DECLARATION

I, Alade, Oluwafemi Adeola hereby declare that this project was undertaken by me, under the supervision of Engr. Musa Abdullahi, the Head of department, Electrical and Computer Engineering Department, Federal University of Technology, Minna, Niger State.

______________________ ______________________

ALADE O. ADEOLA DATE

DESIGN AND CONSTRUCTION OF A CRYSTAL - LOCKED ULTRASONIC MOTION DETECTING SENSOR FOR AN AUTO DIALING SECURITY ALARM SYSTEM.

By:

ALADE, OLUWAFEMI ADEOLA

(98/6863 EE)

A PROJECT THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING.

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN ELECTRICAL/COMPUTER ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY,

MINNA

NIGER STATE.

NOVEMBER 2004

CERTIFICATION

I certify that this project was carried out by me, Mr. Alade Oluwafemi Adeola of the Department of Electrical and Computer Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna under the able supervision of **Engr. M.D. Abdullahi** of the **Electrical/Computer Engineering Department** and that the report has not been presented wholly or partially for any other programme elsewhere. Information derived from published and unpublished work of others have been duly acknowledged in the text.

SIGN DATE

________________ ____________

PROJECT SUPERVISOR
(Engr. Musa Abdullahi)

________________ ____________

HEAD OF DEPARTMENT
(Engr. Musa Abdullahi)

________________ ____________

EXTERNAL EXAMINER

DEDICATION

This project work is dedicated to God almighty who leads and guides me and who is ever teaching me how to grow spiritually and mentally and dwell in his presence and to My Parents Chief & Mrs. O.N. Alade for their love, support and guidance.

ACKNOWLEDGEMENTS

Creating the acknowledgements is the most difficult part of the report writing process. Without the help and support of many individuals, the project work would never have been realized. So, how can someone actually take a few paragraphs and thank and acknowledge everyone involved? I will give it a try anyway.

I sincerely appreciate the invaluable contribution of my supervisor, who incidentally doubles as the Head of Electrical and Computer Engineering Department, Engr. Musa Abdulahi for his thorough supervision of this project work, of which his constructive criticism and encouragement actually made the project a reality. May Almighty God bless you and your family, and enrich you more in knowledge and understanding (Amen).

My appreciation goes to Engr. Paul Attah, The 500L level adviser for his support and guidance during the course of this project and also my stay in school and all the lecturers of the Electrical and Computer Engineering department, Engr. Shehu, Mr. Rumala and the host of them for their immense contribution to my life by drilling me academically and professionally.

I would like to specially thank my Parents, Chief & Mrs. O.N. Alade, they have been the kind of parent anyone can ever dream of having. Their love, support and even their chastisements has helped in making me the person I am today, and also my siblings, all the Alade O.As' (Bukola, Kayode, Tunji), I love you all.

The efforts of the following families are worth being appreciated, for their assistance, love, concerns and encouragement: Deacon and Deaconess Oyedepo (J.P), Engr. & Mrs. Kogi Menson, Mr. & Mrs. Oji.

I would like to appreciate the efforts and contribution of the following people: Engr. Olamide Adeoye, Mr. Sherif Usman - (Mtel Nigeria), Mr. Deji Subairu (Mtel Nigeria), Mr. Jaboo (M-Tel), Mr. Solomon Menson, Engr. Mike Tempo, and Members of the WWJD? Club.

The efforts and contributions of all my friends and course mates are well appreciated. They are all wonderful and good to be associated with, especially the following people: Andrew Kogi Menson, Toyosi Aransiola, Ismaila Suberu, Gbenga Bamgboye, Ochanya Odoh, Stella Daku, Yejide Arotiba, Funsho Oke, Rasaq Raji, Anthony Aimola, Gbolahan Bolarin, Yinka, Biola, Folarin Modupe, Bayo Jegede, Tosin Awodogan, Ezekiel Menson, Lynda Oji, Femi Oguntola, Olumide Oluleye, The Oyedepos' (Kemi, Wole, Gboyega, Muyiwa), Aisha Ahmed, Omodele Ifedayo Oyedepo (Wichita, Kansas), "Aji" (Class Rep 2004 Set - Elect/Cpt. Eng), Bimbola Abbey, Remmy Aiyeru, Muhinat Folaranmi, Tade Durojaiye, Shayo Rowland, Mike Fatunke and a host of others that cannot be mentioned. I appreciate all your efforts, support and love.

I want to specially appreciate the contribution of Godiya Aboki Zhawa, she is just the friend to have; her understanding and support really influenced the success of this work. Thank you.

Much love and respect to those whose names were not written here. God has seen you and will surely reward you for your labor of love.

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ABSTRACT

This project aims at the design and construction of an ultrasonic motion detection system to be used as a sensor in a security alarm system. The construction was done using basic analogue and integrated digital components and circuit principles. The heart of the detector is based on the principle of propagation of sound (ultrasonic sound) in a medium. The design of the ultrasonic motion detection sensor is made up of a complete 40-kHz ultrasonic crystal controlled transmitter and a supersensitive receiver.

The motion detector detects motion from 4 to 7-meters away at a "bird eye" angle of 60 angular degrees. Once motion is detected, a red LED lights and with the additional circuitry being constructed by my partner attached to the output sounds an alarm and call the police. The resultant effect is that, the presence of an intruder would be made known to the people around and the appropriate security outfit.

CHAPTER ONE

INTRODUCTION

1.0 GENERAL INTRODUCTION

A Motion detecting sensor can be used in different applications including security systems and door control. It could be used to display a message when an individual approaches.

In the case of an ultrasonic motion detecting sensor, it monitors a specific area, its sight of view, without the need of placing sensors whose input needs to be broken before it detects motion or disturbing the object itself.

The sensor detects movement by emitting an ultrasonic signal from its transmitter into the ambient area being monitored continuously and picking up of the reflection from different objects in the area. The reflected signal arrives at the receiver of the detector in constant phase if none of the objects is moving. If something moves, the received signal is shifted in phase i.e. a change in frequency modifying the summed received signal level. Thus the motion is detected and the alarm circuit triggered.

1.1 OBJECTIVE.

This project is aimed at designing and constructing an ultrasonic motion detecting sensor, which will detect movement when an individual comes within the range of detection of the sensor which is between 4-7 meters and to make it trigger the alarm circuit being designed by my partner, Suberu

Ismaila. When placed in a museum, supermarket, car garage or even on a porch, i.e. a place where movement is not expected, and a prowler or burglar approaches the area being monitored, an alarm is triggered and the appropriate security outfit notified about the intrusion.

1.2 JUSTIFICATION.

A motion sensor will be a very useful device not only for the security system but can be used to sound a greeting or message when someone approaches.

Using ultrasonic sound, which can not be heard or seen, will make the sensor "invisible" to unsuspecting intruders. Bypassing such a system will be rather difficult if not impossible.

Ultrasonic motion detecting sensors are characterized by small power consumption, low cost and high sensitivity. Thus the construction of such a system is justified.

1.3 PROJECT LAYOUT.

A review of the project:

Chapter one contains general information about the project and the reason behind the construction of the project.

Chapter two contains the literature review and principles behind the operation of the project work.

Chapter three contains a detailed description of operation of the separate components and blocks that make up the motion detecting sensor.

Chapter four contains a description of the construction, testing and discussion of results.

Chapter five contains recommendations, the conclusion and suggestions for future users.

Appendix, glossary of terms used and references are also included.

CHAPTER TWO

REVIEW

2.0 LITERATURE REVIEW.

Sensors have long been in use by humans. In the prehistoric ages, sensors in form of wires tied to a bell to be tripped on were used by individuals hunting for food. When a straying animal trip on the wire, a sound by the bell is made and the presence of the animal is made known to those around. This worked well for unsuspecting individuals but this type of sensor when used as security system was discovered to be full of flaws because an individual can easily bypass the device if the presence of the device is known.

A better way of detecting unsuspecting individual was sort after over the years and many ideas were developed. Examples include the passive infrared motion detecting sensor, photoelectric motion detecting sensor and pressure switches.

The passive infrared motion detecting sensor detects motion by detecting heat energy given off by an individual. If movement of the energy source above a certain velocity is detected, a switch is activated. The problem with this type of motion detecting sensor is that, it can be easily deceived into believing that an individual is not in the position being monitored by reducing his / her body heat by wearing clothes that does not absorb heat but rather reflect it like silk.

The photoelectric motion detecting sensor consists of two parts; a transmitter that emits a beam of light, and a receiver that receives the beam of light. When the beam of light is interrupted or broken by motion, a switch is triggered. The problem with this type of sensor is that it can only be used to monitor an entrance not an area. Placing several sensors in an area to be monitored might solve this problem, but it is rather cumbersome.

The pressure switch could be a thin floor mat, that when stepped on, it triggers on a switch.

It was discovered that measurement of electrical or thermal characteristic of an undisturbed medium could be monitored so that any change in these characteristic would mean an introduction of a foreign object into the medium.

Measurements of thermal and electrical quantities are made by devices called sensors and transducers. The sensor is responsive to changes in the quantity to be measured, for example, temperature, position, or chemical concentration.

The transducer converts such measurements into electrical signals, which can be fed to instruments for the readout, recording, or control of the measured quantities in this case, a phase comparator circuit. Sensors and transducers can operate at locations remote from the observer and in environments unsuitable or impractical for human beings, thus the idea of the ultrasonic motion detecting sensor was born.

For the ultrasonic motion sensor, an ultrasonic transducer converts the electrical signals into to ultrasonic pulse signal.

2.0.1 ULTRASOUND AND ITS APPLICATION - A BRIEF HISTORY.

Ultrasonic pulse is a high-frequency sound wave, usually in the range above 20, 000 Hertz, which is far above the range of sound frequency audible to human which is about 15-20 Hertz and 15,000-20,000 Hertz. The science of ultrasonics has many applications. In the field of technology, it has long been used for detection and communication devices called sonar. Applications of ultrasonics in physics include determination of such properties of matter as compressibility, elasticity. Ultrasonics is employed in medicine as a diagnostic tool such as the acoustic microscope and it is also used to destroy diseased tissue, and to repair damaged tissue

The roots of ultrasonic technology can be traced back to research on the piezoelectric effect conducted by Pierre Curie around 1880. He found that asymmetrical crystals such as quartz and Rochelle salt (potassium sodium tartrate) generated an electric signal when mechanical pressure is applied. Conversely, mechanical vibrations are obtained by applying electrical oscillation to the same crystal.

Until about 1910, ultrasonic waves were little more than a scientific curiosity. Following the successful development of the piezo-electric transducer (a device that generates an electric voltage in response to a mechanical pressure), they were used in an early form of sonar to detect the presence of sub-merged submarines.

Following the development of radar in World War 2, ultrasonic techniques were used in such wide ranging fields as: the study of molecular properties of materials, detection of flaws in metals, 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.

Over the last two decades, ultrasound has been put to use in various ways. One of which is the use of ultrasound to monitor movement.

Other uses of ultrasonic waves known as ultrasound include:

1. **Medicine**: Sound waves are used when performing ultrasound tests. Ultrasound tests (scanning) are used on pregnant women to detect many structural and functional abnormalities in a fetus. Ultrasound may also aid in the detection of heart disease, tumors, gallstones, and other disorders.

2. **Industry**: Manufacturers use ultrasound to measure the wall thickness of metal or plastic pipes and to test the concentration of particles in inks and paints. Sonar devices locate schools of fish, enemy ships, and underwater obstacles through the use of ultrasound. Geophysicists can use sound in exploring for minerals and petroleum and also locate possible mineral or oil bearing rock formations. One way to use sound in industry is through music. Music is based on sound waves, which are used in instruments and amplifiers.

3. **Science**: Scientists have invented whistles and other devices that produce ultrasound. An ultrasonic transducer converts electric energy into ultrasonic waves. These waves can also be converted into electric energy by transducers. One way to use the sound wave in science is a

sonar wave. A sonar wave uses a sound wave to see how far or deep something is. This is mainly used for underwater research.

One of the first applications for ultrasonics was sonar (an acronym for Sound Navigation Ranging). It was employed on a large scale by the U.S. Navy during the World War II to detect enemy submarines.

Japan played an important role in the field of ultrasonics from an early date. Soon after the end of the war, researchers there began to explore the medical diagnostic capabilities of ultrasound. Japan was also the first country to apply Doppler ultrasound, which detects internal moving objects such as blood flowing through the hearth, thus the idea of monitoring motion by ultrasonic pulses.

Ultrasonic waves can be generated using mechanical, electromagnetic and thermal energy sources. They can be produced in gasses (including air), liquids and solids.

Magnetostrictive transducers use the inverse magnetostrictive effect to convert magnetic energy into ultrasonic energy. This is accomplished by applying strong alternating magnetic field to certain metals, alloys and ferrites.

Piezoelectric transducers employ the inverse piezoelectric effect using natural or synthetic single crystals (such as quartz) or ceramics (such as barium titanate) which have strong piezoelectric behavior. Ceramics have the advantage crystals in that it is easy to shape them by casting, pressing or extruding and detection is by the use of piezoelectric receiver or an ultrasonic transducer. For this project, ceramic piezoelectric ultrasonic transducer would be used.

Motion detecting sensors can be categorized into two groups or type.

1. The active motion detecting sensor.
2. The passive motion detecting sensors.

For the passive motion detection sensor, a line of contact, mostly infrared is broken, but for the active motion detecting sensor, the actual movement is detected.

The ultrasonic motion detecting sensor can be grouped under the active motion detecting sensor.

2.1 PRINCIPLE OF OPERATION.

The ultrasonic motion detecting sensor senses motion by sending ultrasonic pulses into the ambient area being monitored from the transmitting ultrasonic transducer. These waves are reflecting from various objects and are reaching receiving ultrasonic transducer. There is a constant interference figure if no moving objects are in the placement, when an object moves; the movement causes a change in the level and phase of the reflected signal i.e. the frequency of the received pulse is changed by a moving object - a frequency change. This frequency change modifies the summed received signal level at the receiving transducer. The level of the received signal is then compared with that of the transmitted signal and if a change is noticed, motion is detected.

This phase shift is caused by an effect known as the Doppler Effect. When an object moves during the period of a sound wave, the effective wavelength experienced by the object is shortened, giving a higher pitch - higher frequency since the velocity of the wave is unchanged. Thus the pulse reflected will be of a different frequency from the one incident on the object.

This phase change would then be detected by the phase comparator in the receiving section of the ultrasonic motion detecting sensor.

The ultrasonic motion detecting sensor is made up of three distinct but interwoven parts.

1. The Transmitter Section (With the Ultrasonic Transmitting Transducer).

2. The Receiver and Triggering Section (With the Ultrasonic Receiving Transducer).
3. The Power Supply Section (9 volts and 5 volts).

The block diagram (FIG. 2.1) showing the relationship between the three stages is shown below:

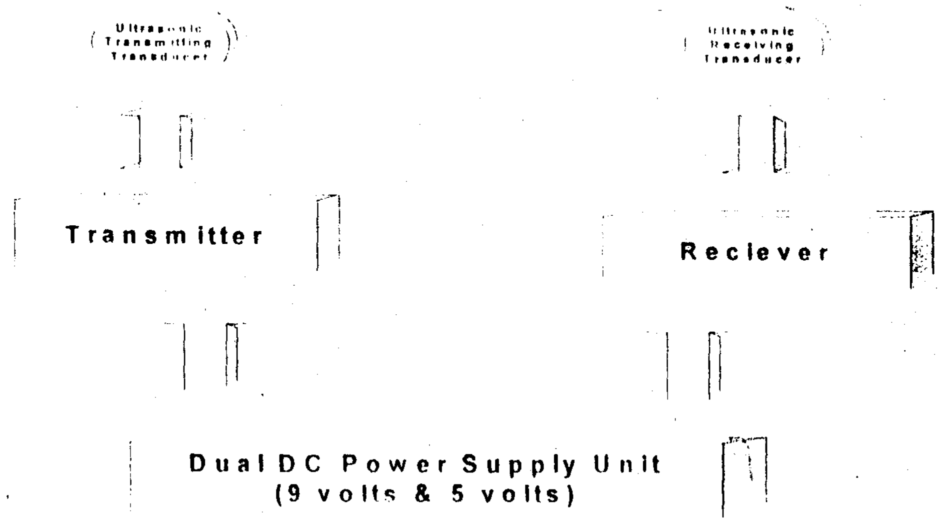


FIG. 2.1

BLOCK DIAGRAM OF THE THREE MAJOR SECTION OF THE DETECTOR

The transmitter section of the ultrasonic motion detecting sensor is basically a crystal-controlled relaxation oscillator built around a 4049 Hex inverter IC, a 40-kHz crystal and a 40-kHz ultrasonic transmitting transducer and it is powered by a 9 volts power source. The 4049 Hex Inverter acts as a linear buffer that drives the ultrasonic transmitting transducer and thus emits a 40-kHz ultrasonic signal into the area being monitored.

