DESIGN AND CONSTRUCTION OF A DIGITAL GROUND SEARCH METAL DETECTOR

BY

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DEDICATION

This project work is dedicated to the loving and tender memory of my late sister Hajia SANNI AISHAT FUNMILAYO, whose care and affection never came short for me in her life time. I pray almighty Allah grant her peace in paradise (Amin).

DECLARATION

This is to certify that this project was wholly done by **TAOHEED A. ISMAIL (2004/18824EE)**, of department of Electrical and Computer Engineering, under supervision of Engr. P.O. Abraham-Attah, and been prepared in accordance with the specifications governing the presentation for the award of B. Eng degree in Electrical and Computer Engineering, Federal University of Technology, Minna.

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Even though man tend to attribute success to his intellectual mind married with his unwavering effort and determination which no doubt is the prerequisite for the achieved success. The Almighty Allah remains the principal dictator of the quantity of success that any man, whatever power he may consider himself to possess, can achieve. I thank Almighty Allah, the beneficent, the merciful, for his grace, provision, protection and sustenance through my stay in school.

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ABSTRACT

The metal detector is a device that incorporates electronic circuitry in the detection of metals, either exposed or hidden beneath the surface. It is basically necessitated by the condition that metals could be hidden beneath a surface without being detected and it was designed as a result of research, taking into cognizance the properties of metals.

It is common knowledge that no gun is ever made without any metallic structure, and so also many other weapons. This implies that weapons can always be detected using these device. This is one of the underlying reasons why the device was ever constructed using discrete components, the main component being transistors and supporting components like 4060B, 4017B, 4013B ICs and diodes.

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CHAPTER ONE

1.0 INTRODUCTION

This project involves the design and construction of a metal detector for the purpose of detecting metallic objects located at level or slightly below ground.

The device can be described as a portable rake-like electronic device with a metal-sensitive search head that is swept over the ground and used to detect "slightly buried metal objects" such as treasures (as in archaeology and treasure hunting), metallic base-pipes and land mines (buried explosives in war zones).

In addition, the device can also detect mere metallic objects not buried in the ground. The design is associated with an earphone for listening to an alarm and a light, both resulting from metal detection.

1.2 AIMS AND OBJECTIVES

The main aim and objective of the project is to design and construct a rake-shaped metal detector for the detection of (buried) metallic objects within about 100mm range to its search head; with both light and alarm detection results. Also, the task is to be accomplished using a simple, but effective, electronic design.

1.3 SCOPE OF THE PROJECT

The following are put into consideration:

1 To make the circuit design as simple as possible.

2 The use of readily available electronics components and materials

3 The use of minimum parts for economic.

4 The use of complementary metal oxide semiconductor (CMOS) integrated circuits

especially for low power consumption.

5 The circuit is to work on battery.

6 The design ought to possess a sensitivity adjustment knob.

7 The package is made around a rake-shaped casing.

1.4 METHODOLOGY

The early part of this project involved intense research on the topic. And, information was gathered from a good number of related books and internet websites before a resulting design was established.

The basic metal detection technique involves the alteration of the main operating frequency of an LC oscillator. The inductive part or inductance (L) of the oscillator is designed into a large coil; serving the sensor of the device. The coil produces an alternating magnetic field in space or region surrounding it. When a piece of electrically conductive metal is brought close to the coil, eddy currents will be induced in the metallic material, and this produces an alternating magnetic field of its own. When a metallic material is reasonable close to the coil, the coil's L value is altered. This change alters the operating frequency of the involved oscillator. Thus, metal detectors mainly use electromagnetic induction to detect metal.

The leading frequency formula is quite importance.

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad \text{.........} 1$$

Where,

F= oscillating Frequency.

L=Inductance of the Oscillator.

C=Capacitance of the Oscillator.

The capacitor is usually kept constant, and the inductor left exposed or outside the circuit for metal detection.

The project involves a digitalized metal detector. It is more advanced and stable in contrast to BFO (beat frequency oscillator) metal detectors that use two oscillators that produce similar radio frequencies and metal detection is achieved through the difference of the frequencies from the oscillator: quite analogue. In this case, a digital frequency sampler, logic control latch and oscillator are incorporated into the design. They monitor the frequency of a LC oscillator for any reasonable change which means a presence of a metal close to the search coil. Moreover, detection of a metal is indicated through the flashing of a light and alarm output.

1.5 LIMITATIONS

1 The device is most suitable for detecting metallic materials located on or slightly buried in the ground.
2 It might have problem in detecting certain metallic materials properly.
3 The detection depth is limited to about 100mm.
4 It preferably detects large area metallic materials.
5 The detection sensitivity is manually adjusted and not digital.
6 It is not designed to suggest the type of detected metal unlike some more complicated commercial metal detectors.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Brief History and Development of Metal Detectors

Metal detectors share similar history with "electricity" and "magnetism". It is quite evident that a great team of devoted scientists worked at different historical period for the combined effort that invented and shaped the device for beneficial applications.

In fact, the device emerged from numerous experiments on Induction Balance (I.B) system invented by the German physicist Heinrich Wilhelm Dove hundred years early. The must noticeably one was preformed by Professor D.E. Hughes, in 1879, for the Royal Society in London. Its purpose was to study the molecular structure of metals and alloys. However, Hughes and his instrument maker, William Groves, soon recognized the potential of the I.B. as a metal locator, and several were supplied to various London Hospitals for locating metal objects in human bodies.[1] The Royal Mint used the Induction Balance for assaying metals and detecting forgeries. Moreover, the well- known American inventors, George Hopkins and Alexander Graham Bell were also credited for modifying the Induction Balance (I.B) for locating metallic ores and treasure chests. Although these early devices were indeed crude and used heavy battery power, their application in finding ore-bearing rocks provided immense advantage to some miners of that era. [2]

The modern development of the metal detector emerged from several experiments on radio wave in the 1930s.Firstly through Gerhard Fisher who was developing a system of radio direction-finding, which was to be used for accurate navigation. The system worked extremely well, but Fisher noticed that there were anomalies in areas where the terrain contained ore-bearing rocks. He reasoned that if a radio beam could be distorted by metal, then it should be possible to design a machine which would detect metal using a search coil resonating at a radio frequency. In 1937 he applied for, and was granted, the first patent for a metal detector. However, it was one Lieutenant Josef Stanislaw Kosacki, a Polish officer attached to a unit stationed in St Andrews, Fife, Scotland during the early years of World War II, which refined the design into a practical detector. His design was of great military importance during the clearance of the German mine fields during the Second Battle of El Alamein when 500 units were shipped to Field Marshal Montgomery to clear the minefields of the retreating Germans, and later used during the Allied invasion of Sicily, the Allied invasion of Italy and the Invasion of Normandy. [1]

The technologies behind majority of metal detectors we see today are noticeably pioneered by both Charles Garrett and Whites Electronics of Oregon. Modern top models are fully computerized, using integrated circuit technology to allow the user to set sensitivity, discrimination, track speed, threshold volume, notch filters, etc., and hold these parameters in memory for future use. Compared to just a decade ago, detectors are lighter, deeper-seeking, use less battery power, and discriminate better.

