DESIGN AND CONSTRUCTION OF AN ULTRASONIC FLAW DETECTOR IN METALS

BY

PETER AMOS

REG. NO 95/4435EE

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA.

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CERTIFICATION

This is to certify that this project titled "Design and construction of an ultrasonic flaw detector in metals" was carried out by Peter Amos under the Supervision of ENGR. K.K PINNE and submitted to Electrical and Computer Department of the Federal University of Technology Minna in partial fulfillment of the requirements for the award of Bachelor of Engineering (B. Eng.) degree in Electrical and Computer Engineering.

....

Project Supervisor Sign & Date

....

Head of Department Sign & Date

.... 17/1/2004

External Examiner Sign & Date

DECLARATION

I hereby declare that this project work is an original work of mine, and that it is a record of my own research work, which has never been presented elsewhere.

Amos peter Apeter ....

Name & Sign

12/01/2001 ....

Date

DEDICATION

This project work is dedicated to God Almighty, that has granted me divine favour to round up my course of study, and to as many that have contributed financially, socially and morally.

ABSTRACT

Described here in this project is the of the most fantastic areas of application of silent sounds i.e. an ultrasonic flaw detector incorporating Aural and Visual interface for fault identification in metals. Basically, this aim is being achieved with the help of an analogue an digital electronic circuit in which a short sharp pulse of a very high frequency is being applied to a piezo transducer which consequently develops a high frequency ultrasonic wave that is applied to a test piece of interest. These waves are reflected at any point of discontinuity, thus generating a fault signal larger than a preset defect standard thus actuating the LED's display and the headphone alarm.

ACKNOWLEDGEMENT

For every success, there are fathers to it, and if the completion of my Bachelors of Engineering degree programme is a success, then I owed it to a number of people, who have helped me in diverse ways.

I wish to give God the glory for what he has done for me. Nothing cn be done except by the will of God.

I am especially grateful to my parents especially my mother MRS. HANNATU MAKADI" who has not been tired of giving me the necessary financial and moral support.

In the course of writing this project, I'm indebted to my able supervisor Engr. K.K. PINNE for guiding me on how to go about writing this project and at the same time taking the pains to go through every aspect of the project. I say thank you for a work well done.

My special gratitude also goes to members of my able family: Miss Grace, Mr. Ibrahim, Mr.Ayuba, Mr. Bako, Mr. Simon, Miss Rahila, Miss Essther for the role they individually and collectively played during my struggle for Bachelor of Engineering degree education.

I must not fail to place on record my sincere appreciation to my project colleague student Engineer Elisha Tiyagnet most especially for making available his technical know – how for the success of the project.

Finally, I wish to thank all my friends Moses, Yunana, Suleiman. Abduallahi and so many other whose names the rule of the game does not permit me to mention.

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CHAPTER ONE

1.1 INTRODUCTION

By way of introduction, ultrasonic is the fascinating world of silent sounds. By way of definition, the term ultrasonic refers to the science and technology dealing with acoustic waves (elastic waves or stressed waves, i.e. mechanical waves), the frequency of which is higher than the nominal limit of audibility by human ear. Worthy of note in the aforementioned statement is the word nominal limit. It must be called nominal limit since it is not definable in exact terms, only on some statistical basis, because it also depends on sex and age, and it varies considerably from person to person. As a convention, 20kHz is usually taken as the lower frequency limit of ultrasonic waves and 500MHz as the upper frequency limit.

The word "flaw" on the other hand refers to any fault, error or abnormality in the internal or external structure of a material. Hence, the intention of this project titled "Design and Construction of an Ultrasonic Flaw detector" is to develop a simple instrument, which could be used, for a non-destructive test of metals by mills, forgers, fabricators, railways and insurance companies etc. by utilizing ultrasonic waves. The blooms, billets and slabs produced by these companies could be inspected for internal conditions such as cracks, segregations, inclusions or other internal discontinuities which will not only be injurious to satisfactory working and ultimate use but represents an economic wastage in terms of money and time used.

Ultrasonic waves are not new many animals have hearing that is sensitive to frequencies above the human hearing range. A dog for example can hear the high frequency whistle, but his master cannot. Some animals have been known to be equipped with ultrasonic sounding devices so that they can emit high frequency waves. Probably, the most familiar ultrasonic emitting and receiving animals are the porpoise and the bat. The porpoise cannot see further than 19 inches, under water; however it can emit radar-like ultrasonic waves which enable it to sense objects at great distances. Experiments have been conducted in which porpoises swim blind folded through an obstacle course. The porpoise emits sonic and ultrasonic waves in water. Water is a better medium for ultrasonic waves than air.

Over the years, man has tried to develop devices, which can "mimic" nature by reproducing ultrasonic waves basically; these reproducers (or transducers) can be classified as either mechanical or electronic. While mechanical reproducers are usually made from piezoelectric crystal material such as quartz, tourmaline, or Rochelle salt, the electronic reproducers could be formed from electronic – oscillator circuit. The resultant devices that have been produced, where used or applied in various areas of human endeavour ranging from sonar navigation and ranging (sonar) for measurement of the depth of water and finding under water obstacles to medical applications where the method of ultrasonic imaging is being used to produce light images of ultrasonic beams, and visual pictures of transmission through live tissues and have been used for the reproduction of pictures through sound and ultrasound holographic methods etc.

1.2 AIMS AND OBJECTIVES

The aims and objectives of this project "Design and Construction of an ultrasonic flaw detector are three fold:

a. To develop a simple low cost device which will ease the prevailing problem being encountered in manufacturing as regards the location of internal or surface discontinuities, determining structure and physical properties and measuring the thickness of metal from one side and at the same time and wastage of metals due to faulty castings.

b. To stimulate the interest of up coming students to take up research topics in advance field of study such as ultra-sonic.

c. To create the awareness and also make fellow students appreciate the wide scope and versatility in the application of ultrasonic inspection.

1.2.1 LITERATURE REVIEW

From time past up to date, the observation stands that scientists and engineers have contributed to the development and perfection of ultrasonic inspection techniques since early in the twentieth century.

Sololoff, in Rusia and Pohlman, Trost, Kruse, and Mulhauser in Germany, were among the first to investigate through transmission using continuous waves. Bergamn's "Derultraschau" is still one of the principal references on the principle pf ultrasonic testing.

A group of scientists, G.V. Blessing and D.G. Eitzen (1988) investigated the use of an ultrasonic surface measurement system for on-line monitoring of machined surface. By using normally incident, pulsed ultrasonic beams with wet or dry coupling, the average amplitudes of the echoed beam could be correlated to the arithmetic surface roughness values.

Similar work was also presented by Jones and others (1989). Although no quantitative analysis was presented other than graphical comparisons. More recently, authors (Y.C. Shin, S.A. Coker 1995), proposed a new ultrasonic method based on focused ultrasonic beams with non-zero incidence angle and demonstrated a possibility of in – process monitoring of surface roughness in wet and harsh manufacturing environment.

In England, Glass, Rankin and others interested in non-destructive testing developed equipment of the pulsed type with two-crystal operation. In the United States for example, Fire stone, Fredrick, Erdman, Wild, Reid, Carlin, Howry and many others contributed to the design and improvement of pulsed type ultrasonic testing instruments accessory B and C types presentations, defects recording and signaling accessories and scanning mechanism. Erwin and Rasweiler developed an ultrasonic-resonance method for measuring thickness from one side.

Branson also contributed to the development and refinement of resonance thickness testing equipment in the portable and factory type tester.

Worthy of note is that relatively recently (1995) U.G. Grimaldi and M. Parvis in a journal of international measurement presented a paper that is concerned with the modeling and reconstruction procedures of surface profiles using focused ultrasonic beams and noise-tolerant ultrasonic distance sensor system based on a multiple driving approach.

1.3.0 PROJECT OUTLINE

Chapter One of this project introduces the project, and reviews some of the related works done by other people. It also contains a mission statement as to why the project was embarked on and its importance.

Chapter Two presents the details of the design of the ultrasonic flaw detector incorporating a diode display and other interfaces for possible connection with a computer or oscilloscope. The chapter also begins by discussing the various sections that make up the project final design.

Contained herein this chapter also is detailed design calculations.

Chapter Three strictly concerns itself with the construction and testing of the project work.

