfrac{\text{RF. Zin}}{\text{RF + Zin}}\right)}{\left(\dfrac{1}{125663.7\text{CF}}\right) + \left(\dfrac{\text{RF. Zin}}{\text{RF + Zin}}\right)}$$

$$\frac{1}{2}\left\{\left(\frac{1}{125663.7\text{CF}}\right) + \left(\frac{\text{RF. Zin}}{\text{RF + Zin}}\right)\right\} = \left(\frac{\text{RF. Zin}}{\text{RF + Zin}}\right)$$

$$\left[\frac{1 + \text{RF Zin (125663.7 CF)}}{\text{RF + Zin}}\right] = \frac{2\ \text{RFZin}}{\text{RF + Zin}}$$

$$\text{RF + Zin + RF. Zin (125663.7 CF)} = 2\ \text{RFZin}$$

$$\text{Zin} + \text{Rf}\ (1 + 125663.7\ \text{CF Zin} - 2\ \text{Zin}) = -\text{Zin}$$

$$\text{RF} = \frac{2271.6 - 39.7j}{(2 - 125663.7\text{CF})(2271.6 - 39.7j) - 1}$$

$\text{RF} = 52.2\Omega$ $\quad\quad$ $\text{CF} = 11.1\mu\text{F}$

2.3.3 CALCULATIONS FOR SIGNAL AMPLIFIER

$$ACL = \frac{-RB}{Ri}$$

$$= \frac{-5K}{1.2K}$$

$$= -4.167$$

The voltage gain with feed back

$$AV = \frac{Vo}{Vin} = \frac{-RB}{Ri}$$

$$==> Vo = \left(\frac{RB}{Ri}\right) Vin$$

Vin = 1.8V

Ri = 1.2K

RB = 5KΩ

$$Vo = \left(\frac{-5K}{1.2K}\right) 1.8$$

$$= -4.167 \times 1.8$$

$$= -7.5Volt$$

The negative sign implies an inversion of the output with respect to the input.

Current into the signal amplifier

$$Iin = \frac{Vin}{Ri}$$

$$= \frac{1.8}{1.2K\Omega}$$

The net loop gain for the inverting circuit

$$\beta = \frac{Ri}{Ri + RB}$$

$$= \frac{1.2K}{1.2K + 5K}$$

$$\beta = 193.55$$

$$A\beta = \frac{ARi}{Ri + RB}$$

$$= \frac{(-4.16A)\,1.2K}{1.2K + 5K}$$

$$= -0.81$$

The resistor Ri into the amplifier

$$Rin = \frac{Vin}{Iin}$$

$$= \frac{1.8}{1.5}$$

$$1.2K\Omega$$

CHAPTER THREE

3.1.0 LAYOUT AND CONSTRUCTION

3.1.1 MATRIX BOARD LAYOUT

First, components were layout on paper, which allows for easy fault identification during construction in case if there is any misconnection. Proper consideration was taken on the size and complexity of each component used, this is to low for neatness as it will appear on the Vero-board. The components weir also soldered on the Vero-board neatly.

The design was divided into two modules, which result in using two Vero boards during the construction.

MODULE 1

Figure 3.1 show the first section or module. This section comprises of the power supply unit. The voltage regulator and the transducer (transmitter).

MODULE 2

The second section or module is made up of the receiver (ultrasonic transducer), the AC amplifier, the filter, the signal comparator, the tone generator and the alarm circuit and the reset switch. Figure 3.2 shows this section.

3.1.2 CONSTRUCTION

The construction work commence after the component/circuits testing on the bread board with the laying of components on the Vero board as outlined on paper in the matrix board layout of figures 3.1 and 3.2.

The soldering work begins after carefully examining the layout. For neat soldering a very good soldering iron of 40 watts with a clean lead was used for soldering. Jumper wires were as while used to link points at equal potentials.

The soldering was carefully done so as to avoid short circuit on the Vero board. Vero board scrappers were used to separate cases of accidental soldering together with suckers. Extra care was taken when connecting the legs of ICs to the power supply and the grounding. Using a digital multimeter various points expected to be at equal potential were tested for continuity and clean cuts were made were necessary.

In cases where ICs were used, IC sockets were soldered on the Vero-board after which ICs were plugged into the sockets to avoid heating during soldering. Finally, the connection leads were the switch and the transducer.

While soldering, the following were taken into consideration.

a) All soldering were made shining rather than dull grey.
b) Care was taken to ensure that the solder had flowed into a smooth paddle rather than formed into a round ball.
c) All solder bridges (pieces of solder cross copper traces) formed were broken with a soldering iron and scrappers.
d) All excess solder were removed.