2.2 Types of Metal Detectors

Here are the three main detector types used today:

1 VLF or Very Low Frequency

2 PI or Pulse Induction

3 BFO or Beat-frequency oscillator

2.2.1 Very Low Frequency (VLF)

These are the most versatile metal detector types, based on the range of metallic objects you can find with them. The VLF detector combines two coils: the outer coil acts as a transmitter, using alternating current to create a magnetic field that is distorted by a metallic object and the inner coil acting as a receiver, reading the secondary magnetic field created by the conductive object. This magnetic field is amplified and converted to an audio tone. The phase demodulators help to discriminate among types of metallic objects. [3]

2.2.2 Pulse Induction (PI)

This type sends repeated pulses of electrical current to the search coil, producing a magnetic field. The coil transmits a pulse toward the ground, generating an answering pulse from the target object. A sampling circuit measures the pulse and sends it to an integrator, which generates an audio tone. They are able to detect objects buried deep underground, more sensitive than VLF detectors. [3]

2.2.3 The Beat-frequency oscillator (BFO)

This simplest type of metal detector and is quite related to the one associated with this project, the difference is merely with respect to the incorporated digital features. The basic beat-frequency metal detector involves two low frequency oscillators which are tuned near the same frequency. The first is called the search oscillator and the other is called the reference oscillator. The outputs of the two oscillators are fed into a mixer which produces a signal that contains the sum and difference frequency components. This signal is feed to a low-pass filter removing the harmonics. As long as the two oscillators are tuned to the same frequency, the output will have no signal. When a metallic object disturbs the magnetic field of the search coil, the frequency of the search oscillator shifts slightly and the detector will produce a signal in the audio frequency range. [3]

2.3 Uses of Metal Detectors

They are used for:

a) Security screening at important location such as bank, airport, and football stadium.

b) Treasure hunting of ancient antiquities

c) Prospecting for valuable metal like gold and silver

d) Industrial checking of contamination of food by metal

e) Searching ungrounded explosive such as land mines

f) Detection of steel reinforcing bars in concrete and pipes and wires buried in walls and floors.

2.4 THE BLOCK DIAGRAM AND BASIC DEVICE OPERATION

The block diagram involves the following units:

a) Search coil

b) Search oscillator

c) Frequency amplifier

d) Frequency sampler

e) Logic control oscillator

f) Control latch unit

g) Light indicator

h) Alarm unit

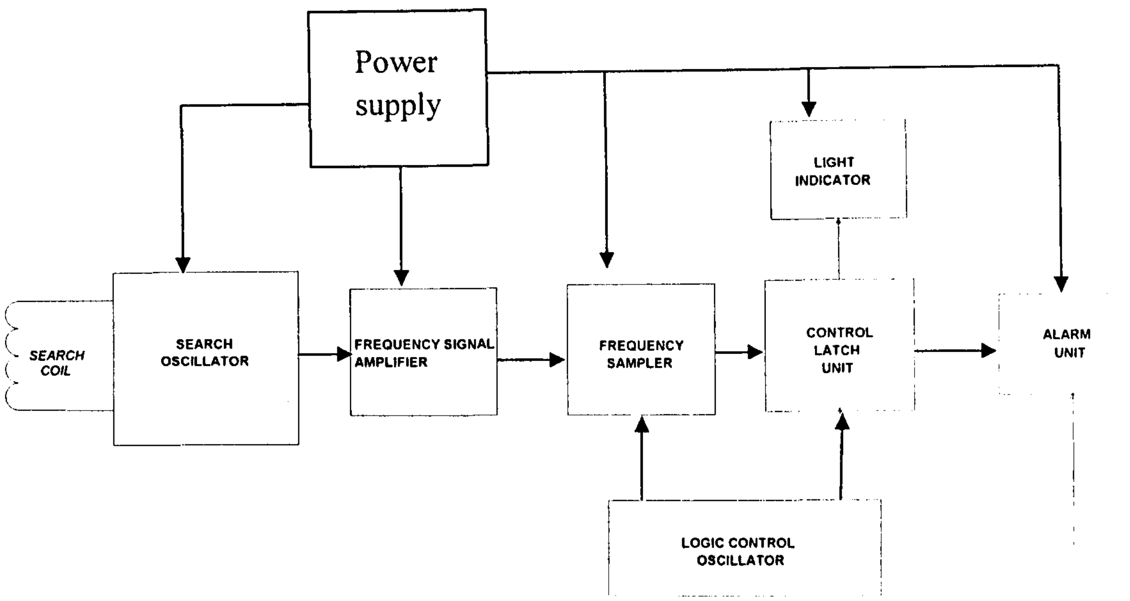


Fig. 2.4 The Block Diagram.

2.4.1 Search coil

The search coil is the metal sensing part of the altogether units. It is a mere few turns copper coil of an inductance L that is related to the LC oscillator (search oscillator).It generates an electromagnetic flux, that is intended to be altered by metal, in space surrounding it when the related oscillator is active.

2.4.2 Search oscillator

It is a simple LC type that generates a low radio frequency. Due to the fact that it is a LC type, any alteration to the values of both capacitance (C) and inductance (L) changes the output frequency. The capacitance is usually kept constant while the inductance is been altered by an external object, a detected metal. The variation of the output frequency of this oscillator when ever a metal is in close proximity with the search coil is the basic technique for metal detection. The other task is to technically show when that is done. In addition, this design utilizes the variable air capacitor for adjusting the sensitivity of the device.