Chapter Four discusses the results obtained and gives some recommendations for further improvement on the design. The final conclusion based on my findings is included herein.

CHAPTER TWO

2.1 THEORIES AND DESIGN ANALYSIS:

In much the same way that infrared light was used to detect the proximity of object, sound can also be used to detect internal flaws in metals.

For ultrasonic flaw detection in metals a short sharp output pulses of ultrasonic sound is send through transducer (transmitter) the sound bounces of on meeting any discontinuity and the echoes will return along the path of the transmitted beam. These echoes are picked up by another transducer (receiver), reconverted to electric signal and can be displayed on any readout interface.

2.1.1 SPEED OF SOUND:-

The speed of sound in dry air at 20^0C is 343.2m/s. contrary to common belief; the speed of sound does not vary significantly with pressure. Humidity can have a small effect on the speed of sound up to about 0.35% at 20^0C. The speed of sound varies proportionally with the square root of the absolute temperature.

$$C = C_0\sqrt{\frac{T(^0K)}{273.15}} = C_0\sqrt{\frac{T(^0C)}{273.15}} + 1$$

Where C_0 is the speed of sound at 0 ^0C 323.3m/s). Near room temperature, the speed of sound varies 0.18% per ^0C to about 1% per 10^0K?

2.1.2 OPERATING FREQUENCY:-

The operating frequencies of ultrasonic transducer vary from below 8kHZ to about 500MHZ or in wavelength from 4.3cm to 0.18cm. The lower frequencies are employed in long-range, high power application where absorption in the air is significant. Frequencies below 14kHZ have the disadvantage of being clearly audible. Higher frequency devices are more compact, produce a narrower beam and higher resolution and are better suited for shorter-range application where absorption is not a problem. In general, acoustic interference form other sources is likely to be a problem, at higher frequencies. Resolution tends to be proportional to wavelength, but is also a function of the sophistication of the associated electronics.

Beam divergence angles also vary with frequency because the wavelength is relatively long compared to the dimensions of the transducer. Ultrasonic energy does not propagate in a well-defined beam like light from a spotlight but rather in a diffused fashion, more intense at the centre and dropping off at the edges. The most common practice however, is to quote 3db-included angle that is the included angle at which the amplitude of the received signal has dropped to 0.707 of the maximum. The 3db include angle may be calculated for sensors radiating uniformly across a circular face using the relation.

$$\theta = 2 \text{ arc } \sin\left(\frac{1.6C}{f \pi D}\right)$$

Where C is the speed of sound, F is the operating frequency; D is the effective diameter of the transducer. Ultrasonic transducer also emits small amount of energy in side modes, which occasionally may result in spurious echoes.

The most suitable targets for ultrasonic transducer are flat, perpendicular surface, either solid or liquid. These reflect the acoustic energy directly back to the transducer. While surfaces at an angle reflect sound away from the transducer, flat surfaces stepped approximately one-half wave length can produce poor echoes due to destructive interference. Rough surfaces can be thought of as reflecting the acoustic energy that strikes them uniformly in all directions. For this reason a coarse bulk solid may often produce a stronger echo than a fine solid with the same angle of repose. The most challenging targets are liquid with large foam layers or diffuse solids that pack poorly; these tend to absorb rather than reflect sound.

2.1.3 GENERATION OF ULTRASONIC VIBRATIONS

Piezoelectric transducers are the most practical means of generating ultrasonic vibration in materials and detecting the transmitted or reflected position of the ultrasonic beam. This is because they have the inherent ability to transfer electrical oscillations into mechanical vibrations and mechanical vibration into electrical oscillations. Natural quartz crystals are most generally used and are mounted in an insulating material with suitable electrical contacts and coaxial cable connector. Other natural and manufactured crystals are also used and in some applications, to better advantage than natural quartz. Lithium sulphate and ceramics, which can be polarized, such as barium titanate, are two typical examples.

2.2. TRANSMITTER MODULE

This module is basically the origin of the ultrasonic wave using the voltage control oscillator (VCO). The piezo-electric transducer and the coaxial cable connector.

2.2.1 THE VOLTAGE CONTROLLED OSCILLATOR (VCO)

A VCO is an oscillator whose frequency can be varied by a voltage applied to its control terminals. The main requirements for a VCO are:

- a linear frequency/voltage characteristics,
- free running frequency easily adjusted to a wanted figure,
- good frequency stability

However, due to the unavailability of a VCO of the required characteristic as needed in this project, a special IC known as the phase locked loop Chip (PLL), which contains both a VCO and a phase detector, was used. The popular CMOS 4046IC was used.

2.2.2 THE 4046 PHASE-LOCKED LOOP INTEGRATED CIRCUIT

This is one of the most popular phase-locked loop IC chip. The pins connections are shown in Fig. 2.8. It can be seen that the IC includes the VCO, the phase detector, the amplifier and the portion of a low pass filter.

The VCO output is brought out to pin 4 and 11 to provide a CMOS compabtible square waveform, which is used to drive the piezo-transducer. The two input pins 3 and 14 must be given identical D.C biased voltages, some where in the range of 3 to 5 volt. The power supply requirement for the 4046 are form to 3 to 15 volt

2.2.3 THE PIEZO-ELECTRICAL TRANSDUCER

These are the most practical means of generating ultrasonic vibration in materials and detecting the transmitted or reflected portion of the ultrasonic beam. Contained here in this project, a disc plate of a tweeter speaker was used as the transducer, which also has the ability of transferring electrical oscillations into mechanical vibrations and vice versa. The structure of a piezo-electrical transducer and its electrical cable connections is shown in Fig. 2.3. The usual methods of applying the ultrasonic vibration are either by application of the transducers to the surface of the material or immersion of material and transducers in a transmitting liquid.

2.2.4 THE WAVE SHAPER CIRCUIT

This is basically a rectifier circuit used as a detector for the echoes received from the work peace. Incorporated with the network is a difference amplifier. The involvement of the difference amplifier here is owing to the fact that the detector cannot transfer a common (ground).

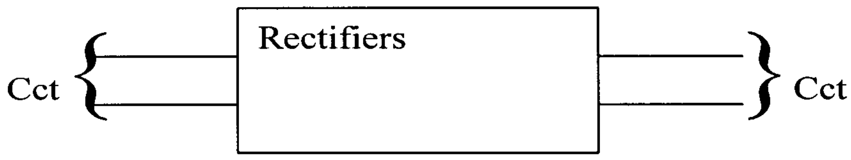


Fig. 2.0 (Rectifier Block Diagram)

The rectifier can only be grounded at one side, which is the A.C. side since it is fed from a single output op-amp, which must work with ground. The difference amplifiers can accept to the right hand side of the rectifier without the need for ground.

The transfer function of the rectifier is

$$\frac{2Vm}{\pi}$$

Where V_m is the amplitude of the output of the amplifier module. The rectifier is a bridge of germanium diodes. Germanium diodes generally have a low forward voltage drop. This improves the efficiency of the rectifier.

Note:- The formula

Is for ideal diodes

$$\frac{2Vm}{\pi}$$

THE DIFFERENCE AMPLIFIER

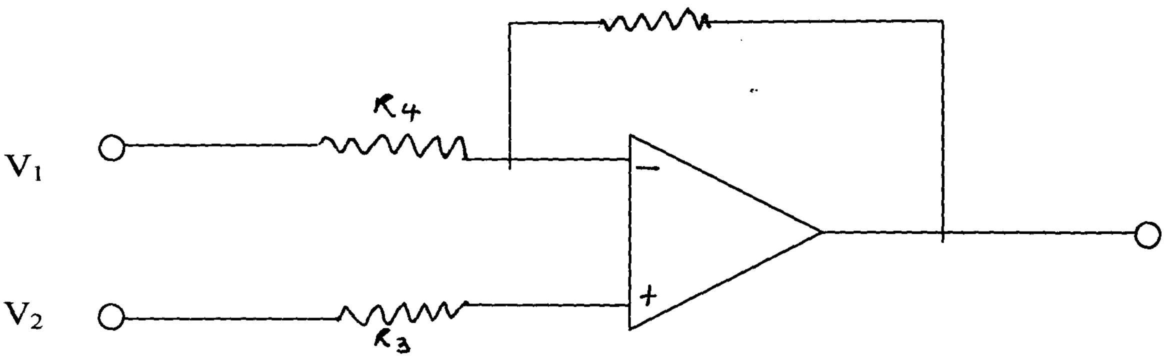


Fig 2.1 The Difference amplifier Circuit

$R_3 = R_1/R_2$. This is to reduce input biasing currents. R_3 thus depends on R_1 and R_2

$$V_3 = \left(\frac{R_1 + R_2}{R_1}\right)V_2 - \left(\frac{R_2}{R_1}\right)V_1$$

