# Inductive Sensor

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## MINI PROJECT REPORT

**Submitted to**

## Visvesvaraya Technological University

**BELAGAVI - 590 018**

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Under the guidance of

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**in partial fulfilment of the requirements for the award of the degree of**

## Bachelor of Engineering


**Department of Electronics & Communication Engineering**

# SDM INSTITUTE OF TECHNOLOGY

# UJIRE - 574 240


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# SDM INSTITUTE OF TECHNOLOGY

(Affiliated to Visvesvaraya Technological University, Belagavi)

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***CERTIFICATE***

Certified that the Project Work titled **' Inductive Proximity Sensor'** is carried out by **Mr. Swaroop P**, USN:4SU21EC088, **Mr. Thejas B R**, USN:4SU21EC091, **Mr. Vijay Kumar K C**, USN:4SU21EC098, **Mr. Selvestar Dsouza**, USN:4SU22EC404 are bona-fide students of SDM Institute of Technology, Ujire, in partial fulfilment for the requirement for VI semester Mini-Project in Electronics and Communication Engineering of Visvesvaraya Technological University, Belagavi during the year 2023-2024. It is certified that all the corrections/ suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The report has been approved as it satisfies the academic requirements in respect of mini project work prescribed for the said degree.

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# Abstract

This project focuses on the design and implementation of an inductive proximity sensor, a crucial component in modern automation and safety systems. Inductive proximity sensors detect metal objects without physical contact, offering high reliability, precision, and durability in various industrial applications, optimized for detecting both ferrous and non-ferrous metals. The design process involves researching existing sensor technologies, selecting appropriate components, and developing a prototype. In this project we use coil to generate electromagnetic force, LC oscillator and trigger circuit. It works on the principle of Faraday's law of inductance and Lenz's law. The main objective of this project is to learn about the inductive sensor and its working and the final product aims to provide a cost-effective, energy-efficient solution for enhancing the accuracy and safety of automated systems in manufacturing, automotive, and other industries.

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# Acronyms and Abbreviations

| | |
|---|---|
| LC | Inductor-Capacitor |
| EMF | Electromotive force |
| UTP | Upper threshold point |
| LTP | Lower threshold point |
| Vref | Reference voltage |
| IC | Integrated circuits |
| Op-amp | Operational amplifier |
| LED | Light Emitting Diode |

# CHAPTER 1

# INTRODUCTION

Inductive sensors are versatile devices widely employed in industrial automation and manufacturing settings for non-contact detection of metallic objects. Operating on the principle of electromagnetic induction, these sensors generate a high-frequency alternating magnetic field. When a metallic object enters this field, it induces eddy currents within the object, altering the field's characteristics. This change is detected by the sensor, signalling the presence of the object.

One of the primary advantages of inductive sensors is their ability to detect metallic objects without physical contact. This feature eliminates the need for mechanical components that can wear out over time, enhancing the sensor's reliability and longevity. Moreover, since inductive sensors do not require direct contact with the object being detected, they can function effectively in harsh environments where dust, dirt, or moisture may be present.

Inductive sensors offer fast response times, making them suitable for high-speed applications in industries such as automotive assembly lines, packaging, and conveyor systems. Their robust construction and resistance to environmental factors ensure consistent performance even in demanding conditions. Additionally, these sensors are available in various sizes and configurations to suit different applications, from small-scale machinery to heavy-duty industrial equipment.

In summary, inductive sensors play a crucial role in modern manufacturing by providing accurate and reliable detection of metallic objects, thereby enhancing efficiency, productivity, and safety in industrial processes.

CHAPTER 2

# LITERATURE REVIEW

## 2.1 General Introduction

A lecture review is a summary and evaluation of a presentation or lecture, highlighting key points and takeaways, Strengths and weaknesses of the presentation, clarity and effectiveness of work, suggestions for improvement. It helps to reinforce understanding, identify areas for improvement, and provide feedback for future development.

## 2.2 Literature Survey

1. Inductive Sensor and Their Application in Metal Detection by Hartmut Ewald, this work was mainly focused on working principle of the inductive sensors, reaction of inductive sensor with metal and non-metal and application of the inductive sensor. It also gives the result of proximity and the range of the sensor that how much distance it can sense.

