Adama Science And Technology University
School of Electrical Engineering and Computing
Program Of Electronics And Communication Engineering

Hand-Held Metal Detector

Prepared by:

1) Yonas Taye.....R/01041/07
2) Yidnekachwe Mekuria.....R/01022/07
3) Wogderes Abebe.....R/00992/07
4) Yitay Mengest.....R/01027/07
5) Habte Tefera.....R/00488/07
6) Melat Abdissa.....R/00282/07
7) Marta Tesema.....R/00658/07

Research Paper for the course purpose in Electrical and Computer Engineering at the Adama science and technology University

Date/February/12/2018

Contents

Abstract

This project aims to design, simulate, and construct a simple and cheap metal detector. The background information of the history and uses of metal detectors, basic elements of metal detectors and the theory behind how a basic metal detector works are presented as well as the design criteria for the constructed metal detector.it lies on the principle of electromagnetic induction and adopts a digital beat frequency technique. The system uses a search coil to detect metallic objects at a close range and gives a visual, auditory indication once the metallic object is detected.

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list of acronyms and abbreviations

ASTU Adama Science And Technology University

BFO Beat Frequency Oscillator

LED Lighet Emitting Diode

PI Pulse Induction

VLF Very Low Frequency

Chapter 1

1.1 introduction

Now a day there has been an increased security threat in public areas. Today terrorist groups, and people hiding weapons are a constant and increasing threat. There is an immediate requirement for law enforcement and homeland security to identify concealed weapons, which may present a threat to official personnel and the general public. This involves bomb, handguns, knife blades and other threatening weapons. Concealed weapons detection is one of the greatest challenges facing the law enforcement community today[1].

Current security detection system which include portals and hand held devices for detecting concealed weapons such as handguns, knives and explosive are common in controlled access setting like airports, entrance to sensitive buildings and public events.

The presence of a portal weapon detection system and hand held device in a security check point warn in advance those individuals trying to hide threatening weapons.

The security detection system also need to be near an individual to work. They generally provide sufficient warning when it comes to detecting a knife[1].

From that time until now the applications of metal detectors have been rapidly increased and critical applications was included, which has led to variety in types, sizes and applications of metal detectors. This project will provide a simple design and implementation of metal detectors.

Chapter 2

2.1 Overview of background

2.1.1 Definition of metal detector

Metal detector is an electronic instrument which detect the presence of metal nearby. Theses detectors are useful for finding metal inclusions hidden within objects. The simplest form of a metal detector consists of an oscillator producing an alternating current that passes through a coil producing an alternating magnetic field. If a piece of electrically conductive metal is close to the coil, eddy currents will be induced in the metal and this produce a magnetic field of its own. if another coil is used to measure the magnetic field, the change in the magnetic field due to the metallic object can be detected[1].

2.1.2 History

The pioneer

If anyone could be regarded as the inventor of metal detectors, he will be English geologist and mining engineer R. W. Fox. It was Fox who first discovered that electricity will flow through metallic ores as well as solid metal objects. He devised a simple metal locater which consisted of nothing more than a battery, several metal rods and a suitable length of wire. His first method of detection was as follows: one metal rod would be driven into the earth where the suspected vein of ore was located; it was connected to one terminal of the battery. The other battery terminal was connected to a floating wire. Other metal rods were driven into the ground at several different points and successively touched with the floating wire.Where a spark

occurred, it was an indication that metal was present. Circa 1870, this device was modified to two rods insulated from each other in a common probe and connected via battery to a bell and plunged into the earth. When contact was made by metallic ore, nugget or metal pipe, the bell rang, thus indicating the presence of a conductive object[3].

Figure 2.2 Fox method for finding metals

Figure 2.1: the pioneer

The induction balance

In 1879, Professor D.E. Hughes demonstrated to the Royal Society in London his Induction Balance (I.B.). 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 locater. The Royal Mint used the Induction Balance for assaying metals and detecting forgeries.

The well- known American inventor George Hopkins modified the I.B. for locating metallic ores, treasure chests and the like. In fact, the Induction Balance forms the basis of most metal detectors used today.[3]

Figure 2.3 A person using induction balance

Figure 2.2: The induction balance

Discrimination

The biggest technical change in detectors was the development of the induction-balance system. This system involved two coils that were electrically balanced. When metal was introduced to their vicinity, they would become unbalanced. What allowed detectors to discriminate between metals was the fact that every metal has a different phase response when exposed to alternating current. Scientists had long known of this fact by the time detectors were developed that could selectively detect desirable metals, while ignoring undesirable ones[4].