2.2.5 THE COAXIAL CABLE CONNECTOR

This has two conductors that share the same axis. A solid copper wire runs down the center of the cable, which is surrounded by a Teflon insulation. A plastic foam insulation, surrounded by a second conductor (a wire mesh tube) metallic foil. The wire mesh act s a shield and protects the wire from Electroplastic foam insulation, surrounded by a second conductor (a wire mesh tube) metallic foil. The wire mesh act s a shield and protects the wire from Electro-magnetic interference (EMI). The structural diagram of a coaxial cable showing its parts in shown in fig

2.2

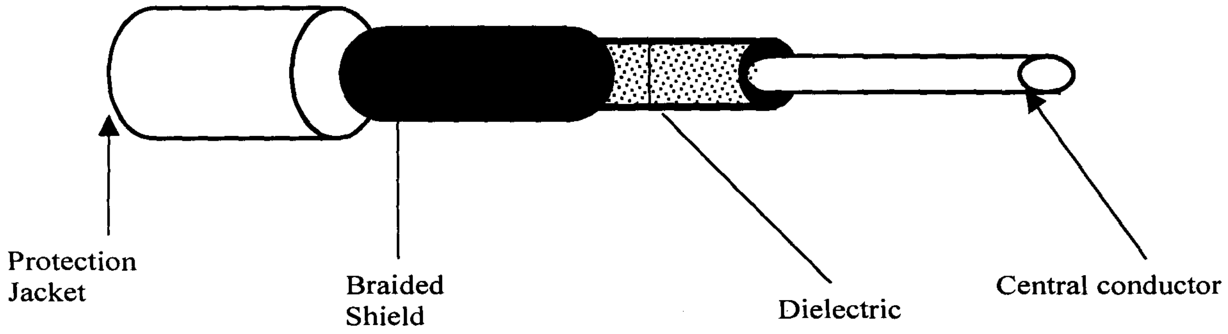


Fig 2.2 the coaxial cable

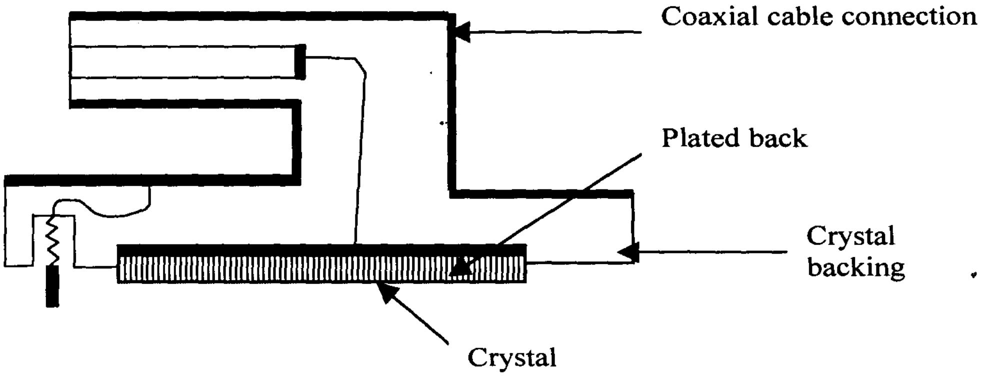


Fig 2.3. The Piezo transducer

2.3 THE RECEIVER MODULE

The module is basically aimed at recovering any reflected wave of sound, converting it into electrical signal, which should be compatible with the next module, which is a digital circuit of CMOS family. This module is composed of three major parts viz the pick up circuit, the voltage amplifier and the voltage converter (wave shaper).

2.3.1 THE PICK UP CIRCUIT

The pick up circuit consist of the receiving terminal and a high pass filter of the RC network type. Fig 2.4 shows the pick up circuit

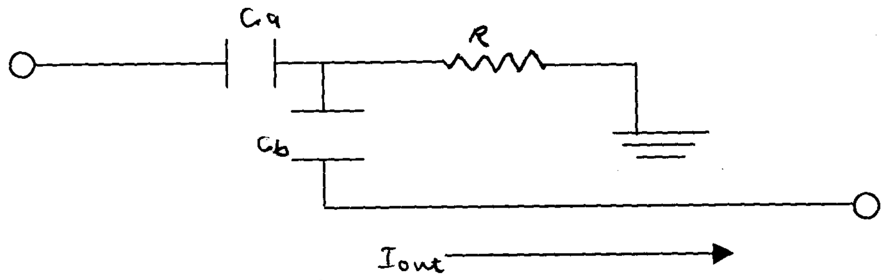


Fig. 2.4 The Pick up circuit

For the transfer function, if $I_{out} = 0$ (i.e. the output connected to a ideal op amp of infinity input impedance,) then the circuit act reduces to Ca and R

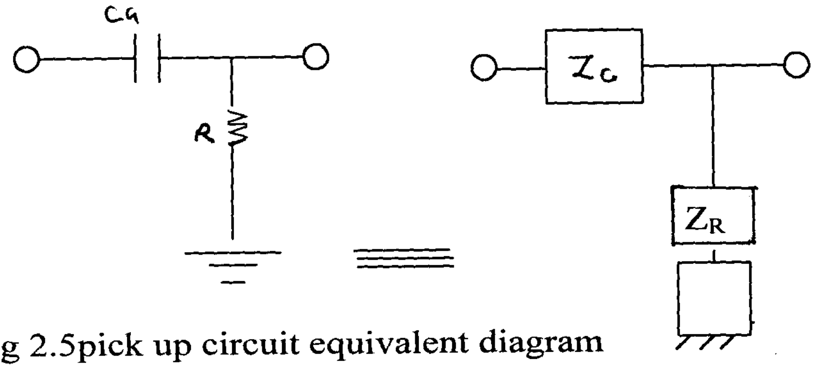


Fig 2.5pick up circuit equivalent diagram

Calculations:

It can be seen above that the two impedance Z_c and Z_r form a voltage divider act

$$\Rightarrow V_{out} = \frac{Z_R}{Z_R + Z_R} V_{in} \text{ but } Z_c = \frac{1}{j\omega c}$$

$$= \frac{1}{\sqrt{2\pi\, fC_a}} = \frac{-j}{2\pi\, C_a} \text{ and } Z_R = R$$

$$\text{Thus T.F} = \frac{V_{out}}{V_{in}} = \frac{Z_R}{Z_C + Z_R} = \frac{R}{R + \frac{1}{\sqrt{2\pi fC_a}}} = \frac{j2\pi fC_aR}{j2\pi fC_aR+1}$$

$$\text{Using the s domain; T.F} = \frac{sRC_a}{1+sRC_a}$$

$$\therefore \lim_s \overset{T.F}{\dashrightarrow} \infty \Rightarrow 0$$
$$\lim_s \overset{T.f}{\dashrightarrow} \infty \Rightarrow 1$$

This implies that a zero for T.F. exists at S = 0 only and D.C is the only kind of voltage with S=0. This implies that Ca filters or blocks D.C from flowing through the circuit. The input of the flaw detector varies due to the metal dimension and for this reason; a tank circuit is not used since it accepts only a particular frequency. Rca is calculated at T.F>0.5 at F>20KHz. Rca = $7.957\text{x}10^{-6}$, R = 780Ω and Ca = 0.01 uF.

2.3.2 VOLTAGE AMPLIFIER

This basically comprises two operational amplifiers stages cascaded together for high voltage gain. The received pulses or waveform from the metal is very weak; that is why it is of high gain.

The Op amp used is a FET input op amp, which has high input impedance for a better performance. The gain in voltage of the Op amp is presentable i.e.

$$\text{Gain} = A_v = \frac{V_{out}}{V_{in}}$$

Calculations:

V_{out} is required to be as high as 8 V_{pp} for a comfortable working of the voltage wave converter module. The input voltage V_{in} can vary due to metal attenuation and transducer frequency.