2. A reference to an article by Sorin Fericean titled "New Non-Contacting Inductive Analog Proximity and Inductive Sensor for Industrial Automation" was made. The paper covered the use of inductive sensors and how they function under various conditions.

## 2.3 Summary

From this literature review, able to understand the working principle of the inductive proximity sensor and its application, how to use the sensor for different applications, and how it works in different conditions.

The Schmitt trigger circuit and its application may be designed by understanding the many types of sensors and their working principles and behaviours. The inductive sensor is a crucial component in both industrial and automation applications.

CHAPTER 3

# PROBLEM STATEMENT AND OBJECTIVE

## 3.1 Problem Statement

Detection of metal objects, Mechanical sensors that require contact can wear out quickly, leading to higher maintenance costs. Contact-based sensing methods are typically slower, which can reduce the efficiency of automated systems. Physical contact can damage sensitive components and objects, especially in precision manufacturing environments, the risk of accidents increases. More frequent maintenance and replacements of contact sensors can lead to increased downtime, affecting overall productivity. The ability to detect objects through non-metallic barriers (e.g., through plastic or cardboard packaging) is lost, leading to higher energy consumption in their absence.

## 3.2 Objective

To design and develop an inductive sensor capable of detecting the presence or absence of metallic objects.

# CHAPTER 4

# METHODOLOGY AND IMPLEMENTATION

The Faraday law of inductance states that when an electrically conducting object is placed in a magnetic field, an electric current known as an eddy will be generated in the object. This law is the basis for the operation of an inductive proximity sensor, which is able to detect metal objects without coming into contact with them. Eddy current, according to Lenz's law, produces an opposing magnetic field to the magnetic field that initially generated it in a conductor.Coils in inductive sensors create electromagnetic fields. When a metallic object enters this field, it induces currents, enabling detection without contact [1][2]. The number of turns in the coil and the frequency of the alternating current are important factors that determine the sensitivity and range of detection for the inductive sensor. LC oscillators in inductive sensors generate alternating magnetic fields.

For this project we need oscillator circuit that is LC oscillator, coil to generate magnetic field and trigger circuit to activate the LED which is non-contact detection is made possible when a metallic object modifies this field because it causes variations in the oscillator's frequency. The inductor and capacitor values control the frequency of oscillations that the LC oscillator produces. This frequency can be adjusted in response to the proximity of a target object, enabling the detection and measurement of its presence. Inductive sensors use trigger circuits to understand changes in electromagnetic fields caused by metallic objects. They trigger reactions, allowing the sensor to identify and indicate whether an object is present or absent in a variety of applications. used to indicate the presence or absence of the metal object as shown in the Fig:4.1

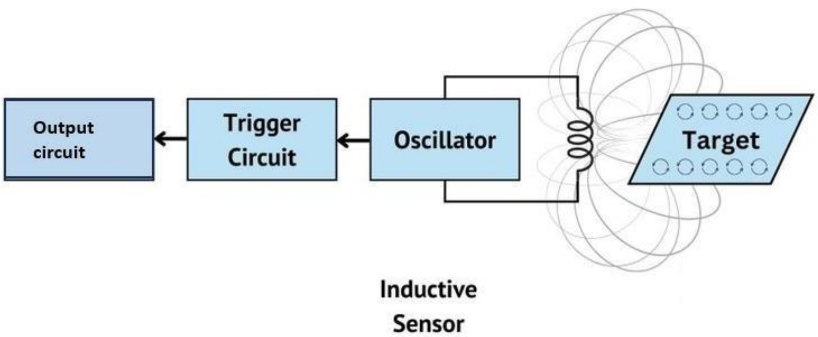



Fig: 4.1 Block diagram of inductive sensor

## 4.1 Hardware Requirements

**IC- uA741:** The uA741 is a widely used operational amplifier (op-amp) IC, it was first introduced in 1967 by Fairchild Semiconductor. The uA741 is a general-purpose op-amp, suitable for various applications, it has a high gain-bandwidth product of 1 MHz, the IC has a high input impedance of 2 MΩ and has a low output impedance of 75 Ω. The uA741 can operate on a single supply voltage of 5 to15 V, it can drive loads up to 10 mA. The uA741 has a wide temperature range of 55°C to 125°C. The IC is widely used in audio, video, and instrumentation applications. It is also used in active filters, integrators, and differentiators.