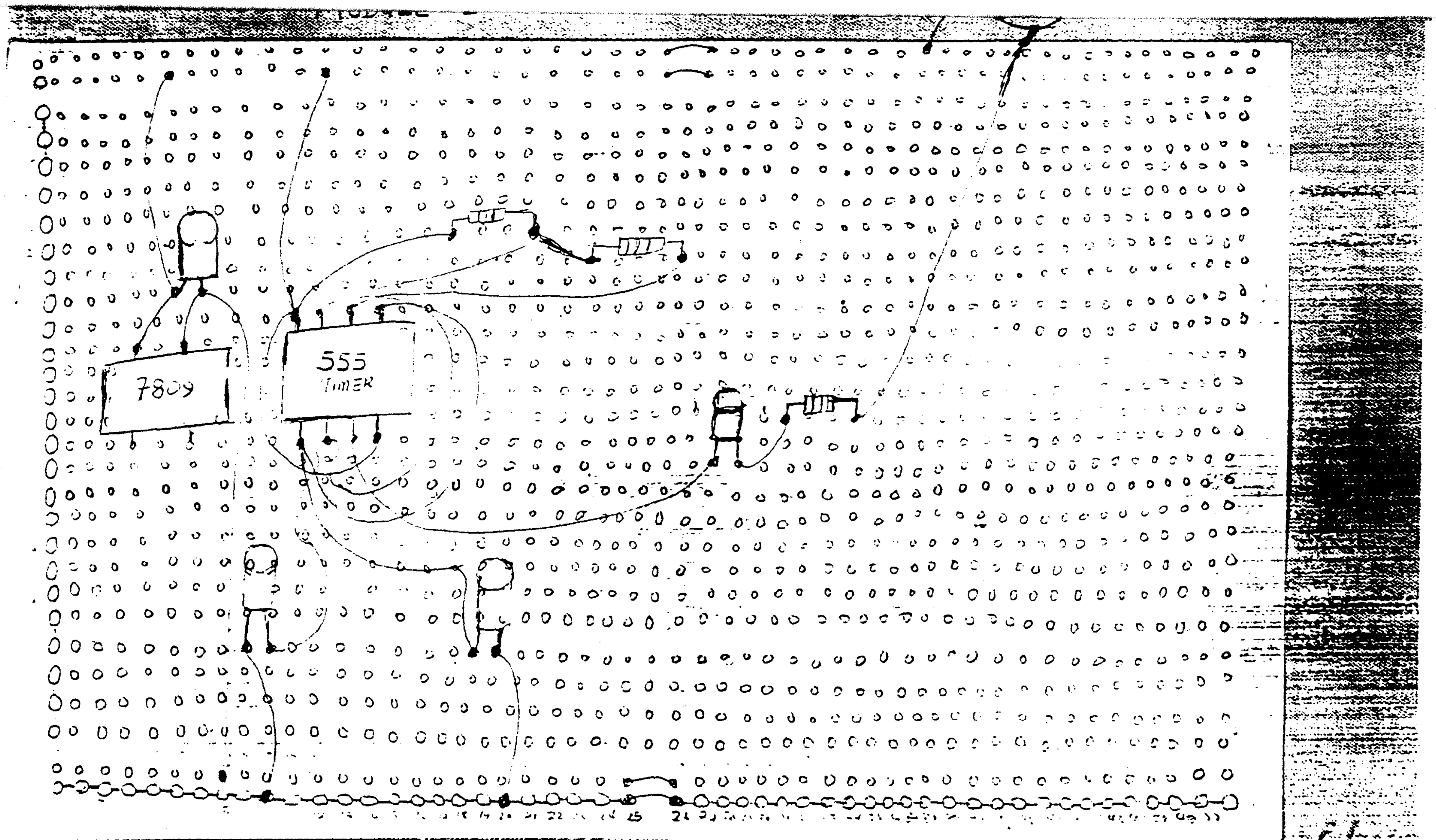


FIG 3.1

4.1.2 PROBLEMS ENCOUNTERED

The project is such a complex one, because ultrasonic wave does not propagate in a new-defined beam like light from a spotlight, but rather in a diffuse cone, which is more intense at the centre and dropping off the edges. This was all first problem noticed.

Acoustic interference from other sources was a problem at the operating frequency.

Lack of proper equipment to assist easy working in the laboratory like frequency analysis was another problem.

Another problem encountered in the execution of this project was the non-availability and high cost of needed components. The ultrasonic transducer is not on sell here in Minna, therefore has to be order from Lagos, which the dealer himself has to wait for orders from broad.

Other problem encountered was components getting burnt at the course of construction.

CHAPTER FIVE

5.1.0 CONCLUSION AND RECOMMENDATION

5.1.1 CONCLUSION

It can be seen in the foregoing report that the design of an ultrasonic intruder detector needs proper planning. In this project a 555 timer was used to generate the frequency that was used. Which was one of the best ways of generating ultrasonic frequency. Ultrasonic transducers were used for transmission and reception; to be precise a 40KHz ultrasonic transducer was used.

The design was tested and found to be functioning as expected. The distance of operation was found to be about 3 to 4 meters.

5.1.2 RECOMMENTDATION

As earlier stated, care most be taken when dealing with ultrasonic wave because of it characteristics. I therefore recommend that project of this nature be given more careful attention and students to work on similar project.

There must be hundred of other applications I therefore recommend that the department embark on this system.

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APPENDIX 1

LIST OF COMPONENTS USED

COMPONENTS	VALUES
R_1	150Ω
R_2	1.8KΩ
R_3	1KΩ
R_4	1KΩ
R_5	1KΩ
R_6	15KΩ
R_7	10KΩ
R_8	10KΩ
R_9	1KΩ
R_{10}	4.7KΩ
R_{11}	4.7KΩ
R_B	5KΩ

CAPACITORS

C1	0.01μF
C2	0.1μF
C3	0.1μF
C4	0.022μF
C5	0.01μF
C6	0.1μF

ICS

555 TIMER

LM 358

DIODE

TRANSDUCERS

Transmitter SCS-40IT

Receiver SCM-40IR

Ic sockets

Jumper Wires

Transformer

Switch

9V Regulator