EE-241 EM FIELD THEORY

B.E. ELECTRICAL ENGINEERING
METAL DETECTOR

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DEGREE	43	**SYNDICATE**	B

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Acknowledgment

We express our heartfelt gratitude to Allah Almighty for His boundless blessings and guidance throughout the completion of this project. We are immensely grateful for the strength and wisdom He bestowed upon us.
We extend our sincere appreciation to Sir Qasim Umar Khan for his invaluable guidance and enlightening lectures, which equipped us with the necessary knowledge and skills to accomplish this project.Lastly, we offer our deepest thanks to our beloved parents, whose unwavering support and fervent prayers have been a constant source of inspiration and motivation.May Allah reward everyone abundantly for their contributions and blessings.

ABSTRACT

Mutual inductance is a fundamental concept in electromagnetism that describes the relationship between two adjacent coils and the induction of electromotive force (EMF) in one coil due to the changing magnetic field produced by the other coil. This phenomenon is governed by Faraday's law of electromagnetic induction. In this paper, we explore the principles of mutual inductance and its mathematical formulation.To quantify this relationship, we introduce the concept of mutual inductance, denoted by M. We derive the mathematical expression for mutual inductance, which depends on the geometrical properties of the coils, such as their shape, size, and relative orientation. The value of mutual inductance determines the level of coupling between the coils and is measured in units of henries (H).Understanding the principles of mutual inductance is essential for engineers and researchers working in the field of electromagnetism, as it forms the basis for many electrical and electronic applications. By analyzing the mutual interaction between coils and the induced voltage, we can design efficient and reliable systems that harness the power of electromagnetic induction.

OBJECTIVES:

Objectives of our project are:

1.Designing a Metal Detector using Mutual Inductance Method.
2.Mathematically verifying the design.
3.Designing Metal Detector using Self Inductance Method.
4.Mathematically verify the design
5.Draw the comparison between both designed prototypes.

MUTUAL INDUCTANCE

WORKING PRINCIPLE:

To calculate mutual inductance between two coils Faraday's law is used.**FARADYS LAW** states that:

When there is a change in the magnetic field through a wire loop, Faraday's law states that an EMF is induced in the loop.

Mathematically, Faraday's law can be expressed as:

EMF = -N * (ΔΦ/Δt)

Formula shows that FARADYS law depends upon:

Number of turns: Let's denote the number of turns in the first coil as N1 and the number of turns in the second coil as N2.

Current: The current flowing through the first coil is denoted as I1. We assume that this current is changing over time, resulting in a changing magnetic field.

Magnetic field: The changing magnetic field produced by the current in the first coil induces an electromotive force (EMF) in the second coil. Let's denote this induced EMF as $\varepsilon 2$.

Flux: The induced EMF is proportional to the rate of change of magnetic flux through the second coil. The magnetic flux is denoted by $\Phi 2$.
Negative sign represents LENZ law.
The second law on which metal detector is based upon is LENZ law:
Lenz's law determines the direction of the induced current in the loop. The induced current always flows in a direction that opposes the change in the magnetic field.
As the induced current flows, it generates its own magnetic field according to the right-hand rule. This magnetic field interacts with the original changing magnetic field.

In **summary,** Faraday's law describes the generation of an induced EMF, while Lenz's law determines the direction of the induced current. Together, they ensure that the induced current opposes the change in the magnetic field, resulting in a mutual working principle that leads to electromagnetic induction.

CALCULATIONS:

Consider two parallel coils, Coil 1 and Coil 2, with N1 and N2 turns respectively. The magnetic flux ($\Phi 2$) produced by Coil 1 that passes through Coil 2 is given by:

$$\mathbf{\Phi 2 = M * I1}$$

Where:

M is the mutual inductance between the two coils.
I1 is the current flowing through Coil 1.
According to Faraday's law, the EMF induced in Coil 2 is proportional to the rate of change of magnetic flux:

$$\mathbf{EMF2 = -N2 * (d\Phi 2/dt) = -N2 * M * (dI1/dt)}$$

Here, the negative sign indicates the opposition to the change in the magnetic field, as per Lenz's law.

