ABSTRACT:

The project for designing a ***'Metal Detector'*** circuit focuses on the adaptation, simulation, and construction of a metal detector.

The background information of the history and uses of metal detectors is presented as well as the design criteria for our project. The theory behind how a basic metal detector works is examined, along with the basic details of a readily available design for a detector. A detailed examination of the chosen schematics and the function of each component is examined and explained, as well as explanations for certain choices of component values. The results of a computer simulation using the software '*Proteus*' are shown, along with the problems encountered are examined.

Metal detectors are gadgets that can detect metal elements on a surface. They are used to sense the weapons and used in the construction industry to identify the steel reinforcing bars in pipes, concrete, wires, pipes buried in walls & floors. The proximity at which the detectors can detect metals depends on the detector's range it can cover. Here in this metal detector circuit, we are using a *Timer IC 555* and an inductor to detect metals and alert the user utilizing an alarm from a simple speaker.

An oscillator generates an *AC* current that passes via a coil generating an alternating magnetic field. When a part of the metal is nearby to the coil, an Eddy current will be induced in the metal object and this generates a magnetic field of its own. If an extra coil is used to measure the magnetic field, the magnetic field can be changed and sensed due to the metal object.

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"Metal Detector Circuit"

Chapter 01: Introduction

1.1 Overview

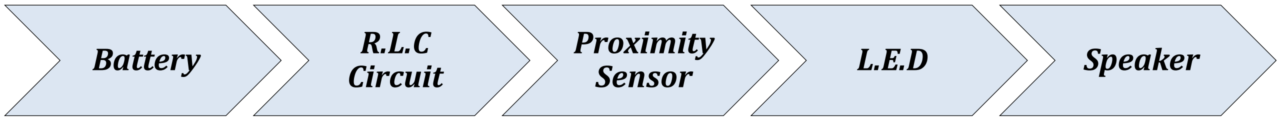
A ***Metal Detector*** is an instrument that detects the presence of metals nearby. They are useful for finding metal inclusions hidden within objects, or metal objects buried underground. They often consist of a handheld unit with a sensor probe which can be swept over the ground or other objects. Metal detectors can be created easily and the circuit for a basic metal detector is not that complex. To avoid any illegal or unauthorized entry of metallic objects, bombs, or guns, a security system is developed by using a proximity sensor which is named '***metal detector'***. It is used in many robotic or electronics projects to detect any present metals which are nearby or the existence of hidden items within objects.

The 'Metal Detector' circuit is designed using *Timer 555 IC,* resistor, capacitors, an inductor, *L.E.D,* and a speaker. The following points explain the working for the circuit.

- When the *LC* circuit (*L1* and *C1*) has got any resonating frequency from any metal which is near to it, an electric field will be created which will lead to induces a current in the coil (inductor) and changes in the signal flow through the coil.
- A variable resistor is used to change the proximity sensor value equal to the *LC* circuit. When the metal is detected, the *LC* circuit will turn on (*1*) and generate a signal. The constant signal is given to the proximity detector (*Timer 555*), which will detect the change in the signal and react accordingly.
- The output of the proximity sensor will be *0mH* when there is no metal detected (*0*) and it will be around *100mH* when the coil is near to the metal (*1*).
- When the output pin is high (*1*), the resistor *R3* will provide a positive signal (*1*) to capacitor *C1.*
- *C1* will be turned on (*1*) and *L.E.D* will glow, and the speaker will produce a sound.

The presence of a metallic object near a coil (inductor) will change its inductance. Depending on the type of metal, the inductance can either increase or decrease. Non-magnetic metals such as *copper* and *aluminum* near a coil reduce the inductance because a changing magnetic field will induce Eddy currents in the object that reduce the intensity of the local magnetic field. Ferromagnetic materials, such as *iron*, near a coil (inductor), increase their inductance because the induced magnetic fields align with the external magnetic field.

