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Pulse Induction Based Metal Detector

COLLEGE OF
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COLLEGE OF ELECTRICAL AND MECHANICAL ENGINEERING

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PROJECT REPORT

PULSE INDUCTION BASED METAL DETECTOR

Submitted to the Department of Electrical Engineering
in partial fulfillment of the requirements
for the degree of

Bachelor of Engineering
in
Electrical
2023

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CERTIFICATE OF APPROVAL

It is to certify that the project **"Pulse Induction Based Metal Detector"** was done by **ASC Touqeer Afsar**, and **ASC Ghulam Mohi-ud-din** under supervision of **DR. Usman Ali**.

This project is submitted to **Department of electrical engineering**, Collage of Electrical and Mechanical Engineering (Peshawar Road Rawalpindi), National University of Sciences and Technology, Pakistan in partial fulfilment of requirements for the degree of Bachelor of Electrical Engineering.

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DECLARATION

We affirm that the content presented in this Project Thesis is original and has not been submitted in support of any other degree or qualification at this or any other educational institution. We acknowledge that any act of plagiarism will result in full responsibility and may lead to disciplinary action, including the potential cancellation of our degree, based on the severity of the offense.

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ABSTRACT

The project titled "Pulse Induction Based Metal Detector" presents the design and implementation of a metal detection system utilizing two coils and voltage difference measurement. The system incorporates a microcontroller to generate pulses that are transmitted through a primary coil, inducing an electromagnetic field. The secondary coil receives the reflected pulses, and the voltage difference between the two coils is measured and analyzed. The primary objective of the project is to detect and identify metal objects based on the analysis of the voltage difference between the transmitted and received pulses. By measuring the variation in voltage caused by the presence of a metal object, the system can effectively detect and differentiate between different types of metals. The project emphasizes the optimization of detection accuracy by employing advanced signal processing techniques and calibration methods. The microcontroller precisely measures the voltage difference and applies appropriate algorithms to classify and identify metal objects. The proposed metal detector has broad applications in fields such as security screening, industrial quality control, and archaeological surveys. Its pulse induction technology, combined with voltage difference analysis, enables the detection of concealed or buried metal objects with high reliability. The project implementation involves the integration of hardware components, including a microcontroller, transmitter and receiver coils. Software algorithms are developed to control the microcontroller, process the received signals, and perform voltage difference calculations. Experimental results demonstrate the effectiveness and accuracy of the pulse induction based metal detector using voltage difference measurement. The system achieves reliable metal detection and identification, accurately differentiating between various types of metals based on their unique voltage signatures. In conclusion, the "Pulse Induction Based Metal Detector" project offers an innovative and efficient solution for metal detection applications. By utilizing two coils and measuring the voltage difference, the system achieves reliable and accurate metal detection, making it a valuable tool in diverse industries and scenarios requiring precise metal identification.

SUSTAINABLE DEVELOPMENT GOALS

The creation of a "Pulse Induction based Metal Detector" primarily aligns with the following Sustainable Development Goals (SDGs):

1. Industry, Innovation, and Infrastructure (SDG 9): By developing and utilizing a pulse induction-based metal detector, you contribute to promoting innovation and improving industrial infrastructure. This technology enhances the efficiency and accuracy of metal detection, which can have applications in various sectors, including mining, construction, security, and archaeology.

2. Sustainable Cities and Communities (SDG 11): A pulse induction-based metal detector can be employed in ensuring the safety and security of urban areas by detecting hidden metallic objects that may pose a threat. This contributes to creating safer and more resilient cities and communities.

3. Responsible Consumption and Production (SDG 12): Metal detectors can aid in responsible consumption and production practices by facilitating the efficient recovery and recycling of valuable metallic resources. By identifying and separating metallic materials, these detectors support sustainable waste management and resource conservation.

4. Climate Action (SDG 13): While the direct connection between a metal detector and climate action may not be obvious, the efficient use of metal detectors can contribute to reducing environmental impacts. For instance, by accurately locating buried metallic objects, excavation activities can be more precise, minimizing unnecessary digging and associated carbon emissions.