Mutual Inductance Between a Coil and a Straight Wire:

Consider a coil with N1 turns and a straight wire carrying current I2. The magnetic flux (Φ2) produced by the wire that passes through the coil is given by:

Φ2 = M * I2

Where:

M is the mutual inductance between the coil and the wire.
I2 is the current flowing through the wire.
The induced EMF in the coil is then:

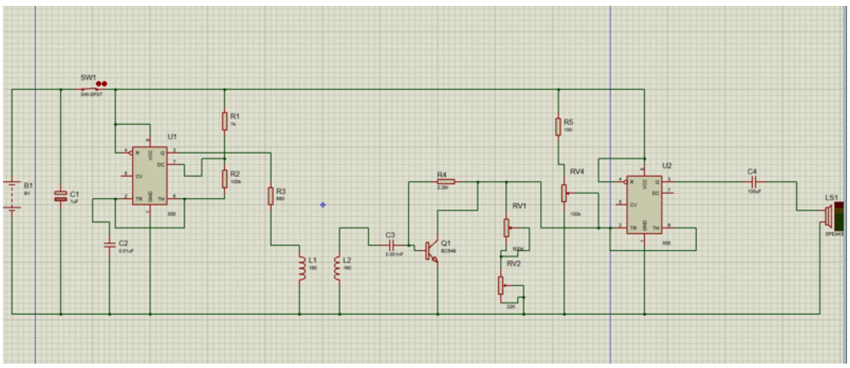
EMF1 = -N1 * (dΦ2/dt) = -N1 * M * (dI2/dt)

Again, the negative sign indicates the opposition to the change in the magnetic field.

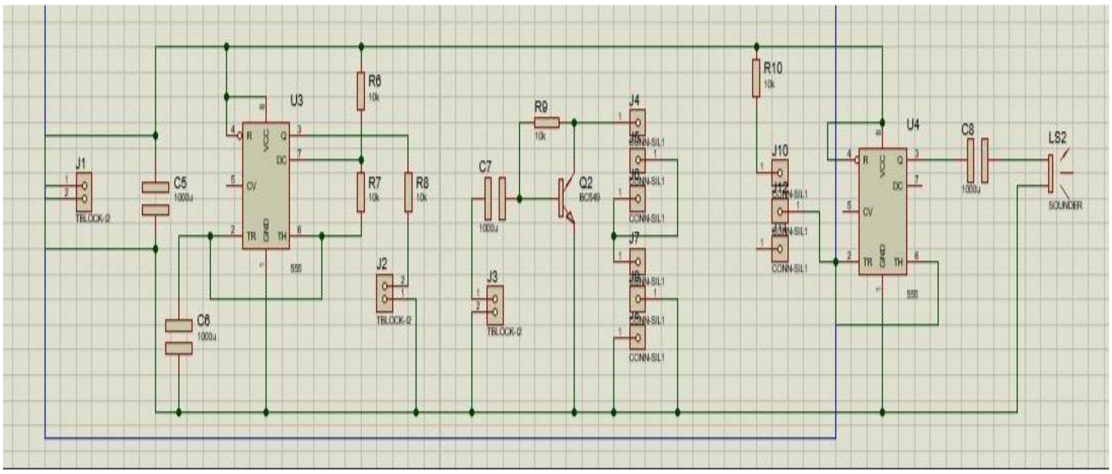
In both cases, the mutual inductance (M) can be determined experimentally or by using techniques such as calculating the magnetic field due to one circuit and integrating it over the area of the other circuit. The units of mutual inductance are typically henries (H).

It's important to note that these calculations assume ideal conditions, such as perfect coupling between the circuits and negligible resistance. In real-world scenarios, factors like the physical arrangement, geometry, and presence of nearby conductors can affect the mutual inductance.

