DESIGN AND CONSTRUCTION OF A METAL DETECTOR

BY

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DECLARATION

I hereby declare that this project work is a genuine one, which wholly and solely designed and constructed by me under the supervision of DR Y.A.. Adediran . Information derived from published and unpublished work of other has been dully acknowledged in the text.

CERTIFICATION

The undersigned certify that this project titled DESIGN AND CONSTRUCTION OF A METAL DETECTOR by Anagbe Helen with registration number 2003/14954EE an has been read and approved as meeting the requirement of the Department of Electrical and Computer Engineering of the Federal University of technology Minna, for a project in partial fulfillment of the requirements for the award of the degree of Bachelor of Engineering.

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I am indebted to my beloved parents Mr. and Mrs. Paul Anagbe for their wonderful love, care, moral and above all financial support. Special thanks to my beloved brothers and sisters, friends and well-wishers for their wonderful support during this project.

DEDICATION

I dedicate this work to my beloved parents Mr. and Mrs. Paul Anagbe.

ABSTRACT

This thesis presents all the work done towards designing and construction of a metal detector, which is portable, durable sensitive, and environmentally independent, and of various applications.

A 9 volt DC source is supplied to the various segments of the block diagram, the 9 volt source is supplied to the micro controller and to the oscillator and lastly, the sensitivity select also supply power to the micro controller. When a metal is detected, the buzzer makes a sound thereby signifying that a metal has been detected.

TABLE OF CONTENTS

PAGES

LIST OF FIGURE **PAGE**

CHAPTER ONE

1.1 INTRODUCTION

In our present day, the rate of crime in companies, supermarkets and even shops by robbers and petty thieves are continually on the rise. Even the presence of security operatives, who are harmless in checking unscrupulous people when entering into such buildings, is no deterrent to the men of the underworld. Metal detectors are commonly used for security in industries and for recreation.

The use of metal detectors comes in handy to check for metallic objects such as hand guns, knives and metallic sheets in people when entering such places which are majorly used in perpetrating the evil acts. It can help to reduce crime rate reasonably. Walk-through and smaller hand - held metal detectors are used to detect hidden weapons at airport and social events. Metal detectors are also useful in mining, where they can guide miners along the path of a gold-ore vein in rock. It is also used in archaeology in the examination of materials and artefacts usually dug up from the ground. It is also used by the military to detect land mines.

In order to ensure food safety, metal detectors are often used to detect small metallic particles that have contaminated food products. During food preparation, such as the sawing or cutting of fresh meats, small metallic pieces (e.g. saw teeth) can break off and become mixed with the food. By running the food product through a metal detector, food suppliers make sure that small pieces of metal do not find their way into the food supply.

Furthermore, a child's creative mind can be expanded using the metal detector as a play tool rather than have toys with no developmental capability. With this, they can increase their level of inquisitiveness by searching out metallic object in the house and in the wall around the house. This I believe is one way to make the future more technologically inclined and we could have children talking about gold detectors and searching out the principle behind its workings. Moreover, the metal detector can be used as a household item to search for missing items with metallic property within the house.

Metal detectors work on the principle of electromagnetic induction. There are three types of metal detectors: Pulse-Induction metal detector, Induction balance metal detectors and magnetometer. Induction-balance metal detectors use a power source and two coils of tightly wound wire to detect the presence of a metal. One coil is the send coil or search coil, and the other is the receive coil or pick-up coil. A current of electricity is sent through the send coil, which will eventually create a magnetic field around the coil. The field induces a current in the receive coil. The receive coil is adjusted to read null, or Zero on a meter. When a metallic object comes within the magnetized field of the send coil, a small electric current is induced in the metal. The induced current produces a magnetic field, which alters the null reading of the receive coil. The detector registers the change and signals the presence of metal.