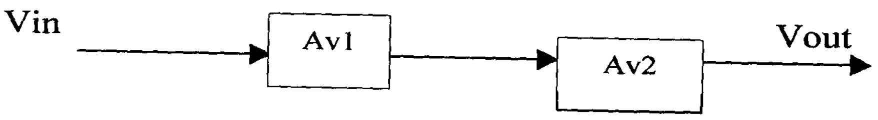
V_{in} ranges between 50uV to 0.1mV.

The gain should then vary between

$$\frac{8}{5.0\text{x}10^{-6}} \text{ and } \frac{8}{0.1\text{x}10^{-3}}$$

$$\Rightarrow 160\text{x}10^{3} \leq A_v \leq 80 \text{ x } 10^{3}$$

One of the Op am stages will have a fixed voltage gain and the other variable. The one with fixed Av will have its voltage gain not greater than 80x 10^3 and the other variable. The one with fixed Av will have its voltage gain not greater than 80 X 10^3



$$\Rightarrow Av = \frac{V_{out}}{V_{in}} = Av_1.Av_2$$

The variable one depicts the sensitivity of the devise. Its voltage gain can be derived to vary between unity and the ratio of the highest voltage gain to the constant voltage gain.

$Av_{max} = 160; Av_{min} = 80$

$Av_{const} = 80; Av_{1min} = \frac{Av_{min}}{Av_{const}} = 1$

Where AV_2 is the constant voltage gain (Av constant)

$$\Rightarrow A_{vmax} = \frac{AVmax}{AV_{const}} = \frac{160}{80} = 2$$

However, in practice, 80,000 is too high a voltage gain for an Op amp. A real Op am can have an open-loop gain less than that. To solve the problem, Av_1 and Av_2 can equally share their gains. This is done by finding the square root of the maximum gain.

Where n = number of Op amps used

I – the particular op amp of interest

$$\Rightarrow \sqrt[n]{A_{vmax}} = Av_I$$

Here, n=2, Avmax = 160,000

$\therefore$ Avi = 400

This implies that the first Op amp can have a fixed gain of 400 and the second have a variable of

$$\frac{8000}{400} < Av_2 < 400$$

$$200 < Av_2 < 400$$

The two Op amps are inverting amplifiers. Thus from

$$Av = \frac{-Rf}{Ri}$$

Then for $A_{v1} = 400$ then $R_{f1} = 400R_{i1}$

From table of resistors available in the market, combinations of 1.2kΩ as Ri and 470kΩ as Rf will considerable give a gain close to 400.

However, practically

$$Av = \frac{470k\Omega}{1.2k\Omega} = 391.667$$

Thus making A_{v2} to have a maximum gain of 408.51 to be precise. A_{v2} will have a minimum of 204.25. For this Op amp R_{rf2} will have variable values.

$$\frac{Rf_{2max}}{Ri_2} = \frac{Av_{2max}}{1} = 408.51$$

Thus making Av_2 to have a maximum gain of 408.51 to be precise. Av_2 will a minimum of 204.25. For this Op amp R_{f2} will have variable values.

Thus $Rf_{2min} = 408.51R_{f2}$……………………………….(1)

$Rf_{2min} = 204.75R_{f2}$…………………………………….(2)

But $V_{R1} = R_{f2max} - R_{f2min} \equiv$ Variable component of R_{f2} but variable resistors come in powers of ten and multiples of five. R_{f2} variable part has to be chosen.

Let $R_{f2max} - R_{f2min}$ be 100kΩ………………..(8). Then an equation can be formed.

$$\begin{array}{llllllll}
Rf2max & + & 0 & - & 408.51Ri2 & = & 0 \\
0 & + & Rf2min & - & 204.25Ri2 & = & 0 \\
R_{f2max} & - & R_{f2min} & + & 0 & = & 100 \text{ X } 10^3
\end{array}$$

Substituting (1) and (2) into (2)

$408.51R_{i2} - 204.25R_{i2} = 100 \text{ X } 10^3$

$\Rightarrow \quad 2R_{i2} \ - \quad R_{i2} \quad = \quad 489.596$

$\Rightarrow \quad R_{i2} \quad = \quad 489.596\ \Omega$

470Ω can easily be obtained from the space parts shop.

Thus $R_{i2} \quad = \quad 470\Omega$

Thus R_{i2max} = 470 x 408.52 = 191.997kΩ

= 200KΩ

R_{f2min} = 470 X 204.25 = 9599.75Ω

= 92kΩ (fixed) since 92kΩ is available in the spare part shop

Rf1 92kΩ 200kmax

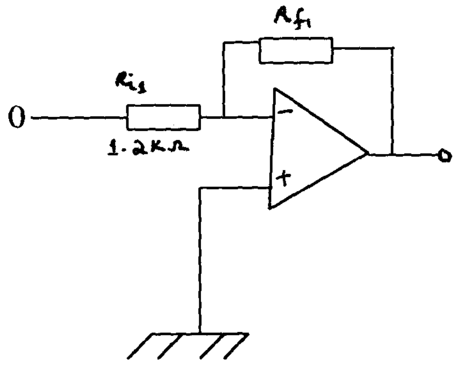


Fig 2.6. First amplifier stage

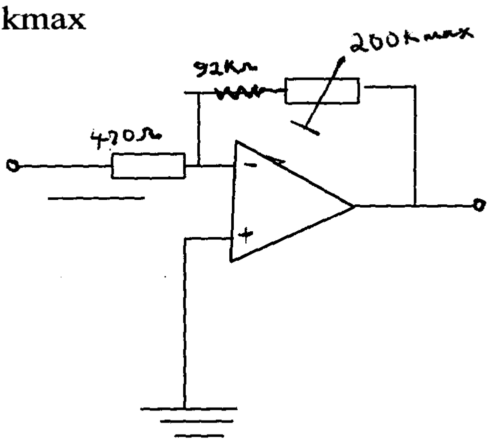


Fig 2.7 second amplifier stage.

Wave form. The value of this coupling capacitor is ideally large so as not to offer reactive impedance to the ultrasonic frequency voltage signal.

$$Z_c = \frac{1}{2\pi fC}$$

If $f \geq 20$kHz then Z_c = 7.95 µf

Z_c approaches unity as C approaches 7.95uF. At least Z_c must be less than unity thus $C \geq 7$µF.C here can be bought as 10uF from the shop.

If $R_2 >> R_1 + R_2 \approx R_2$ since most of the voltage amplification is achieved by the previous 2-stages cascaded voltage amplifiers, the gain here is not critical.

The gain $\frac{V_3}{V_2 - V_1}$ is approximately = $\frac{R_2}{R_1}$ (where R2 >≳ R1)

Note that V_3 should be saturated wherever a difference in V_2, V_1 voltage exist. A gain of 20 can be approximated.

⇒ 20Ω can easily be obtained from the shop.

C_5 is the filter capacitor while R_{16} is to discharge C_5. Using the formula ripple

$\% = \frac{V_dCT}{R_LC}$ where $R_L = R_{16}$ and since

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

for larger $\frac{T}{20}$ = 1 kHz i.e 50µ sec for $T = \frac{1}{\text{upper freq.}}$ The larger T is used here

$$V_dC = \frac{2V_m}{\pi}$$

Where V_m varies with reception of echoes. If has been designed that V_m is expected to be alone circuit noise and must be approaching V_{dd} (saturation). A compromise of V_m being half of V_{dd}

$$\text{i.e. } \frac{9}{2} = 4.5 \Rightarrow \frac{4.5x2}{\pi} = 2.86478v$$

$$\text{Thus } \frac{2.86478 \text{ x } 50\mu \text{ sec}}{R_LC} = \frac{2.86478 \text{ x } 50}{R_{16}C_5}$$

$R_{16}C_5 = 143.239\mu\Omega F$

Choosing 0.1 μ F for C_5, then $R_{16} = 1.4329k\Omega$

$R_{16}=1.5K\Omega$

2.4.0 THE DIGITAL READER INTERFACE

This module is aimed at presenting the information from the reflected ultra sonic beam or the energy transmitted through a material. There are many different method of presenting this information. However, in this project, the aural and visual method incorporating an audio headphone and a bar of light emitting diodes (LED's) was used for reasons of simplicity and economy. Certain LEDs or the audio circuit are actuated by defect signals larger than a preset defect standard using grating circuit with adjustable discriminator lever.