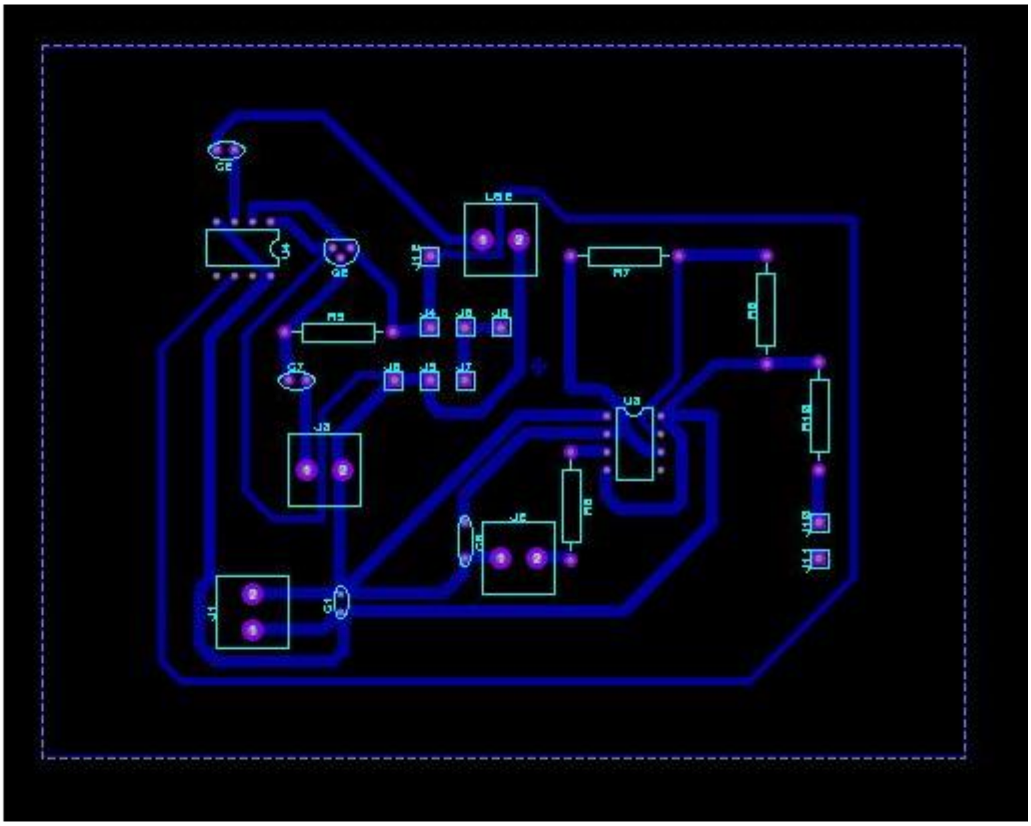
PROTEUS SIMULATIONS:

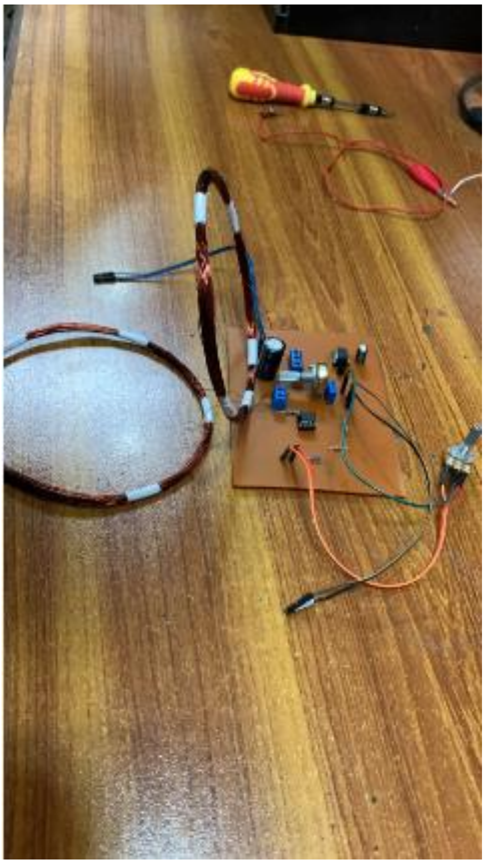


PCB DESIGN ON PROTEUS:



PCB LAYOUT:





COMPONENTS AND MATERIAL REQUIRED

COMPONENTS
IC 555
BC549
POTENTIOMETER
RESISTORS
CAPACITORS
COIL
PCB BOARD
FLUX
COPPER WIRE
ACID

SELF INDUCTANCE

WORKING PRINCIPLE:

- A metal detector consists of coil of wire which act as insulator.
- When alternating current is passed through the coil, it creates magnetic field around it.
- The change in magnetic field induces a current in the coil.
- The metal detector detects this change in current and alerts the user indicating the presence of metal.

CALCULATIONS:

To derive the formula for self-inductance, we start with Faraday's law of electromagnetic induction, which states that the induced electromotive force (EMF) in a coil is proportional to the rate of change of magnetic flux through the coil.

Let's consider a coil with N turns and a magnetic field B passing through it. The magnetic flux Φ through the coil is given by:

Φ = B * A

where **A is the cross-sectional area of the coil.** Now, let's assume that the current through the coil is changing at a rate of di/dt (where i represents the current).