2.4.3 Frequency signal amplifier

The frequency signal amplifier simply strengthens the output frequency signal from the search oscillator so that digital analysis is made possible.

2.4.4 Frequency sampler

From its name, this unit is incorporated to sample the frequency output from the search oscillator with reference to a value so that a logically indication is generated whenever the incoming value diverts from the marked point. It is merely a method for the circuitry to detect metal through alteration of the output frequency of the search oscillator.

2.4.5 Logic control oscillator

Moreover, sampling is a function of time .Thus, a reliable separate oscillator with a suitable frequency as related to the search oscillator is needed. The logic control oscillator does just that with addition function of synchronizing the altogether operation of the circuit and generating the output alarm. It is in fact a 4060B oscillator integrated circuit that is capable of generating ten different output frequencies at once. It is more advanced than 555timer IC in terms of stability and flexibility.

2.4.6 Control latch unit

The control latch unit is just a logically gate way for directing a smooth result to the output. The unit is controlled by the control oscillator so that the result from early sampling is held at the output (light indicator and alarm) before a new or fresh result is made. This leading operation minimizes output error.

2.4.6 Light indicator and Alarm unit

These are the output of the circuit that come on whenever metallic material are been detected.

CHAPTER THREE

3.0 CIRCUIT ANALYSIS

The circuit can be divided into the following units in block:

1) Power Unit
2) Sensing coil/oscillator
3) Frequency signal amplifier
4) Control oscillator
5) Frequency sampler
6) Control Latch unit
7) Light indicator
8) Alarm unit.

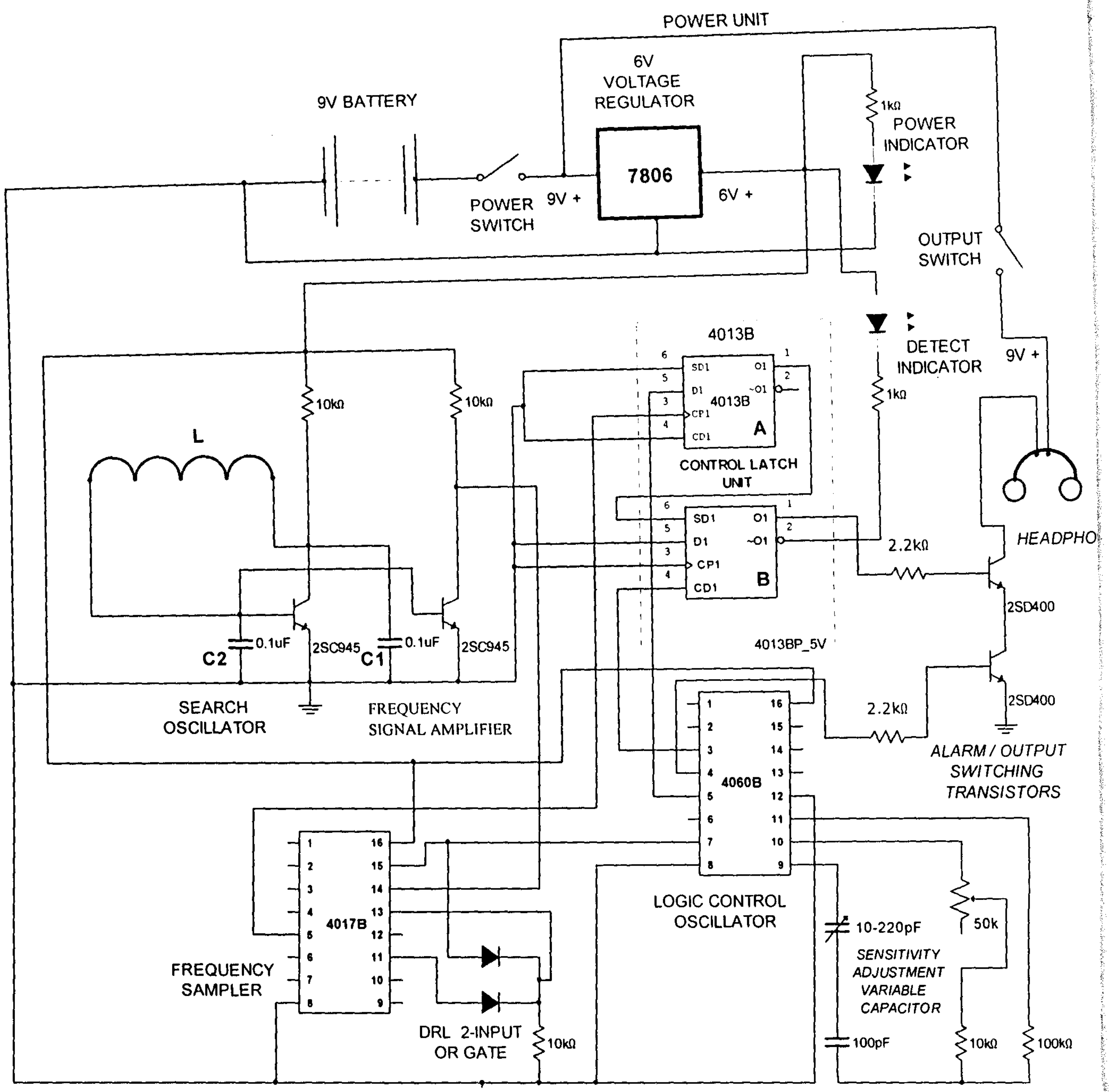


Fig 3.0. The complete circuit diagram for the digital ground search metal detector

3.1 Power Unit

The power unit is built around an old- transistor radio 9V battery. It is connected to a 6V regulator to provide a stable 6V power supply to circuit. The alarm part of the circuit is directly supplied from the 9V.