A magnetometer passively monitors the naturally occurring magnetic field of the earth. Magnetic lines of forces, called flux lines, circle earth in parallel lines. Metallic items disturb these parallel lines of magnetic force, and the magnetometer measures this disturbance. Minerals in the ground do not affect magnetometers as much as induction-balance detectors. Nevertheless, magnetometers are less stable and less sensitive than the other types of detectors.

1.2 AIMS AND OBJECTIVE OF THE PROJECT

i. To construct a metal detector using the principle of electromagnetic induction.

ii. To design and construct an effective means of detecting dangerous weapons made of metal so as to reduce the rate of crime in the society.

iii. To construct a metal detector that can be used for treasure hunting.

1.3 METHODOLOGY

The methodology used in this project entailed paper designed initially, after which a simulation was done using electronic workbench software. The design circuit was then constructed on a bread board to allow for placement adjustment, and then on the actual soldering unto a Vero board.

1.4 SCOPE OF WORK

The design of metal detector is expected to give an audible sound whenever a metal is detected by the search coil of the induction coils.

1.5 SOME IMPORTANT APPLICATION OF METAL DETECTOR

i. **Item Recovering:** To help an individual search for a lost item such as a piece of Jewelry, coins e.t.c.

ii. **Engineering** : To locate pipes and cable buried inside the ground and wall.

iii. **Building security**: To screen people entering a particular building such as schools, offices, prisons e.t.c.

iv. **Event Security:** To screen people entering a sporting event, concert or other large gathering of people.

v. **Air Port security:** To screen people before allowing access to the boarding area and the plane.

vi. **Treasure Hunting:** for archaeological exploration to find metallic items of historical significance.

vii. **Geological Research:** To detect metallic composition of soil.

1.6 BLOCK DIAGRAM OF METAL DETECTOR SYSTEM

The power supply for this project is a single 9V DC battery obtained from a Liezer cell; at the regulator stage, it regulate the 9V source coming directly from the power supply in order to avoid any damage to the system. The micro controller is dual in-line package chip which is programmed to check the stage of I/O pins. Also the induction coil serves as search coil having a total of 25 turns and receiving coils of 35 turns. And lastly the alarm section is a circuit which incorporates a bleeper as its alarm device to give an audible warning whenever a metal is detected by the search coil of the induction coils.

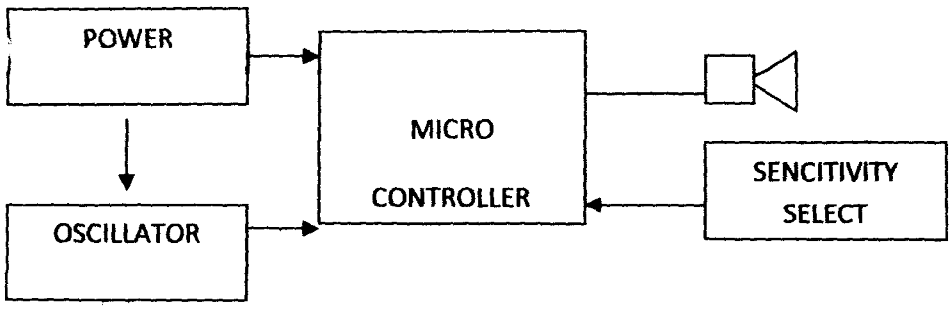

Fig 1.0 Block diagram

CHAPTER TWO

LITERATURE

2.1 HISTORICAL BACKGROUND

Metal detectors have been around for much longer that most people realize toward the end of the 19th century, Man in his conscious efforts to better himself began a research that will help him produce a machine or device that would pinpoint a metal. However, the constantly growing security problems both in private and public sector have called for security of man's basic need. These constantly increasing danger potentials, as well as the increase of intelligence of the residual minds, have necessitated the need for a typical technical equipment that will help to protect lives and property of individuals. Intruder detection faces not only the important challenge of reducing treats to lives and property but also in reducing the delay times as well as the reaction time of security personnel. This means that it must be ensured that problems can be prevented after the problem had been detected.