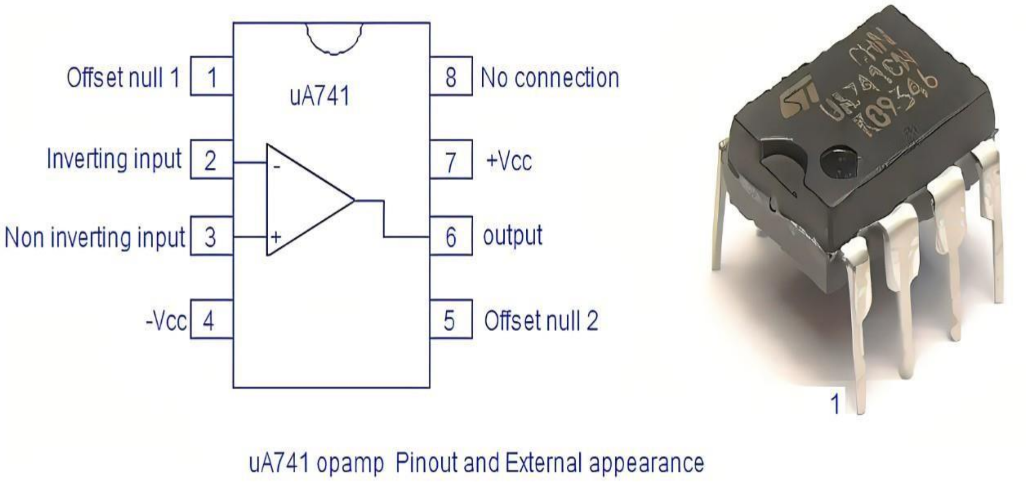



Fig: 4.2 uA741 op-amp

**LED:** LED stands for Light Emitting Diode, they are semiconductor devices that emit light. They work by passing a current through a p-n junction. LEDs are available in various colours, including red, green, blue, and white. They have a long lifespan, typically up to 50,000 hours. LEDs are energy-efficient, using up to 90% less power than incandescent bulbs, they are durable and resistant to shock, vibration, and extreme temperatures. LEDs are used in various applications, including lighting, displays, and indicators. They have a fast-switching time, making them suitable for high-frequency applications. LED is shown in Fig:4.3.

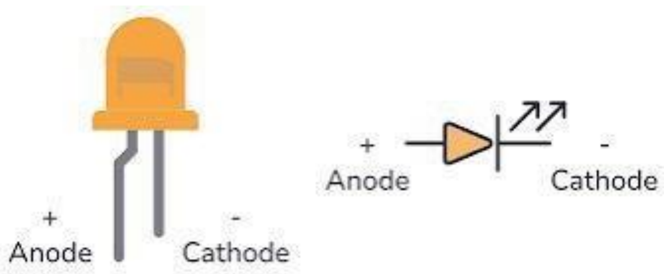



Fig: 4.3 LED

**Resistor:** A resistor is a passive electronic component that opposes the flow of current, they are used to control voltage and current levels in a circuit. They are available in various resistance values, measured in ohms (Ω). Resistors have a power rating, measured in watts (W), indicating maximum power handling. They come in different types, including fixed, variable, and adjustable resistors. Fixed resistors have a constant resistance value. Variable resistors allow for adjusting the resistance value. Adjustable resistors have a fixed range of resistance values, here fixed resistor is employed. Resistors are made from materials like carbon, metal film, or wire-wound. They have a tolerance value, indicating accuracy of the resistance value. Resistor is shown in Fig:4.4


Fig:4.4 Resistor

**Capacitor:** A capacitor is a passive electronic component that stores energy in an electric field. Capacitors consist of two conductive plates separated by an insulating material (dielectric), they are used to filter, regulate, and store energy in electronic circuits and they are measured in farads (F), with common values ranging from pF to mF. Capacitance (C) is directly proportional to plate area and inversely proportional to plate separation, dielectric materials determine the capacitor's properties, such as capacitance and breakdown voltage. Capacitors have a voltage rating, indicating the maximum voltage they can handle. They also have a tolerance value, indicating accuracy of the capacitance value. Types of capacitors include ceramic, film, electrolytic, tantalum, and supercapacitors. Ceramic capacitors are suitable for high-frequency applications. Electrolytic capacitors are polarized and used for power filtering and energy storage; resistor is shown in Fig:4.5.