1.2 Block Diagram



1.3 Work Division

- The first group member, (*Mahnoor Sadiq*) will be introducing to the main objectives of our project to design a ‘Metal Detector’ with the procedure and its working. Then, verification of the respective truth table and its simplifications will be done according to the circuit design. The results will show if the speaker activates and produces a sound when any metal item is placed nearby or not.
- The second group member, (*Wania Shafqat*) will be making the logic circuit diagram according to the components used. Along with that, its respective figures, truth tables, Karnaugh maps, and simplified equations will also be done. The working and usage of components will also be introduced.
- The third group member, (*Areej Dar*) will be concluding by simulating the circuit for the ‘metal detector’ with all the required components mentioned above. All the labeled pictures are attached along with an explanation of simulation results.

Chapter 02: Design

2.1 Problem Statement

Metal detectors work by transmitting an electromagnetic field from the search coil into the ground. Any metal objects (targets) within the electromagnetic field will become energized and retransmit an electromagnetic field of their own. The detector's search coil receives the retransmitted field and alerts the user by producing a target response. Special metal detectors can discriminate between different target types and can be set to ignore unwanted targets. The circuit makes a beeping sound whenever it is near some sort of metal.

2.2 Truth Table

Resistor (R)	Capacitor (C)	Inductor (L)	L.E.D (X)
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

2.3 Karnaugh Maps & Equations

$RC \setminus L$	00	01	11	10
0	0	0	0	0
1	0	0	1	0

Sum of Product (*SOP*) Expression:

$\boldsymbol{X} = R \,.\, C \,.\, L$

Product of Sum (*POS*) Expression:

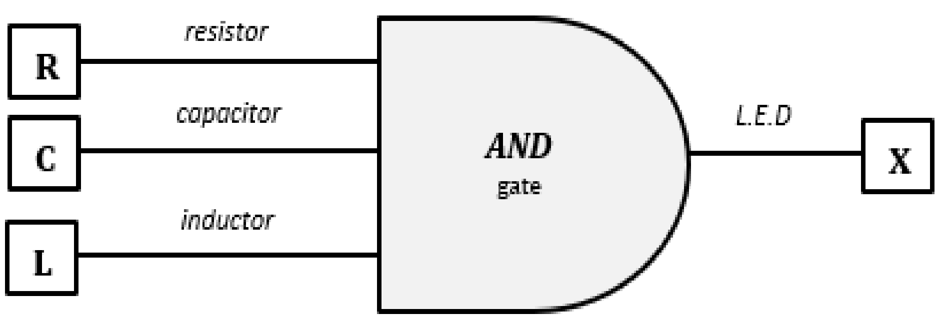
$\overline{\boldsymbol{X}} = \overline{R} + \overline{C} + \overline{L}$

$\overline{\overline{\boldsymbol{X}}} = \overline{\overline{R} + \overline{C} + \overline{L}}$