All intrusion detectors make use of sensitive sensor, which is based on a very different basic physical principle, indicates the presence of an intruder by opening an alarm contact in a closed circuit signal line. Metal detector is a device that is used to locate or detect the presence of a metal or metallic object. The metal detector design in this project makes use of electromagnetic induction. The units consist of an oscillator, which has an inductor as its frequency determining component. The oscillator operates at a particular frequency; the output frequency from the oscillator is fed into the sampler. The work of the sampler is to sample the frequency and pass it on to a latch. Thus latch holds the frequency and gives an output based on whether the value of its input changes or remains the same. The frequency of the oscillator is synchronized with the sampler; then, the output of the latch is connected to an alarm. The sampler, the latch, as well as the alarm are all connected to a mini- controller whose function is to monitor and control the operation of the whole unit. The control unit senses change in the output frequency of the oscillator through the response of both sampler and the latch. If a metallic object is brought close to the detector which is the frequency determining component of the oscillator, there will be a magnetic field generated around the inductor. This will cause the frequency of operation of the oscillator to be changed. This change in the output frequency of the oscillator will be sensed by the sampler and the latch. The control unit, which is sensitive to any change in the sampler, and the latch will trigger the alarm by transmitting a signal to the output device.

2.1 HISTORICAL BACKGROUND

Scientists and Engineers have contributed to the development and perfection of metal detector techniques. Broadly speaking, there are five main ways of detecting metals:

1. Beat frequency oscillation (BFO)
2. Off resonance
3. The magnetometer
4. Pulse induction
5. Induction Balance

In the subsequent section we will look at some of these technologies briefly and others considered being of importance in details to see how they work.

1. **THE MAGNETOMETER:** this works by detecting small anomalies in the earth's magnetic field strength. This type of metal detector is fascinating. But useless for treasure hunting, since it can only detect famous objects.

2. **OFF- RESONANCE:** this type operates by detecting the small changes in the search soil inductance which occurs when a small object is present. It suffers from a basically poor sensitivity.

3. **BEAT FREQUENCY OSCILLATOR (BFO):** this is the simplest or basic way to detect metal, but suffers from poor sensitivity. It operates just like the off-resonance by detecting small charges in the search coil inductance which occurs when a metal object is present. Thus, this metal detector works on the beat frequency oscillations principles. When the output from the two oscillations is mixed together, two total different frequencies are produced. One is the sum of frequencies of the individual oscillations: the other is the difference in the frequencies. The latter made use of two beat or mix the output from the two oscillators in a mixer, obtain the difference frequency called the frequency. In the working state of this device, the operation of the BFO metal detector circuit is based on superheterodyne principle used in "superhet" receivers. In the absence of metal this device produces a zero beat frequency and thus no sound from the loudspeaker. But when a metal is brought around (within) its capture range, the magnetic flux of this metal changes its inductance, making the beat frequency not to be zero and

the loudspeaker being activated, sound after the mixer/detector output has been amplified to a reasonable level to drive the loudspeaker.

4. **PULSE INDUCTION:** The pulse induction metal detector uses both transmitter and receiver, or they have two or three coils of current through its coil of wire. Each pulse generates brief magnetic field. It also listens between pulses for signals due to eddy currents set up in any metal object present in the field. These types of metal detectors are very sensitive, but the most expensive detector type are available, despite their sensitivity they have a couple of important drawbacks; their battery consumption is heavy due to the power required by the pulse transmitters and they are extremely sensitive to even tiny famous objects. Their use is primarily restricted to beach searching, where objects are likely to be buried at considerable depths, and where large holes can be easily and rapidly dug.