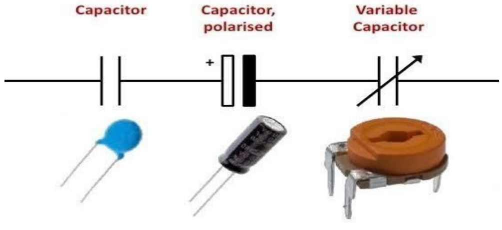



Fig:4.5 capacitor

### 4.1.1 Oscillator Circuit

An oscillator circuit is an electronic circuit that generates a periodic, oscillating signal without needing an input signal. It produces a continuous output waveform of a specific frequency, typically sinusoidal or square wave. They utilize active components such as transistors, operational amplifiers, or integrated circuits to sustain oscillation and generate the desired frequency output. As inductive sensor needs higher frequency rage to enhance the magnetic field produced by the coil, the best suitable for this sensor is Colpitts oscillator. A Colpitts oscillator is a type of LC oscillator circuit that uses an LC resonant tank circuit (inductor L and capacitor C) to generate sinusoidal oscillations where feedback is derived form a capacitive divider. It is named after its inventor Edwin H. Colpitts. Colpitts oscillator offers a balanced combination of simplicity, stability, and frequency range, making it a popular choice in various electronic circuits requiring a reliable oscillator [1][2]. The aim was to generate more than frequency range of 1Mhz, then it was designed for the frequency 1.41Mhz, the circuit diagram for the Colpitts oscillator is shown in Fig: 4.6.