$\boldsymbol{X} = (R)\,(C)\,(L)$

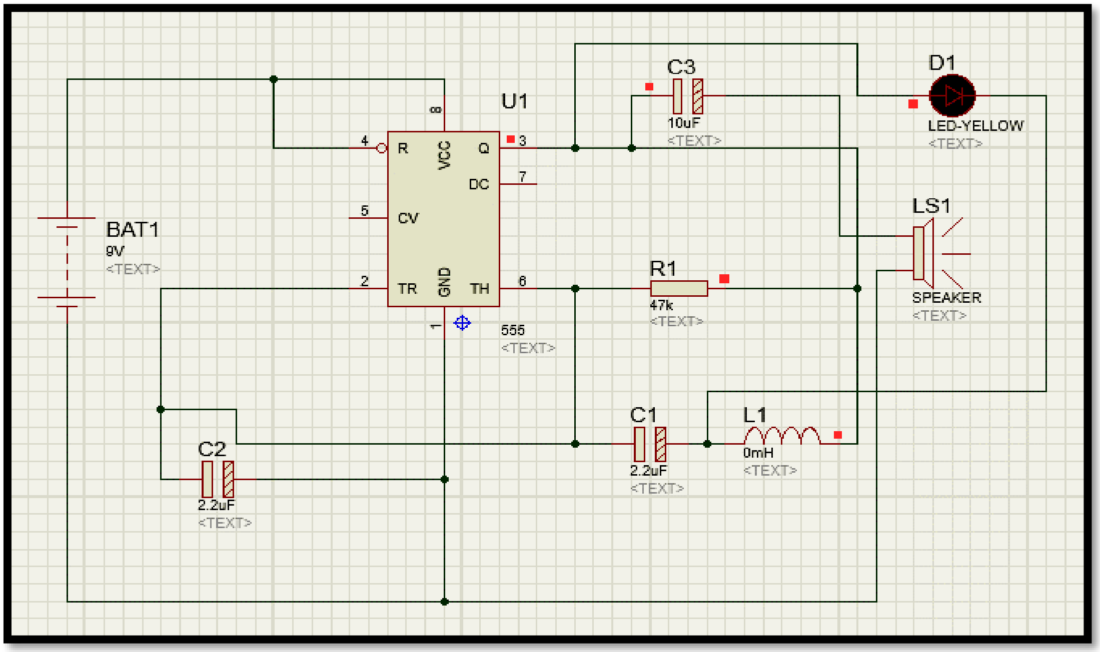
2.4 Logic Circuit Diagram

The logic circuit diagram for the Metal Detector shows three inputs; a resistor, capacitor, and an inductor labeled as *R, C,* and *L* which are connected in parallel to a 3-input *AND* gate, with an output referring to the *L.E.D* of the circuit labeled as *X.*



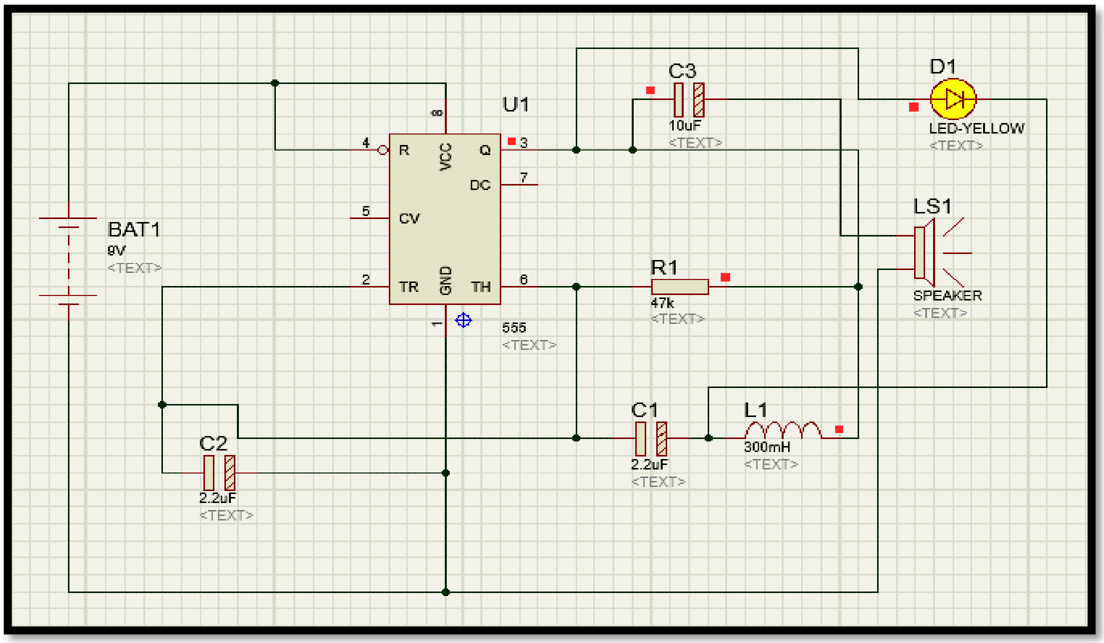
2.5 Simulation Results

The following images show the computer simulation of the metal detecting circuit done on the '*Proteus*' software. According to the circuit, the change in the value of the Inductor *L1* shows whether the metal is detected or not.



The inductor L1 at 0mH; the L.E.D does not glow, and the speaker produces NO sound.