5. **INDUCTION BALANCE:** This type of metal detector is also known as the very low frequency or Audio frequency metal detector. It has become more or less the standard general purpose detector for both serious treasure hunters and detecting hobbyists alike. It has two distinct coils in its search head; the Driven coil (the transmitting coil) is fed with a signal, which sets up an alternating field around it. The other coil, (pick up or receiving coil) is placed so that normally the field around it balances has no electrical output. A metal object approaching the coils will distort the field, resulting in an imbalance so the pickup coil will produce an electrical output. This can be amplified and used to inform the operator, of a "find" in a variety of ways. Frequently in simple detectors an audio modulated transmitted signal is used, the output from the pickup coil can then be amplified and demodulated like an AM (amplitude modulated) radio signal.

There are many possible coil arrangements, but most detectors available today use one of the two common coil arrangements listed below:

i) **"Widescan" coil arrangement:** in which case its most sensitive area extends right across the coils.

ii) **"Pinpoint" coil arrangement also known as "4B":** This is by far the better coil in use, as widescans have poor pinpointing ability and then to give false signals for famous objects off center, coins on edge and the like. This project work uses the pinpoint coil winding.

CHAPTER THREE

3.1 DESIGN REVIEW

The controller- based metal detector system embodied the under listed subsystems:

1. System power supply
2. 8-bit system controller
3. LC-tank circuit oscillator
4. Audio sounder
5. System status indicator

3.2 SYSTEM POWER SUPPLY

For portability, a battery operated realization was adopted. The system supplies voltage and was derived from a 9V battery via a 7805 5-volt 1-amp regulator as illustrated below:

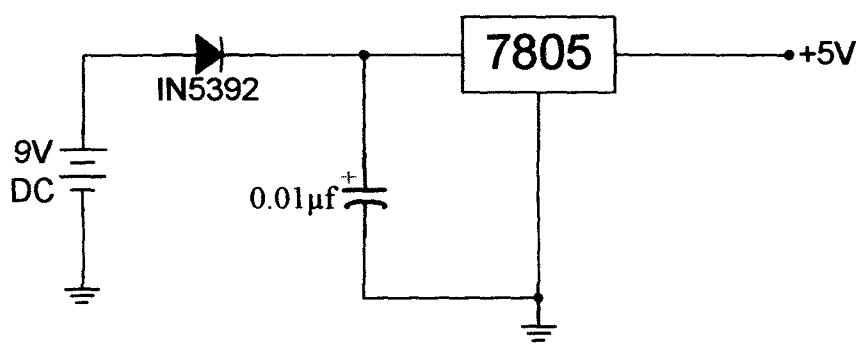

Figure 3.1: System Power Supply

The digital system required a regulated 5-volt DC supply. The supply was arranged as depicted in fig. 3.1. The 9 –volt DC was buffered by a 2200 μf and noise filtered by a 0.01 μf capacitor. It was then regulated down to 5v by a 7805 regulator. The regulated 5v supply was then stabilized by a 2200 μf capacitance.

3.3 8 - BIT SYSTEM CONTROLLER

For flexibility, a software driven frequency shift method of detection was adopted, hence, the requirement for a micro controller.

An 8-bit 89C51 device was incorporated. The device was configured as shown in fig. 3.2