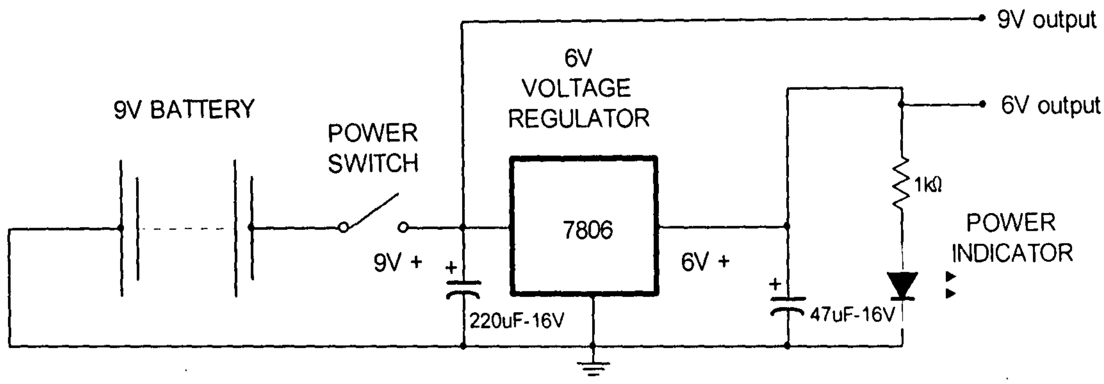


Fig. 3.1. The circuit diagram of the power unit

3.2 Power Indicator Circuit

The power indicator circuit is designed to show power supply to the circuit. It consists of a LED and a current limiting resistor.

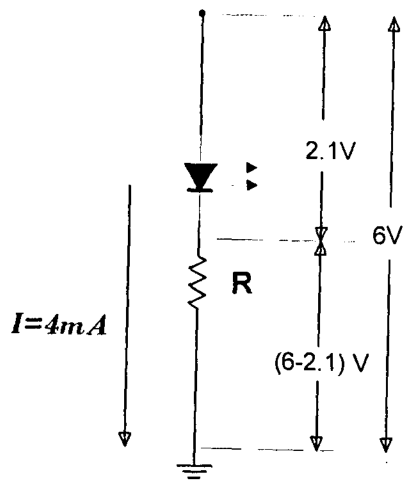


Fig. 3.2. The Schematic Diagram of the Power Indicator Circuit

The voltage across and current flowing through the LED are 2.1V at 4mA respectively.

$$R = \frac{V}{I} \qquad \text{.......... Eqn 2}$$

(Using ohms law)

$$R = \frac{(6-2.1)}{4\times10^{-3}} = 975\Omega$$

A 1000Ω resistor is a better choice. It is close to the calculated value and available in the conventional resistor series.

3.3 Sensing coil/oscillator

The sensing oscillator is designed to detect metal. It is the input part of the circuit. It consist a NPN transistor amplifier and LC tank. It is designed to produce a frequency of about 100 KHz

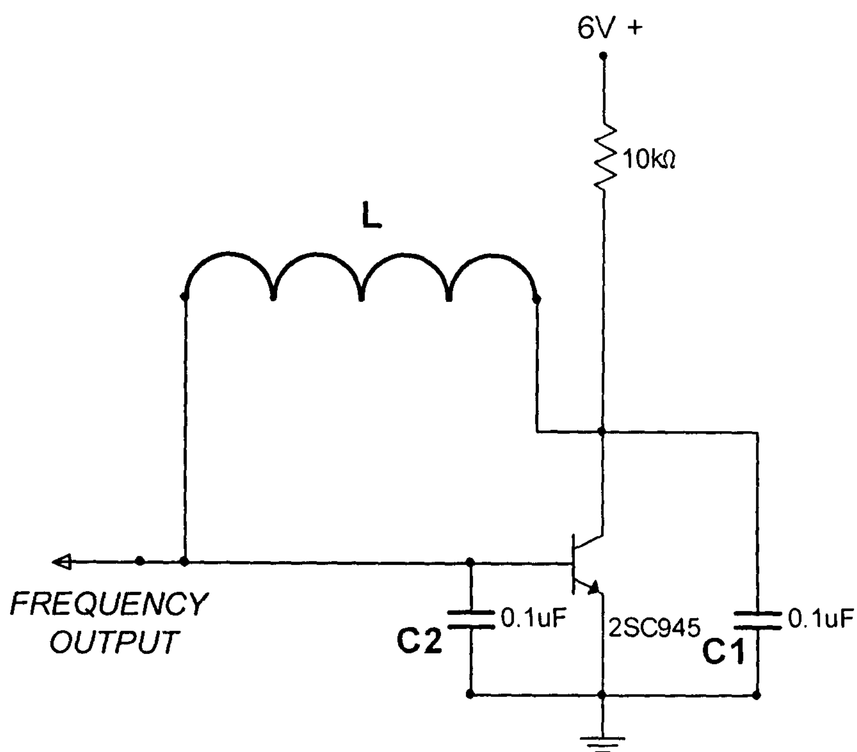


Fig. 3.3 The Circuit of the Search Oscillator

The frequency calculation is as follows:

$$f = \frac{1}{2\pi\sqrt{LC}} \quad \text{...Eqn 3}$$

Substituting the following value:

$C_1 = C_2 = 0.1\mu F$

$L = 12.5\mu H$ (10 turn of GAUGE 22 copper wire, 8 inches diameter)

$$C = C_1 + C_2 \quad \text{... Eqn 4}$$

$$C_1 = 0.1\mu F$$
$$C_2 = 0.1\mu F$$
$$C = (0.1 + 0.1)\mu F$$
$$C = 0.2\mu F$$

$$f = \frac{1}{2\times\pi\times\sqrt{((12.5\times10^{-6})\times(0.2\times10^{-6}))}} = \frac{1}{9.934\times10^{-6}} = 100658.42Hz$$

$f = 100.7KHz$

Due to the nature of an inductor, the above calculated frequency can be varied or altered by moving the coil near a metallic object.

3.4 Frequency signal Amplifier

The frequency Amplifier is designed to increase the strength of the frequency output from the oscillator. It is a single stage NPN common emitter type.