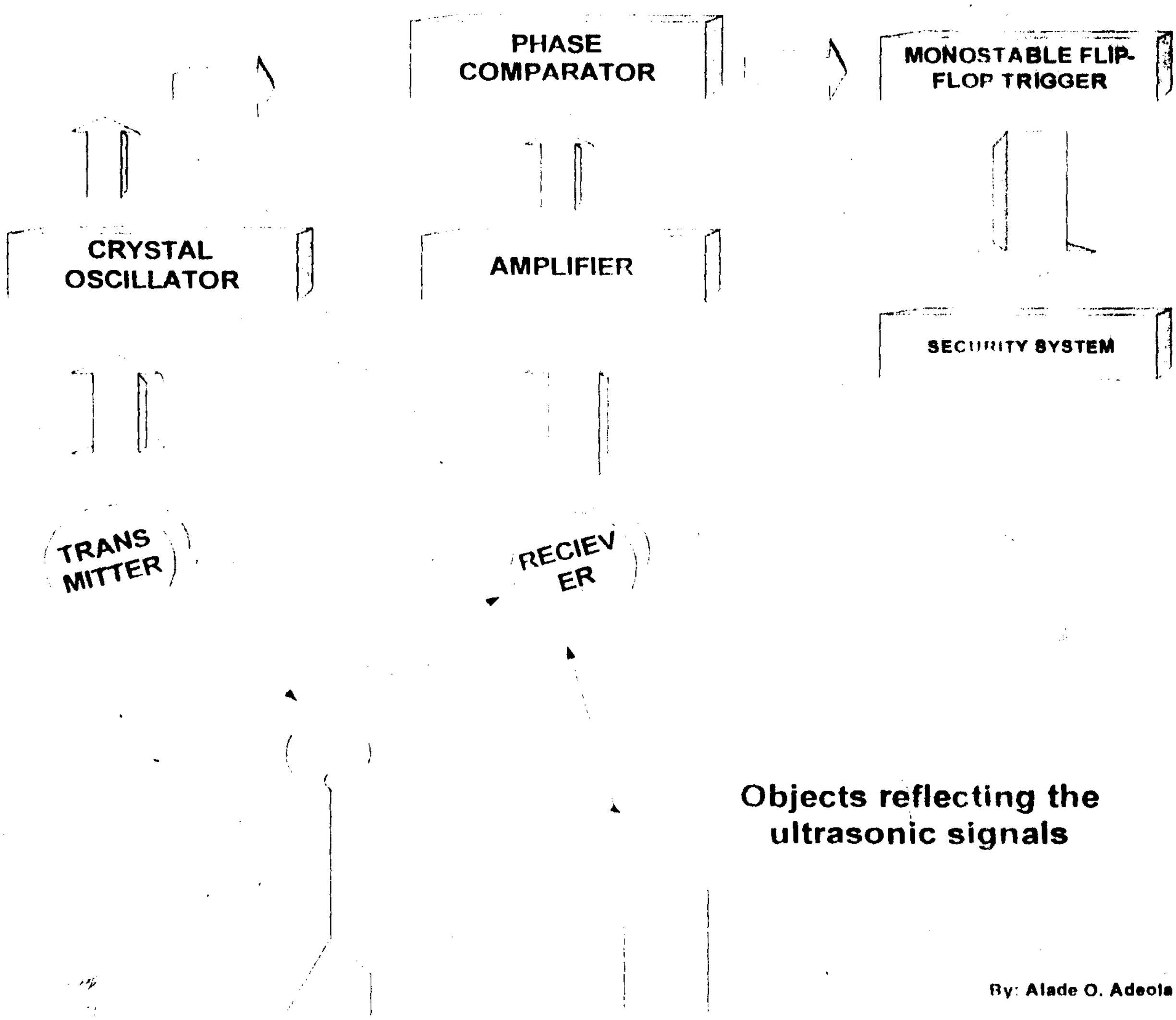
The receiver section of the motion detecting sensor is built around a LM324 internally frequency compensated operational amplifier, a receiving ultrasonic transducer and a PNP transistor used for switching. It has an input voltage of 5 volts that is modulated by the reflected signal received by the 40-kHz receiving ultrasonic transducer and then fed into operational amplifier, where it is amplified and fed into a phase comparator circuit designed to detect if there is a change in the summed received signal from the level of the signal transmitted, .i.e. reflected by an object and received by the receiving ultrasonic transducer.

The phase comparator is designed as a summed frequency comparator realized by using a negative peak detector circuit and a window detector circuit using diodes and differential amplifier circuits, this circuit is designed to operate normally at 40-kHz and a change in the frequency causes the circuit to trigger itself.

The triggering section is built around a mono-stable flip-flop. This converts signals received from the phase comparator section into pulse substantial enough to turn on the transistor that in turn trigger the alarm circuit connected to it via a relay which in turn lights up a LED.

The power section that powers the motion detecting sensor has two parts; one giving out 5 volts and the other giving out 9 volts. This is realized by using a 9 volts battery and a 78L05 voltage regulator IC to generate the 5 volts needed.

Below (FIG. 2.2) is a block diagram of how the ultrasonic motion detecting sensor works:



BLOCK DIAGRAM OF THE ULTRASONIC MOTION SENSOR FIG. 2.2

And below (FIG. 2.3) is the circuit schematic of the three sections (Transmitter, Receiver and Power section) of the ultrasonic motion detecting sensor. IC1 (a-b) are the four section of the LM 324 operational amplifier, IC2 (a-f) are the six section of the 4049

Hex inverting buffer, IC3 is the voltage regulator used, BZ1 is the receiving ultrasonic transducer, BZ2 is the transmitting ultrasonic transducer, and XTAL1 is the Crystal.

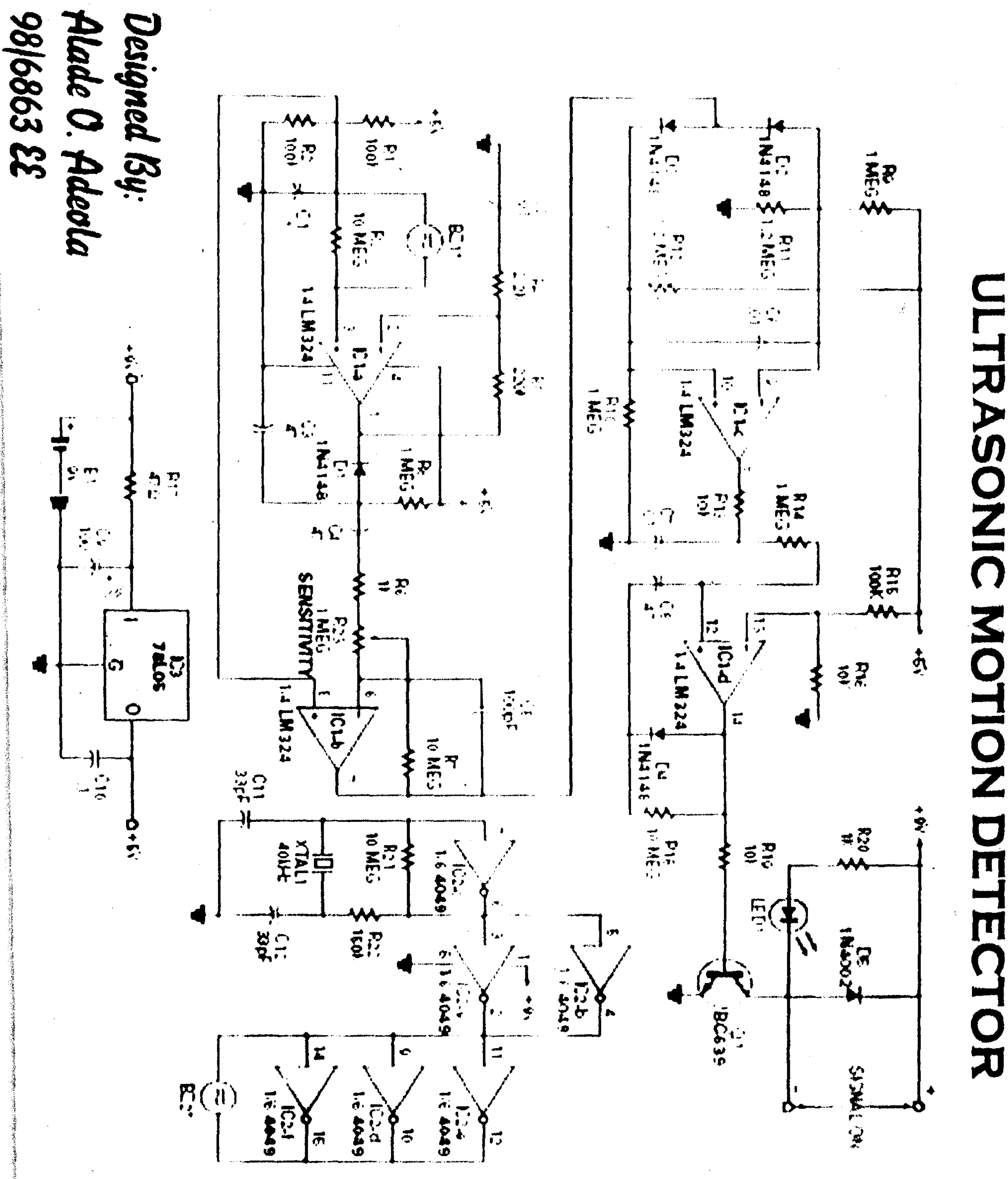


FIG. 2.3

CHAPTER THREE

THEORY AND DESIGN

3.0 THEORY.

The basic knowledge of the principles that govern the way some of the components used for this project work is discussed in this chapter, for example the transistor as a switch, mono-stable flip-flops, operational amplifiers as comparators and detectors, Hex Inverters as drivers etc.

3.0.1 DESCRIPTION OF THE CIRCUIT SCHEMATICS.

The schematic for the ultrasonic motion detecting sensor is shown FIG. 2.3. A 9 volts battery, B1, directly provides power for some sections of the circuit. The battery is also connected to a 78L05 regulator, IC3, which provides a 5-volt DC power source for other sections of the circuit.

The transmitter section of the sensor is basically a crystal controlled relaxation oscillator built around a 4049 hex inverter, IC2. One of the 4049 sectionsIC2-c, along with resistor R21 and R22, and the capacitors C11 and C12, "pings" the 40-kHz into a sustained oscillation. The remaining 4049 section acts as linear buffer to drive a 40-kHz ultrasonic transmitting transducer, BZ2.

The receiver section of the circuit is made up of four AC-coupled stages, each built around one of four section of an LM 324 Op Amp, IC1.

In the first stage, the input voltage developed across R1 and R2 is modulated by a 40-kHz ultrasonic receiving transducer, BZ1, and is then fed to IC1-a, where it is amplified. The receiving transducer detects any reflected sound produced by the transmitting transducer BZ2. If there is no movement, the resulting envelope signal is just a straight line: diode D1 and resistor R8 operate as a negative peak detector to recover the envelope can be followed; the output of the second stage is a DC level that represents the strength of the envelope. If there no is movement, the envelope will reflect it in form of a positive or negative signal.

At the input to the third stage a differential amplifier built around IC1-c there are two diodes, D2 and D3. They detect both positive and negative pulses. When there is no movement, the voltage at pin 7 of IC1-b is half the supply voltage and neither D2 nor D3 can conduct. The voltage at pin 8 of IC1-c is then low. If the signal rises above +0.7 volts (a silicon diode's breakdown voltage), D3 conducts causing the output on pin 8 to go high. If the signal falls below -0.7 volt, D2 conducts, which also causes the output to go high. Thus we have a windows detector. If detects voltages that move both below and above a given range.

The fourth stage, built around IC1-d, is set up as a mono-stable flip-flop. That stage converts any signal that gets through the filter into a pulse substantial enough to turn on transistor Q1. When Q1 conducts, LED1 turns on and an output signal is provided to drive a separate relay that powers the alarm circuit. The time constant of the mono-stable flip-flop is about half a second and is set by C8 and R18. Diode D4 is used to separate the charge and discharge time constants. It lets the circuit switch on immediately when movement is detected but allows about a half-second delay for reset.

THE RECEIVER SECTION.

3.1 TRANSISTORS AS A SWITCH.

3.1.1 BRIEF DESCRIPTION OF THE TRANSISTOR.

Electronic circuits inevitably involve reactive elements, in some cases intentionally but always at least as parasitic elements. Although their influence on circuit performance may be subordinate for particular circuit reactive elements always introduce an ultimate limitation on frequency response/switching speed. Reactive elements introduce 'past history' into the analysis of a circuit. The voltage across a capacitor, for example, is proportional to the capacitor charge, and the charge is a cumulative result of past current into and out of the capacitor to change the voltage across a capacitor the stored charge must change, i.e., there must be a current to transport charge into (increase voltage) or out of (reduce voltage) the capacitor. There is therefore inevitably a delay in changing capacitor voltage since a finite current requires a finite time to transport a finite charge.

A similar historical dependency is associated with an inductance. Energy is stored magnetically by the current flowing in an inductor. A current change requires a change in stored energy, and for a finite power capability a finite time is required for an energy change. Here we shall examine switching delays associated with circuit inductance. There are related delays associated with the internal device phenomena, generally significant only for very fast changes.

THE RECEIVER SECTION.

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3.1.2 TRANSISTOR SWITCHING.

Switching is examined here in the context of a bipolar junction transistor (BC 639) switching an inductive relay coil.

The BC 639 transistor is an NPN bipolar junction transistor made from the same N-Type and P-Type semiconductor materials as diodes and employ the same principle. However the transistor has two P-N junctions. It has an emitter made from N-type material and its base is a P-Type material for the transistor to operate, the emitter must be connected to negative, the base to the positive and the collector to the positive. Current flow between the emitter and base controls the current flow between emitter and collector. By regulating the current at the emitter base junction, the amount of current allowed to pass from the emitter to the collector can be controlled.

The table below, Table 1.1, shows the ratings, electrical characteristics, typical characteristics graph and physical dimensions of the BC 639 NPN Transistor.

Absolute Maximum Ratings T_a=25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CER}	Collector-Emitter Voltage at R_{BE}=1KΩ		
	BC635	45	V
	BC637	60	V
	BC639	100	V
V_{CES}	Collector-Emitter Voltage		
	BC635	45	V
	BC637	60	V
	BC639	100	V
V_{CEO}	Collector-Emitter Voltage		
	BC635	45	V
	BC637	60	V
	BC639	80	V
V_{EBO}	Emitter-Base Voltage	5	V
I_C	Collector Current	1	A
I_{CP} *	Peak Collector Current	1.5	A
I_B	Base Current	100	mA
P_C	Collector Power Dissipation	1	W
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 ~ 150	°C

* PW≤5ms, Duty Cycle≤10%

Electrical Characteristics T_a=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
BV_{CEO}	Collector-Emitter Breakdown Voltage	I_C=10mA, I_B=0				
	BC635		45			V
	BC637		60			V
	BC639		80			V
I_{CBO}	Collector Cut-off Current	V_{CB}=30V, I_E=0			0.1	μA
I_{EBO}	Emitter Cut-off Current	V_{EB}=5V, I_C=0			0.1	μA
h_{FE1}	DC Current Gain : All	V_{CE}=2V, I_C=5mA	25			
h_{FE2}	BC635	V_{CE}=2V, I_C=150mA	40		250	
	BC637/BC639		40		160	
h_{FE3}	All	V_{CE}=2V, I_C=500mA	25			
V_{CE}(sat)	Collector-Emitter Saturation Voltage	I_C=500mA, I_B=50mA			0.5	V
V_{BE}(on)	Base-Emitter On Voltage	V_{CE}=2V, I_C=500mA			1	V
f_T	Current Gain Bandwidth Product	V_{CE}=5V, I_C=10mA f=50MHz		100		MHz

TABLE 1.1: ELECTRICAL CHARACTERISTICS OF THE BC639 TRANSISTOR

Package Dimensions

TO-92

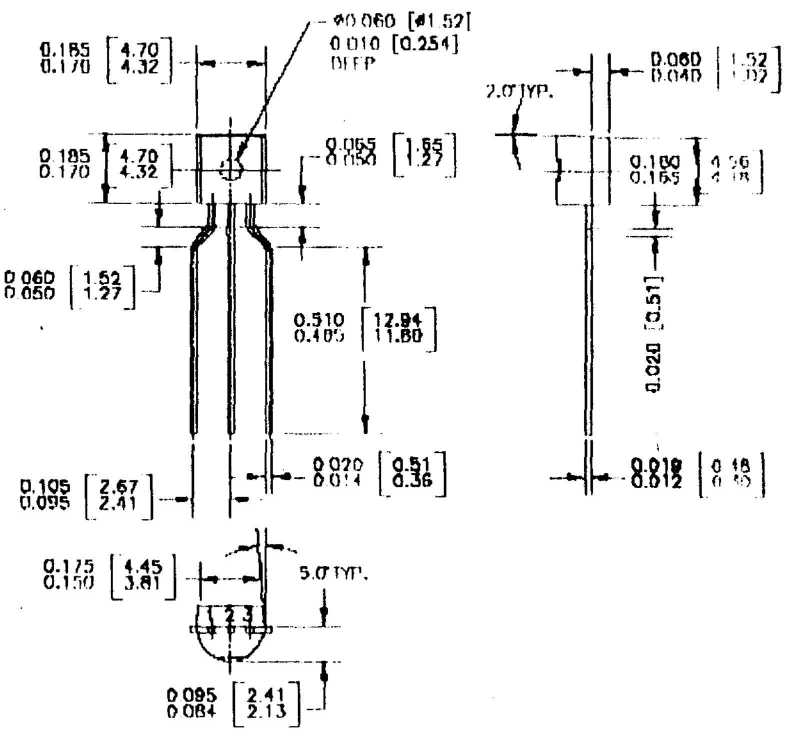


FIG. 3.0

PACKAGE DIMENSION OF THE BC639 TRANSISTOR

Because of the fundamental conflict between the physical laws associated with the inductive effect and the practical and economic constraints of monolithic construction, the phrase **integrated circuit inductor** are important in a number of applications; low current mechanical relay switches are an example.