2.4.1 THE PHASE LOCKED LOOP (4046):

This is a PLL. Its components are VCO, phase detector [type I and type II] and some miscellaneous features such as lock indicator for LED. For the project, the phase detectors are not needed: only the VCO is needed for oscillation. The VCO output frequency is given by

$$F = \left[\frac{K}{R_T C_T}\right] [V_{in} - V_B]$$

Where K = a constant which solely depends on chip and on V_{dd} slightly.

V_B is a threshold voltage below which oscillation is not possible. V_B is about 18% V_{dd}.

$\Rightarrow K \infty V_{dd}$

However, a better quality square (pulse) wave output is got when V_{dd} approaches 15V. It is very difficult to get up to 1MHz with 5V V_{dd}. Similarly, distortion in output is observed at high frequency.

The chip as shown in fig 2.1 (a) has pin 5 "INHIBIT" which is active high, for use, it is connected to Vss (low). V_{in} is provided by potentiometer for which the user can vary the pulse time.

2.4.2 THE NOR-GATE (4078)

This is an 8-input NOR gate without any additional features. The NOR gate output is given by the expression

$$Y_i = \overline{A+B+C+D+E+F+G+H}$$

Where Yi is output. The diagram showing the pins of the NOR gate is shown in Fig. 2.9

2.4.3 THE AND GATE IC (4082):-

This is quad 2-input AND gate of CMOS family packed in a dual in-line package (DIP). Supply voltage is 3 to 15 volt.

2.4.4 THE HEX INVERTER IC (4069)

The schematic diagram showing the pins is shown in Fig. 2.10. It is a Hex inverter NOT gate without additional features. It is represented by the Boolean expression $Y_i = \bar{A}_i$ i.= 1,2,3,4,5,6

2.4.5 DEMULTIPLEXER (4514B)

This is a triple mode digital LSI IC of the complementary mosfet family. It is packed in a 24 pin dual-inline plastic case. A schematic showing the pins and the 16 lines output of the demultiplexer IC is shown in fig. 2.11

The realization of demultiplexing a signal from one line to sixteen lines using the demultiplexer mode was used.

Latch Component	**Comment**	**Pin**
Strobe	To write into latch	1
INHIBIT	To read latch	23
4 BIT SELECT	WORD (data to be latched	2,3,21,22

To read record WORD = $\overline{\text{inhibit}}$. Word (reader EQUATION) => to write a word, we use the equation

Write WORD STROBE = WRITTEN WORD

When the above named I.C is used as a decoder, the necessary requirements are as follows:

Components	**Requirements**
STROBE	1
INHIBIT	0
4 bit Select	WORD INPUT

However, when it is used as a demultiplexer as was the case in this project, the requirements are as enumerated below:

Components	Requirements
STROBE	1
INHIBIT	Signal input
4 bit Select	Address (4-bit) of LED

2.4.6 DUAL DECODER/DEMULTIPLEXER (4555B)

This is a two mode digital MSI I.C of CMOS family. Its function is 1. Decorder (dual) 2. Demux (dual). It is basically a 16pin Decoder/Demux is needed. Fig 4.0 and Table 4.0 shows the schematic of the pins and a state table showing the input and output respectively.

From the table in fig. 4.00 it can be observed that

$SO = \bar{E}\bar{A}\bar{B} = D\bar{A}\bar{B}$

$SI = \bar{E}\bar{A}B = D\bar{A}B$

$S2 = \bar{E}A\bar{B} = DA\bar{B}$

$S3 = \bar{E}AB = DAB$

Where the input "D" is wired to the Enable E as $\bar{D} = E$ or $\bar{E} = D$

2.4.7 RIPPLE COUNTER I.C (4040)

This is basically a modulo 12 ripple counter, i.e. it is capable of dividing any frequency by 2^0 to 2^1,......2^{12} ie 64K maximum. Mathematically, it implies that state n is

$$\frac{1}{2^n} f_0 =$$

Where f_0 is the input frequency and n is the counter's modulo

i.e Bin (p).............$\sum p\ 2^{12}$

Bin (p).............12^{12}......I $\sum p > 12^{12} \times I$ where I = 1,2,3,4..

Where also Bin (P) is a binary word generator e.g. if p=10 pulses say i.e. 10 ripples then

Bin (p) – Bin (10) = 1010_2. This I.C is also CMOS packed in 16 pin DIP with an active high preset as shown in fig 4.1

2.4.8 TH 555 TIMER IC

The 55 timer IC is used as an astable multivbrator to drive the headphone, which is used for the aural detection of flaws. The schematic of the 555 timer as an astable multivibrator is as shown below.

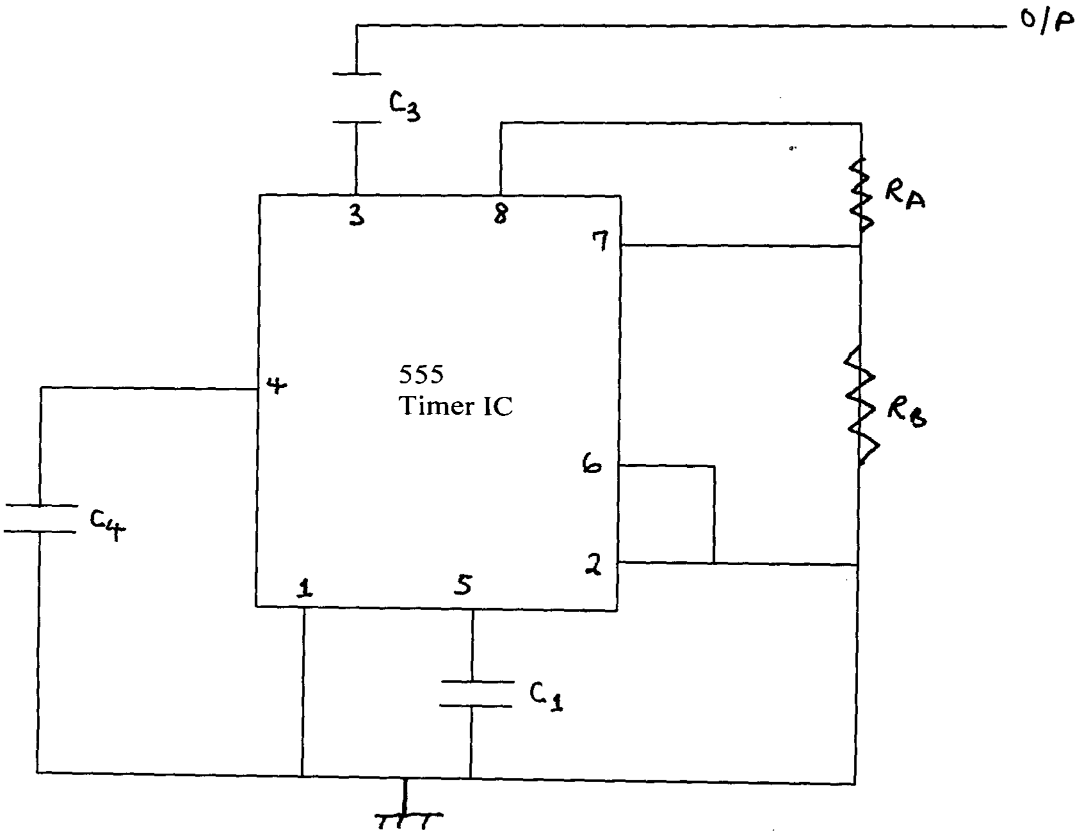


Fig 2.8 The 555 timer

The 555 timer frequency is fixed at 1.5 KHz for the Beep.