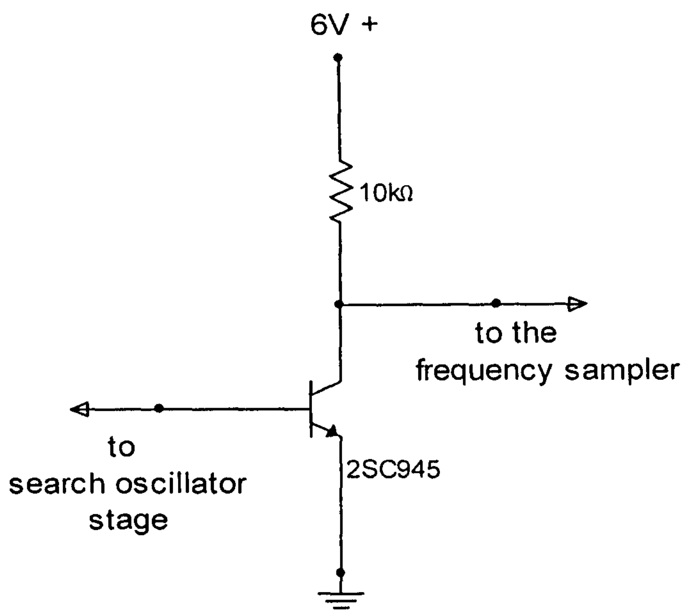


Fig. 3.4 The frequency signal amplifier

3.5 Control Oscillator

The Control oscillator is designed out of 4060B integrated circuit to generate mainly three different frequencies or pulses in which both the logic metal detection and sensitivity adjustment of the device is accomplished. The integrated circuit is set at the RC mode. The resistance, in the RC circuit, is variable but it is set at a fixed value. It is often used for adjusting the frequency of the oscillator.

The capacitor has an approximately range of 45-200pF and resistance is marked around 33KΩ. The frequencies are set by these values.

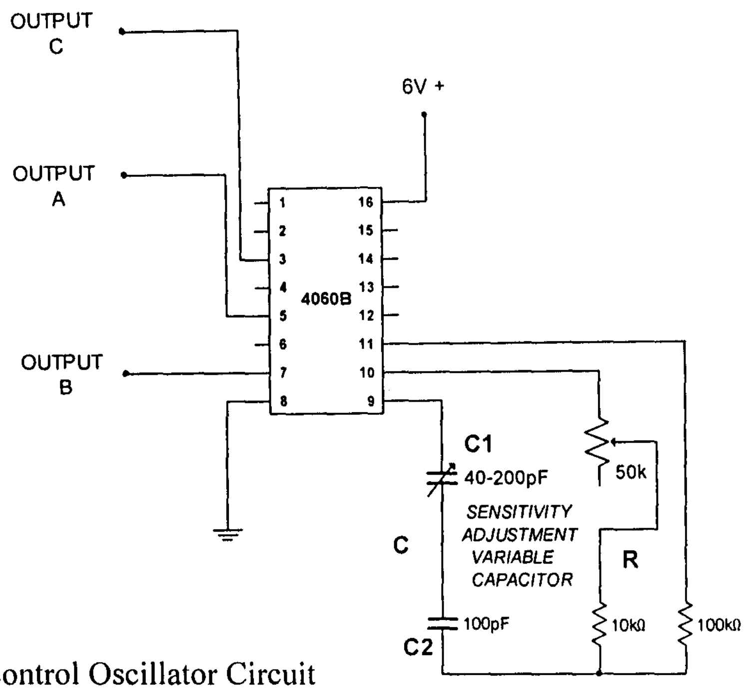


Fig. 3.5 The Control Oscillator Circuit

Using the early stated formula, the leading three frequencies can be calculated as follows:

$$f_m = \frac{1}{2.3R_{TC}C_{TC}} \qquad \text{......... Eqn 5}$$

$$C_{TC} = \frac{1}{C_1} + \frac{1}{C_2} \qquad \text{......... Eqn 6}$$

$$\frac{1}{C_{TC1}} = (\frac{1}{100} + \frac{1}{45})pF = \frac{1}{31}pF$$

$$C_{TC1} = 31pF$$

$$\frac{1}{C_{TC2}} = (\frac{1}{100} + \frac{1}{200})pF = \frac{1}{66.7}pF$$

$$C_{TC2} = 66.7\,pF$$

The effective capacitor range is roughly 31-66.7pF.

The main frequency range of the capacitor is given below:

$$f_{m1} = \frac{1}{2.3 \times 33 \times 10^{3} \times 31 \times 10^{-12}} = 425007.4Hz$$

$$f_{m1} \approx 425KHz$$

$$f_{m2} = \frac{1}{2.3 \times 33 \times 10^{3} \times 66.7 \times 10^{-12}} = 197529.7Hz$$

$$f_{m2} = 198KHz$$

$$f_{m} = 198 - 425KHz$$

Output frequency A range, from pin 5 whose Q value is 5, of the 4060B integrated circuit is given below:

$$f_{O5} = \frac{f_m}{2^5} \qquad \text{.. Eqn 7}$$

$$\left\{\frac{198KHz}{2^5}\right\} - \left\{\frac{425KHz}{2^5}\right\}$$

$\{6.2-13.3\}\ KHz$

Output frequency B range, from pin 7 whose Q value is 4, of the 4060B integrated circuit is given below:

$$f_{O4} = \frac{f_m}{2^4} \qquad \text{.. Eqn 8}$$

$$\left\{\frac{198KHz}{2^4}\right\} - \left\{\frac{425KHz}{2^4}\right\}$$

$\{3.1-6.6\}\ KHz$

This frequency range is merely twice the early.

Output frequency C range, from pin 3 whose Q value is 13, of the 4060B integrated circuit is given below:

$$f_{O14} = \frac{f_m}{2^{14}}$$

$$\left\{\frac{198KHz}{2^{14}}\right\} - \left\{\frac{425KHz}{2^{14}}\right\}$$

$\{12.1-26\}\ Hz$

Table 3.5 Frequency Table

NO	FREQUENCY	USE
1	A	It is connected to the frequency sampler for the purpose of clocking.
2	B	It is used for clocking data into output/control latch A.
3	C	It is used for refreshing output/control latch B.

3.6 Frequency Sampler

The frequency sampler is all about a 4017B integrated circuit. It uses output frequency B for producing a definite output wave form in accordance with the frequency output from the search oscillator. So that as the frequency is altered by a metal near the inductor of the oscillator, a particular digital signature of the changes is accomplished.