Even with discriminators, it was still a challenge to avoid undesirable metals; because some of them have similar phase responses. Thus, improperly tuning out certain metals increased the risk of passing over a valuable find. Another disadvantage of discriminators was that they reduced the sensitivity of the machines[3].

Alexander Graham Bell, the inventor of the telephone, was working on an electrical induction device for locating metals in 1881.

In 1890 test were made to locate sulfides through the medium of conductivity, using a telegraphic receiver connected in series with a battery and a wire brush. Electrical contacts were made in the earth, and a brush was then moved over the surface. Whenever it touched sulfides, the brush would complete the circuit, indicated by a click in the receiver. Since it could be used only on exposed mineralized surfaces, the method was of limited

value. Further attempts at metal detection were made, using the Wheatstone bridge circuit for measuring resistance. Here again, conductivity was the determining factor, but the conductivity between two points on the earths surface had to be calculated indirectly by first measuring resistance. This method also proved impractical[3].

In 1925 an electrical gate checker was designed to help factories cut down on rampant thefts of tools and products. Its operation was based on the use of electromagnetic waves. Two German physicists, Dr. Geffeken and Dr. Richter of Leipzig, designed the original gate checker. Their work was continued by Gebr Wetzel. An electromagnetic field was caused to flow across the passageway. Metal carried by persons passing through the door caused alteration of the electromagnetic field and a signal was given[3].

The modern development of the metal detector began in the 1930s. Gerhard Fisher had developed 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[3].

The wireless age

With the very rapid development of wireless techniques during World War I, it was only natural that this technique would be adapted to metal locaters and prospecting equipment. One of the first pioneers to exploit this technology for locating buried treasure was English man George Williams, being fully conversant with wireless techniques, and seeing the somewhat primitive treasure locators available then, he decided he could improve the existing technology by designing a Radio-Locater[3].

The first industrial metal detectors were developed in the 1960s and were used extensively for mining and other industrial applications. Uses include de-mining (the detection of land mines), the detection of weapons such as knives and guns, especially in airport security, geophysical prospecting, archeology and treasure hunting. Metal detectors are also used to detect foreign bodies in food, and in the construction industry to detect steel reinforcing bars in concrete and pipes and wires buried in walls and floors.[8]

Further refinements

Many manufacturers of these new devices brought their own ideas to the market. Whites Electronics of Oregon began in the '50s by building a machine called the Ore-master Geiger Counter. Another leader in detector technology was Charles Garrett, who pioneered the BFO (Beat Frequency Oscillator) machine. With the invention and development of the transistor in the '50s and '60s, metal detector manufacturers and designers made smaller lighter machines with improved circuitry, running on small battery packs. Companies sprang up all over the USA and Britain to supply the growing demand.

Larger portable metal detectors are used by archaeologists and treasure hunters to locate metallic items, such as jewelry, coins, bullets, and other various artifacts buried shallowly underground[2].

2.1.3 Review Of Current Technology

There are many metal detector technologies available, such as:

Very low frequency(VLF)

Very low frequency is the most popular detector technology used today. It uses two coils for detection operation. One of the coils has variable magnetic field across it and the other acts as an antenna to pick up and amplify frequencies coming from target objects in the ground.

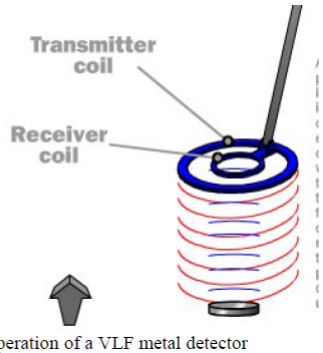

Fig. 1. Operation of a VLF metal detector

Figure 2.3: Typical VLF

Very low frequency detectors work by producing a relatively low frequency(5-50 kHz) time-varying magnetic field with a large (6-12 inch) inductor. A second, smaller coil, is shielded from detecting any direct fields induced by the first coil, and is tuned to listen for possible fields due to Eddy currents generated by near by metal objects[5].

Pulse induction(PI)

It is less common form of metal detectors. It is based on VLF but it uses single coil for detection operation. The field here comes from current pulses applied on the coil.