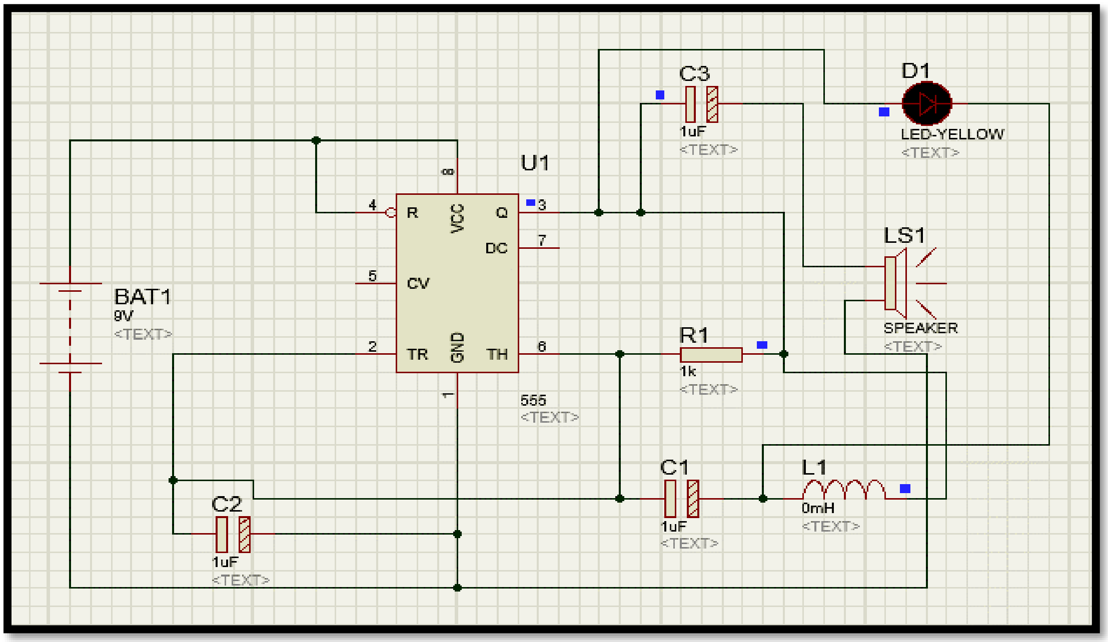
NO presence of metal found!



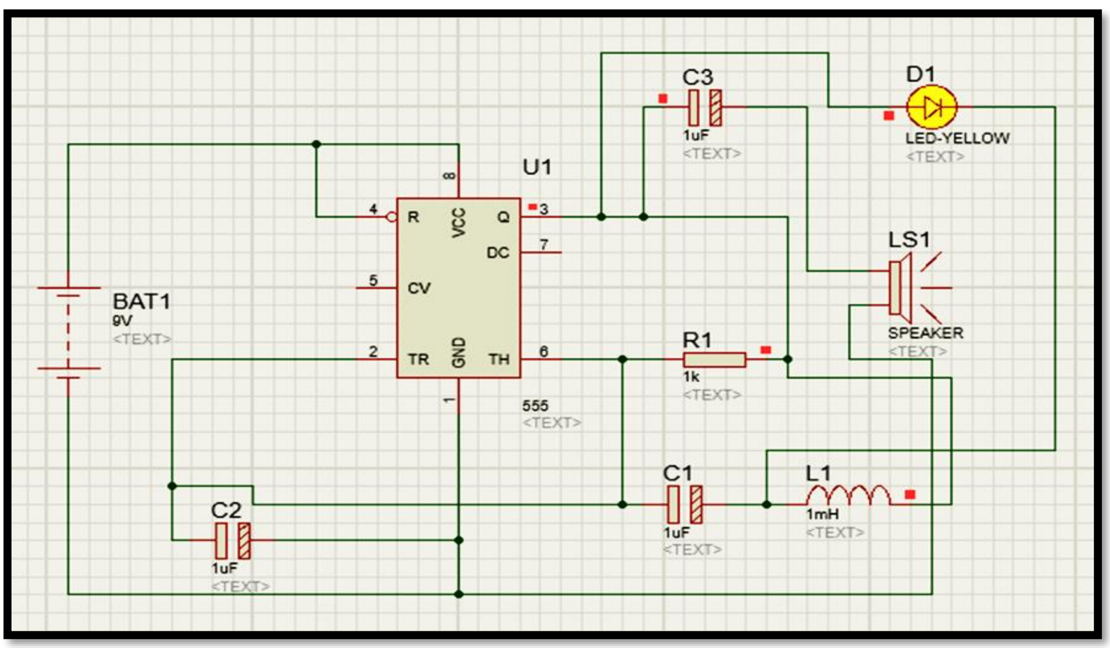
The inductor L1 at 300mH; the L.E.D glows, and the speaker produces a beeping sound.