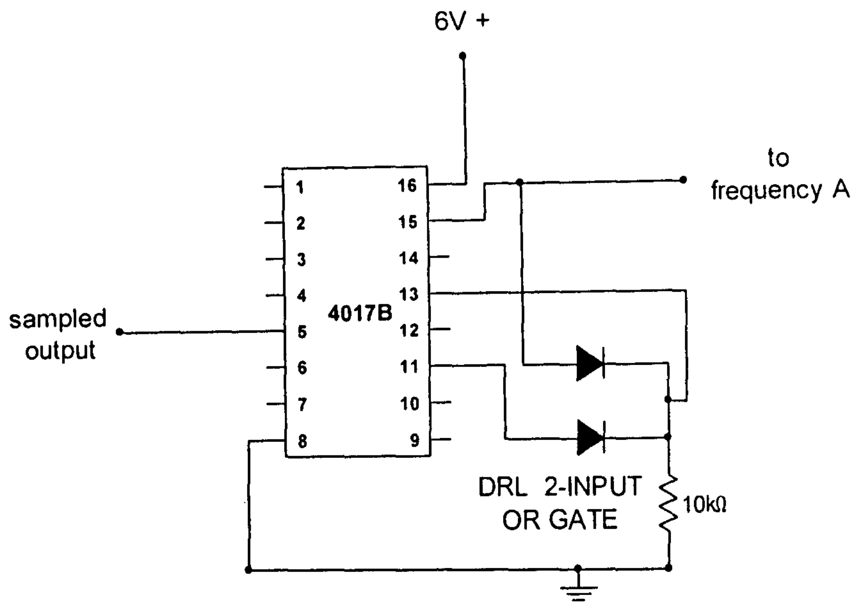


Fig. 3.6a The Frequency Sampler Circuit

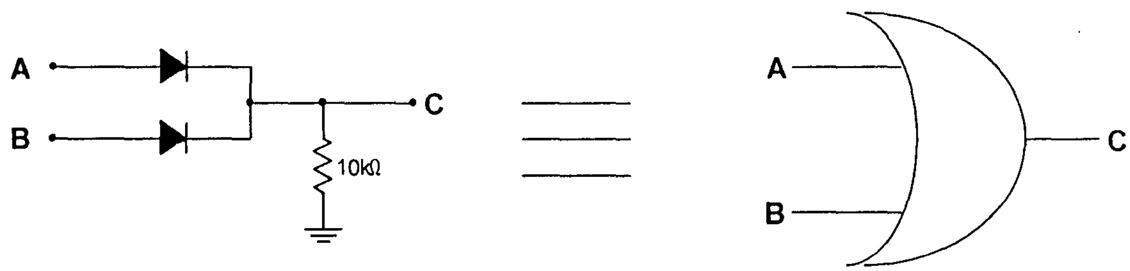
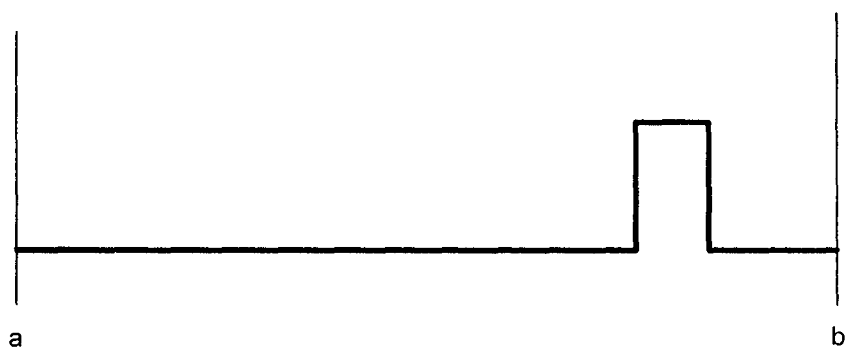


Fig. 3.6.b A Diode-Resistor Logic (DRL) 2-input OR gate

The OR gate is incorporated into the circuit to provide a limit for the sampling.

The frequency sampler produces the following digital signatures at its pin 5 for the leading conditions:

No-metal-detect condition



Metal-detect condition

Therefore, the detection of metal is transferred into a digital wave form pattern. The timing of limit "ab", at the above diagrams, must be in accord or proper relationship with the frequency from the search oscillator and this is accomplished by a variable capacitor at the logic control oscillator.

The sampler's output is fed into the control latch unit.

3.7 Control Latch Unit

This unit embodies two identical flip-flops from a 4013B integrated circuit. Each device is assigned with a particular task, and the combined digital elements solve the problems of using the detection of metal to switch on and off a Light Emitting Diode (LED) and alarm.

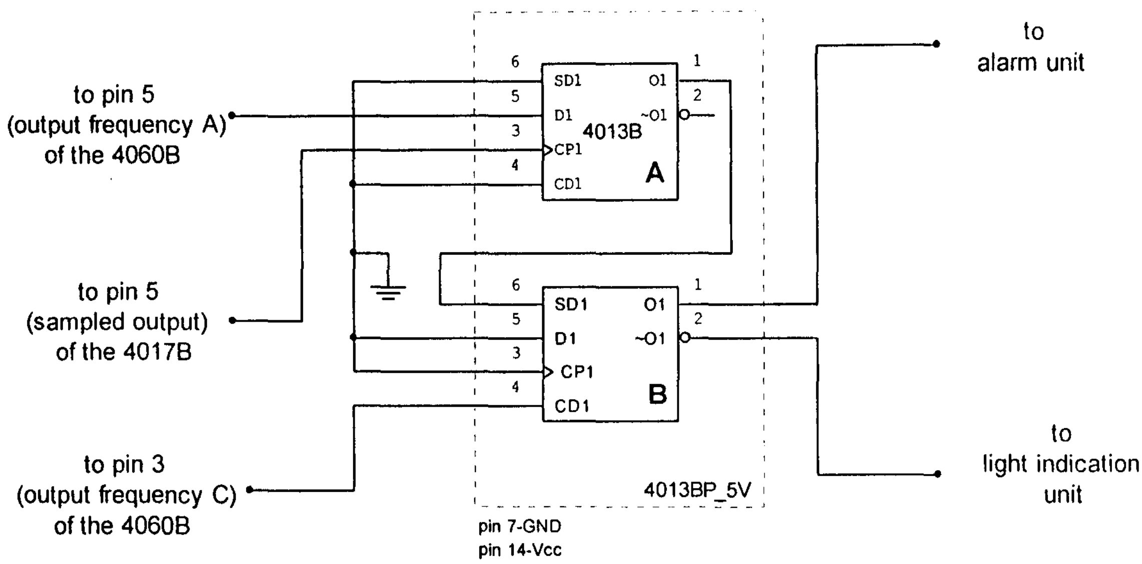


Fig. 3.7 The logic latch Unit

3.7.1 4013B A Circuit

Moreover, this unit provides the output interface from the input.4013B A is incorporated into the circuit to logically define the early conditions (no-metal-detect and metal-detect).Q1 output of this latch goes LOW, logical 0, whenever the input condition is "no metal detect". This output is logical 1 when there is metal-detect condition.