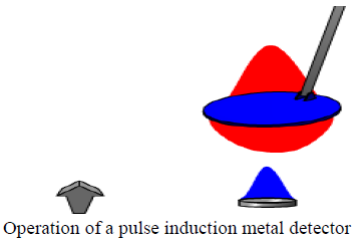

Figure 2.4: pulse induction method

Pulse Induction detectors work much like SONAR on a submarine. Electric current is sent in microsecond long pulses through a coil of wire that causes a brief magnetic field to be induced. If this pulse hits a meal object, it is reflected back to the coil of wire, which measures the reflected pulse. While pulse induced detectors arent very good at determining different types of metal, their effective working depth is much greater than that of a VLF detector[5].

Beat-frequency oscillation(BFO)

It is the most basic type of metal detector. This type uses two coils each coil is connected to an oscillator which generates a steady frequency, with each coil having a slightly different frequency. This difference in frequencies will cause a steady "beat" which can be picked up by the receiver in the control box. Any metal or mineral in range of the signal will interfere with the frequency in the search coil, causing a change in the duration and tone of the beat frequency. A beat frequency oscillator (BFO) style detector works by

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comparing two different frequency oscillators in order to detect meal objects. The large search head coil is tuned to match the frequency of a reference oscillator, typically located inside the control box. As the head is swept over metal objects, the inductance of the head changes, causing a frequency shift in the oscillating circuit. As the two frequencies change in reference to each other, some simple circuitry alerts the operator that there is nearby treasure. Initially, it seems the beat frequency oscillator detector will be the best choice to build due to its relatively simple circuitry, which will allow us to focus more on the electromagnetic theory during the project[5].

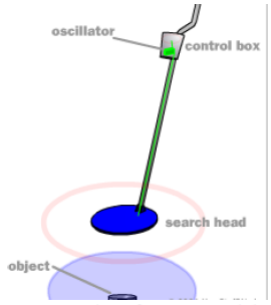

Fig. 3. Operation of a BFO metal detector

Figure 2.5: Beat frequency oscillator

RF oscillators

Resonant-frequency oscillators are the simplest type of metal detector. It uses one coil for the detection operation. It is the cheapest and simplest technology for building a metal detector[6].

2.1.4 some prototype of current metal detectors

portable hand held metal detector

Figure 2.6: Portable hand held metal detector

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personal walk-through metal detector

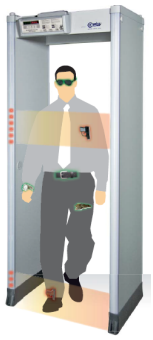

Figure 2.7: Walk through metal detector

2.1.5 principle of operation of metal detector

A metal detector operates by generating an electromagnetic field which is swept along the Ground. As it does so, any metal found will affect the electromagnetic field by changing it and this change will be displayed for the operator to see and also may be indicated by an audible sound produced by the metal detector. Inside a metal detector there are two sets of copper wire windings. An electrical current is passed through one of the windings and this creates the electromagnetic field. This is called the transmit winding. As metal conducts electricity, any metal object brought into the field will alter it and this alteration is picked up by the second winding, known as the receive winding. [4]This is then sent to the control box which the operator can use to control the types of metals he or she wants to detect. This information is then displayed through a meter or LED display and, often, with an audio signal. The more sophisticated the detector the more information is displayed. There are various refinements to metal detectors designed to filter out unwanted metals and give a signal on the wanted metals only. This is called discrimination and is achieved by the detector being set for a specific level of conductivity[4].

Different metals conduct electricity in different degrees. Silver is an excellent conductor of electricity for example whereas nails are a very low conductor of electricity. Conductivity of each metal is known of course and so a metal detector can be set to detect gold or silver and reject any others. The size

of the metal found is not particularly important in this case. It is just the ability or the willingness of metal to conduct electricity that is detected.[5]

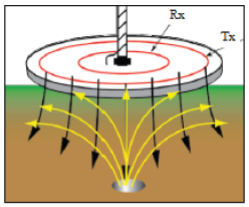

Figure 2.4 Metal detector windings

Figure 2.8: Metal detector

Chapter 3

3.1 Research focus

3.1.1 Research problem

In our campus our security system at every entrance gate is very low.in spite of the fact that the threat of our security are highly increasing, our security system is not at the level of detecting concealed weaponry. One of the problem is that the security guards have no way to check whether the entrant have got concealed weaponry or not. Having such a low security system will risk our lives and also our infrastructures, like buildings, network servers, and costs more eventually we can see that the present Security mechanism found in our campus is not efficient.

3.1.2 Research question

One our main reason which initiate us for doing this research was that to find the possibility of building and designing a cheap metal detector that used for concealed weaponry detection purpose. Generally, we conduct our research due to the following reasons.