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Acronyms

PIMD Pulse Induction based Metal Detector

Chapter 1 - INTRODUCTION

1.1. Introductory Background:

Metal detection technology has proven to be invaluable in various fields, ranging from security and law enforcement to archaeology and industrial applications. The ability to accurately detect and locate metallic objects hidden beneath surfaces plays a crucial role in ensuring safety, enhancing productivity, and preserving valuable historical artifacts. Traditional metal detectors based on electromagnetic induction have been widely used, but they often face limitations in terms of depth penetration and discrimination capabilities.

1.2. Problem Statement:

The problem addressed in this thesis is the limitations of traditional metal detectors in terms of depth penetration and discrimination capabilities. Conventional metal detectors based on electromagnetic induction struggle to accurately detect and differentiate metallic objects buried at significant depths or in complex environments. These limitations hinder their effectiveness in various domains, including security, archaeology, and industrial applications. Therefore, there is a need to develop a Pulse Induction based Metal Detector (PIMD) system that overcomes these challenges and provides improved depth detection and enhanced discrimination capabilities. The objective is to design and optimize a PIMD system that offers superior performance and reliability for accurate and efficient metal detection in real-world scenarios.

1.3. Purpose of study:

The purpose of this thesis is to explore and develop a Pulse Induction based Metal Detector (PIMD) system that addresses the shortcomings of conventional metal detectors, offering improved depth detection and enhanced discrimination capabilities. The focus of this research is to design, optimize, and evaluate the performance of the PIMD system, ultimately providing a more reliable and efficient solution for metal detection applications.

1.4. Objectives:

The primary objectives of this study are as follows:

1.4.1. Design and development:

Design and development of a Pulse Induction based Metal Detector system, incorporating advanced signal processing techniques and innovative circuitry.

1.4.2. Optimization of the PIMD:

Optimization of the PIMD system parameters to achieve maximum depth penetration, sensitivity, and discrimination between different metal targets.

1.4.3. Performance evaluation:

Performance evaluation and comparison of the developed PIMD system with existing metal detection technologies, assessing its effectiveness in real-world scenarios.

1.4.4. Analysis:

Analysis of the practical applications and potential benefits of the PIMD system in various domains, including security, archaeology, and industrial sectors.

1.5. Significance of study:

The development of a Pulse Induction based Metal Detector (PIMD) has significant implications for multiple fields and industries. By addressing the limitations of traditional metal detectors, the PIMD system has the potential to revolutionize metal detection practices, enabling more accurate and efficient detection of metallic objects, even at greater depths. The outcomes of this research will contribute to advancements in security systems, improved archaeological exploration, enhanced industrial operations, and ultimately, the overall safety and productivity of diverse sectors.

1.6. Structure of thesis:

This thesis is structured into several chapters, each focusing on specific aspects of the Pulse Induction based Metal Detector (PIMD) system. The subsequent chapters will provide a comprehensive overview of the existing metal detection technologies, the theoretical foundations of pulse induction, the design and development of the PIMD system, experimental methodologies, performance evaluation, and the analysis of the obtained results. The final chapter will summarize the key findings, draw conclusions, and discuss the potential future directions for further research and development in this field.

By investigating and developing the Pulse Induction based Metal Detector (PIMD) system, this thesis aims to contribute to the advancement of metal detection technology, providing a valuable tool for various applications that require accurate and reliable detection of metallic objects.

Chapter 2 – BACKGROUND AND LITRATURE REVIEW

2.1. Introduction:

This chapter provides an overview of existing knowledge on Pulse Induction based Metal Detectors (PIMDs). It examines the limitations of traditional metal detectors and explores research on PIMDs, including signal processing algorithms, coil design, and circuitry optimization. The literature review highlights the practical applications of PIMDs in security, archaeology, and industrial sectors. By synthesizing current understanding and identifying research gaps, this chapter serves as a foundation for the subsequent research and development in the thesis.

2.2. Background:

Metal detection technology plays a crucial role in various fields, including security, archaeology, and industrial applications. The ability to accurately detect and locate metallic objects hidden beneath surfaces is essential for ensuring safety, improving productivity, and preserving valuable artifacts. Traditional metal detectors based on electromagnetic induction have been widely used, but they often face limitations in terms of depth penetration and discrimination capabilities.