Metal is DETECTED in this case!

According to the truth table, the metal is detected only when the inductor is *1*. The value for the resistor *R1* and the conductor *C1, C2*, and *C3* is not dependent for the metal detection.



The resistor R1 and conductor C1, C2, C3 are turned on (1) but the inductor L1 is turned off (0).
So, the L.E.D does not glow, and the speaker produces NO sound. ***NO presence of metal found!***

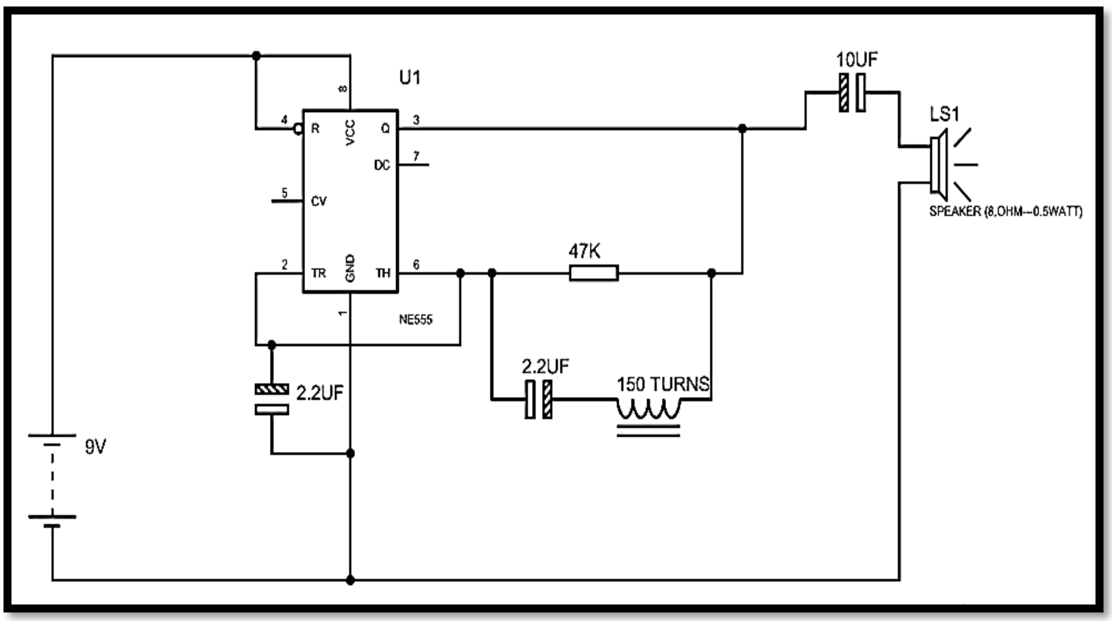


The resistor R1, conductor C1, C2, C3 and the inductor L1 are turned on (1).
So, the L.E.D glows, and the speaker produces a beeping sound. ***Metal is DETECTED in this case!***

2.6 Simulation Issues / Results/ Observations

- After simulating the 'Metal Detector', it has been concluded that the *L.E.D* used for the output, along with the speaker to show result was flickering almost every time whenever the inductance is increased.
- We could not find the *IC TDA0161*, neither in the *MultiSim* nor the *Proteus*, so we *used IC 555 Timer*, as an alternative for the Proximity Detector while simulating in *Proteus.*
- We faced few simulation errors in *Proteus* due to some wiring errors.

2.7 Detailed Schematic of Design and its Description



Components

Components used to make a circuit for 'metal detector' are mentioned below.

- (1) x *555* Timer; Proximity Detector IC
- (2) x 2.2uF Capacitors
- (1) x 10uF Capacitor
- (1) x 47 KΩ Resistor
- (1) x Inductor (coil)
- (1) x 9V Battery
- (1) x 5V Speaker
- (1) x 5mm *L.E.D*

2.8 Details of ICs used

IC Number:

'555 Timer - Proximity Detector IC.'