1. Is concealed weaponry was security threatening in public areas such as hotels,schools, cinemas,meeting halls?

2. If our security is not safe, what shall we do? What control mechanism can improve our current security system? Can we improve it by using metal detector? The answer is totally yes!.so the main reason that we are not using it is due to its cost.

3. So, can we design and construct a cheap metal detector that will give the same purpose as the previous one?

3.1.3 Research aim

- The aim of this project is to design and construct simple and cheap metal detector circuit. This detector should be capable of detecting metal pieces near to its region.
- This project is mainly aimed for developing concealed weaponry detection system for Adama Science and Technology University in order to decrease security threat.
- Decreasing security threat caused by concealed weapons in public areas like hotels, cinemas, theater, schools, shopping malls, stadiums, museum.

Chapter 4

4.1 Research methodology

4.1.1 Qualitative Research

We observe that there is no metal detection system in ASTU as well as governmental schools. We can easily think that the present security screening method found in our campus is not safe as any body can transfer concealed weaponry inside campus. Checking with hand in very safe at time since the size of weaponry are significantly decreasing it is hard to notice and identify. We can also estimate how much damage will be occurred with this week security.as we know there are a lot of infrastructures in our campus like network servers, generators, building.it will be costly to recovery any damage happening to any of this area. With the following reasons we intend to develop a low-cost metal detector system that will prevent any concealed weaponry from entering in our campus

4.1.2 Quantitative Research

With doing some investigation we are able to know the cost of metal detector available today.

Table 4.1: current cost of metal detector

NO	item	Unit	price
1	Handhleld metal detector price for testing Weapon and Gun Security Scanner Super Scanner	1	65 dollar(1820 Birr)
2	Reasonable pric hand held metal detector with LCD display	1	75 dollar(2100 Birr)
3	Handheld Metal Detector more economical the best price possesses rechargeable built-in battery	1	60 dollar(1680 Birr)
4	Cheap Price Handheld Metal Detector MD-300	1	75 dollar(2100 birr)
5	Chepest price mini hand-held metal detector full body scanner 410 x 45mm two warning mode	1	55 dollar(1540 birr)

4.1.3 Elements of metal detector

The first step was to determine the types of the circuits that are to be used in the project, and the needed frequency was calculated to determine the values of the components used. The following factors should be considered while selecting the material:[7]

1. Availability of the materials.
2. Comfortably of the materials for the working condition.
3. The cost of the materials which is available at the desired value.

After considering avialibility ,cost and property of materials we choose the following matierlas

1. voltage compartor(op-amp 741)
2. Diode
3. Resistor
4. Transistor
5. Capacitor
6. LED

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4.1.4 Design and Construction

Construction of circuit

Since the electromagnetic principles support the fact that whenever there is a metallic object in an electromagnetic field there would be an electric current flowing in this object and via versa, based on this fact the design was started and the first step in the design was to introduce an electronic circuit that produces an electromagnetic field. Search was done and the best choice found was the Colpitt oscillator, it was found that the Colpitt oscillator can produce the required magnetic field.

Design analysis

Design was done based on the principle of operation keeping in mind availability of components and getting the output in tangible manner i.e. using LED. So, two circuits were to be used, first the circuit which produces the magnetic field and second the circuit that monitors the output.

Figure 4.1: block diagram Metal detector

coil

The coil is a flat spiral coil, with 13 turns, which have the diameter of 12 cm. we will use copper wire has a diameter of 1.5 mm. The coil is made in the spiral shape to get the magnetic field as wide as possible.

- Typical copper wire
- wire diameter=1.5mm
- Coil diameter=12cm
- Turn of coil =13

We can find our cross-sectional area

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$$A = (\pi r)^2 \tag{4.1}$$
$$= 3.14 * (1.5mm/2)^2 \tag{4.2}$$
$$= 1.76mm^2 \tag{4.3}$$
$$\tag{4.4}$$

so, we can calculate our average radius and inductor size.

$$\mathbf{A} = (Di/25.4 + N(W/25.4 + S/25.4)) * 1/2 \tag{4.5}$$
$$= (120mm/25.4 + 13(1.5mm/25.4))/2 \tag{4.6}$$
$$= 2.74inch \tag{4.7}$$

Coil inductance

$$\mathbf{L} = N^2 * A^2/30 * a - 11 * (Di/25.4) \tag{4.8}$$
$$= (13^2 * 2.742^2/30 * 2.74 - 11 * (120/25.4)) \tag{4.9}$$
$$= 41.91 * 10^-6H \tag{4.10}$$
$$\tag{4.11}$$