This is achieved through the following technique, as explained:

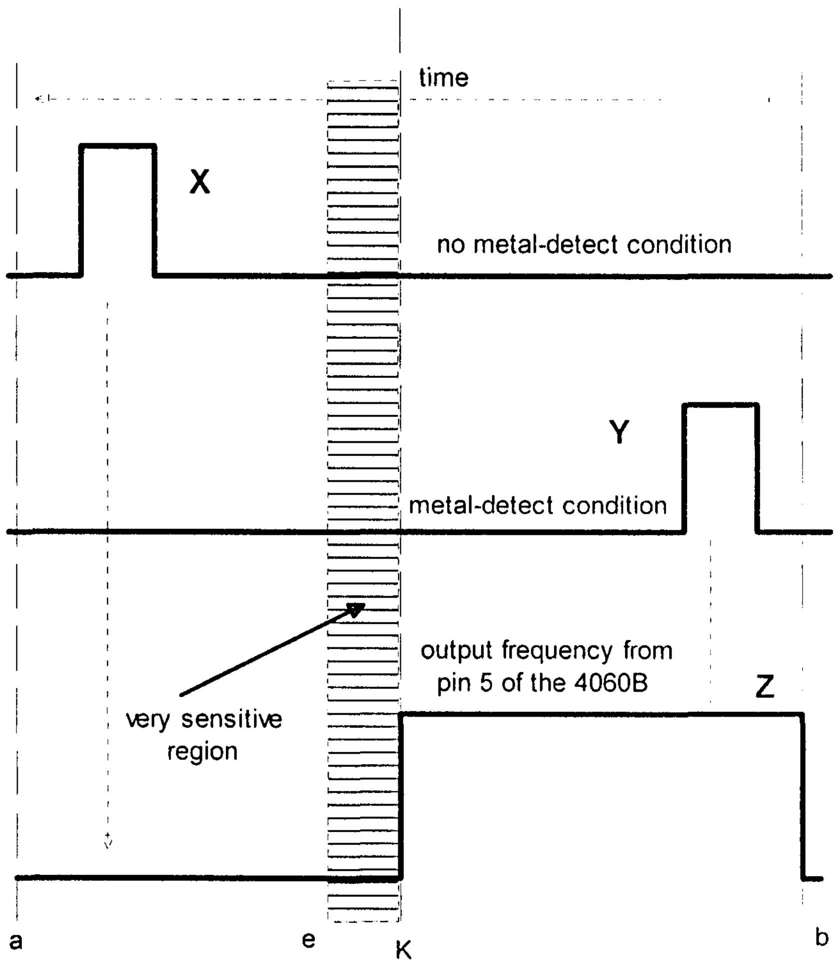


Fig. 3.7.1 Latching technique timing wave-form

The above timing diagram explains how latch A in logical identifying the condition at the input of the altogether circuit. X is the output wave form from pin 5 of the 4017B sampler at the no metal-metal condition. Y occurs at the other condition. Z is a uniform pulse from pin 5 of the 4060B, control oscillator.

Latch A is configured as a D-type latch (R and S inputs are ground) in which the logical level at D input is clocked or stored into the Q1 output (~Q1 holds the complementary logical level) whenever the clock input is subjected to a positive logic transition .Sampled signal from the 4017B and the uniform pulse from pin 5 of the 4060B are the clock and D input of the latch respectively.

Using the above timing diagram as reference, the Q1 output of the latch would always be logical 1 whenever the condition is "no metal-detect". The logical level is logical 0 at metal-detect condition. Whenever the X pulse condition occur very close to the K boundary, e.g. somewhere in the shaded region, the metal detector is very sensitive because detection would occur reasonable distance to a metal. That is, the result easily clocks positive section of Z. The variable capacitor in the control oscillator unit is adjusted to alter the sampling timing to attain the leading condition.

The Q1 output of latch A is not smooth due to it high speed of operation. A technique is required to eliminate the leading problem

3.7.2 4013B B Circuit

This latch is incorporated into the unit to smoothen the Q output of latch A. It is configured as a SR latch or flip-flop; D and Clock input are ground in this case. The S (set) input is connected to the Q1 output of the early latch while the R (reset) terminal is connected to a relatively slow pulse from pin 3 of the control latch. The pulse possesses 12.1-

26 Hz frequency range. The range does not really matter, it slow rate is the must significant factor for refreshing the latch for smooth operation.

The Q1 and ~Q1 outputs serves the light indication and alarm unit respectively. Whenever a metal is detected, Q1 is logical 1 or HIGH and switches on the alarm. ~Q1 is logical 0 or LOW at one and the same condition switching on the light indicator. No-metal-detect condition gets them off, altogether.

3.8 Light Indication Unit

This unit comprises of a Light Emitting Diode (LED), D, and current limiting resistor (R).The circuit is merely designed to show a light to indicate metal detection.

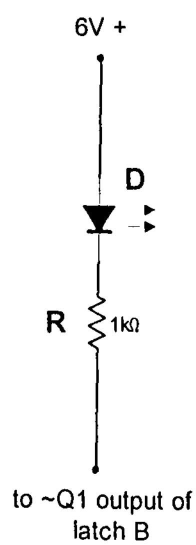


Fig. 3.8a.The Light Indication Circuit

Whenever there is metal detection, ~Q1 goes logical 0 or negative and completing the circuit. At no-metal-detect condition, the terminal is HIGH or positive close to 6V and it switches off the light indicator.

The value of the current limiting resistor is calculated by considering the on- state of the LED in which a current of about 4mA is required to flow. A red LED is in use and it has a voltage drop of roughly 2.1V.