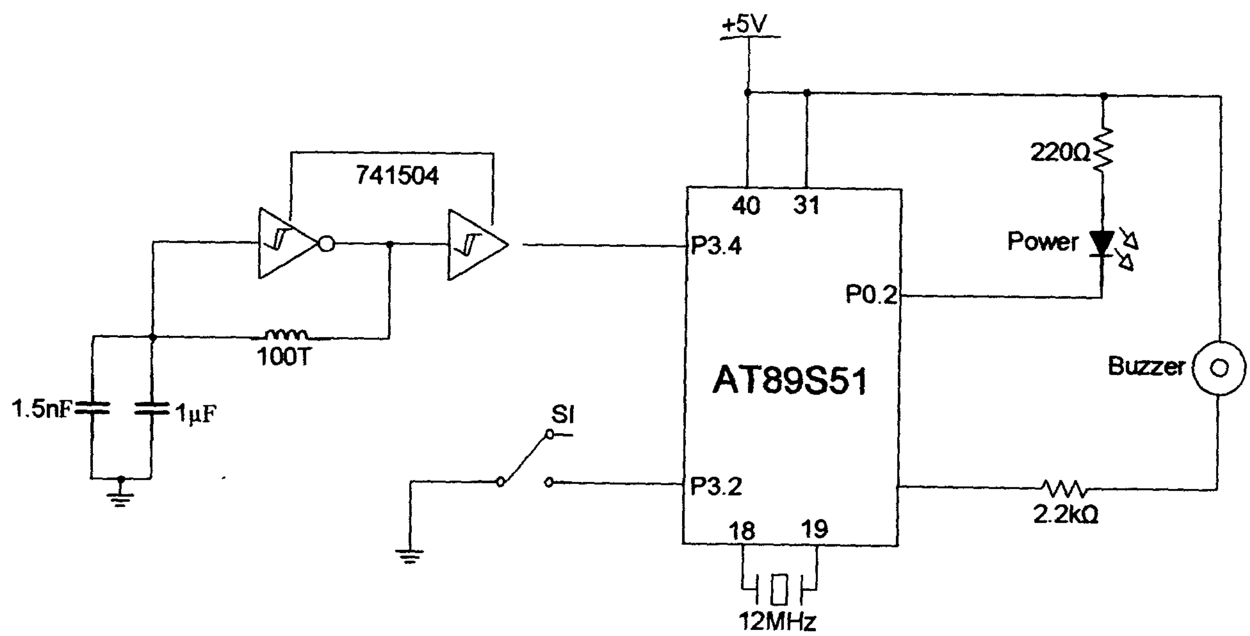

Figure 3.2: System Controller

The microcontroller was interfaced over PO.2 to an LED that provided a system operational status. The LED illuminates under software control on an indication of programme execution.

The microcontroller was configured for TO (timer O) counter operation in mode 1 (16-bit mode).

Running on a 12MHz clock source yielding an instruction execution cycle of 1μs, the software was designed to measure the frequency of the IC oscillator appearing at pin3.4.

T1 was run in the 8-bit auto reload mode for a 1 second gating window required for the frequency measurement. The free-running frequency of the oscillator was determined at 51.07 kHz. To reduce software complexity without unduly sacrificing performance, only the high byte of the TO register (THO) was used. It was compared with hard coded MSB value of the 51.07 kHz.

The reference value was computed from 51.070/256 = 199KHZ

To account for tolerance in the LC circuit, a second value of 200 was also used for comparison. The oscillator frequency output was gated for 1 second, after which THO was then compared with 199 and 200. If THO assures any value other than these two, then a frequency shift was detected. The change in frequency arises as a result of the change in the inductance of the tank circuit occasioned by the presence of a metallic object in the field of the electromagnetic energy generated by the LC tank. Upon detecting an appreciable frequency shift, the software beeps an audio alert continuously until the metallic body is then away from the tank. In essence, the software relies on the "retuning" effect to detect metals.

A change - over switch was used to provide a selection of the reference value of either 199 or 200. The switch was connected to P3.7 of the system controller.

3.4 LC TANK OSCILLATOR

An LC oscillator was used for generating the input frequency into the TO counter. The oscillator was designed around an 74LS14 hex Schmitt input NOT gates and shown in fig 3.3.

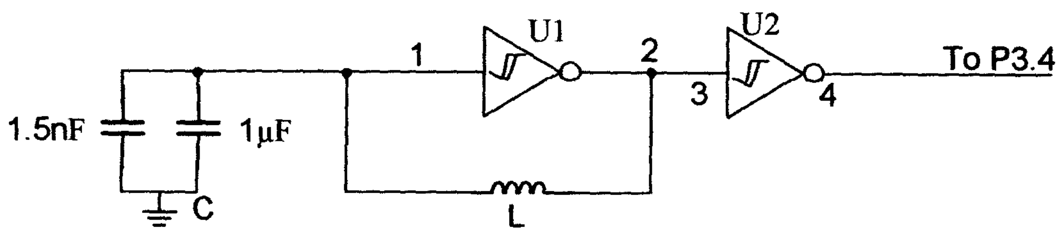

Figure 3.3: IC Oscillator

A gate was used to minimize frequency shift arising from changes in the characteristics of the active element employed in oscillation, i.e. transistors. A Schmitt input gate was used, otherwise the system does not work. The gate was configured as shown in Fig. 3.3.