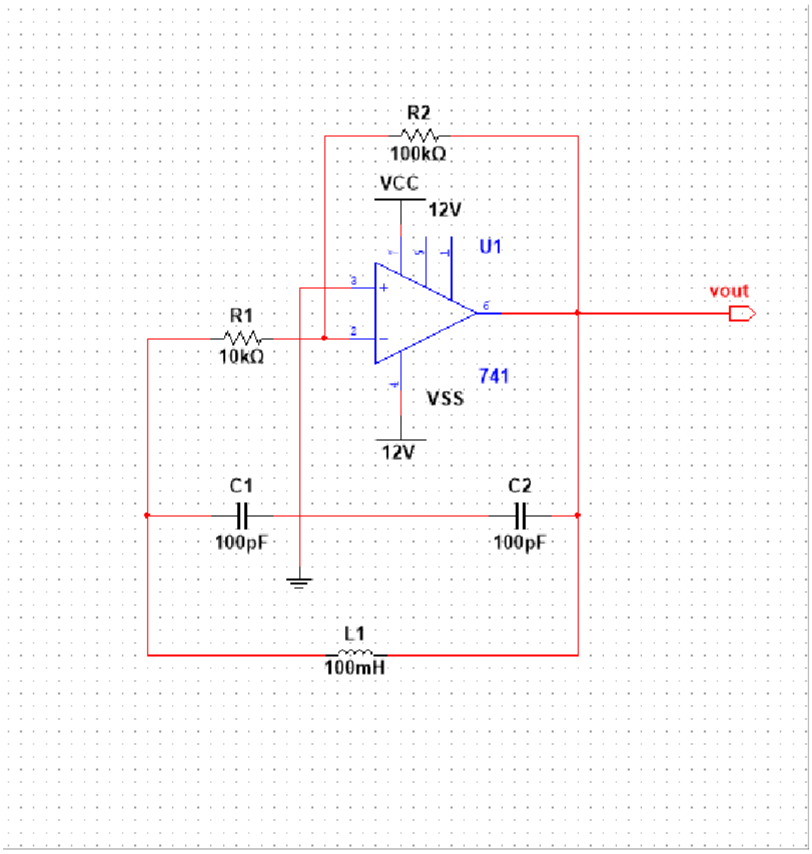



Fig: 4.6 Circuit diagram of Colpitts oscillator

**Design:** the frequency of Colpitts oscillator is given by [1],

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

choose c1= c2= 100 pF and L= 100 µH

$$C = \left(\frac{c1 \times c2}{c1 + c2}\right)$$

$$C = \frac{100p \times 100p}{100p + 100p} = 50pF$$

$$f = \frac{1}{2\pi\sqrt{100\mu \times 50p}}$$

f=1.41Mhz

### 4.1.2 Coil

Coils, play a crucial role in generating and interacting with magnetic fields. When current flows through a coil, a magnetic field is generated around it according to Ampère's circuital law. The strength of this magnetic field is directly proportional to the current passing through the coil. Faraday's Law states that a changing magnetic field through a conductor induces an electromotive force (EMF) or voltage in the conductor which is given by,

$$\mathcal{E} = -\frac{\mathbf{N\triangle\Phi}}{\mathbf{\triangle t}}$$

$$\mathcal{E} = -\frac{\mathbf{N(\Phi f - \Phi i)}}{\mathbf{\triangle t}}$$

$$\mathcal{E} = -\frac{\mathbf{N(AB\cos\Phi f - AB\cos\Phi i)}}{\mathbf{\triangle t}}$$

Ɛ=induced electromotive force in V

N=number of turns in the coil

A=area of the coil in $m^2$

B=magnetic field

Φ=magnetic flux in $T \cdot M^2$

△ t=time is takes for the flux to change

The magnetic field strength produced in the coil is directly proportional to the current in the coil and number of turns and inversely proportional to the radius of the loop[2], it is given by

$$B = \frac{\mu o \text{ n I}}{2\pi R}$$

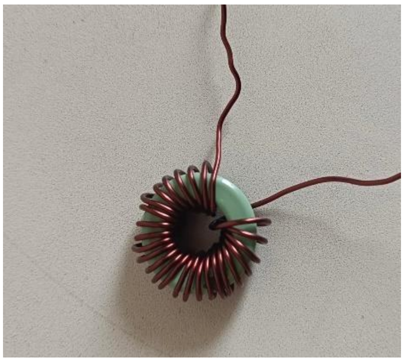
Here, B = Magnetic field strength (tesla)

I = Current (amps)

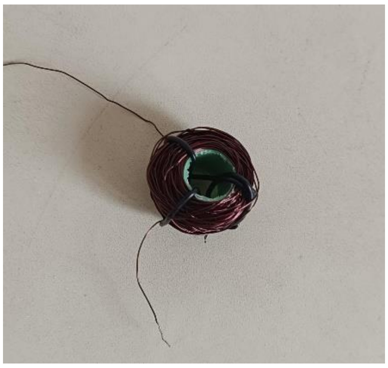
uo = Permeability of free space (4π*10^-7 m/A)

R = Distance from the wire (m)

For the inductive sensors, it was aimed to get better and high magnetic strength, hence the number of turns was increased and tested for different coils, as shown in coil-a, the coil has 25 number of turns and in coil-b has 543 number of turns and in coil-c the coil has 750 number of turns as shown in Fig: 4.7.



Coil- a



coil-b

coil-c

Fig 4.7 Coils with different number of turns

## 4.1.3 Trigger and output Circuit

The Schmitt trigger circuit is a type of comparator circuit, it uses positive feedback to implement hysteresis. The circuit has two thresholds called upper threshold point (UTP) and lower threshold point (LTP). The upper threshold is determined by R2/(R1+R2). The circuit switches high when input exceeds upper threshold point. The circuit switches low when input falls below lower threshold. The circuit is less sensitive to noise due to hysteresis, Schmitt trigger circuits are used in analog-to-digital conversion, they are also used in level detection and noise reduction. The circuit can be implemented using operational amplifiers, Schmitt trigger was designed for reference voltage Vref 2 v. When the voltage in the input is higher than the reference voltage then the circuit output is high that is more than Vcc-1 and when the voltage in the input is lower than the reference voltage then the circuit output is -Vcc+1 [3]. The Schmitt trigger circuit is shown in Fig:4.8.