A simplified transistor-actuated switch circuit is shown in FIG. 3.1. The dotted rectangle represents a switch having a winding resistance R_L and an inductance L.

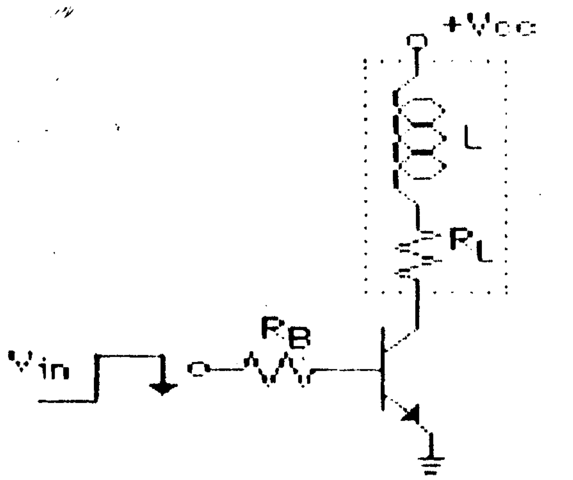


FIG. 3.1

A SIMPLIFIED TRANSISTOR ACTUATED SWITCH

When a pulse is applied to the base of the transistor, the transistor is temporarily from a cut off state to a conducting state. The coil of the relay stores energy in a current flow, in general turning off the power supply means turning off the current flow. A coil responds to a changing current by generating a voltage which attempts to mitigate the change; the faster the change the larger the generated voltage magnitude. Unfortunately the result, particularly where care is not taken, quite often produces a destructive release of the stored energy. A sketch of a representative pulse trajectory on the I_c - V_{CE} plane is drawn in FIG. 3.2. Initially the cutoff and the operating point is at V_{CC} (0). When the base drive turns the transistor on. The operating point must lie on the transistor characteristics which correspond to the base current. On the other hand, the inductance of the relay coil prevents the collector current from changing immediately. To accommodate both requirements the collector voltage drops immediately and moves to the zero-current intersection of the collector characteristic; the collector voltage change is provided by the inductive reaction to an attempt to change the current. Note however that the current is in the process of increasing. Operation moves up the saturation part of the collector characteristics and over until the load line is intersected. This corresponds to the steady-state operating point. In most instances the operating point will be selected to saturate the transistor so that the collector dissipation will be relatively small.

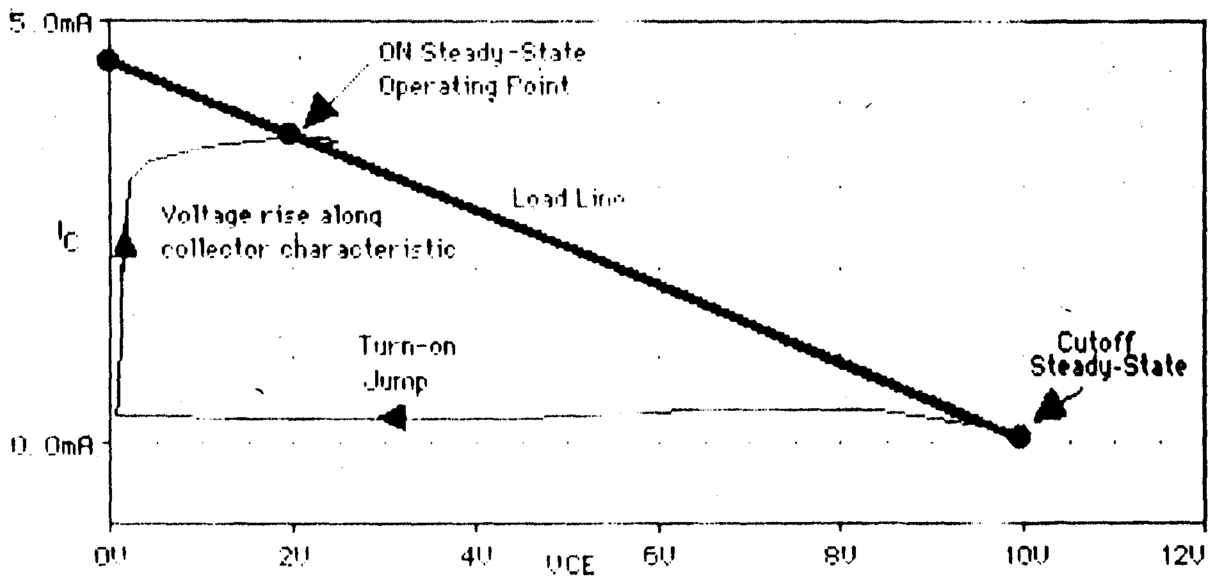


FIG. 3.2

<u>**GRAPH OF THE PULSE TRAJECTORY**</u>

The turn-on transient response is drawn below (FIG. 3.3) (input step starts at 10μs). Note that the collector current remains zero initially and then rises approximately exponentially (along the collector characteristics) into steady state (with a small overshoot). Similarly the collector voltage initially drops rapidly towards zero (through saturation), and remains low as the current rises (along the saturation portion of the collector characteristics). As the operating point moves to the intersection of the load line and the collector characteristics, the voltage and current increase to their steady-state values.

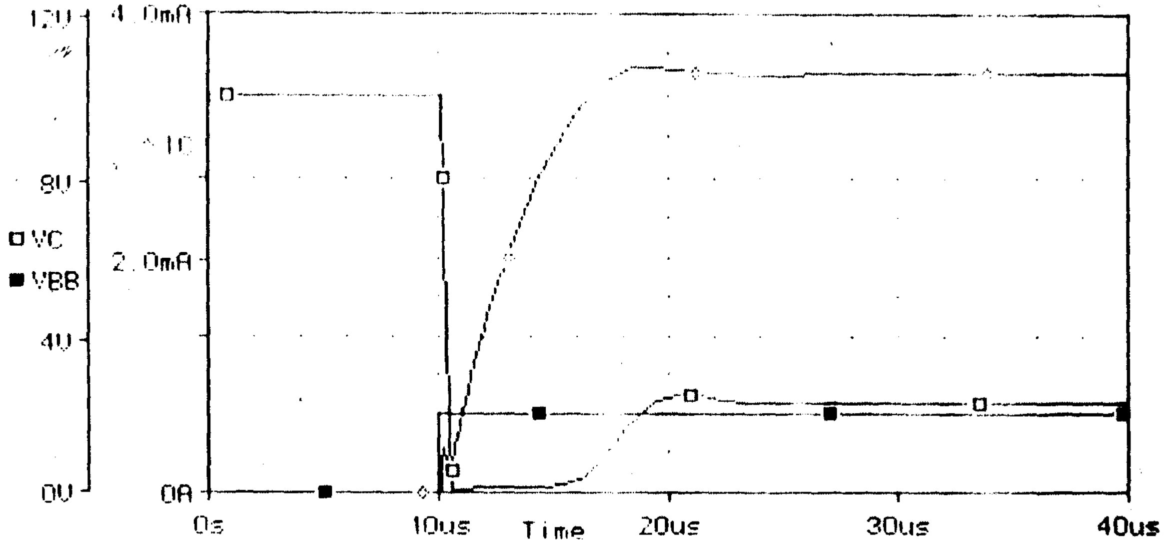


FIG. 3.3

GRAPH OF TURN-ON TRANSIENT RESPONSE OF THE TRANSISTOR

The energy stored in the relay coil can not simply disappear, i.e., the current through the inductor cannot immediately drop to zero. The faster the current attempt to decrease the higher the inductive voltage generated ($E= L\frac{di}{dt}$) and as noted before operation becomes erratic and more often than not destructive. The inductive increase in collector voltage at first tends to increase the collector current (because of the Early effect). Unfortunately a fast current change causes a very large induced voltage, ordinarily increasing the reverse bias of the collector junction to a point where junction breakdown begins. This new current flow mechanism leads into unstable operation with the usual consequences being destruction of the transistor. A modification of the circuit above would avoid the problem. The general nature of a solution is fairly straightforward; simply provide a current path to replace conduction through the transistor which enables the stored inductive energy to be dissipated harmlessly. This added current path should be activated only when the transistor is turned off since energy is supposed to be stored when the transistor is turned on. One method to accomplish the objective illustrated in the circuit FIG. 3.4 is to add a resistor and a diode as shown. When transistor is turned on the diode blocks current flow though the added branch and the turn-on operation is as described before. On turn-off however, the inductive voltage generated increases the collector voltage to the point where the diode is turned and the initial collector current flows through the resistor R. The figure (FIG. 3.5) following is a sketch illustrating the turn-off transient; the turn-on transient also is shown to present a coordinate picture of events. On turn-off the collector drops immediately the base drive is removed. However the inductor current is diverted through the diode branch, which is turned on by the inductive voltage generated.

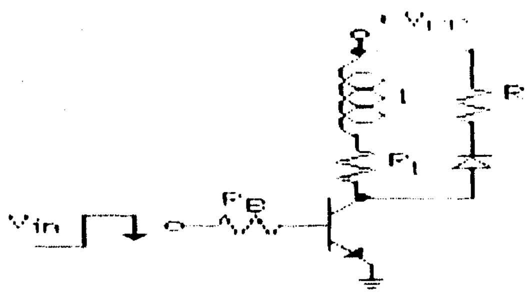


FIG. 3.4

<u>TRANSISTOR ACTUATED SWITCH WITH DIODE PROTECTION</u>

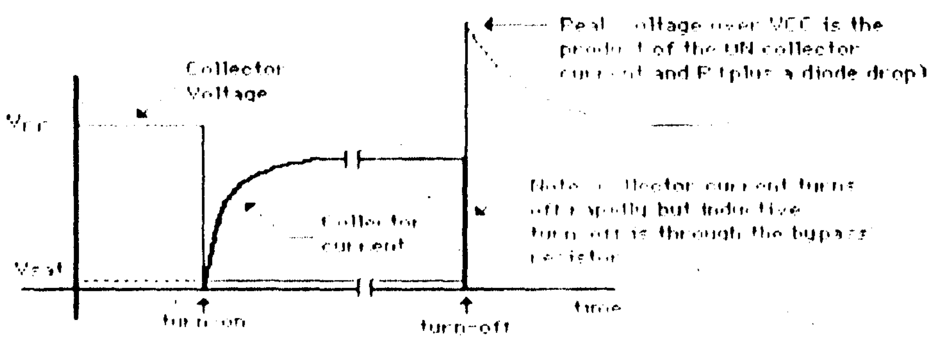


FIG. 3.5

<u>TURN-OFF TRANSISENT RESPONSE OF THE BC639 TRANSISTOR</u>

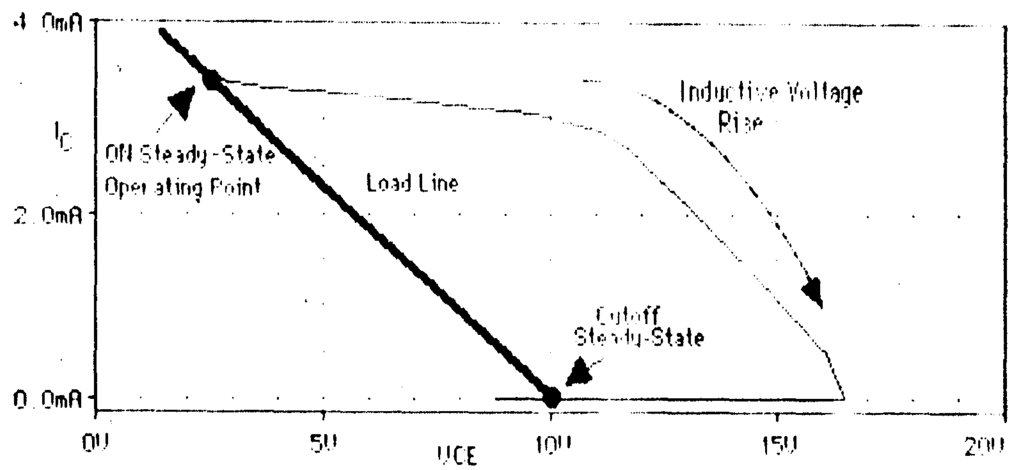
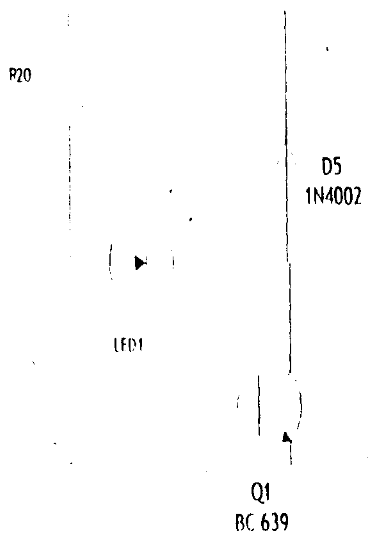


FIG. 3.6

3.1.3 TRANSISTOR SWITCHING AS USED IN THE PROJECT.

The BC 639 transistor is used in the motion detecting sensor to trigger on a relay connected to it which in turn switches on the alarm circuit connected to the sensor. Signals coming from the fourth stage of the LM 324 operational amplifier IC set as a mono-stable flip-flop drives the transistor. When the transistor conducts, the LED 1 turns on and an output signal is provided to drive a separate relay. The diode D5 is used to protect the transistor. It provides a current path to replace conduction through the transistor when it's off which enables the stored inductive energy of the coil to be dissipated harmlessly. This added current path is activated only when the transistor is turned off since energy is supposed to be stored when the transistor is turned on. When transistor is turned on the diode blocks current flow though the added branch. On turn-off however, the inductive voltage generated increases the collector voltage to the point where the diode is turned and the initial collector current flows through the resistor R 20. On turn-off the collector drops immediately the base drive is removed. However the inductor current is diverted through the diode branch, which is turned on by the inductive voltage generated, thus protecting the transistor. Below in FIG. 3.7 is the circuit diagram of the triggering section of the ultrasonic motion detecting sensor.



$$V_{in} = (I_B R_B + V_{BE})$$

$$hfe = \frac{I_C}{I_B}$$

$$R_B = \frac{V_{in} - V_{BE}}{I_B}$$

$I_B = BaseCurrent$

$I_C = CollectorCurrent$

$V_{in} = InputVoltage$

$hfe = CurrentGain$

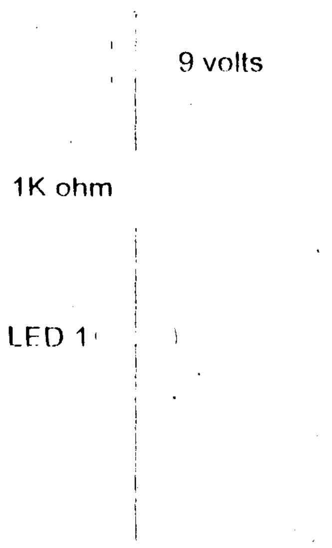
FIG. 3.7

CIRCUIT DIAGRAM OF THE SWITCHING SCETION OF THE DETECTOR

3.1.4 THE OUTPUT INDICATOR (LIGHT EMITTING DIODE).

The **LED** connected across the collector pin of the transistor Q1 and resistor R20 lights when motion is detected. It is connected through a series-current limiting resistor of value based on the input voltage from the 9 volts battery. The resulting voltage drops across the resistor in series with the **LED**. This prevents the **LED** from burning out due to excess current. Typical voltage across a green **LED** is about 1.7V and it requires 7.3mA to produce a good glow.