A free - running frequency of 1.07 kHz was observed at U2's output using a frequency meter.

The frequency of an LC oscillator is given by the relation.

$F = (1/2\pi\sqrt{LC})Hz$

L was 100 turns of 24 Swg turns of enameled copper wire. It was wound around an air former. The capacitance in the tank circuit was composed of two parallel devices of 1.5 nf and 1nf respectively, giving a total of 2.5 nf capacitance. From the capacitance and value of the free running resonance frequency, the inductance was evaluated as

$L = 1/4\pi^2 F^2C$

$L = 1/(4\pi^2)(51, 070)^2. (2.5 \times 10^{-9})$

$L = 3.885$ mH

3.5 AUDIO SOUNDER

To generate an indication of detection after an appreciable measured detuning, an audio sounder was incorporated. The sounder was connected to P2.0 via a 2.2 kΩ resistance as shown in fig 3.4

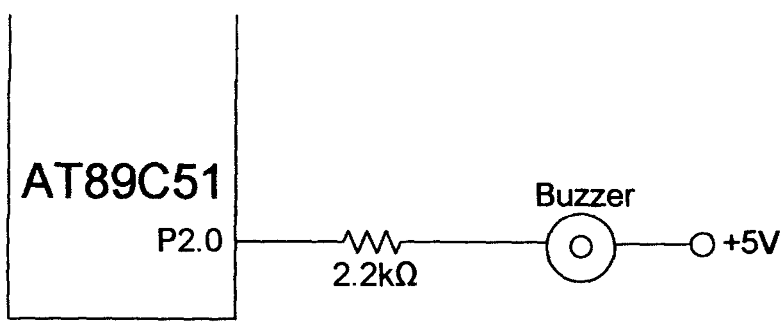

Figure 3.4: Audio Sounder

P2.0 is cleared to zero for 1- second to generate an audio tune, and thereafter set to 1 to stop the audio tune. The sounder was connected through a 2.2kΩ resistance to limit the current through it.

3.6 SYSTEM STATUS INDICATOR

A green LED provided system on indication, the LED was connected to P0.0 through a 220Ω resistance evaluated from the expression

$R = V_{LED}/I_{LED}$

$R = 1.7/0.02 = 3.3/0.02$

$= 165\Omega$

A 220Ω resistance was used instead for a slightly reduced LED current.