N=Turns on coil; A=Average Radius; Di=Inner Diameter; W=Wire width; S=Spacing between wires

Our total capacitance will be

$$\mathbf{C}total = (C1 * C2)/(C1 + C2) \tag{4.12}$$
$$= 39nF * 39nF/39nF + 39nF \tag{4.13}$$
$$= 19.5nF \tag{4.14}$$
$$\tag{4.15}$$

Main circuit (Colpitt Oscillator circuit)

The Colpitts Oscillator is a type of LC oscillators. This circuit consists of an LC resonance sub-circuit connected between the emitter and the base

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of a single stage transistor amplifier producing frequency output[8]. By the current flowing through the coil a magnetic field is induced around the coil, when a metallic object enters field region a magnetic field induces in the object which reduce the field of the circuit,

- The Oscillator makes a frequency change when some metal is near the detector coil. At the same the inductance will change.so we will have input voltage change also.
- The system will accept the change of input and compare with the reference voltage.

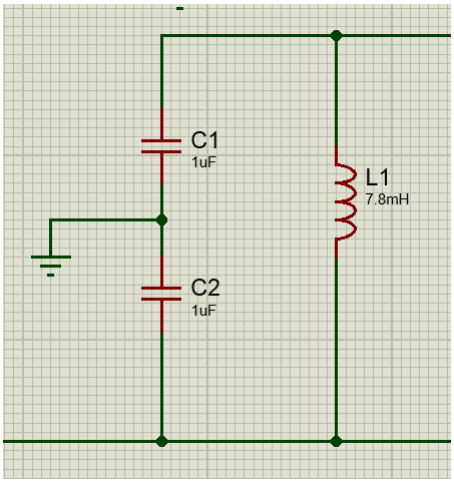

Figure 4.2: Colpitt Oscillator

Frequency output of the circuit

$$\mathbf{F}oscilation = 1/2\pi\sqrt{(LC)} \tag{4.16}$$

$$= 1/2\pi\sqrt{(41.91 * 10^{-}6H((39nf * 39nf)/(39nf + 39nf)))} \tag{4.17}$$

$$= 81.72pH \tag{4.18}$$

This is the operation (reference frequency).

Voltage comparator (op-amp 741) The main function of this comparator

is to accept the input from the colpitt oscillator and compare with the reference voltage assigned.

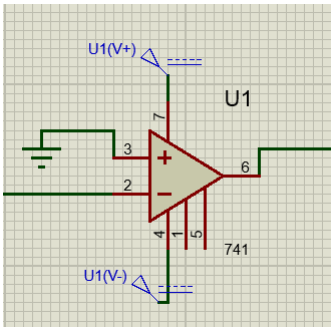

Figure 4.3: Comparator

Induction Circuit In this circuit LED is connected to output terminal of our voltage comparator. whenever the frequency of our colpitt oscillator there will a change of input voltage, our system will notify the change by the LED.

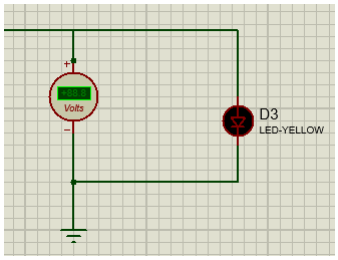

Figure 4.4: Output Display

Amplifier circuit

The main purpose of this circuit to produce amplify the signal generated from the colpitt LC oscillator.

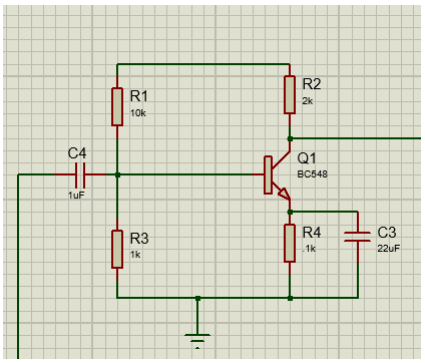

Figure 4.5: Amplifier circuit

Possible Cases

- When there is no other field near to our inductor

  There is no change of input voltage,so the input to comparator are equal

  Vout=input voltage-reference voltage

  Vout=0

  When there is no metal our input to comparator will be fully sinusoidal. So, the led will blink more. But it is just blinking.

- When there is another field near to the metal detector

  Out inductance will change, also our input voltage has a slight difference

  Vout=vinput-reference voltage

  Input voltage¿reference voltage

  So,the led will light.