2.3. Literature Review:

In recent years, there has been a growing interest in the development of Pulse Induction based Metal Detectors (PIMDs) as an alternative to conventional metal detection technologies. PIMDs offer several advantages, including enhanced depth detection and improved discrimination capabilities. Pulse induction operates by generating brief and powerful electromagnetic pulses, which induce eddy currents in metallic objects. By measuring the response of these eddy currents, PIMDs can detect and differentiate between various types of metallic targets.

The design and optimization of a PIMD system require a thorough understanding of the underlying principles and techniques. Previous research and literature have contributed valuable insights into the development and performance of PIMDs. Several studies have focused on signal processing algorithms, coil design, and circuitry optimization to enhance the capabilities of PIMDs.

One important aspect of PIMD development is the optimization of system parameters to achieve maximum depth penetration and sensitivity. Research efforts have focused on optimizing pulse repetition rate, pulse width, and receiver coil design to enhance the detection range and sensitivity of PIMDs. Additionally, discrimination algorithms have been developed to improve the ability of PIMDs to differentiate between different types of metallic targets, such as ferrous and non-ferrous metals.

Existing literature also highlights the practical applications of PIMDs in various domains. In the field of security, PIMDs offer improved detection capabilities for concealed weapons and contraband materials. In archaeology, PIMDs assist in locating buried artifacts and ancient metallic structures without damaging the surrounding environment. Furthermore, in industrial sectors such as mining and construction, PIMDs are used for detecting buried utilities and assessing subsurface conditions.

While significant advancements have been made in PIMD technology, there are still challenges that need to be addressed. Depth accuracy, discrimination accuracy, and interference from environmental factors are areas that require further investigation and improvement.

This thesis aims to contribute to the existing body of knowledge by designing, optimizing, and evaluating a Pulse Induction based Metal Detector (PIMD) system. The research will focus on exploring novel signal processing techniques, coil designs, and circuitry optimizations to enhance the depth detection and discrimination capabilities of the PIMD system. The study will also assess the practical applications and potential benefits of the PIMD system in various domains.

By conducting an in-depth review of the background literature and incorporating the existing knowledge into the research, this thesis endeavors to advance the field of metal detection technology and contribute to the development of more reliable and efficient PIMDs.

Chapter 3 – CONCEPTUAL DESIGN

3.1. Introduction:

The Conceptual Design chapter explores the initial phase of developing a Pulse Induction based Metal Detector (PIMD) system. It focuses on translating research objectives into a conceptual design framework. This chapter highlights the importance of considering depth penetration, discrimination capabilities, power consumption, and ergonomics. It discusses generating and evaluating design concepts for coil design, signal processing algorithms, and circuitry configurations.

3.2. Functional Requirements:

3.2.1. Microcontroller:

The utilization of microcontrollers in Pulse Induction based Metal Detectors (PIMDs) has revolutionized the field of metal detection technology. Microcontrollers play a crucial role in enhancing the functionality and performance of PIMD systems.

By integrating a microcontroller into a PIMD, various tasks and functions can be efficiently managed. One of the key functions performed by the microcontroller is frequency comparison. The microcontroller measures and analyzes the frequencies generated by the pulse induction circuitry, allowing for accurate detection and discrimination of metallic targets.

Moreover, the microcontroller enables the implementation of advanced signal processing algorithms, providing enhanced target identification and discrimination capabilities. It can employ digital signal processing techniques to filter out noise and interference, resulting in improved detection accuracy.

The microcontroller also facilitates the control and coordination of various components within the PIMD system. It manages the timing and synchronization of pulse generation, signal acquisition, and data processing. Additionally, it can be utilized to implement user interfaces, such as LCD displays and keypad inputs, making the PIMD more user-friendly and accessible.

Another advantage of using a microcontroller is its flexibility and programmability. The microcontroller can be programmed to adapt to different environmental conditions or specific target characteristics, allowing for customization and optimization of the PIMD system.

Furthermore, microcontrollers offer compactness and low power consumption, making them suitable for portable and battery-powered PIMD applications. They provide a cost-effective and efficient solution for implementing complex control and processing tasks within limited physical and power constraints.

In summary, the incorporation of microcontrollers in PIMD systems enhances their functionality, control, and signal processing capabilities. These microcontrollers enable precise frequency comparison, advanced signal processing algorithms, and the integration of user interfaces. Their programmability and low power consumption make them an ideal choice for implementing intelligent and efficient metal detection solutions.