From $F = \dfrac{1.44}{(R_A + 2R_B)C}$ $R_A = R_4$, $R_B = R_5$.

$$=> 1.5 X 10\text{-}3 = \frac{1.44}{(R_A + 2R_B)C} => (R_A + 2R_4)\,C = \frac{1.44}{1500}$$

$$= 0.0009533$$

Choosing c = 0.1uF then $R_A + 2R_B = 9.533K$

Choosing $R_A = 1k$ so that $R_A << R_B$ for a good duty ratio

Thus $2R_B = 9.5k - 1K$

= (8.5K)/2

= 4.25k

The closest value is 4.7kΩ

The same values for R_{16} and C_5 is used for R_{18} and C_9 respectively

The same values for R16 and C5 is used for R18 and C9 respectively

2.4.9 OPERATING PRINCIPLE

This device basically displays a time graph. That is Bar graph depicting time. The time referred here is the time to travel for the ultrasonic wave.

Pulses are generated by the oscillator at ultrasonic frequencies in which one out of 16 pulses is selected by logic combination. The rest of the pulses (15 pulses) are used as the "wait for return" (read Echo) state.

The wait return mode is when the device switches from transmitting a pulse to receiving one form the tested piece.

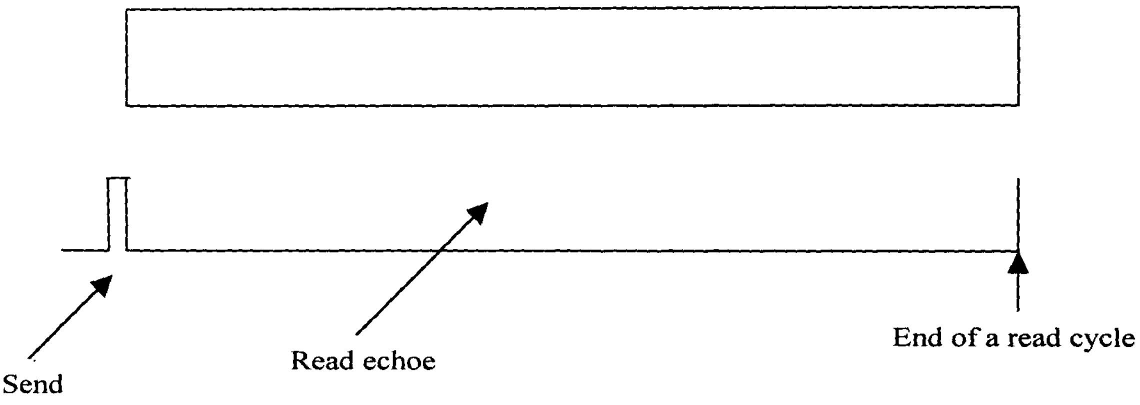


Fig 2.9 A diagram showing operating principle

By choice of convenience, the same transducer can be used for the receiving if the job piece is too large to be scanned from both of its sides. However, two transducers were used in this project i.e. when reception location has to be different from the transmitting location and when the job piece is small.

The potentiometer is used in presetting a convenient time to travel value for the metal concerned. This is done by observing the bar graph, which is lit on power on. The LED's that go off denote signal (pulse presence). Since waves travel on. The LED's that go off denote signal (pulse presence). Since waves travel with a given velocity. This implies that the length of the test piece is proportional to T (i.e. period of read cycle).

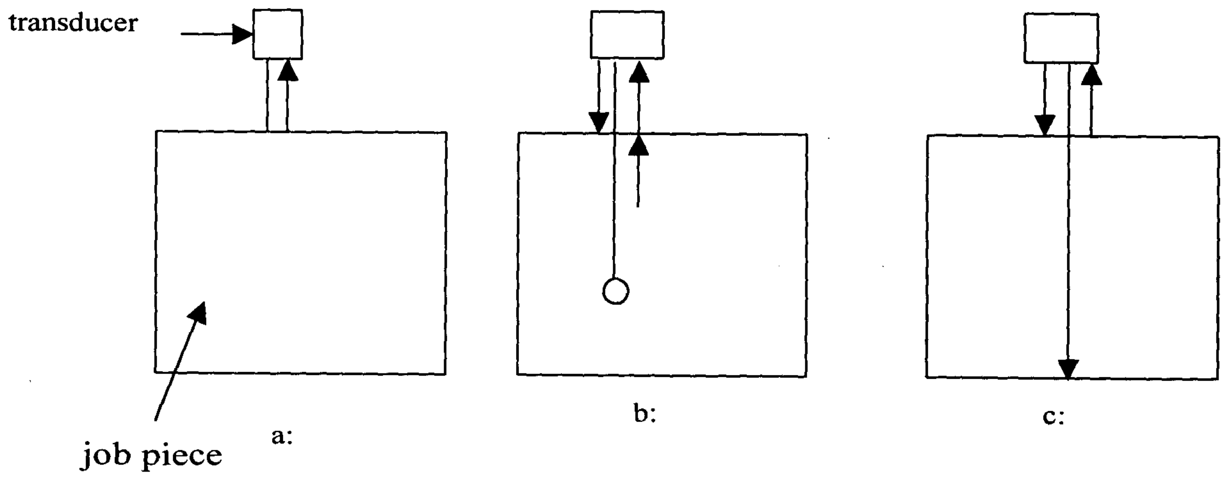
Thus the potentionmeter helps adjust the length (depth) of the job piece by varying the frequency of the VCO.

However, for a single transducer; there are three regions of interest on this bar graph.

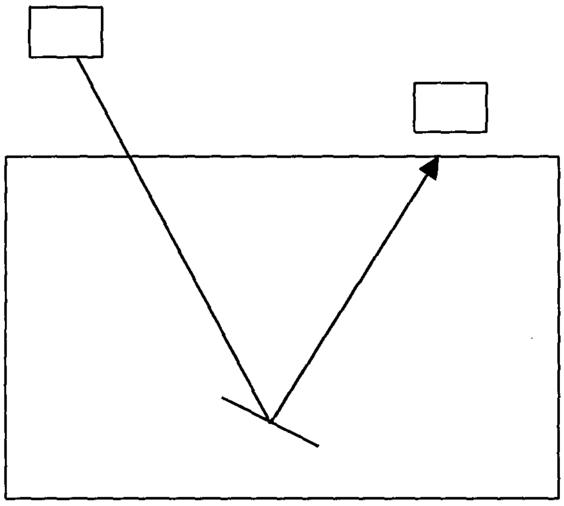
a. **The first region** – This is due to some reflection at the first phase change i.e. when the wave is incident on the surface of job. There is generally a change in medium at which partial reflection occurs. This reflection is received as an echo. This is observed by the first few LED's going off. [The presence of echo turns off the LED's]

b. **The internal fault region** – This sums up way into the middle of the bar graph. This depict the internal reflection of wave if an only if there is faults.

c. **The last boundary region** – This is the change in medium at the other end of job piece. Here, the total internal reflection occurs.



Reflection is easier done at incident angles far less than 90^0. This type of tests uses two transducers.



In summary the first few and last few LEDs go off. If however, the last few are on then it is either that the time that was given for wave travel is too small such that the bar graph closes (ends) before the echo returns. On the other hand, echoes occurring right in b region can be due to too long a read. So the VCO frequency will have to be adjusted to get a: and c: region as far apart as possible from each other.

CMos 4046 PLL IC

Voo=3 to 15V.