Description:

The *555 Timer* IC is one of the most popular and versatile integrated circuits ever produced. It is a combination of digital and analog circuits. It is a highly stable controller capable of producing accurate timing pulses. With the monostable operation, the time delay is controlled by one external resistor and one capacitor.

Features:

- High current drive capability (200mA)
- Adjustable duty cycle
- Temperature stability of 0.005WC
- Timing from p. Sec to Hours
- Turn off timeless than 2u. Sec

Applications:

- Precision timing
- Pulse generation
- Time delay generation
- Sequential timing

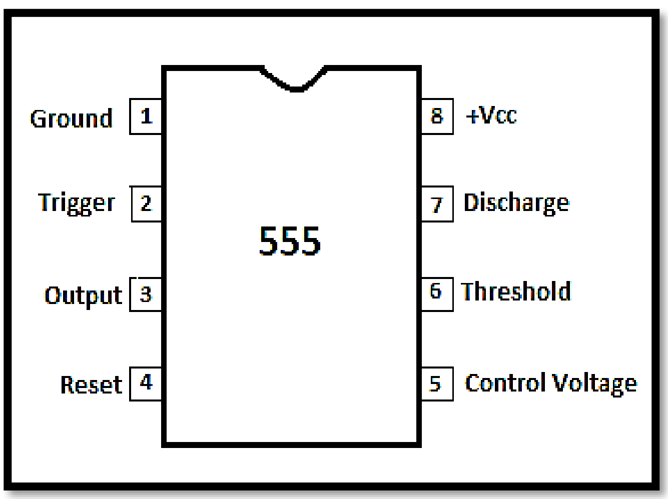
Function Table:

S	R	Q	$\overline{Q}$
L	L	*NO CHANGE*	
L	H	L	H
H	L	H	L
H	H	X	X

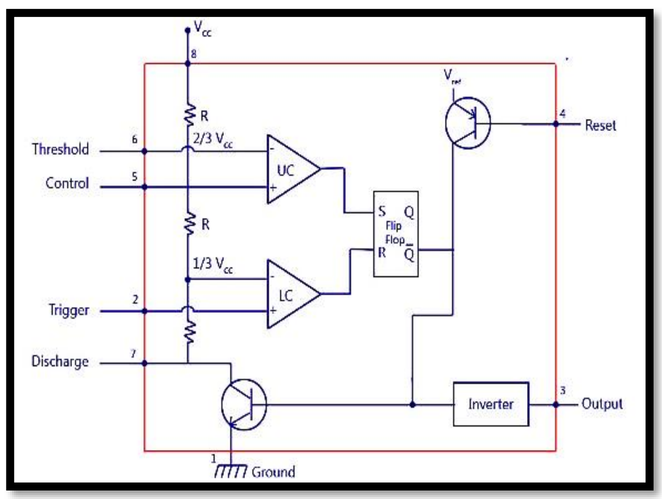
Formulas:

- **Time High (*T1*)**
  - *Formula:* 0.693 × (R1+R2) × C1
  - *Units:* Seconds (*s*)
- **Time Low (*T2*)**
  - *Formula:* 0.693 × R2 × C1
  - *Units:* Seconds (*s*)
- **Time Period (*T*)**
  - *Formula:* 0.693 × (R1+2×R2) × C1
  - *Units:* Seconds (*s*)
- **Frequency (*F*)**
  - *Formula:* 1.44 / (R1+2×R2) × C1
  - *Units:* Hertz (*Hz*)
- **Duty Cycle**
  - *Formula:* (T1/T) ×100
  - *Units:* Percentage (*%*)

Schematic:



Pin Diagram for IC 555 Timer



Block Diagram for IC 555 Timer

2.9 Details of Other Components Used

- **Capacitor:**

A capacitor (originally known as a *condenser*) is a passive two-terminal electrical component used to store energy in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors separated by a dielectric (an *insulator*). For example, one common construction consists of metal foils separated by a thin layer of an insulating film.

- **Resistor:**

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. The current through a resistor is in direct proportion to the voltage across the resistor's terminals.

- **Inductor:**

An inductor (also a *coil* or *reactor*) is a passive two-terminal electrical component that stores energy in its magnetic field. For comparison, a capacitor stores energy in an electric field, and a resistor does not store energy but rather dissipates energy as heat.