3.2.2. Detection Range:

The range of a Pulse Induction based Metal Detector (PIMD) is a critical functional requirement that determines the depth at which metallic objects can be detected. In the case of this specific PIMD system, the range is limited to approximately 6 inches. This means that the detector is optimized to detect metallic objects buried within a depth range of up to 6 inches below the surface. This range is carefully calibrated to strike a balance between sensitivity and depth penetration, allowing for efficient detection of various types of metallic targets within this specific depth limit.

3.2.3. Coil:

The coil is a fundamental component in Pulse Induction based Metal Detectors (PIMDs) that plays a crucial role in the detection of metallic objects. It serves as the primary sensing element responsible for generating and receiving electromagnetic fields.

The coil in a PIMD is typically wound with multiple turns of wire, forming a coil or a loop. It is designed to produce a time-varying magnetic field when an electric current is passed through it. This magnetic field induces eddy currents in nearby metallic objects, causing a secondary magnetic field to be generated in the target material.

The interaction between the primary magnetic field generated by the coil and the secondary magnetic field produced by the metallic target leads to a change in the inductance of the coil. This change in inductance is detected by the PIMD system, indicating the presence of a metallic object.

The design and characteristics of the coil significantly impact the performance of the PIMD system. Factors such as the number of turns, the diameter of the coil, and the choice of wire material can influence the sensitivity, detection range, and discrimination capabilities of the detector.

Coil geometry also plays a role in determining the detection pattern and depth penetration of the PIMD system. Different coil configurations, such as concentric coils or Double-D coils, offer varying degrees of sensitivity and coverage area. The choice of coil design depends on the specific application requirements and the desired trade-off between detection depth and target discrimination.

Additionally, the coil is often accompanied by a coil housing or frame that provides mechanical support and protection. The housing shields the coil from external interference and helps maintain its shape and stability during operation.

The coil in a PIMD is a critical element that directly interacts with the target material and facilitates the detection process. Its design, configuration, and characteristics are carefully considered to optimize the sensitivity, range, and discrimination capabilities of the metal detection system.

3.3. Flow Diagram:

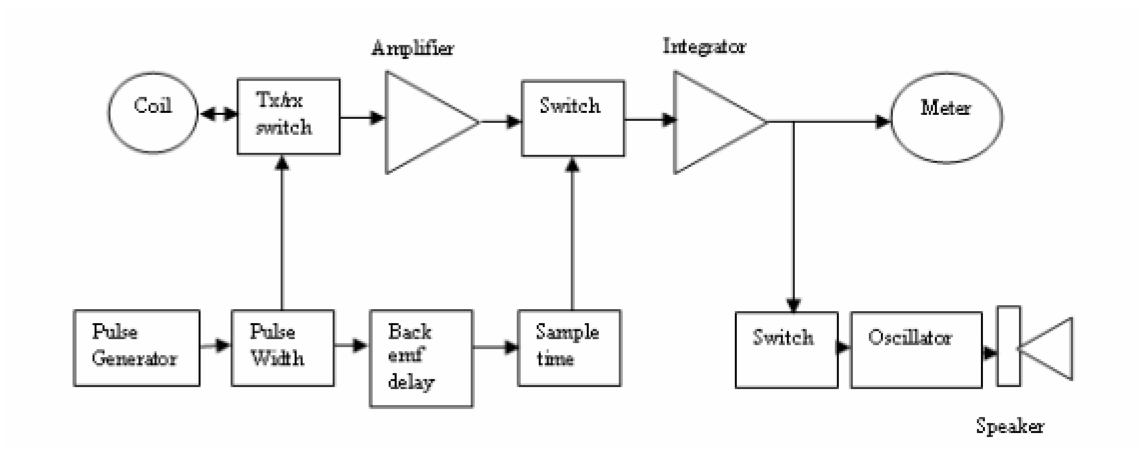

Figure 3.1. Flow Diagram showing parts of PIMD.