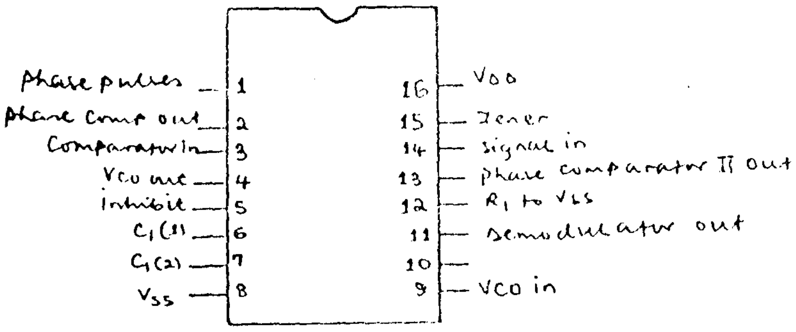


fig 2·8(a)

8 input NOR gate, Voo = 3 to 15V
(4078)

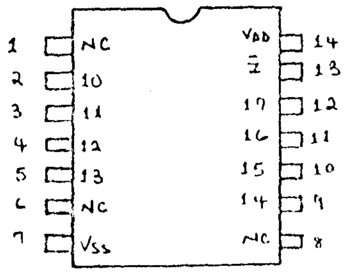


fig 2·9(b)

4069 Hex inverter, Voo = 3v to 15V

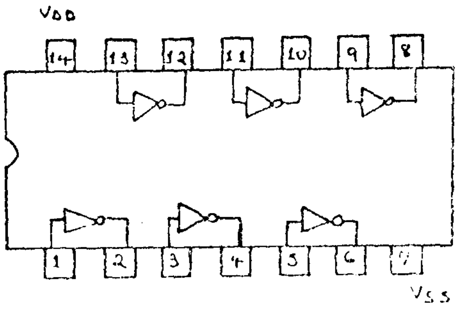
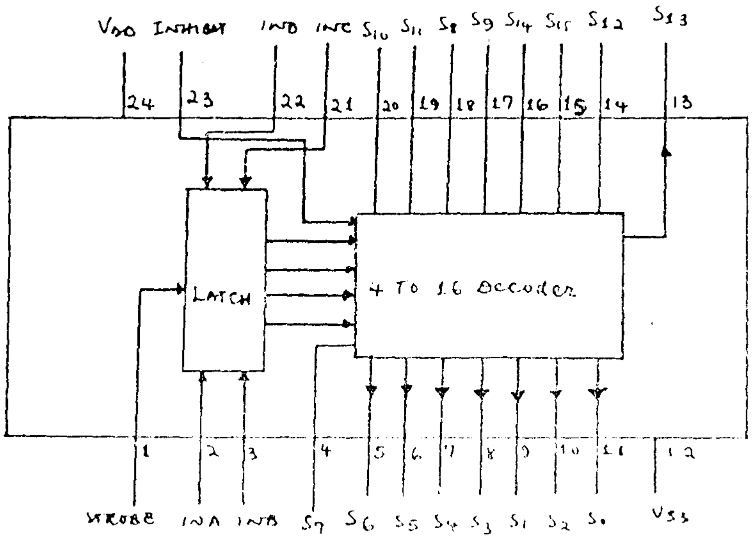
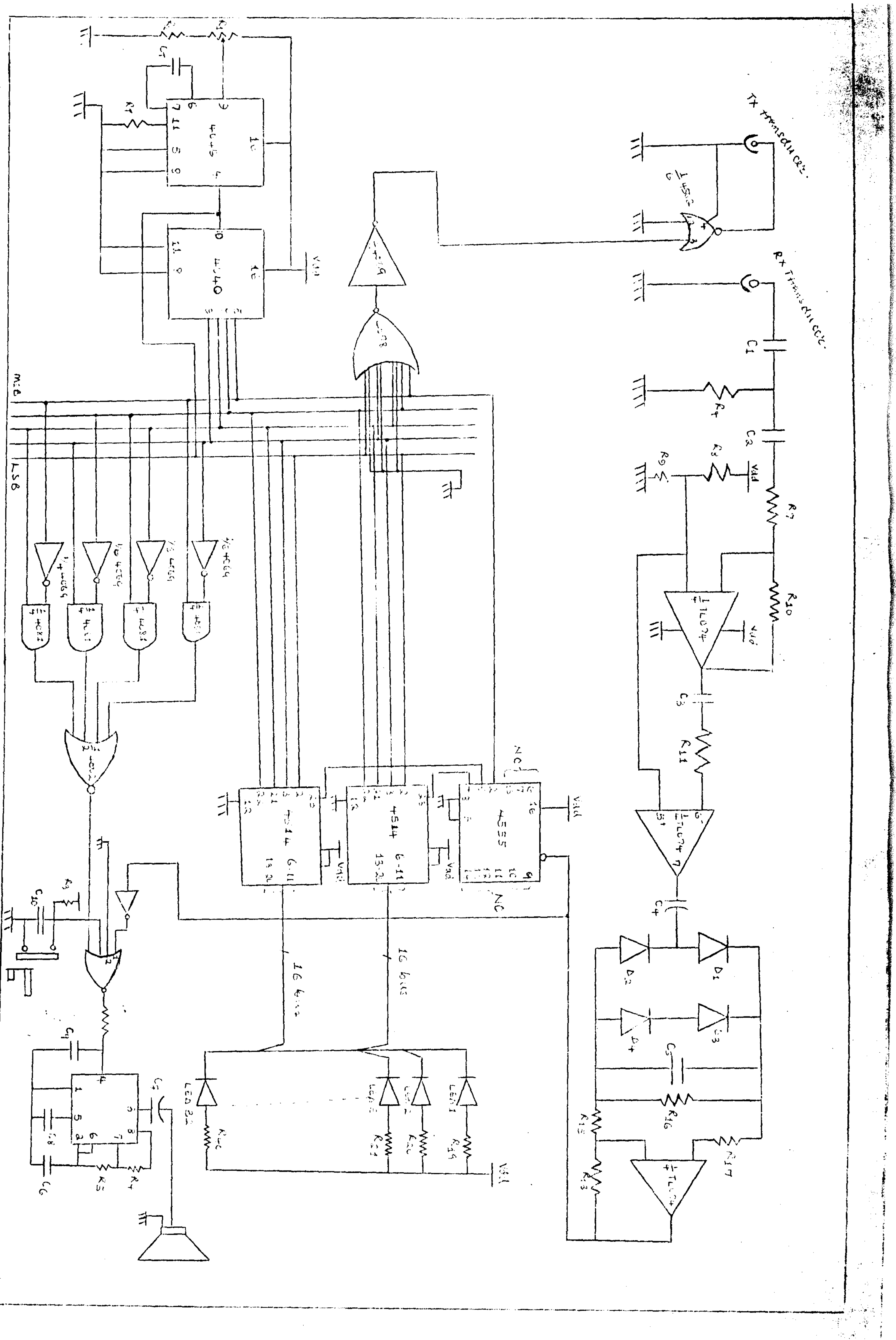


fig 2·10(1)

4-bit Latch/4-to-16 Line Decoder (Active high), VDD = 3V to 15V.





ULTRASONIC FLAW DETECTOR CIRCUIT DIAGRAM

CHAPTER THREE

3.1.0 CONSTRUCTION

The components that were used are as follows:

Capacitors C1 through C4

C_1 = Ca = 0.01μF

C_2 = Cb = 0.01μf

C_3 = 22μf

C_4 = 22μF

Germanium diodes (X 7 units)

Current limiting resistors for LED: Total 32 resistors of the range 330Ω – 1 KΩ

32 units of L.ED out of which one is given in colours and other red

R_1 = 1.2k

R_2 = 470 = R_3

R_4 = 92k

R_5 variable resistor = 200k max

R_6 = 10k

R_7 = 200k;

Piezo-electric sounder (1 unit/2 unit optional

Audio cable (phone cable)

Potentiometer (1 unit)

Phone jack (4 units)

Battery terminal

Strands of telephone wires for inter connections.

9V Battery unit (1)

Beeper of Head phone jack

14 pin IC base 4 units

16 pin I.C. base 4 units

8 pin I.C. base (1 unit)

15, 24 pin I.C. base 2 units

Linear I.C TL 074 (quad Op-amp)

Digital Ics as follows:

4514	(2 units)
4002	(1 unit)
4078	(1 unit)
4555	(1 unit)
4046	(1 unit)
HA 17555	(1 unit)
4069	(1 unit)
4502	(1 unit)
4040	(1 unit)

(Equipment)

The tools required for the construction are as follows:

(i) Soldering iron

(ii) Soldering lead

(iii) Multimeter tester

(iv) A cathode ray oscilloscope (CRT)

(v) Picker

(vi) Cutter

(vii) Vero-board 24by 55 holes (2 units)

(viii) Bread-board

(ix) Long-nose plier

(x) 220-240V mains supply

A plan (layout of the stripped board is made on plain paper to show where each I.C. is to be connected. This is drafted by:

1. Counting how many I.C.'s are involved
2. Assessing how many I.C. a board can accommodate
3. Considering the relationships (Interface) between each of the I.C.s