Below in FIG. 3.8 is a diagram showing the LED in series connection.



Using Ohm's law to derive series resistance as follows,

(Assuming LED resistance to be negligible),

$$R = V/I = (9 - 1.7)/7.3mA = 7.3/7.3mA = 1,000\Omega.$$

R is chosen to be 1KΩ or higher depending on the available standard values of resistors.

CIRCUIT DIAGRAM OF THE LED INDICATOR SECTION. FIG. 3.8

3.2 OPERATIONAL AMPLIFIERS AS AMPLIFIERS, COMPARATORS AND DETECTORS.

3.2.1 BRIEF DESCRIPTION OF OPERATIONAL AMPLIFIERS.

An operational amplifier IC is a solid-state integrated circuit that external feedback to control its functions. It is one of the most versatile devices in all of electronics.

Operational amplifiers are built for a wide range of purposes ranging from detecting the incredible weak signals from radio astronomy telescopes or satellite broadcasts to giants producing many horsepower of outputs to power the speakers of a rock band.

Operational amplifiers are high-gain, differential input amplifiers. The name operational amplifier, which is universally shortened to op amp, comes from the fact that they can be used to perform mathematical operation such as addition, subtraction, integration and others.

The very high gain op-amp IC's uses external feedback networks to control responses. The op-amp without any external devices is called 'open-loop' mode, referring actually to the so-called 'ideal' operational amplifier with infinite open-loop gain, input resistance, bandwidth and a zero output resistance.

However, in practice no op-amp can meet these ideal characteristics.

The operational amplifier IC used in this project is the LM 324. The LM 324 consist of four independent, high-gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide voltage range. Application includes transducer amplifier, DC gain blocks and all the conventional OP Amp circuits which now can be easily implemented in single power supply systems.

Below in FIG. 3.9 is the internal block diagram, showing the pin configurations and the four independent stages and the schematic diagram (one section only) of the LM 324 operational amplifier.

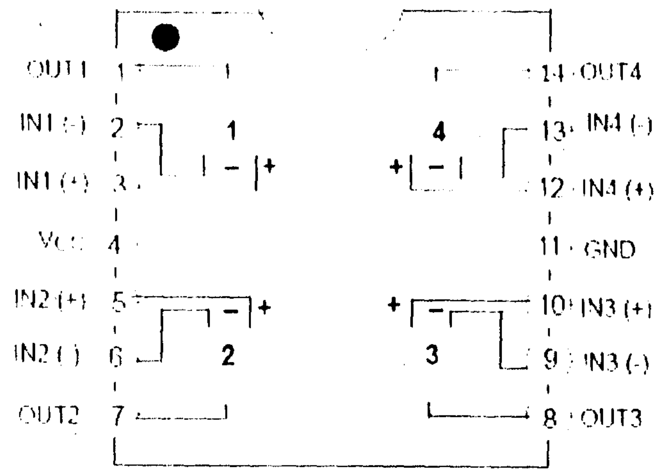


FIG. 3.9

INTERNAL BLOCK DIAGRAM OF THE LM324

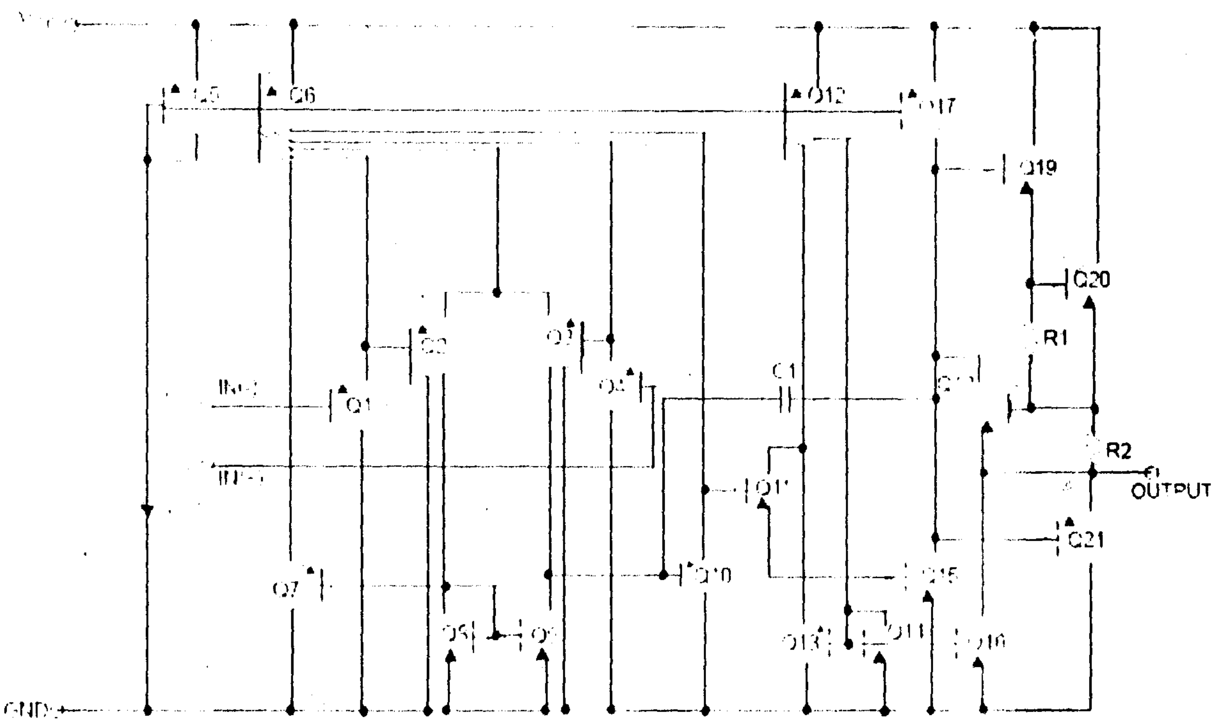


FIG. 3.10

ONE SECTION SCHEMATIC DIAGRAM OF THE LM324

Below in Table 3.1 is the characteristics table of values of the LM 324 operational amplifier.

Parameter	Symbol	Value
Power supply voltage	V_{cc}	±16 or 32 volts
Input Voltage	V_I	-0.3 to +32 Volts
Differential input voltage	$V_{I(DIFF)}$	32 volts
Output short circuit to ground	Continuous	
Power dissipation at 25°C	P_D	1310 mW
Operating temperature range	T_{OPR}	0 - 25^0 C
Common mode rejection ratio	CMRR	75

TABLE 3.1

ABSOLUTE MAXIMUM RATINGS TABLE

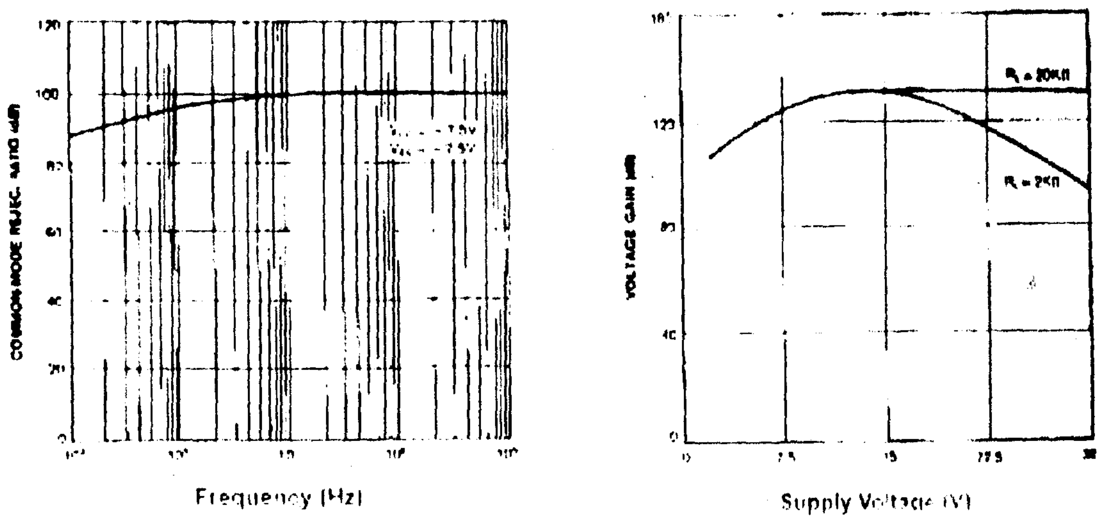


FIG. 3.11

TYPICAL PERFORMANCE CHARACTERISTIC GRAPH

(On the left is the graph of input voltage range versus supply voltage and on the left is the graph of the Common mode rejection ratio)

Mechanical Dimensions

Package

Dimensions in millimeters

14-DIP

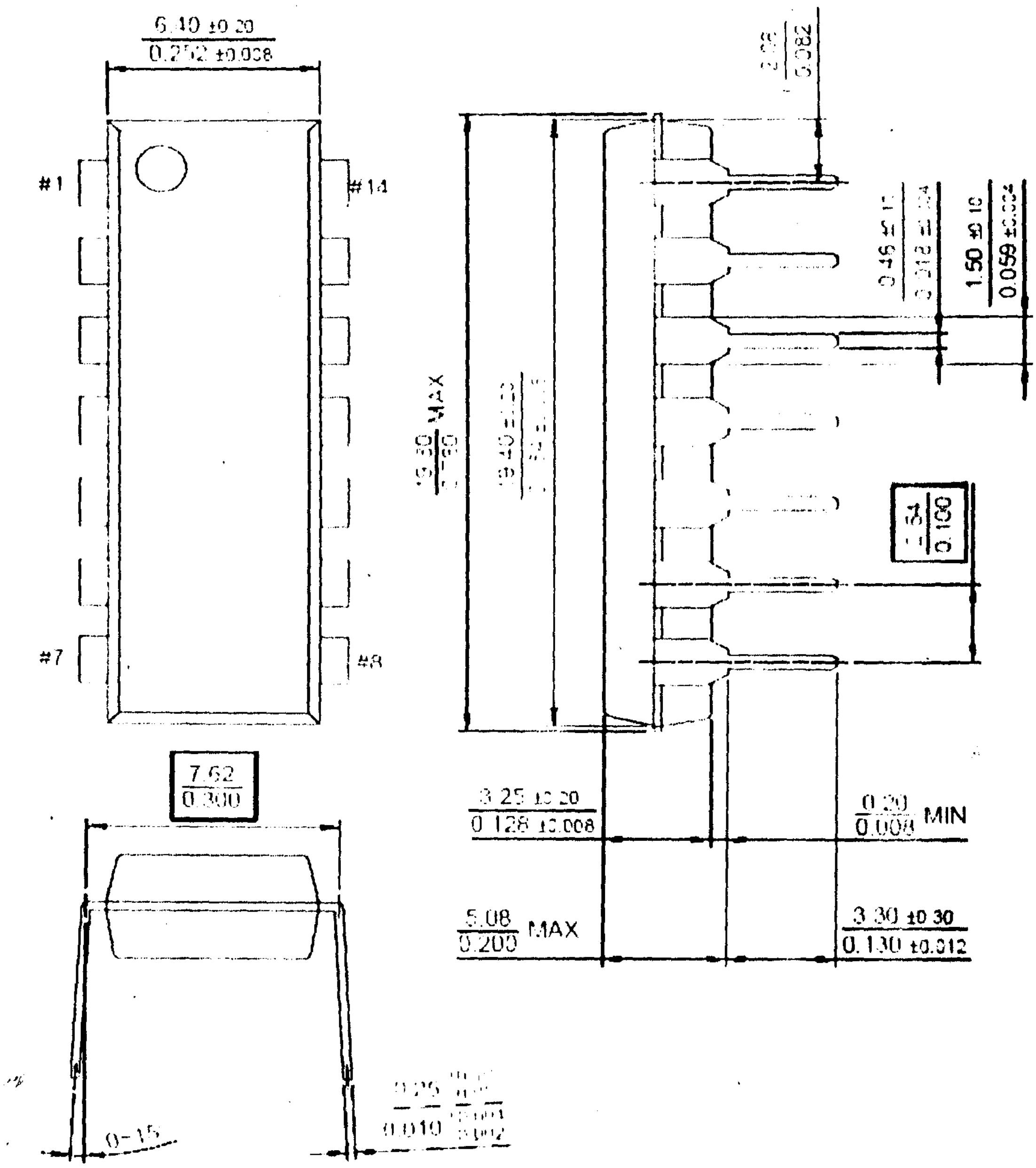


FIG. 3.12

PACKAGE DIMENSION FOR THE LM324 QUAD OP-AMP.

3.2.2 BRIEF HISTORY OF OPERATIONAL AMPLIFIERS.

The term 'op-amp' was originally used to describe a chain of high performance dc amplifiers that was used as a basis for the analog type computers of long ago. Let's go back in time a bit and see how this device was developed.

The term "operational amplifier" goes all the way back to about 1943 where this name was mentioned in a paper written by John R. Ragazzinni with the title "Analysis of Problems in Dynamics" and also discovered the work of technical aid George A. Philbrick. The paper, which was defined to the work of the U.S. National Defense Research Council, was published by the IRE in May 1947 and is considered a classic in electronics. The very first series of modular solid-state op-amps were introduced by Burr-Brown Research Corporation and G.A. Philbrick Researches Inc. in 1962. The op-amp has been a workhorse of linear systems ever since.

The first op-amp offered to the public in 1963 was the µA702 manufactured by Fairchild Semiconductors but it had very weird supply voltages such as +12 and -6volts and had a tendency to burn out when it was temporarily shorted. Despite all these little shortcomings this device was the best in its day. In 1965 the next major change was introduced in op-amp design with the µA709 from Fairchild Semiconductor. It had higher gain, a larger bandwidth, lower input current, and a more user-friendly supply voltage requirement of approximately +15 Volt DC.

National Semiconductor decided to jump on the bandwagon with the release of a more versatile op-amp version in the form of the LM101 in 1967. It had an increased gain (up to 160K) and operation range. One of the nicest features of the LM101 was 'short-circuit' protection, and simplified frequency compensation. This was accomplished by placing an external capacitor across selected connection pins. The first op-amp to provide this internally was the hybrid LH101, which was basically a LM101 with a capacitor in a single package. But Fairchild was not done yet. It introduced in May 1968 an internally compensated op-amp called the µA741. However, the differences between their LM101 and the µA741 were very slight. Frequency compensation is accomplished using an 'on-chip' capacitor. Offset null is accomplished by adjustment of currents in input stage emitters. On the LM101, Offset is achieved by adjusting current in input stage collectors.

In December 1968, an improved version of the LM101, the LM101A, was devised. This device provided better input control over the temperature and lower Offset currents. National Semiconductor introduced the LM107, which had the frequency compensation capacitor built into the silicon chip. The LM107 came out at the same time as the LM101A. In 1968, Fairchild Semiconductor issued the µA748. The device had essentially the same performance characteristics as the µA741. The difference was external frequency compensation. The first multiple op amp device was Raytheon Semiconductors RC4558 in 1974. Characteristics of this new device are similar to the µA741 except that the latter uses NPN input transistors. Later in that same year, the LM324 quad op amp from National Semiconductor became public to the delight of manufacturing industry and hobbyist alike. It is similar in characteristics in comparison with the µA741 in speed and input current.

The LM324 is especially useful for low-power consumption. The beauty of this chip, according to some engineers, is its single-power-supply requirement. Now the snowball was rolling. The first FET input op amp was the

CA3130 made by RCA with this addition to the op-amp family; extremely low input currents were achieved. Its power can be supplied by a +5 to +15vdc single supply system. A beautiful piece of work this CA3130.

In July 1975, National Semiconductor came out with the J-FET type LF355. This was the first device created using ion implantation in an op amp. Texas Instruments introduced the TL084 op amp in October 1976. It is a quad JFET input op amp; it also is an ion-implant JFET. Low bias current and high speed are two of its beautiful attributes. In dated sequence, the op-amp developed like this: 1963-μA702, 1965-μA709, 1967-LM101/LH101, 1968-μA741, 1974-RC4558/LM324, 1975-A3130/LF355, and in 1976 the TL084. Most of the mentioned op-amps have of course been replaced over time, keeping the same model number, with cleaner and low-noise types. Meaning, the silicon cutting laser in the early 60's was not of the same quality as the 70's or the 80's, etc. Other companies like RCA discontinued their semiconductor line all together. Today, and since that month in 1976, the types of op amps have increased almost daily. We now enjoy a variety of op amps that will provide the user essentially with anything s/he needs, such as high common-mode rejection, low-input current frequency compensation, CMOS, and short-circuit protection. All a designer has to do is expressing his needs and is then supplied with the correct type.

Shown in FIG.3.13 at the right are op-amp symbols as used today. The one on the right is an older way of drawing it but still used in books like the ARRL (American Radio Relay League) and older schematics. It is common practice to omit the power supply connections as they are implied.