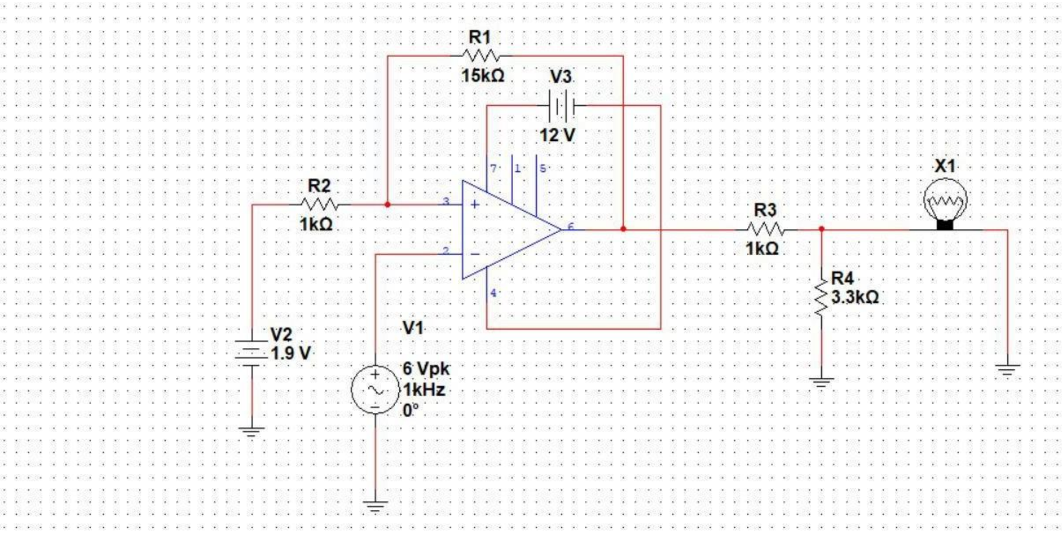



Fig:4.8 Schmitt trigger circuit

Design:

Design for Schmitt trigger circuit for UTP =2v and LTP=1.5v

Always UTP>LTP

UTP= $\frac{R2}{R1+R2}(vsat) + \frac{R1}{R1+R2}(vref)$ ---(1)

LTP= $\frac{R2}{R1+R2}(-vsat) + \frac{R1}{R1+R2}(vref)$ ---(2)

UTP + LTP = $\frac{2\,R1}{R1+R2}(vref)$ ---(3)

UTP - LTP = $\frac{2\,R2}{R1+R2}(vsat)$ ---(4)

$3.5 = \frac{2\ R1}{R1+R2}(vref)$

$1.5 = \frac{2\ R2}{R1+R2}(vsat)$

Choose $vsat$= +12V

From (4) $\frac{2\ R1}{R1+R2} = \frac{1.5}{12}$ = R1= 15R2

Choose R2=1KΩ, R1 =15KΩ

$vref = \frac{3.5(1K+15K)}{2*15K}$ = 1.86 V $\boldsymbol{vref = 2}$

## CHAPTER 5

# RESULTS AND ANALYSIS

## 5.1 Results

This project on inductive sensor can be divided into 3 stages that is oscillator, coil and trigger circuit. The oscillator circuit was designed for the production of 1.41 MHz frequency but practically it was able to generate frequency ranges from 1.24 MHz to 1.6 MHz, the output of Colpitts oscillator is shown in Fig:5.1.


Fig:5.1 Output of Colpitts oscillator

The output of the oscillator circuit was given to input of the coil to produce the magnetic field. The outcome is displayed in Fig. 5.2. The coil with 550 turns was able to generate a magnetic field and see the deflection of the magnet, however some of the coils did not produce a magnetic field.

Fig:5.2 Magnetic field test

The output of the coil was given to the input of the trigger circuit. It was designed to detect the variation in the coil’s voltage, that is, the LED in the trigger circuit will turn on when the metal is not in the coil's magnetic field and will turn off when the metal is in the coil's field. Capable of creating both the trigger and the output of the trigger circuit, the LED will turn on when the input voltage is greater than 2 volts, as illustrated in Fig. 5.3, and turn off when the voltage is less than 2 volts, as illustrated in Fig. 5.4.