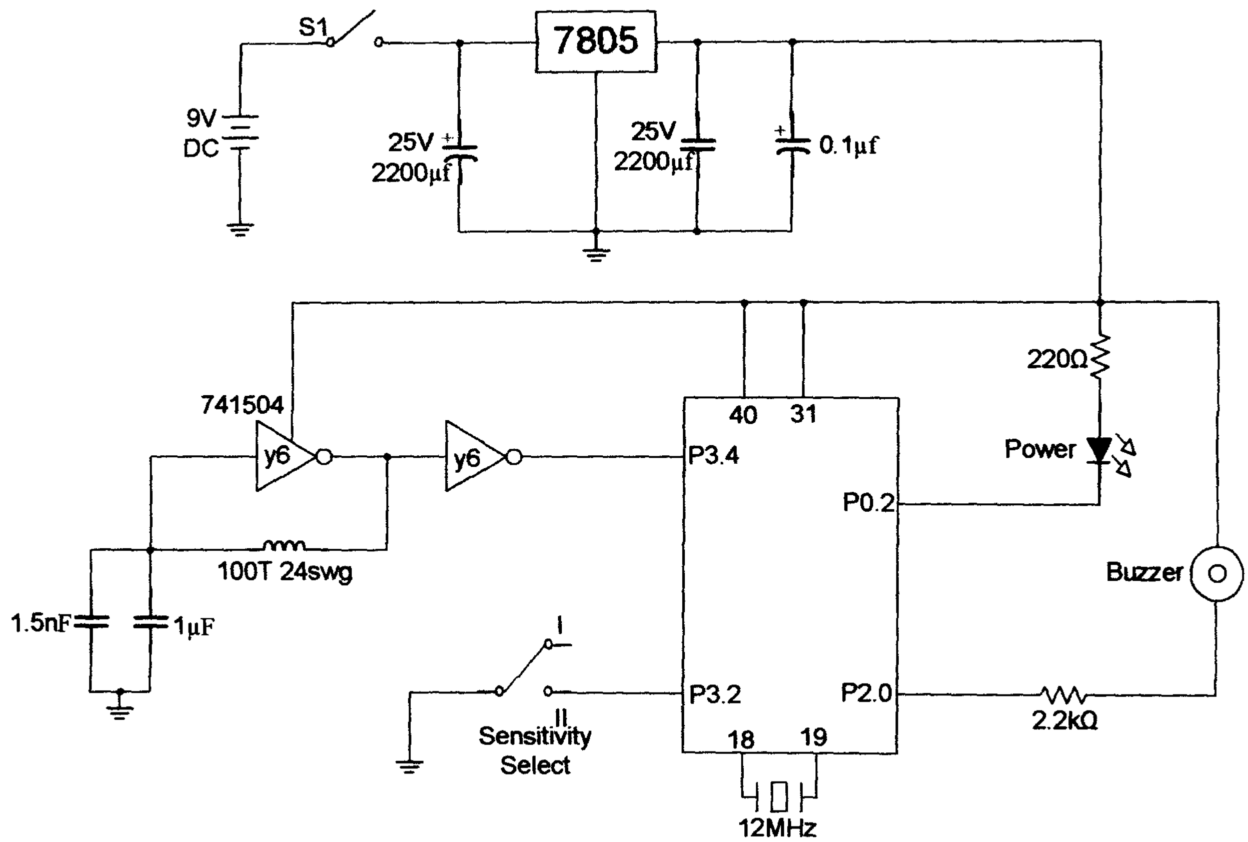

Fig. 3.5 CIRCUIT DIAGRAM OF A METAL DETECTOR

CHAPTER FOUR

4.1 TESTING

Component used in testing include a metallic object. The unit was tested on various substances and found to be most responsive to strongly metallic object. The buzzer was used as the output device from which we can hear the alarm sound. The metallic object serves as the object to be detected when an object was brought close to the wounded coils that form the inductive component of the LC oscillator. The detection distance was discovered to be a function of size of the object under investigation. Smaller object require close placement of the detection, and vice versa. In all, the unit was constructed in line with the design objective.

4.2 OBSERVATION

It was observed that when a metallic object was brought close the wounded coil, there was sound heard from the speaker.

4.3 POWER SUPPLY

The power supply unit used in this project was a cell battery of 9v.

4.4 EXPLANATION OF CIRCUIT DIAGRAM

The circuit is divided into seven main units. They work together to achieve the aim of a metal detector through frequency sampling. The technique is achieved by the use of complementary metallic, oxide semi-conductor (CMOS) logic. The use of such leading logic provides an enhanced mode of digitizing the circuit. The first unit is the oscillator. It is an LC Oscillator with a limited number of components. The Oscillator serves as the input of the whole circuit. By making the inductor side of the circuit external, any alteration to the coil simply varies the resultant frequency of the oscillator. The frequency output of the LC oscillator can be estimated with the frequency formula involving only the inductor and capacitor as variable parameters.