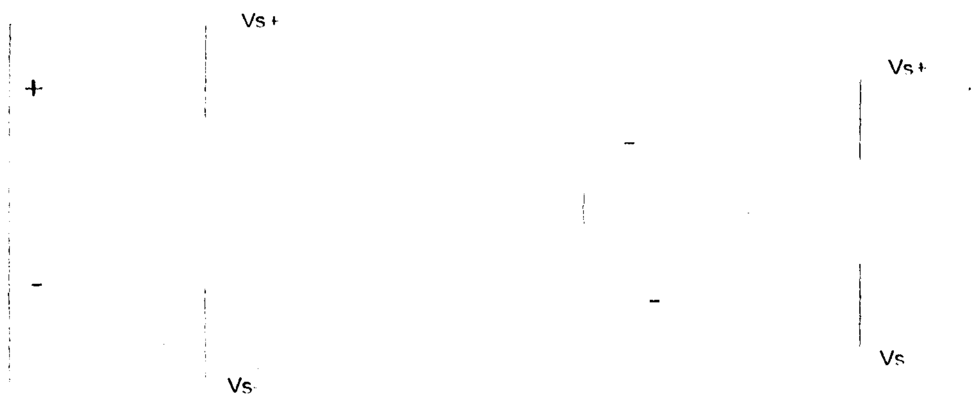


FIG. 3.13

OP-AMP SYMBOL

3.2.3 OPERATIONAL AMPLIFIERS AS POWER AMPLIFIERS.

Ideal operational amplifiers have infinite gain. If the voltage at the positive terminal is larger than the voltage at the - terminal then the output voltage will increase until it reaches the positive power supply. Likewise, if the voltage at the positive terminal is smaller than the voltage at the negative terminal then the output voltage will decrease until it reaches the negative power supply. If both terminals are equal, the output will no longer be driven by the op amp. These characteristics allow feedback to be used in order to drive the output of the op amp to a useful value.

Operational amplifiers can be used as voltage/signal amplifiers. Non inverting amplifiers are very powerful because signals can be amplified without having a negative rail (depending on the op amp's specifications). With reference to FIG. 3.14, when a voltage is applied to V_{in}, V_{out} begins to rise because of the finite amplification. This rising voltage is consequently applied across the voltage divider or R1 and R2 in such a way that the voltage at the negative terminal of the op amp begins to rise as well. Once the voltage at the negative terminal has reached the same value as the positive terminal, the amplification stops and V_{out} remains constant. If for some reason the output voltage pushed further up, the voltage at R1 will go up causing the op amp to have a negative voltage across it and pull V_{out} back down again.

The formula expressing the ideal V_{out} is :

$$V_{in}\left(\frac{R_1 + R_2}{R1}\right)$$

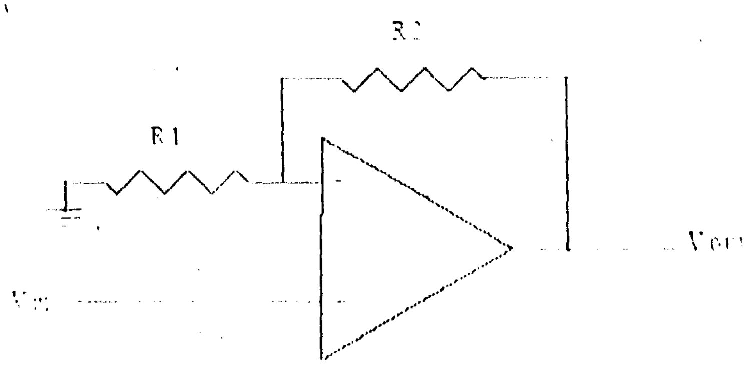


FIG. 3.14

CIRCUIT DIAGRAM OF AN OP-AMP AS A VOLAGE AMPLIFIER

The first two stages of the LM 324 operational amplifier is used as a voltage amplifier with pin 3 and pin 6 being the input i.e. V_{in} and pin 1 and pin 7 the output i.e. V_{out}. The output signal from pin 1 is the amplified version of the ultrasonic signal received by the receiving ultrasonic transducer. It is amplified by 1000 times (75dB from the Electrical characteristic table). The output signal from pin 1 is fed into a negative peak detector before it is fed into the second stage of the operational amplifier. The peak detector is used to recover the envelope signal.

The output from the second stage of the LM 324 operational amplifier is a DC level and it either negative, positive depending on the difference in the voltage level at the inputs, i.e. if there is movement it will be oscillating and if there is no movement it will be a straight line.

The amplifier section of the receiver/triggering section of the ultrasonic motion detecting sensor is shown in FIG. 3.15

FIG. 3.15

CIRCUIT DIAGRAM OF THE AMPLIFIER SECTION OF THE DETECTOR

3.2.4 PEAK DETECTOR AND SENSITIVITY CONTROL.

A peak detector allows the highest voltage value that a signal produces over a period of time to be determined. The circuit in FIG. 3.16 is an example of a peak detector for slowly varying signals. The diode located at the output of the op amp allows the op amp to add charge to the capacitor C while not allowing it to discharge the capacitor. Because of this V_{out} will rise until both the negative and positive terminal of the op amp are equal. The, if V_{in} drops, the op amp will no longer be pumping charge into the capacitor, and the resistor R will allow charge to slowly escape the and voltage at V_{out} to drop. Rand C are picked based on how fast V_{out} must drop after detecting a peak.

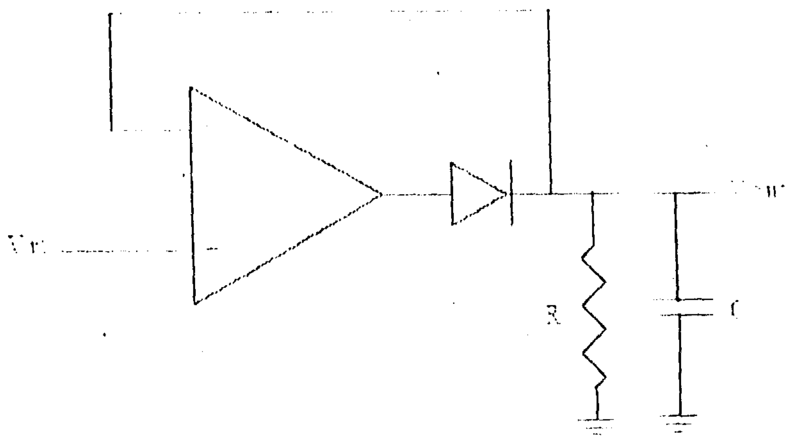


FIG. 3.16

A peak detector is created in between the output of the first stage of the LM324 operational amplifier and the input of the second stage of the LM324 operational amplifier. It is used to recover the input voltage of 5 volts modulated by the receiving ultrasonic transducer and amplified by the first stage of the LM324 operational amplifier.

The time constant of the signal entering the second stage of the LM 324 operational amplifier is quite slow so that the envelope signal can be easily followed.

FIG. 3.17 depicts the schematic of the peak detector as used in the receiver section of the ultrasonic motion detecting sensor, with diode D1, resistor R8 and capacitor C4 being used to recover the envelope signal.

The variable resistor placed at the input of the second stage of the LM 324 serves as a sensitivity control. It functions by varying the voltage drop across the negative input which in turn varies the difference in the level at which the positive input must be so as to make the output pin 7 high.

FIG. 3.17

CIRCUIT DIAGRAM OF THE PEAK DETECOR

3.2.5 OPERATIONAL AMPLIFIERS AS DIFFERENTIAL AMPLIFIER WINDOW DETECTOR.

Operational amplifiers can also be used as a difference amplifier, also known as the differential amplifier.

The idea of the differential operational amplifier is not new. The first commercial operational amplifier, the K2-W, utilized two dual section tubes (4 active circuit elements) to implement an op-amp with differential inputs and outputs. It requires a ±300V DC power supply, dissipating 4.5 watts of power, had a corner frequency of 1 Hz, and a gain bandwidth product of 1MHz.

Fully differential output op-amps were abandoned in favor of single ended op-amps. Fully differential op-amps were but forgotten, even when IC technology was developed. The main reason appears to be the simplicity of using single ended op-amps. The numbers of passive components required to support fully differential circuit is approximately double that of single ended circuit. The thinking may have been "Why double the number of passive components when there is nothing to be gained. Almost 50 years later, IC processing has matured to the point that fully-differential op-amps are possible that offer significant advantage over the single ended cousins. The advantages of differential logic have been exploited for 2 decades. More recently, advanced high speed A/D converters have adopted differential inputs. Single ended op-amps require a problematic transformer to interface to these differential inputs A/D converters. This is the application that spurred the development of fully differential op-amps.

The easiest way to construct a fully differential circuit is to think of having inverting op-amp feedback topology.

The feedback paths must be closed in order for the fully-differential op-amp to operate properly.

Figure 3.18 shows an ideal difference amplifier. It is no mistake that the resistors in the two inputs have the same name; they must have the same value if the circuit is to work correctly.

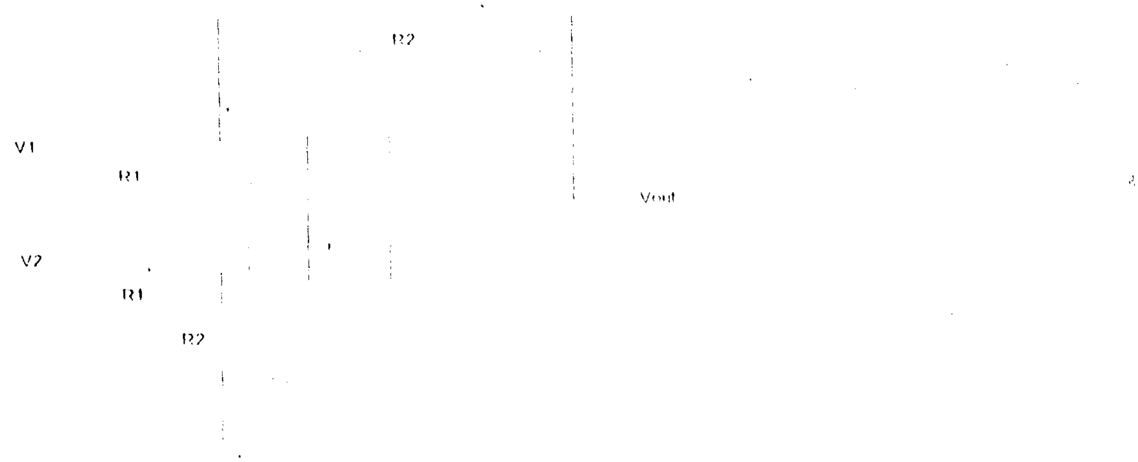


FIG. 3.14

CIRCUIT DIAGRAM OF AN IDEAL DIFFERENCE AMPLIFIER

The output V_{out} is given by:

$$V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$$

The derivation of this result is as follows. The voltage at the non-inverting input is:

$$V_+ = V_2\left(\frac{R_2}{R_1 + R_2}\right)$$

Since the voltage at the inverting input is the same as the non-inverting input, applying KCL to the inverting input gives:

$$\frac{V_1 + V_+}{R_1} = \frac{V_+ - V_{out}}{R_2}$$

Eliminating V_+ and rearranging gives V_{out}.

For the circuit above to work well, the resistors need to be carefully matched.

The third section of the LM 324 operational amplifier is built as a differential amplifier with diodes D2 and D3 serving as a window detector.

The schematic of the differential amplifier as used in the ultrasonic motion detecting sensor amplifier is shown in FIG. 3.19

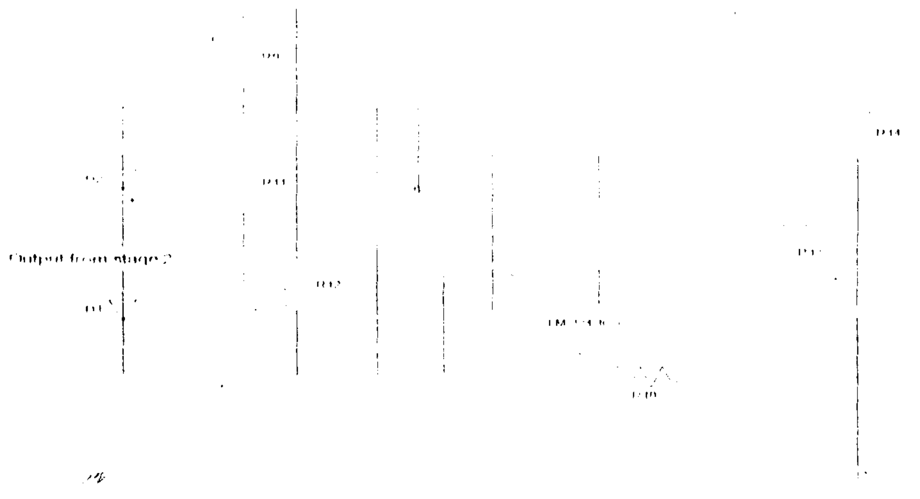


FIG. 3.19

CIRCUIT DIAGRAM OF THE DIFFERENTIAL AMPLIFIER AS USED IN THE DETECTOR

Diodes D2 and D3 detect both negative and positive pulses. When the voltage the output from stage 2 is half the supply voltage neither D2 nor D3 can conduct. The voltage at the output of the third stage of the LM 324 operational amplifier is low. If the signal rises above +0.7 volts (a silicon diode's breakdown voltage), D3 conducts causing the output of the third stage of the LM 324 operational amplifier to go high. If the signal falls below -0.7 volts, D2 conducts, which also causes the output to go high. Thus a window detecting differential amplifier is realized. It detects voltages that move both below and above a given range.

3.2.6 OPERATIONAL AMPLIFER AS A MONOSTABLE FLIP-FLOP.

The mono-stable flip flop, sometimes called a 'one shot' is used to produce a single pulse each time it is triggered. It can be used to debouche a mechanical switch so that only one rising and one falling edge occurs for each switch closure, or to produce a delay for timing applications and in this case, it is used as a mechanical switch.

The circuit in FIG. 3.20 is an example of a mono-stable flip flop. It employs two logic inverters which are connected by the timing capacitor. When the switch is closed or the input goes negative, the capacitor will charge through the resistor generating an initial high level at the input to the second inverter which produces a low output state. The low output state is connected back to the input through a diode which maintains a low input after the switch has opened until the voltage falls below half the value of V_{cc} at pin 3 at which time, the output and input return to a high state. The capacitor then discharges through the resistor R and the circuit remains in a stable state until the next input arrives. The 10,000 ohm resistor in series with the inverter input (pin 3) reduces the discharge current through the input protection diodes. This resistor may not be needed with smaller capacitor values.

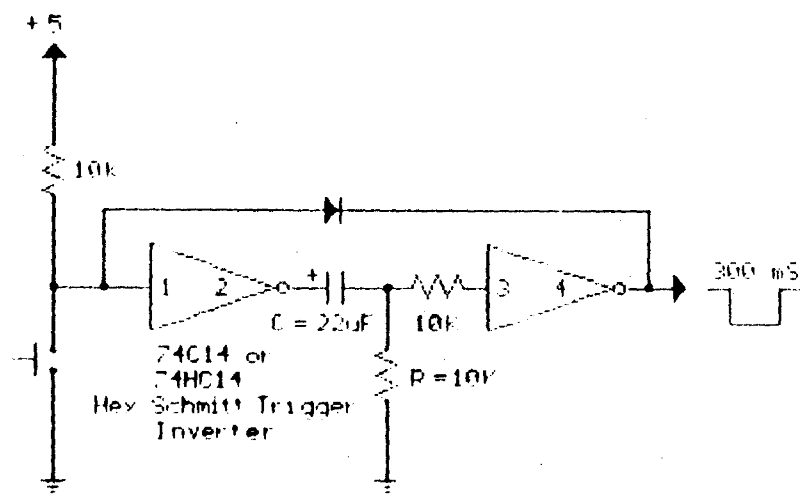


FIG. 3.20

CIRCUIT DIAGRAM OF A HEX SCHMITT TRIGGER USED AS A MONO-STABLE FLIP-FLOP

The circuit is not re-triggerable and the output duration will be shorter than normal if the circuit is triggered before the timing capacitor discharges, which requires about the same amount of time as the output.

The circuit in FIG. 3.21 shows how the fourth stage of the LM 324 operational amplifier is set up as a mono-stable flip flop.