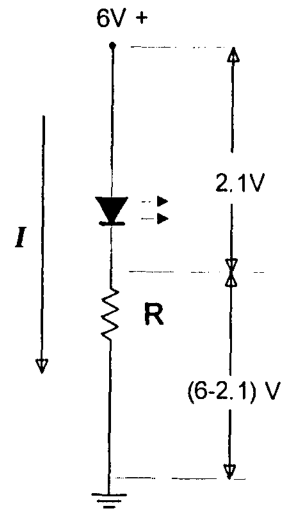


Fig. 3.8b. The Light Indication Circuit

$$R = \frac{V}{I}$$

(Using ohms law)

$$R = \frac{(6-2.1)}{4\times10^{-3}} = 975\Omega$$

A 1000Ω resistor is a better choice. It is close to the calculated value and available in the conventional resistor series.

3.9 Alarm Unit

The alarm unit is incorporated into the circuit to define metal detection through a high audio frequency. It is switched by a simple NPN 2SD400 transistor common emitter circuit.

The transistor requires a logical 1 or positive voltage at its base to switch on. The 2.2KΩ is the base bias resistor. It is required to put the base of the transistor to 0.6V at a suitable current.

The head phone requires a current of 100mA to work at 9V.This justifies the choice of the transistor whose maximum allowable collector current is 1000mA.

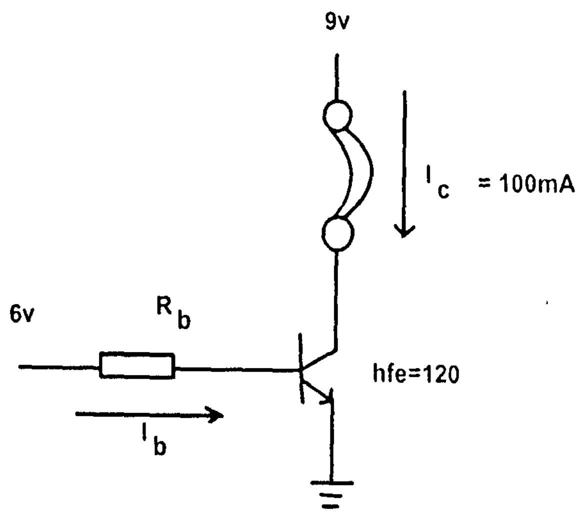


Fig. 3.9 The Alarm Circuit B with the Ear Phone.

When $I_c = 100mA$

$$I_b = \frac{I_c}{hfe} \quad \text{.. Eqn 9}$$

$$I_b = \frac{250mA}{100} = 2.5mA$$

$$I_b = 2.5mA$$

Therefore,

$$R_b = \frac{(6-0.6)V}{2.5mA} = 2.16K\Omega$$

$$R_b = 2.16K\Omega$$

A 2.2KΩ resistor is used instead in the circuit.

CHAPTER FOUR

4.0 CONSTRUCTION, TESTING AND DISCUSSION OF RESULTS

4.1 CIRCUIT CONSTRUCTION

The circuit construction was established using the circuit diagram. Bread board test was not implemented due to the high frequency nature of the design. The construction was made directly on the Vero-board.

4.2 The Main Construction Precautions

a) The number of turns of the inductor was carefully counted to correctly set its inductance.

b) The power supply was prevented from short circuit.

c) The soldering operation was done neatly to avoid unnecessary circuit inductance.

d) Connecting wires were firmly held to the board to prevent removal.

4.2.1 TESTING

The testing was aimed at checking out the ability of the device to sense or detect metallic materials or objects. A successful result must be attributed to triggering on of both light indicator and alarm on metal detection. It also involved testing the sensitivity of the device; large and relatively small metallic materials were used for the test. The diagram below illustrates the mentioned procedures.

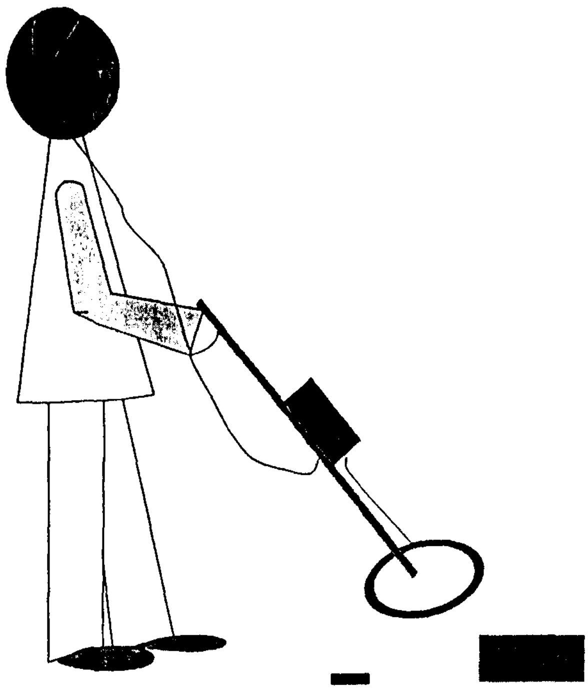


Fig 4.2 An illustration of the test

4.3 RESULT DISCUSSION

The constructed metal detector was able to detect metallic materials by triggering on the light indicator and alarm. The result confirmed that the design and construction were excellent.

Moreover, it was noticed that relatively large metallic materials were detected better than smaller ones. Also, soft metals, such as aluminum, proofed to be easily detected.

In addition, the distance of detection for an average metallic material was estimated to about 60mm.In fact, the device is not might to be too sensitivity to prevent earth's magnetism interference with the performance of the device.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

I conclude that the ability of the device to sense and detect some metallic materials was achieved through both light indicator and triggering of an alarm.

In the case of buried metallic materials, such as landmines and large surface area metals, its detects within about 100mm range to its search head.

Therefore the stated objectives were achieved except for its limitations in detecting some metals e.g. with small surface area and low metallic properties. It has high sensitivity for ferrous metals and landmines.

5.2 RECOMMENDATIONS

The use of microcontroller in the future design of metal detectors could be incorporated in the future metal detectors, to improve and enable sensitivity, discrimination, notch filters, threshold volume, nature of metal detected etc, and to hold these parameters in memory for future use.

Future metal detector designers should consider how to make a detector that will be lighter, deeper seeking, use less battery power or preferably a rechargeable battery.

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