F=frequency

$$f = \boxed{\frac{1}{2\pi\sqrt{LC}}}$$

L = Value of inductor used

C = value of capacitor used

The formula can be simply explained by the fact that for every increase in the value of the inductance or capacitance in the circuit the frequency decreases, causing an opposing affect to the early result. Therefore, the frequency output from the oscillator is inversely promotional to both the capacitance and inductance. In the design, the capacitance is kept constant. So the only parameter that varies the frequency output of the oscillator is the inductance.

Moreover an inductor or coil responds to metallic influence in its electromagnetic region. For instance putting a metal close to the circuit, the inductor causes the inductance to vary. And by putting the metallic object away, the inductance drops down. For the circuit, the inductor in the inductance vary. The inductor in the oscillator serves as the metal sensor. The metallic influence on the coil varies the output frequency of oscillator 2.

The resistor alters the base current and slightly the frequency of the oscillator. The technique enhances the frequency adjustment of the oscillator. Another resistor 20kΩ is connected to the ground and base of transistor Q1.

The output of the oscillator to the other stages or unit passes through RC filter. The filter links the oscillator to a frequency sampler.

CHAPTER FIVE

5.1 CONCLUSION

The metal detector was found to be sensitive to change in frequency, which is due to digital circuit employed in the design of the unit.

Also from the result obtained in chapter one was achieved since the principle used for the system work as required.

5.2 IMPLEMENTATION

The implementation of this project was done on the breadboard. The power supply was first derived from a bench power supply.(To confirm the workability of the circuits before the power supply stage was soldered).

Stage by stage testing was done according to the block representation on the breadboard, before soldering of circuit commenced on Vero board. The various circuits and stages were soldered to meet desired workability of the project.

5.3 TROUBLESHOOTING

The problems encountered in this project and how they were solved and maneuvered are listed below.

1. Ensuring continuity on the Vero board such that no soldered points bridge unnecessary. This meant extensive testing and inspection at each instance soldered done.

2. Calculating for the proper amount of inductance from the number of loops of wire wound into the coil in cognizance of the fact that the greater the coil diameter the greater the penetration depth but the less sensitive it is to small objects.

3. The problem of Micro phonics (audible vibration caused by the vibration of some mechanical part) was resolved by securely anchoring the coil to prevent its individual wires moving.

5.4 RECOMMENDATION

1. The university laboratory should be well equipped with the equipment that would help students in their project works

2. There should be a proper project course schedule in the university syllabus to get students prepared for their final project work.

REFERENCES

[1] Robbert L. Boylestad & Louis Nashelsky, ELECTRONCS DEVICES AND CIRCUIT THEORY, 8^{TH} edition, PRINCE-HALL, 2002

[2] R.J Maddock & D.M Calcutt, ELECTRONICS; A COURSE FOR ENGINEERS (page 341-349,IC timers, 249-263 counters, 290-293 decoder drivers). LONGMAN,1994

[3] Tom Duncan, SUCCESS IN ELETRONICS

(pages 44-75, other passive compinents), LONGMAN.1983.

[4] Lueck G. J.P Miz AND W.N Carr, SEMICONDUCTOR MEMORY DESIGN AND APPLICATIONS, (chap.3&4, general references). McGRAW-HILL BOOK COMPANY, 1973.

[5] EVERYDAY ELECTRONICS HOURNAL, May 1998 Rd (power supplies and multivibrators). WIMBORNE PUBLISHING.

[6] Clayton Hallmarkic, COOKBOOK, (pin configurations of all the IC's) Mc –GRAWHILL BOOK COMPANY, 1986.

[7] Metal Detectors-Microsoft Encarta ® 2007,© 1993-2006 Microsoft Corporation

[8] http:// en.wikipedta.org/Metal detector.htm

[9] www.wikkipidia.com

[10] _ Dr.S. C. Liew.Electromagnetic Waves (English). Centre for Remote -Imaging sensing and processing Retrieved on u2006-10-27