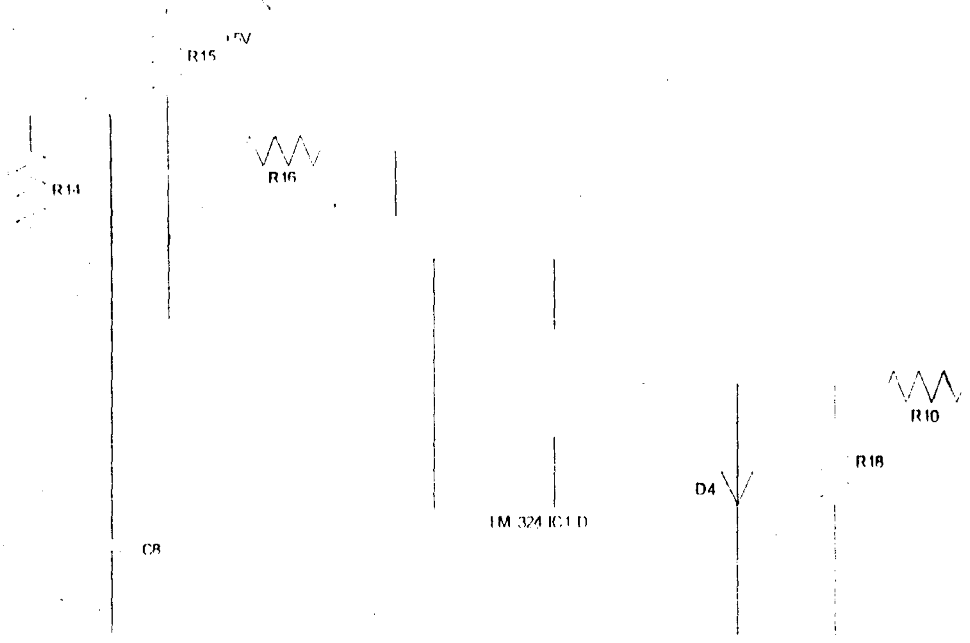


FIG. 3.21

CIRCUIT DIAGRAM OF THE SECTION-D OF THE LM324 AS A MONOSTABLE FLIP-FLOP

The time constant of the circuit above is about half a second and it is set by resistor R18 and capacitor C8. Diode D4 is used to separate the charge and discharge time constants. The circuit allows about half second delay for the reset.

THE TRANSMITTER SECTION

3.3 THE 4049 HEX INVERTING IC AND QUARTZ CRYSTAL AS A RELAXATION OSCILLATOR AND LINEAR BUFFERS.

3.3.1 BRIEF DESCRIPTION OF THE 4049 HEX INVERTING IC.

The 4049 Hex inverting IC are monolithic complementary metallic oxide semiconductors (CMOS) integrated circuit constructed with N- and P- channel enhancement mode transistor. It features logic level conversion using only one supply voltage. It is intended for use as hex buffers, CMOS to DTL/TTL converters, or as CMOS current dividers.

The 4049 Hex inverting IC provides six inverting buffers with high current output capability suitable for driving TTL or high capacitive loads.

Below are diagrams showing the functional diagram, pin assignment diagram of the 4049 Hex inverting IC, schematic diagram and physical dimension.

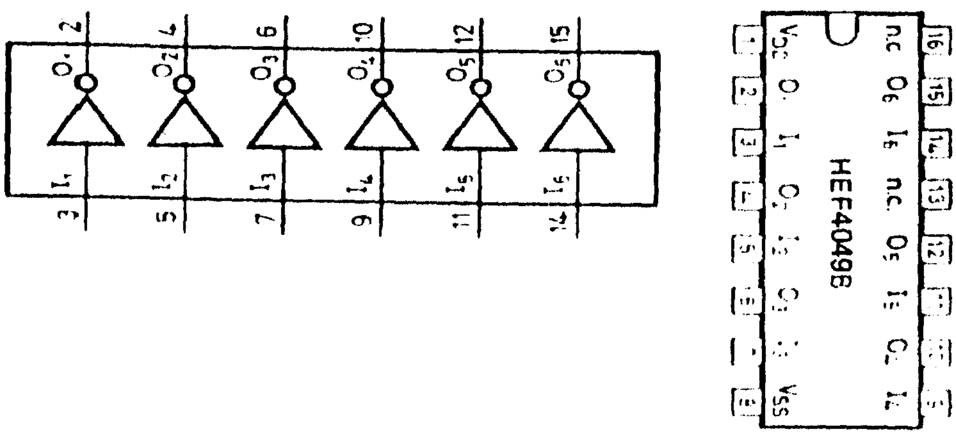


FIG. 3.22

BLOCK DIAGRAMS OF THE 4049 HEX INVERTING IC

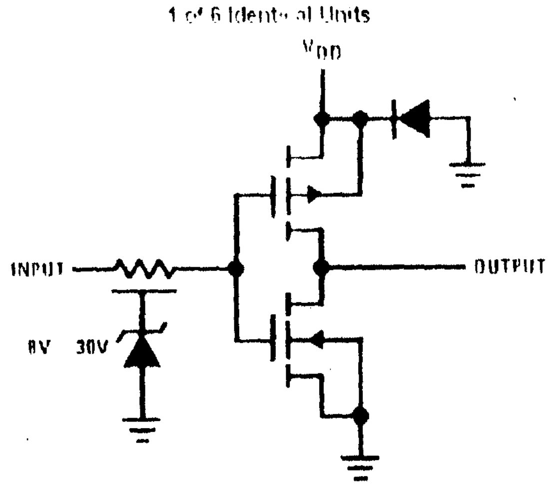


FIG. 3.23

SCHEMATIC DIAGRAM THE 4049 HEX INVERTING BUFFER

Physical Dimensions

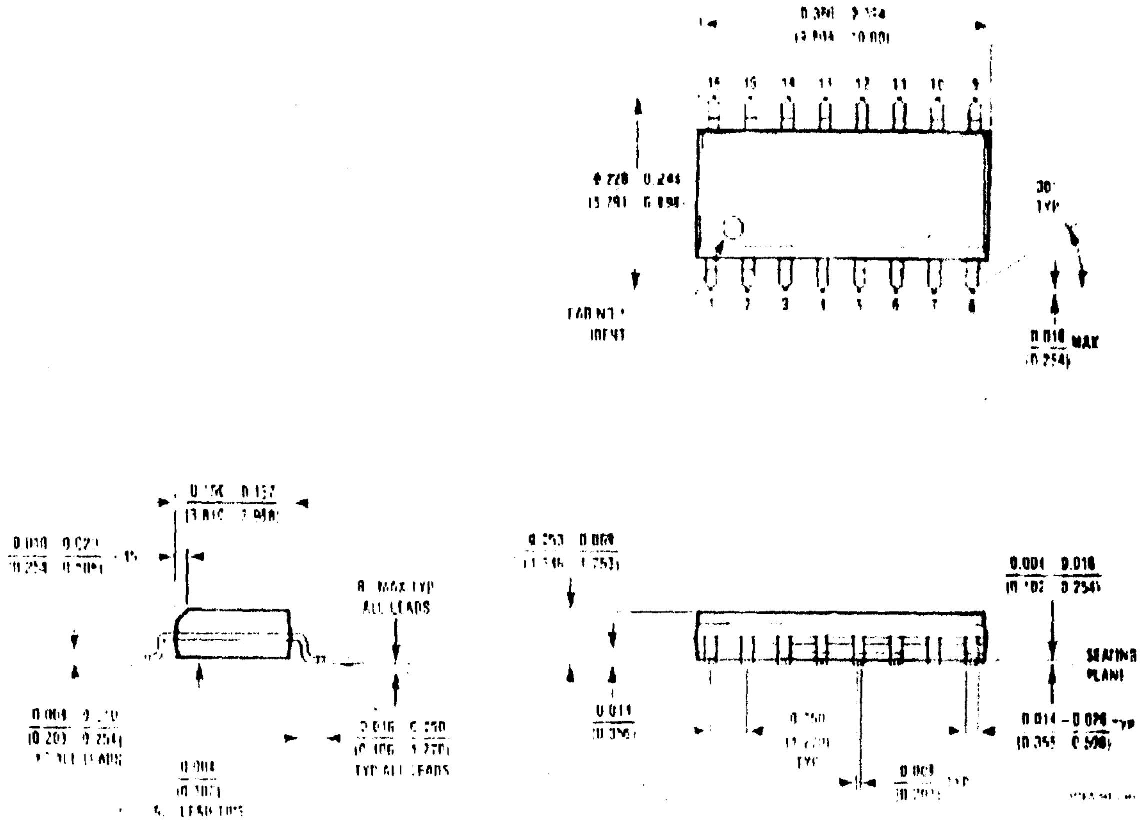


FIG. 3.24

PACKAGE DIMENSION OF THE 4049 HEX INVERTING BUFER

3.3.2 THE QUARTZ CRYSTAL RESONATOR.

A quartz crystal resonator is simply a circular piece of quartz with electrodes plated on inside an evacuated enclosure. Designing of resonators demands knowledge of mechanics, piezoelectricity and electronic circuit theory. Quartz is ideal for resonators because it is flexible, dimensionally stable, non-conducive, and most important, piezoelectric.

The piezoelectric effects link the mechanical and electrical properties of the resonator. Electrical voltages causes in mechanical movements. Likewise, mechanical displacement generates an electrode potential. Therefore, a crystal mechanical resonance can be treated as if it were electrical in nature.

Physical atomic displacement of an operating resonator is minuscule, generally only a few atomic diameters, but tremendous mechanical forces are in play. For example, the surface acceleration of a crystal exceeds five million gravities.

Resonator electric parameters are measured with crystal Impedance Bridge, a vector voltmeter, or a network analyzer. The impedance of a resonator varies sharply with frequency.

Resonators are passive. They do not oscillate without additional circuitry and a source of energy. A resonator, placed as a feedback element around an amplifier, makes an oscillator. The amplifier replaces energy lost in the resonator. The resonator controls the frequency of oscillation.

Two conditions must exist to start and sustain oscillations. First, there has to be a phase shift. Second, the gain around the amplifier must be equal or greater than one.

Crystal oscillator circuits traditionally are labeled as parallel or series resonant, with the crystal specified accordingly.

Crystal operates in the inductive region between series and parallel resonance.

3.3.3 THE 4049 HEX INVERTING IC AND THE CRYSTAL RESONATOR AS A RELAXATION OSCILLATOR.

Oscillation is a very natural phenomenon and you can see many different examples including physics, biology, chemistry, and electronics as well.

Oscillators are used in many electronic devices (computers, radios, quartz watches, wireless devices, etc). Their common purposes are to generate a periodic signal. Every oscillator has at least one active device acting as an amplifier. All rely on the same basic principle: employing an amplifier whose output is fed back to the input in phase. Thus, the signal regenerates itself. This is known as a positive feedback.

A relaxation oscillator is a circuit that repeatedly alternates between two states with a period that depends on the charging of a capacitor. The capacitor voltage may change exponentially when charged or discharged through a resistor from a constant voltage, or linearly through a constant current source.

For this project, the relaxation oscillator will be realized using a 40 kHz crystal and a 4049 Hex inverting CMOS IC.

Crystals has two modes of resonance, the series and the parallel resonances. In the series mode, the crystal shows low impedance at the resonant frequency. This impedance is on the order of 100 ohms to a few kilo ohms. In the parallel mode, the crystal together with a specified capacitance in parallel, normally 30 pF, shows a high impedance at the resonant frequency.

All crystals have resonances at the odd harmonics, 3, 5..., times the fundamental. At frequencies above 25 MHz, crystals are often made to operate at one of the harmonics. In all cases the external circuit must be made to suppress operation at the wrong harmonics or fundamental.

Normally crystals are specified for the parallel resonance mode. The circuit in FIG. 3.25 is designed for such configuration. The crystal and the 30pF parallel capacitor are here transformed into a pi filter network by dividing the 30pF capacitor into two 60pF capacitor and grounding the middle node. When one end is driven with low impedance, the network will have a 90 degrees phase shift at the frequency of maximum gain.

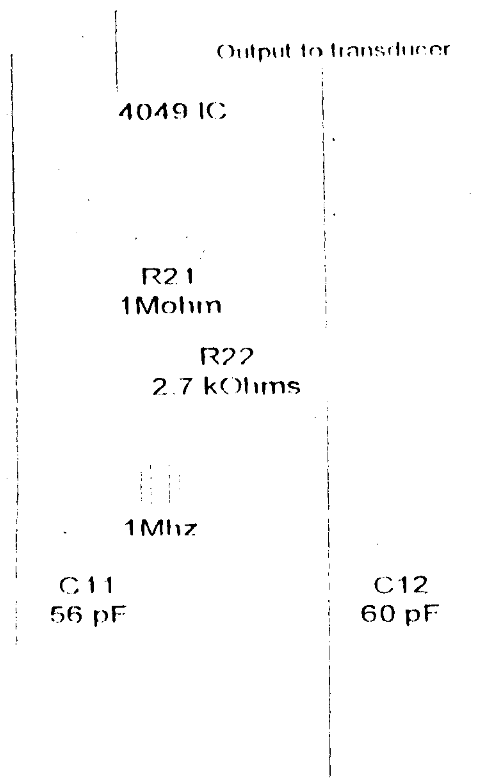


FIG. 3.25

CIRCUIT DIAGRAM OF A CRYSTAL CONNECTED IN THE PARALLEL RESONANCE MODE

With suitable driving impedance, the phase shift is brought close to 180 degrees, thus the 2.7 K ohm resistor. Other good reasons for it are that harmonics are damped by the resulting RC Filter, and that the inverter output is removed from the load of the crystal network. A rule of thumb for determining the value of the output to crystal resistor is that it should have the same impedance as the capacitor at the operating frequency.

$$R = \frac{1}{(2*\Pi*F*C)}$$

For a 40 kHz oscillator this resistor becomes 150 K ohm. The gain and 180 degrees phase shift of an inverter is now all that is needed to make this circuit oscillate at the right frequency with no twiddling necessary. The resistor between input and output is essential to put the gate in the range of linear operation so the necessary gain to start oscillation will be there. Since a CMOS inverter has very high input impedance, the value can be large. It is not critical, but a low value will increase power dissipation. The frequency is fine tuned by trimming the capacitors.

The circuit in FIG. 3.26 below shows the transmitter section of the ultrasonic motion detecting sensor.

FIG. 3.26

CIRCUIT DIAGRAM OF THE TRANSMITTER SECTION OF THE DETECTOR

The crystal is arranged in the parallel resonance mode. One of the 4049 sections, IC2-c, along with resistor R21 and R22, and capacitors C11 and C12, "pings" the crystal into sustained oscillation. The remaining 4049 sections act as linear buffers to drive the ultrasonic transmitting transducer, BZ2.

3.4 THE POWER SECTION.

3.4.1 THE THREE TERMINAL VOLTAGE REGULATOR.

The power section of the ultrasonic motion detecting sensor consist of a 9-volt battery, which directly provides power for some sections of the circuit, a 78L05 voltage regulator which provides a 5-volt DC power source for other sections of the circuit.

A block diagram of an active regulator is shown below. The capacitor stores charge from pulse to pulse. The control logic compares V_{out} (or some fraction of it) to a reference voltage and adjusts the series pass element to keep V_{out} constant. Thus if V_{out} starts to decrease, the series pass element is adjusted to compensate for the decrease. This type of regulator gets its name from the fact that the series element is continually adjusted; thus, active efforts are made to keep the output voltage at the preset value.

The following define the labels on the next figure,

SPE Series Pass Element, CL - Control Logic, Ref Reference

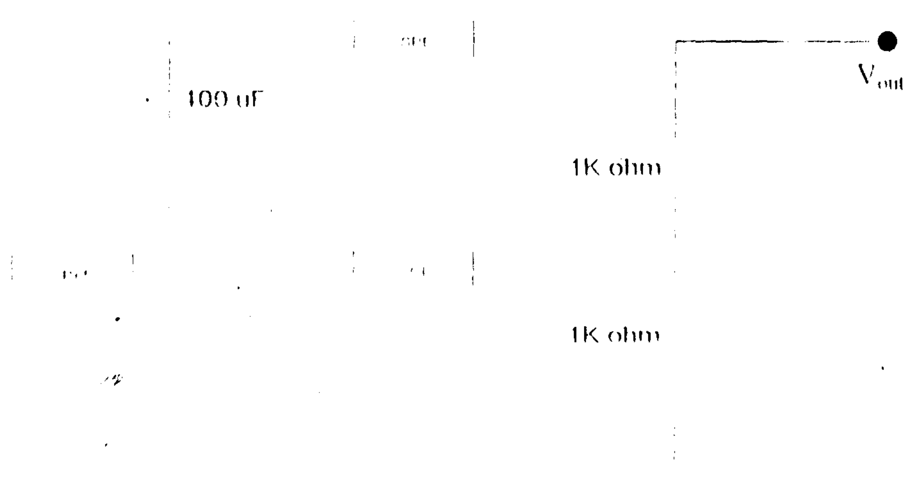


FIG. 3.27

SCHEMATIC OUTLINE OF A REGULATOR.

The LM78LXX series of three terminal positive regulators is available with several fixed output voltages making them useful in a wide range of applications. When used as a zener diode/resistor combination replacement, the LM78LXX usually results in an effective output impedance improvement of two orders of magnitude, and lower quiescent current. These regulators can provide local on card regulation, eliminating the distribution problems associated with single point regulation.