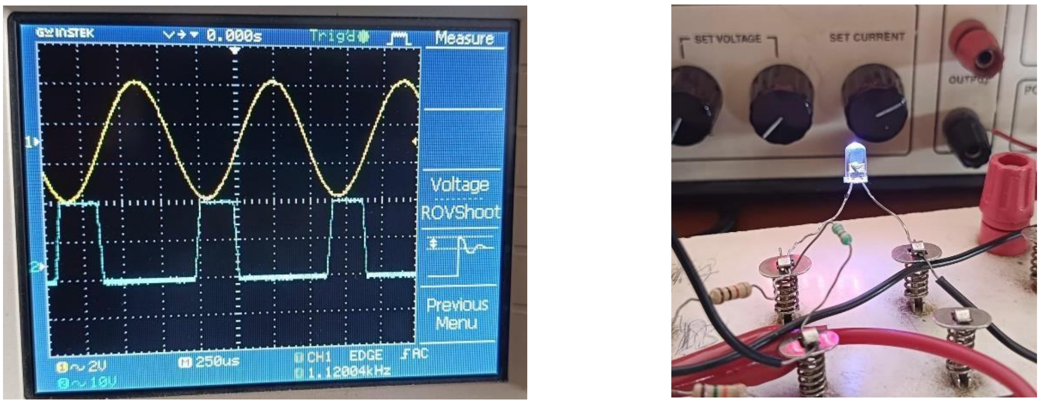



Fig:5.3 Output when the absence of metal object

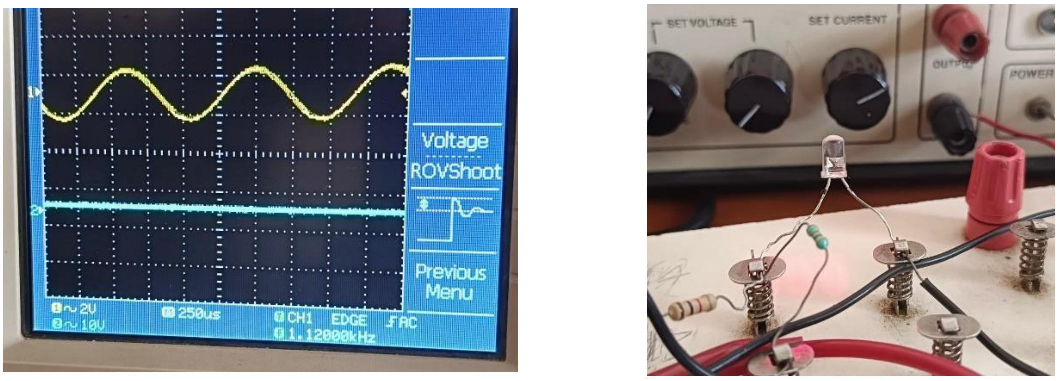



Fig:5.4 output when the presence of metal object

# Conclusion

The design and implementation of the inductive sensor project have proven to be a significant endeavour with several noteworthy outcomes. Through meticulous planning, experimentation, and iterative refinement, this underscores the effectiveness of the chosen design methodologies and the robustness of implementation. Key findings from the project include the sensor's high sensitivity to metallic materials, demonstrating its potential applicability in industrial automation, robotics, and security systems where non-contact detection is paramount. The sensor's ability to operate reliably in various conditions further validates its practicality and versatility. Throughout the project, challenges such as producing of electromagnetic fields and developing coil for the production of electromagnetic field. These efforts ensured that the defectivity of the construction and development of sensor, enhancing its reliability and performance. Additionally, exploring opportunities for miniaturization and integration with IoT platforms could expand its usability in smart devices and IoT applications.

In essence, the design and implementation of the inductive sensor project have provided valuable insights into sensor technology, offering a solid foundation for future advancements and applications in the field of sensing and automation. This project not only met its objectives but also paved the way for potential innovations that could significantly impact various industries in the near future.

# References


[1]. Hartmut Ewald, " Inductive Sensor and Their Application in Metal Detection ", Google Scholler, University of Rostock, Institute of general electrical engineering, 27 May 2014

[2]. Sorin Fericean, “New Non contacting Inductive Analog Proximity and Inductive Sensor for Industrial Automation”, IEEE international conference 2015, 118, 42-59.

[3]. Mohamed R Elmezayen, " Accurate Analysis and Design of Integrated Signal Input Schmitt Signal Input Schmitt Trigger Circuit ", MPDI, J. Low Power Electron, 28 June 2020

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