According to Faraday's law, the induced EMF, E, is given by:

E = -dΦ/dt

Differentiating the flux equation with respect to time, we get:

dΦ/dt = d(B * A)/dt
= A * dB/dt

Substituting this into the expression for the induced EMF, we have:

$E = -A * dB/dt$

Now, according to the fundamental equation of electromagnetism, the induced EMF is equal to the rate of change of magnetic flux linkage (Λ), which is the product of the number of turns N and the flux Φ:

$E = -d\Lambda/dt$

Since $\Lambda = N * \Phi$, we can rewrite the equation as:

$E = -N * d\Phi/dt$

Comparing this with the earlier expression for E, we have:

$A * dB/dt = N * d\Phi/dt$

Rearranging the equation, we find:

$dB = (N * d\Phi) / A$

Now, consider the relationship between magnetic field B and magnetic field intensity H, given by $B = \mu_0 * H$, where μ_0 is the permeability of free space. Substituting this into the equation, we get:

$\mu_0 * dH = (N * d\Phi) / A$

Now, let's consider the magnetic field intensity H as the result of the current passing through the coil. We know that $H = (N * i) / l$, where l is the length of the coil. Substituting this into the equation, we have:

$\mu_0 * ((N * di) / l) = (N * d\Phi) / A$

Simplifying the equation, we get:

$\mu_0 * (di/dt) = (N^2 * d\Phi) / (l * A)$

Finally, the self-inductance L is defined as $L = \Phi / i$. Substituting this into the equation, we have:

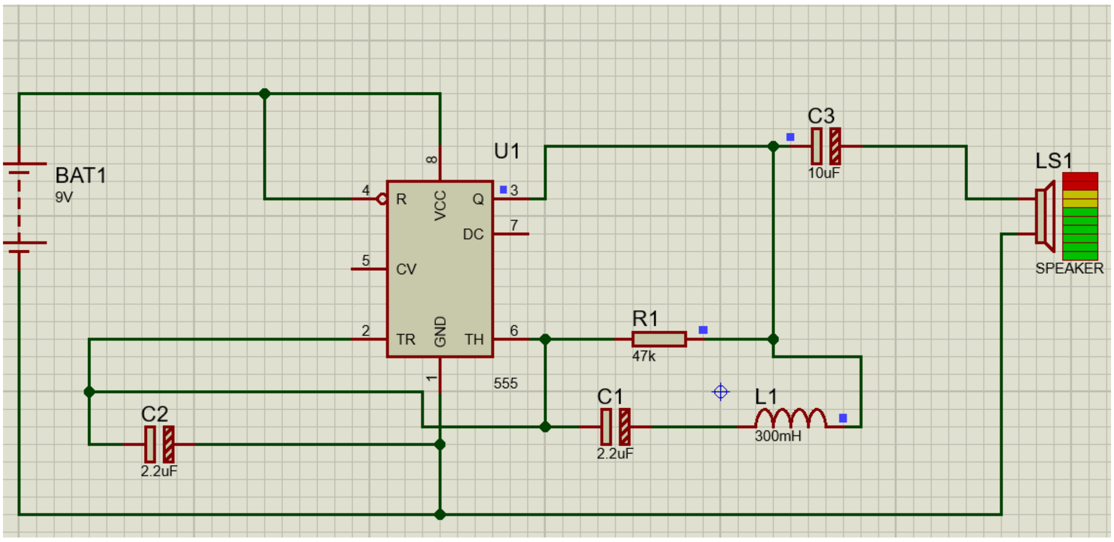
$\mu_0 * (di/dt) = (N^2 * L) / (l * A)$

Rearranging the equation, we obtain the formula for self-inductance:

L = (μ_0 * N² * A) / l

This is the derived formula for self-inductance, which represents the relationship between the number of turns, cross-sectional area, length, and permeability of free space in a coil.

PROTEUS SIMULATIONS:



We have not implemented the circuit of self inducatance because of its cancellation before three weaks of project submission.All of the data regarding self inductance has been provided.

CONCLUSION:

In conclusion, the project on metal detector has been an enlightening and challenging experience. Throughout our journey, we encountered various obstacles that required our utmost dedication and problem-solving skills. The issues pertaining to coil winding, including the need for precision and accuracy, presented significant challenges. Additionally, loose connections proved to be a hindrance, demanding meticulous attention to detail and thorough testing. Moreover, the inconsistencies in certain component values further added complexity to the project. However, with perseverance, continuous learning, and collaboration, we successfully overcame these challenges and achieved a functional metal detector. This project has provided us with invaluable insights into the intricacies of circuit design and has enhanced our skills in troubleshooting and critical thinking.