The voltages available allow the LM78LXX to be used in logic systems, instrumentation, Hi-Fi, and other solid state electronic equipment.

With adequate heat sinking the regulator can deliver 100mA output current. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistors is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Features of the 78L05 voltage regulator IC used include:

- Output voltage tolerances of ±5% over the temperature range.
- Output current of 100mA.
- Internal thermal overload protection.
- Output transistor safe area protection.
- Internal short circuit current limit.

- Output voltages of 5.0V, 6.2V, 8.2V, 9.0V, 12V, 15V.

The schematic equivalent of the 78LXX voltage regulator using transistors, diodes and resistors is shown in FIG. 3.21.

Equivalent Circuit

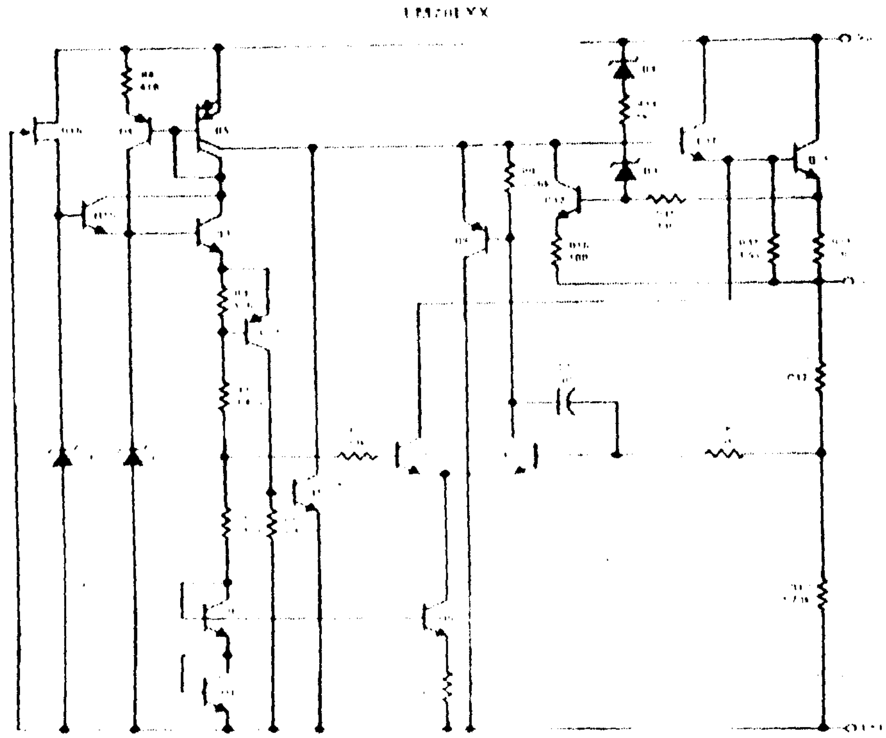


FIG. 3.28

EQUIVALENT TTL CIRCUIT REPRESENTATION OF THE LM78L05 REGULATOR

The schematic of the power section as used in the ultrasonic motion detecting sensor is shown in FIG. 3.29.The capacitor across the output improves the transient response.

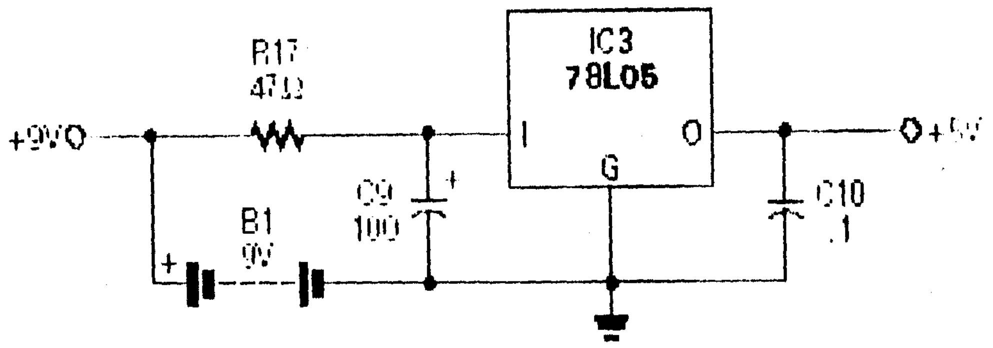


FIG. 3.29

CIRCUIT DIAGRAM OF THE POWER SECTION OF THE MOTION DETECTOR

The +9v output supplies power to the part of the circuit that requires 9 volts power and the +5v output gives power to the part of the circuit that requires 5 volts.

3.5 THE ULTRASONIC TRANSDUCER.

Measurements of thermal and electrical quantities are made by devices called sensors and transducers. The sensor is responsive to changes in the quantity to be measured, for example, temperature, position, or chemical concentration.

An ultrasonic transducer converts electrical signals into ultrasonic pulse and vise versa.

A 40-kHz transducer was used for this project. This transducer separates into two kinds for the transmitter and the receiver. For the transmitter, it is OD25 -16 and for the receiver, it is RD25-16. O denoting output and R denoting receive. 25 shows the resonant frequency of the ultrasonic (40 kHz). 16 shows the diameter of the sensor.

Below in FIG. 3.30 is a cross-sectional view of the transducer.

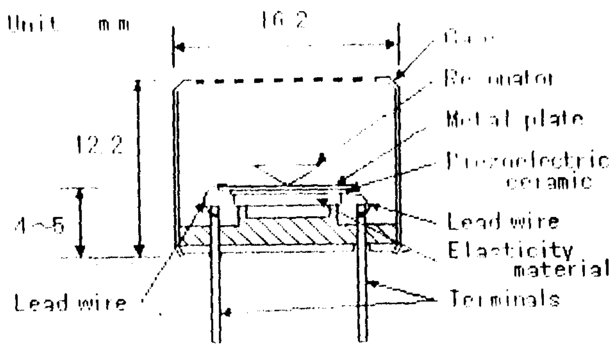


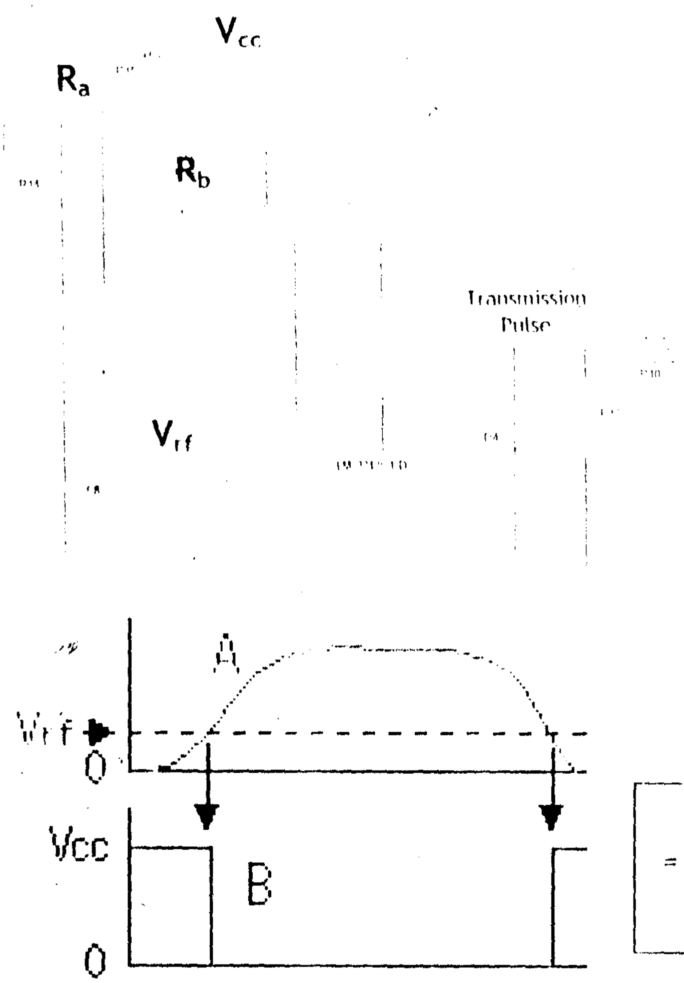
FIG. 3.30

CROSS-SECTIONAL VIEW OF THE ULTRASONIC TRANSDUCER

3.6. HOW MOTION IS DETECTED

Motion is detected at the fourth stage of the LM324 Op-amp. This circuit is the circuit which detects the ultrasonic which returned from the object. The operational amplifier amplifies and outputs the difference between the positive input and the negative input.

In this case the operational amplifier has no negative feedback, at a little input voltage; the output becomes the saturation state. Generally, the operational amplifier has tens of thousands of times of mu factors. So, when the positive input becomes higher a little than the negative input, the difference is tens of thousands of times amplified and the output becomes the same as the power supply almost (It is the saturation state). Oppositely, when the positive input becomes lower a little than the negative input, the difference is tens of thousands of times amplified and the output becomes 0 V almost (It is in the OFF condition). The output from the peak and window detector circuit is connected to the positive input of the differential amplifier and the negative input kept constant.



$$V_{rf} = (R_b \times V_{cc}) / (R_a + R_b)$$
$$= (100K\text{-ohm} \times 5V) / (10K\ \text{ohm} + 100K\text{-ohm})$$
$$= 4.5V$$

FIG. 3.31

<u>SIGNAL DETECTOR CIRCUIT WITH GRAPH</u>

So, when the rectified ultrasonic signal becomes more than 4.5 V, the output of the signal detector becomes the H level (Approximately 4.73V) and the transistor switch is activated, thereby activating the relay to activate the alarm circuit.

CHAPTER FOUR

CONSTRUCTION, TESTING, RESULTS AND DISCUSSION OF RESULTS.

4.0 INTRODUCTION.

Construction of the device was done using a Vero board and the various components were laid out according to the circuit diagram of FIG. 2.3.

4.1 CONSTRUCTION.

The initial stage of construction, which was the design and simulation, was done using an electronic computer aided design application known as **MULTISIM 2001 Power Professional Version** developed by **Interactive Image Technologies Ltd. U.S.A. 1992 - 1999 ©**

The components where then placed on a bread board as illustrated in FIG. 2.3 to simulate a real life prototype of the work. After this, the components where then moved and soldered to a Vero board.

A Vero board is a board lined with parallel copper tracks. The circuit is wired as shown in the circuit from FIG 2.3. The legs of each component are pushed through the holes on the top of the board and are soldered to the bottom of the board where the copper tracks are lined up. To join the components according to the circuit, strings of wire (jumpers) were soldered to the components or to the tracks corresponding to where a component was initially soldered. On the board, the approximate distance between the holes is 3.8mm.

Integrated circuit sockets were soldered to the board for the **LM324** - operational amplifier chip and the 4049 - Hex Inverting CMOS chip. The sockets are 14 pin and 16 pin sockets respectively. This enables easy changing of the chips in the event of a fault occurring in any of them.

4.2 SOLDERING TECHNIQUES.

The most fundamental skill to assemble any electronic project is soldering. The process of joining electrical parts together to form an electrical connection is called soldering. It involves using a mixture of molten lead and tin (solder) with a soldering iron (with a heating element inside of it).

A large range of soldering irons is available. The following are the characteristic that were watched out for when deciding on the type of soldering iron to be used.

Voltage: Most irons run from the mains at 240 V. However, low voltage types (e.g. 12V or 24V) generally form part of a "soldering station" and are designed to be used with a special controller made by the manufacturer.

Wattage: Typically, they may have a power rating of between 15-25 watts; a higher wattage means more power in reserve for coping with large joints.

Temperature control: The simplest and cheapest types don't have any form of temperature regulation. Simply plug in and switch on. Unregulated irons form an ideal general purpose iron for most work.

There is another type of soldering iron that does not run from the mains, they are called gas-powered soldering irons, rather, they use butane. They have a catalytic element which, once warmed up, continues to glow hot when gas passes over them.

Another type is the solder gun. It's a pistol shaped iron, typically running at 100W or more, and is completely unsuitable for soldering modern electronic components.

Soldering irons are best used along with a heat-resistant ***bench-type holder***, so that hot iron can be safely parked in between use.

A 240V 60W unregulated soldering iron was used in the process of constructing the circuit.

4.2.1 PRECAUTIONS.

i. The tip of the soldering iron was cleaned before soldering and any rust on it was scraped off.
ii. The legs of the components and any wires that were soldered were filed to remove any layer of oxidation and rust that could hinder the solder from solidifying firmly.
iii. The soldering iron was allowed to heat up properly so that the solder could melt when it was touched to the tip of the iron.
iv. The temperature of all the parts were raised to roughly the same level before applying solder, so that the solder will flow much more readily over the joint
v. When a soldered joint was allowed to cool, it was shaken to make sure the joint was firm.

4.3 TESTING.

Testing was done in stages using a digital multi-meter.

4.3.1 POWER SUPPLY.

The voltage source from the supply is switched on to supply power to the circuit. The current source is a 9V battery.

The output voltage across the regulator output pin was measured using a digital multi-meter when the battery was connected to the input voltage supply, with the ground being the ground pin of the voltage regulator. This voltage was found to be between 4.96v and 5.2v depending on how long the battery has been connected

4.3.2 THE REVCIEVER SECTION.

The LM 324 Operational Amplifier.

The voltage difference between pin 2 and 3 of the LM 324 Op-Amp was found to be -0.21v and the voltage at the output pin 1 being 4.14v.

The voltage at pin 7 was found to be 2.30v when there was no movement and 2.6v when there was movement.

The voltage at pin 8 was found to be 0v when there is no movement and 1.73v when there was movement.

The voltage at pin 14 was found to be 4.73v when there was movement and 0.03v when there was no movement.

THE OUTPUT INDICATOR.

The voltage across the LED was found to be 1.92v

4.3.3 THE TRANSMITTER SECTION.

This section is built around the 4049 Hex Inverting IC.

The voltage across the ultrasonic transducer was found to be 6.5 volts and voltage across the crystal resonator was found to be oscillating, the minimum recorded voltage was 1.92 volts and the peak recorded voltage was 3.16 volts.

4.4 RESULTS.

The alarm circuit designed by my partner, Ismaila Suberu, was connected to the trigger output of the ultrasonic motion detecting sensor and when motion was detected .i.e. a human standing in front of the motion detector moves, an alarm was sounded and the appropriate security department was dialed.

4.5 DISCUSSION OF RESULT.

It was discovered that when the moving object was more than 4 meters away from the motion detector, the detection was poor, though increasing the sensitivity helped; the motion detector was triggered even by air movement.

It was also discovered that if the circuit was often triggered, its sensitivity reduced and the battery power also reduces.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The design of the project is quite simple with readily available components. The objective of the project was achieved quite satisfactorily.

5.2 RECOMMENDATION

Firstly, the power section could be improved on by designing a separate power supply with input from the mains instead of using the battery.

Secondly, the ultrasonic transducer could be placed at places remote from the main circuit itself, places where it cannot be easily seen or discovered i.e. well hidden locations.

Thirdly, a microcontroller could be incorporated into the circuit and many transducer sensor placed at different location could be connected to the controller and LED representing the different location would light up when motion is detected at the location.

APPENDIX

A. Part List.

SEMICONDUCTORS

D1-D4	=	1N4148 silicon diode.
D5	=	1N4002 silicon rectifier diode.
IC1	=	LM324 quad op-amp integrated circuit.
1C2	=	4049 hex-inverter integrated circuit.
IC3	=	78L05 5-volt regulator integrated circuit.
LED1	=	Light-emitting diode, green.
Q1	=	BC639 NPN transistor.

RESISTORS

(All fixed resistors are 1/4-watt, 5% units.)

R1, R2, R15	=	100,000-ohm.
R3, R7, R18, R21	=	10-Megohm.
R4	=	2200-ohm.
R5	=	220,000-ohm.
R6, R20	=	1000-ohm.
R8-R10, R14	=	1-Megohm.
R11, R12	=	1.2-Megohm.
R13, R16. R19	=	10,000-ohm.
R17	=	47-ohm.
R22	=	150,000-ohm.
R23	=	1-Megohm potentiometer.

CAPACITORS

C1, C10	=	0.1-mF, ceramic-disc.
C2, C6, C7	=	0.01-mF ceramic-disc.
C3, C4, C8	=	0.47-mF ceramic-disc.
C5	=	100-pF, ceramic-disc.
C9	=	100-mF, 16-WVDC, electrolytic.
C11, C12	=	33-pF, ceramic-disc.