Whenever there is metal near to the system, the inductance will change, the frequency of the colpitt decrease. Eventually the frequency drops. As we know a signal having low frequency is called DC.so our led stops blinking and just bright.

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Chapter 5

5.1 Merit of the research

5.1.1 The Advantages

The feeling of safety can be created while in university, hotel, college, office building, or any other area where these detectors are being used. People that are using them can control who enters a specific area and what he/she brings inside it. With the help of a hand-held detector, security personnel can physically detect if a person is carrying a metallic object. the hand-held metal detectors are more affordable and are able to still able to identify metallic objects that are considered to be potentially dangerous.

- Easy to build
- Cheap
- Low Current / Voltage

5.1.2 The Disadvantages

As for the disadvantages of using any type of metal detector, they cause privacy concerns. A lot of people can find it uncomfortable while passing through a detector scanning them for potentially dangerous metallic objects. In some cases, it is possible that they ask to be manually searched when the rules of safety allow such actions.
In many situations, metal detectors can give a false alarm if people are wearing some kind of jewelry, watch, phone, loose change or similar. This can make some people feel embarrassed and can cause panic for no reason.

A false alarm caused by detectors can be inconvenient both for the security personnel and the person to whom the alarm turned on.

- Difficult to make working on long distance

Chapter 6

6.1 Literature review

A metal detector was successfully constructed using colpitts oscillator. Colpitt oscillator is a type of RF oscillators which produces a magnetic field, this field change if a metallic object comes near to it. The change on the field appears as a change in the intensity of light of a LED connected to the colpitt oscillator using MOSFET transistor.This detector detects metallic objects near to it.
The limitations of this detector are:

1. It cannot distinguish between several types of metals.
2. Its detection region is small.

6.1.1 Futures Work

There are many updates which could be applied to this detector in the future in order to solve the limitations of this detector and get detector that can be practically used.

Possible modifications are:

- Increase the detection region of the detector
- Use LCD or headset as indicator
- Make it portable by using portable supply such as mobile battery. (make it rechargeable)

- Update this detector and let it determine the type of metal it detects, to do this another technology is to be used.

Chapter 7

7.1 Research protocol

7.1.1 Proect Scope Statement

- The project covers detail description of metal detector
- defining the working principle of metal detector
- history of metal detector
- merit and demerit of metal detector
- The circuit design and simulation of circuit before implementation

7.1.2 Constraint

- It cannot determine the type of the metal, simply detect the presence of and the absence of the metal
- metal detectors can give a false alarm if people are wearing some kind of jewelry, watch, phone, loose change or similar

7.1.3 Activity List

- Research title selection
- Data collection from different source
- Analyzing data collected
- Designing of the circuit

7.1.4 Schedule Of Our Work

Table 7.1: schedule of our work

No	**Activity**	**Week 1-2**	**Week 2-3**	**Week 3-4**	**Week 4-5**	**Week 5-6**	**Week 7-8**	**Members participate**
1	Literature review	xxxxxx xxxxxx						All
2	Data collection		xxxxxx					All
3	Analyzing collected data	xxxxxx xxxxxx						All
4	possible solution finding			xxxxxx xxxxxx	xxxxxx xxxxxx			All
5	proposal writing			xxxxxx xxxxxx	xxxxxx xxxxxx			All
6	Discussion between members	xxxxxx xxxxxx xxxxxx	xxxxxx xxxxxx xxxxxx	xxxxxx xxxxxx xxxxxx	xxxxxx xxxxxx xxxxxx	xxxxxx xxxxxx xxxxxx	xxxxxx xxxxxx xxxxxx	All
7	Design shematics					xxxxxx xxxxxx	xxxxxx xxxxxx	All
8	final testing and verification						xxxxxx xxxxxx	All
9	Present full project						xxxxxx xxxxxx	All

7.1.5 Budget estimation

labor and other cost

Table 7.2: Other Cost

No	Item	Price/Month
1	Electricity	100 birr
2	Transport	300 birr
3	Labor	1000 birr
4	Hardware parts	100 birr
5	Total	15000 birr

Source:https://www.ebay.com/b/Electrical-Supply-Equipment

7.1.6 Project Cost Estimation

parts

Table 7.3: Cost of Parts

No	**Part**	**Price/Unit**	**Quantity**
1	Resistor	3 birr	
2	LED	10 birr	
3	PCB board	50 birr	1
4	Soldeting materials and lead	100 birr	1
5	Comparator		1

Source:http://www.electricalmarketing.com/industry-stats/electrical-price-inde

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