- **Speaker:**

This change in inductance results in a change in the duty cycle of the output pulse that goes to the speaker. We can observe the change in the tone of the speaker. This change in tone indicates the presence of metal before the detector.

- **L.E.D:**

A light-emitting diode (*L.E.D*) is a semiconductor device that emits light when an electric current is passed through it. Light is produced when the particles that carry the current combine within the semiconductor material.

Chapter 03: Project Applications & Further Suggestions

Applications:

- Security Purposes and Screening:

Metal detectors are excessively used for security purposes in airports, railways, hotels, military facilities, government buildings, etc. They can be used for security screening in airplanes. In common with the developments in other uses of metal detectors both alternating current and pulse systems are used, and the design of the coils and the electronics has moved forward to improve the discrimination of these systems. In *1995,* systems such as the '*Metor 200'* appeared with the ability to indicate the approximate height of the metal object above the ground, enabling security personnel to locate the source of the signal more rapidly. Smaller handheld metal detectors are also used to locate a metal object on a person more precisely.

- Archaeology:

Many historic artifacts from the post-Paleolithic age are metallic. These valuable items which generally include pots, vessels, weapons like spears, swords, tools like hammers, chisels, and the remains of extinct species can be easily detected with metal detectors of appropriate calibration. Their excavation and preservation are greatly facilitated due to metal detectors.

- Prospecting:

Metal detectors are used to identify metals like iron, gold, silver, etc. It can help scan for nails, metal scraps, etc. which are not easily spot able by the naked eye.

- Coin Shooting:

Coin shooting is looking for coins after an event involving many people, like a baseball game, or simply looking for any old coins. Serious coin shooters will spend hours, days, and months doing historical research to locate long-lost sites that have the potential to give up historical and collectible coins.

- Industrial Purposes:

Metal detectors are also used for industrial purposes like; in the pharmaceutical, food, beverage, textile, garment, plastics, chemicals, lumber, and packaging industries. Contamination of food by metal shard from broken processing machinery during the manufacturing process is a major safety issue in the food industry. For this purpose, they are widely used and integrated into the production line. Current practice at garment or apparel industry plants is to apply metal detecting after the garments are completely sewn and before garments are packed to check whether there is any metal contamination (needle, broken needle, etc.) in the garments. This needs to be done for safety reasons.

Suggestions & Improvements:

Further suggestions and improvements to get better performance of the metal detector:

- More battery power and change to rechargeable ones.
- Power supply monitor (with μC analog comparator).
- Change the coil to a coax cable.
- To get a longer detecting distance, there must be more power to the coil.
- Add in a receiver/amplifier for better performance.
- Add an oscillator and make it more stable.
- Add a few more *L.E.Ds.*

The motivation to design this device is to ensure the safety of people. It is a step towards defending people from danger in public places. The technology is simple and portable, making it cost-effective for a range of safety and security applications in the military in minefields, airports, and other security checkpoints.

Chapter 04: Future Recommendations

Our final *Digital Logic Design* project was a successful first step in designing a '**Metal Detecting Circuit'**. Results for this project show that; on placing the metal near the sensor, a sound is produced by the speaker and the *L.E.D* glows brightly. Whereas, when the metal has been removed or is far away from the sensor, the speaker stops generating the detecting sound. Likewise, the simulations show the increase and decrease in inductance are followed by a glowing L.E.D and a beeping sound.

While working on this project, we have learned numerous things about the metal inductance specifically, as well as the design process in general. We hope to use the knowledge and experience obtained working on this project on future tasks in practical life.

Some of the issues with the current system include the very fine sensitivity of the metal detector. We hope to continue to work by building on its existing platform with new hardware and behaviors.

We are interested in adding some of the more advanced features of our proposal that were not implemented in the final design, such as more advanced search algorithms. We may even carry over the concept to a new platform with more capabilities, such as better operations of the metal detector on rough surfaces. Changing the battery power supply and coil may improve the circuit's performance. Adding in a receiver or an amplifier will add more capabilities to it. This has been a genuinely fun and informative project for us, and we would like to continue exploring applications of logic designing.

Chapter 05: References / Bibliography

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