4. Using the plain sheet as the board area, then using a pencil, rectangle are drawn in it.

e.g

a=4078

b = 4082

c =……

d =……

etc

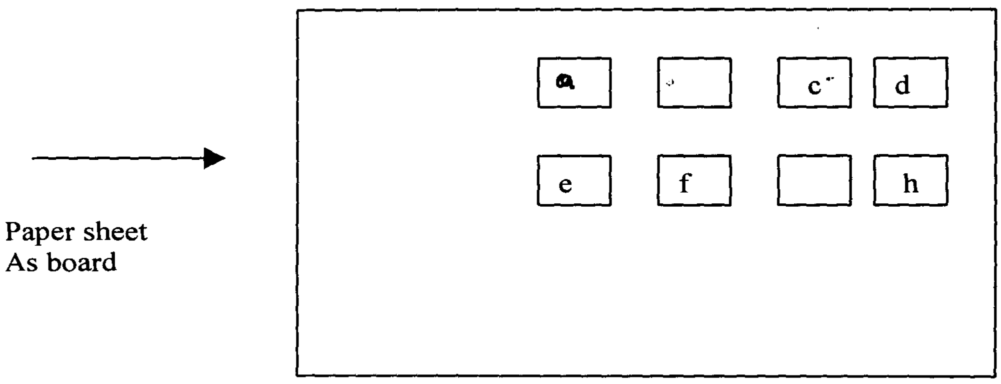


Fig 3.0 Layout of IC arrangements

After planning the board/board. Another planning has to be done. This has to do with interconnections.

A table is made for each I.C Each table is titled by the I.C. it has two and #+1 rows where # is the number of pins that I.C has.

The first column contains the pin numbers of the I.C. starting from pin 1 to # The second column contains what is connected to that corresponding pin of the I.C. as shown below

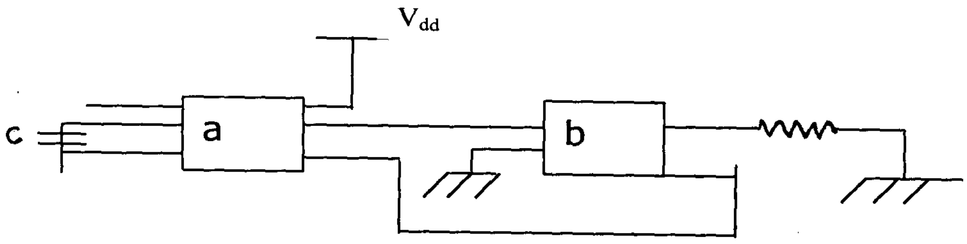


Fig 3.1 A typical IC interconnection

Table 3.0

#	IC a
1	NC
2	C (pins I of C)
3	C (pin II of C)
4	Pin 5 of b
5	Pin 1 of b
6	Vdd

Table 3.1

#	IC b
1	Pins 5 of a
2	NC
3	Vss (GND)
4	NC
5	R to Vss
6	Vdd

After all these connection, soldering can then begin using the layout; all I.C bases (I.C Sockets) were inserted in the strap board according to layout. The diagonal pins of the basin are then bent on the other side of the board (solder side) t hook them on the board so as no to fall off.

Using these connection tables, telephone wires are cut to lengths and inserted into holes relevant to the interested pins of the I.C, each I.C. is connected one at a time from its table. Towards the end of the connections i.e interconnections one will always discover reflections of connections. i.e. interconnections already done by other I.C.s so there will be no need to repeat that connections.

In addition to the above, the different interconnections were later tested using a digital multimeter for shunt faults. Any detected faults must be corrected before ending the soldering. It was however noted that common faults occurring beyond the space allocated.

3.20 TESTING

To test the ultrasonic flaw detector the oscillator producing the energy to power the transducer is switched on. This oscillator is usually pulsed so that is produces short sharp output pulses of perhaps several hundreds per second. This short output pulse will then be applied to the transducer, which is usually coupled to the castings. Similarly, the second transducer is being placed on the other end of the test piece.

As the waves travel along the test piece, any defect that is encountered along the test piece will consequently generate a defect signal, which is larger than a preset defect standard thus actuating the alarm, which is represented by the going off of certain LED's

CHAPTER FOUR

4.10 CONCLUSION

The objectives of this project work has been achieved to large extent: viz to construct a simple inexpensive device which could be used for the non-destructive test of metals for internal conditions, and to arouse the up-coming students interest to take up challenges in advance project topics.

Aural and visual techniques were used for the identification of faults thus Eliminating the necessity of using an oscilloscope to visualize the defects which is usually very expensive to afford and required a skilled personnel to operate it.

However, little problems were encountered such as the unavailability of a certain made piezo-transducer that suits my specification hence making the device not working to design specification. Also the unavailability of certain gates in I.C form, which however were improvised from discrete components, was a problem.

4.20 RECOMMENDATION

Following the strategic importance of ultrasonic testing in manufacturing industries, and the successes and limitations so far-recorded in this project work. I wish to recommend as follows:

- Better and custom made peizo-electric transducer which can accommodate higher frequency signals should be employed.
- Other methods of visualizing defects e.g. using the computer by the provision of suitable interface ports should be considered in future developments.

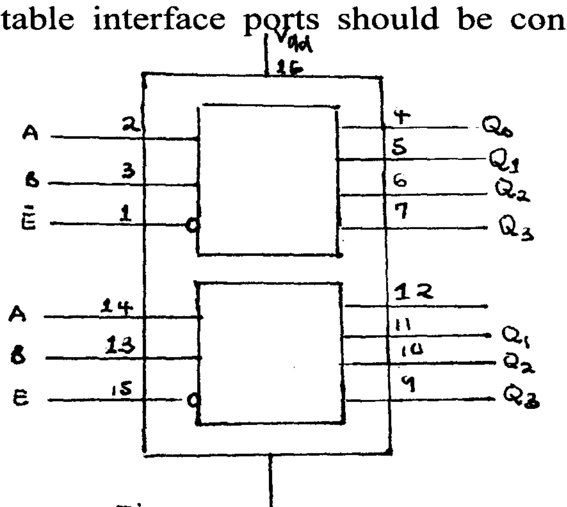


Fig 4·0 dual decoder / demultiplexer

Fig. 4.0 Dual Decoder/Demultiplexer

Table 4.0 showing inputs and outputs

I	N	PU	T		OU	TP	UT
A	B	E	E	S0	S1	S2	S3
0	0	0	1	1	0	0	0
0	1	0	1	0	1	0	0
1	0	0	1	0	0	1	0
1	1	0	1	0	0	0	1
0	0	1	0	0	0	0	0
0	1	1	0	0	0	0	0
1	0	1	0	0	0	0	0
1	1	1	0	0	0	0	0

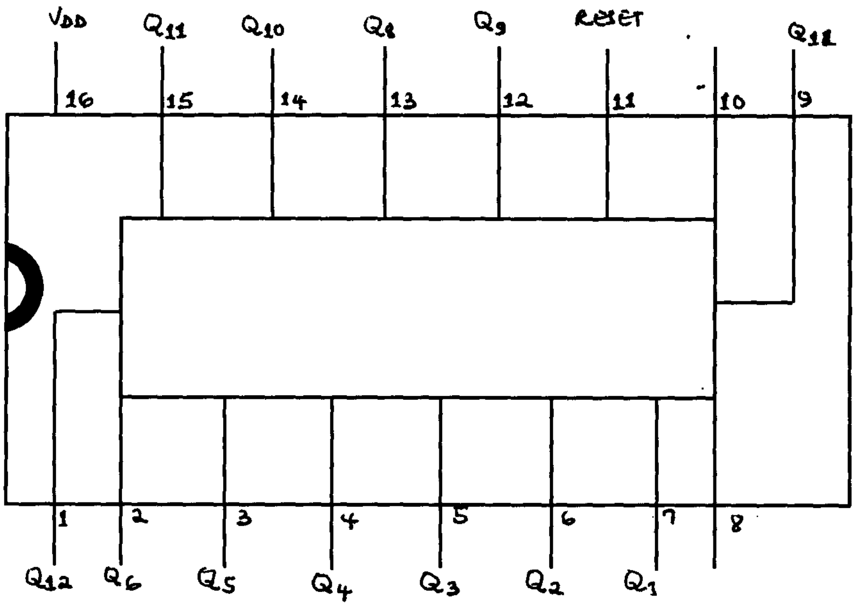


Fig. 4.1 Ripple Counter I.C.

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