ADDITIONAL PARTS AND MATERIALS

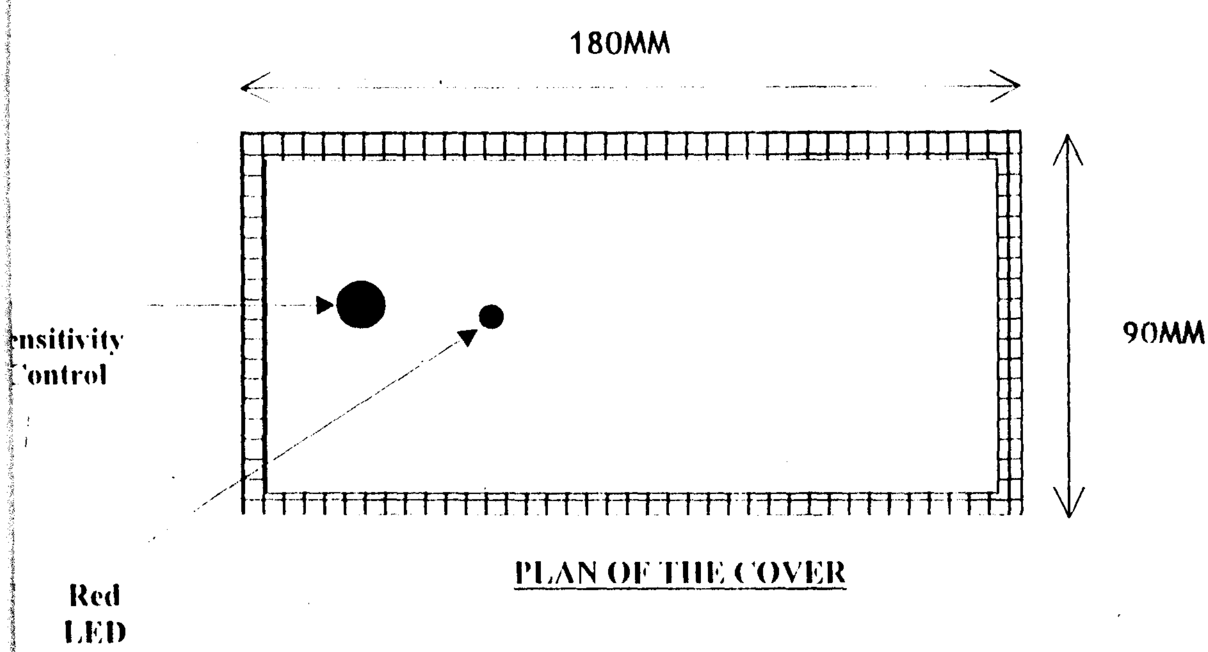
XTAL1	=	40-kHz crystal.
BZ1	=	40-kHz ultrasonic receiving transducer.
BZ2	=	40-kHz ultrasonic transmitting transducer.
B1	=	9-volt battery.

B. Design of the Casing

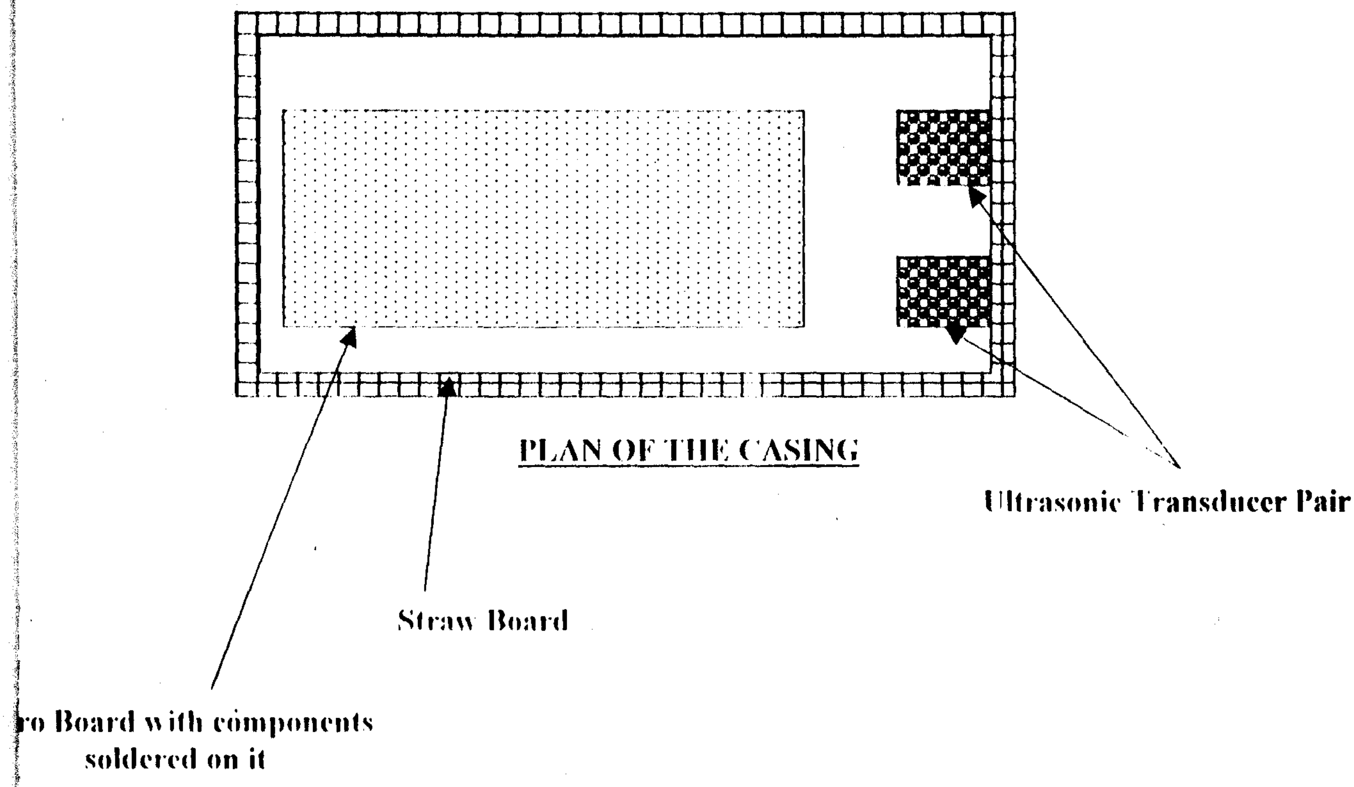
The casing fabricated for the device is made of straw board and covered with card board. Its dimensions are given below including the cross-section of the casing.

C. Plan and Side View of the casing

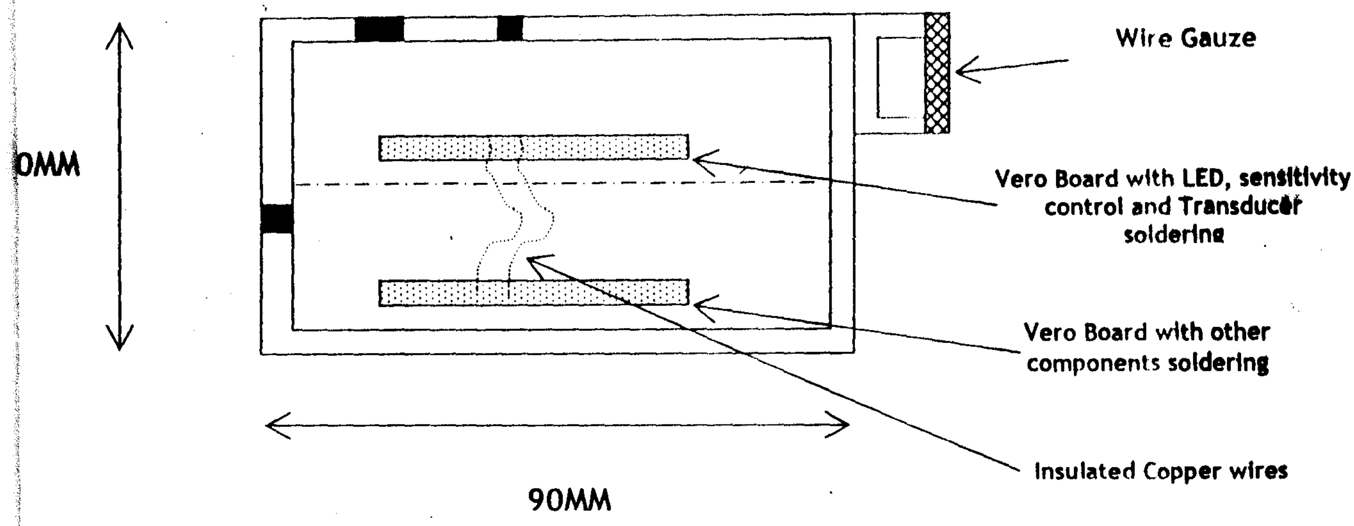
The dimensions of the casing are given as:



PLAN OF THE COVER

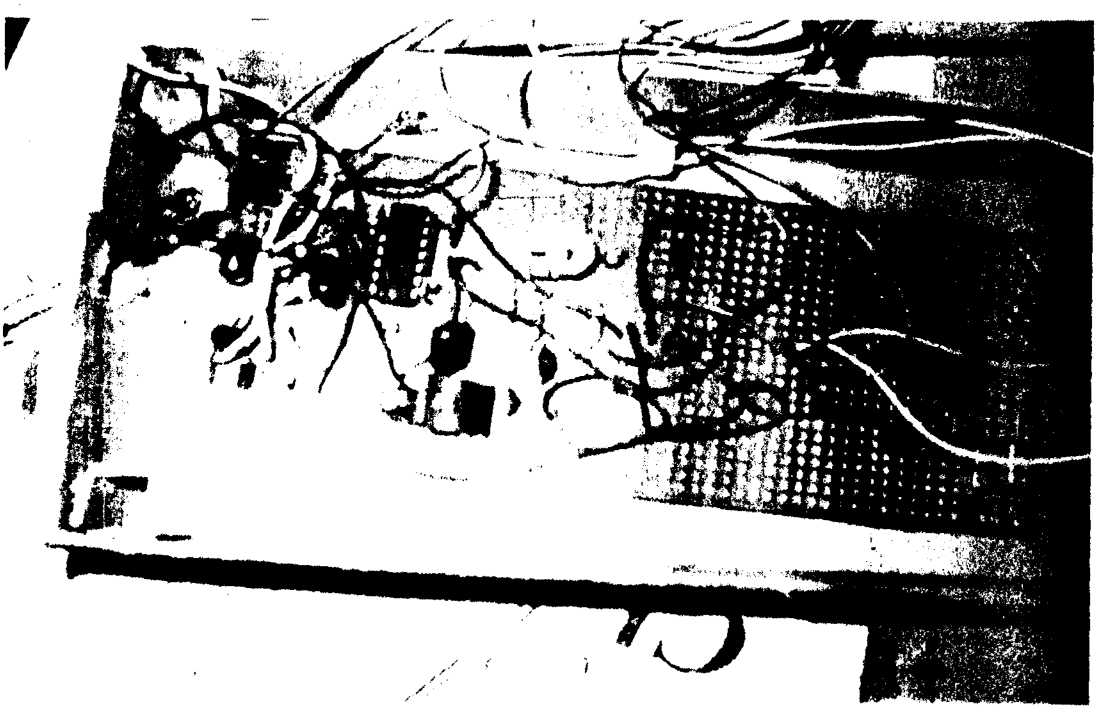


PLAN OF THE CASING

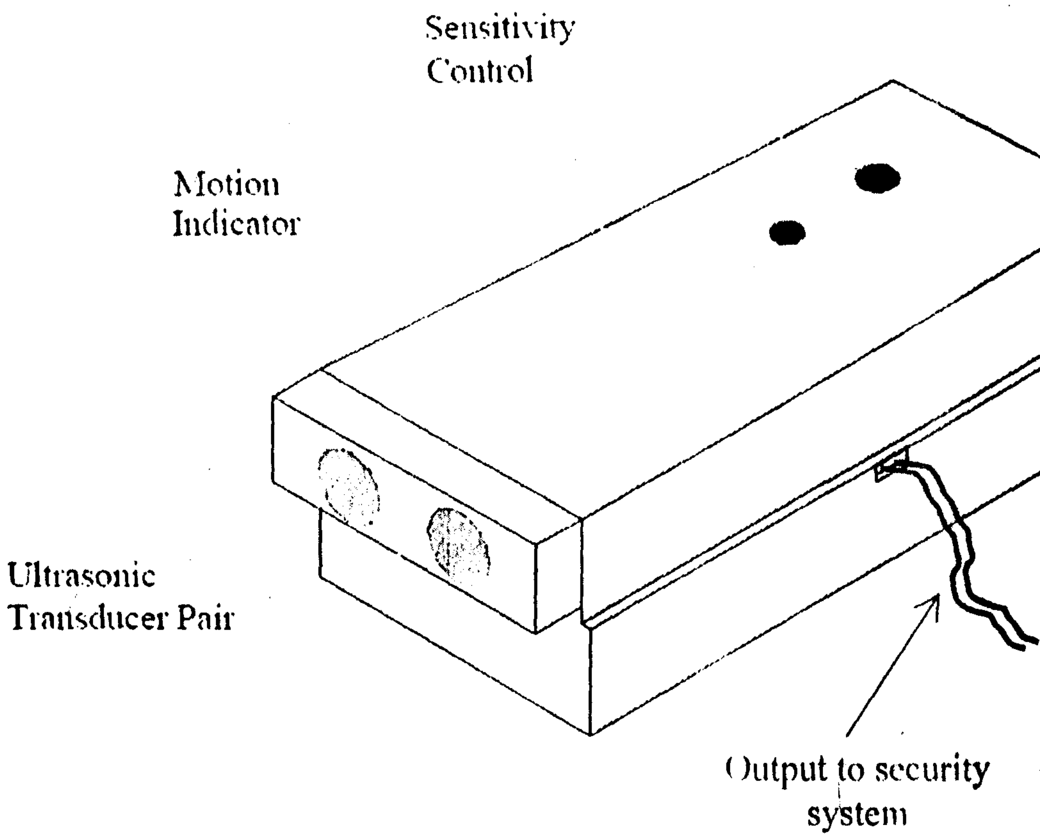


SIDEVIEW OF THE CASING

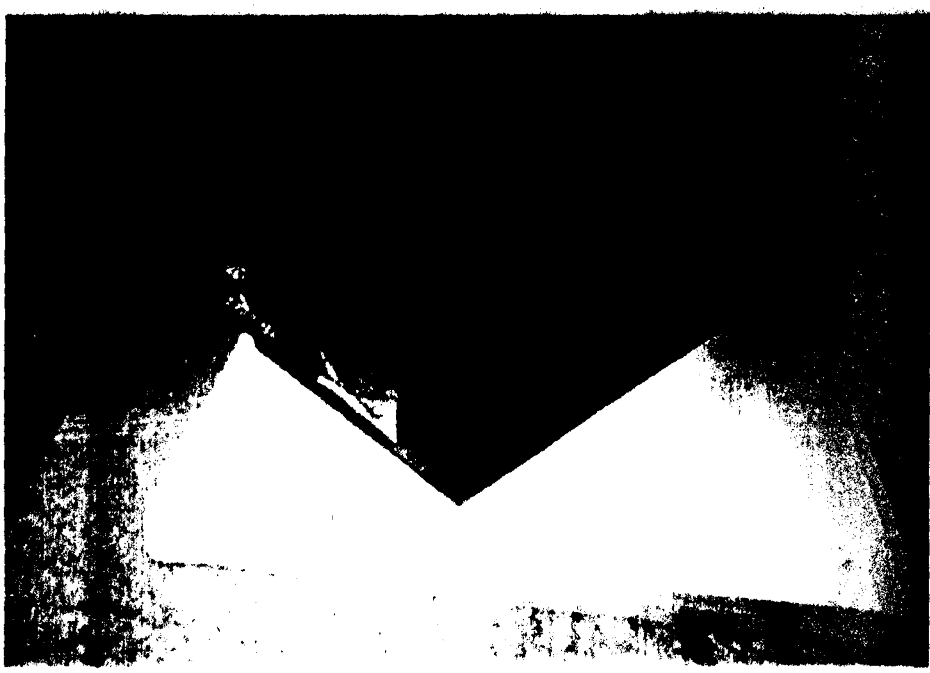
D: PHOTOGRAPH OF THE VERO BOARD WITH COMPONENTS SOLDERED ON



E: A 3D DESIGN OF THE CASING



F: PHOTOGRAPH OF THE PROJECT ON COMPLETION



GLOSSARY

GLOSSARY OF TERMS USED

Gain: Increase in value.

Inductance: The property of an electric circuit or component whereby an electromotive force is created by change of current in it or a circuit near it.

LED: Light emitting diode.

Magnetostrictive: Movement due to magnetic field effect.

Resistance: A property of an electrical circuit or component that shows its opposition to an electric current.

Resonance: A state of oscillation that occurs at a very specific. frequency in an electrical circuit consisting of inductive and capacitive components.

Piezoelectric: Electricity from crystals under stress.

Trajectory: Curves intersecting at a constant angle.

Voltage: Electric potential measured in volts.

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