Chapter 4 – IMPLEMENTATION

4.1. Introduction:

The Implementation chapter delves into the practical realization of the Pulse Induction based Metal Detector (PIMD) system. It focuses on the actual construction, assembly, and integration of the various hardware and software components that form the PIMD system. This chapter provides a detailed account of the steps taken to transform the conceptual design into a functional prototype.

The chapter begins by discussing the selection and procurement of the necessary components, including the metal detection coil, microcontroller, signal processing circuitry, power supply, and user interface elements. It highlights the considerations and criteria used for choosing specific components based on their compatibility, performance, and availability.

Next, the chapter delves into the physical implementation of the PIMD system. It covers the construction of the coil housing, the assembly of electronic circuits, and the integration of various subsystems. This includes soldering, wiring, and mounting of components, ensuring proper connections and structural integrity.

4.2. Components:

The following components are used during the implementation of PIMD:

4.2.1. Components Table:

RESISTORS (Ohms)	CAPACITORS (Farads)	TRANSISTORS	LEDs	MICROCONTROLLER	PUSH BUTTON	SPEAKER
220k	15P(2)	BC557 (2)	1(green)	PICF12629	1	1
1k	100u, 16V(1)	BC547(2)	1(red)			
100 (2)	10u,63V (1)					
10k (5)	22n					
55						
3k						
2.7k						

COIL	DIODE	Voltage regulator IC	BUZZER	BATTERY	OSSCILATOR
150 Turns 0.3mm wire	IN4007	LM317	1(5V)	1(9V)	1(20MHZ)

Table 4.1. Components Table

4.2.2. Use of Microcontroller:

4.2.2.1. Introduction:

The use of microcontrollers in Pulse Induction based Metal Detectors (PIMDs) has revolutionized the field of metal detection technology. One such microcontroller, the PIC12F629, has emerged as a popular choice for implementing frequency comparison in PIMD systems. This section explores the history of microcontrollers and highlights the significance of the PIC12F629 in the context of PIMD.

4.2.2.2. History of Microcontrollers:

Microcontrollers, integrated circuits designed to perform specific tasks within embedded systems, have a rich history dating back to the 1970s. They evolved from early microprocessors and became widely used in various applications, including industrial automation, consumer electronics, and medical devices. The development of microcontrollers enabled the integration of processing power, memory, and input/output peripherals into a single chip, making them ideal for compact and efficient systems.

4.2.2.3. The Role of PIC12F629 in PIMD:

The PIC12F629 microcontroller, developed by Microchip Technology, has found its application in PIMDs due to its versatility and features that align with the requirements of metal detection systems. This 8-bit microcontroller offers low-cost, low-power operation while providing sufficient processing capabilities for frequency comparison in PIMD circuits.

In a PIMD system, the PIC12F629 plays a crucial role in measuring and comparing the frequencies generated by the pulse induction circuitry. By utilizing its on-chip timer and interrupt capabilities, the microcontroller accurately captures and processes the frequency signals produced by the metal detection coil. It enables the implementation of advanced algorithms for discriminating between different types of metallic targets and improving the accuracy of target identification.

Furthermore, the PIC12F629 offers a range of peripherals, including analog-to-digital converters (ADCs) and digital input/output (I/O) pins, which facilitate the integration of additional sensors, user interfaces, and communication modules in the PIMD system. This flexibility enables the customization and expansion of the PIMD functionality according to specific application requirements.

The use of the PIC12F629 microcontroller in PIMDs underscores the significance of microcontroller technology in advancing metal detection capabilities. Its incorporation into PIMD systems enables precise frequency comparison, enhanced discrimination capabilities, and the potential for future expansion and integration of additional functionalities.

In conclusion, the PIC12F629 microcontroller has emerged as a vital component in Pulse Induction based Metal Detectors (PIMDs), contributing to their improved performance and versatility. By harnessing its features and capabilities, PIMD systems can achieve accurate frequency comparison and advanced target discrimination, marking a significant milestone in the evolution of metal detection technology.

4.2.3. Coil Specs:

The coil used in the Pulse Induction based Metal Detector (PIMD) system is a single ferrite core coil with specific specifications: it consists of 150 turns and utilizes a wire with a diameter of 0.3mm. The ferrite core serves as a magnetic material that enhances the coil's inductance and improves its performance in generating and detecting electromagnetic fields for the detection of metallic objects.

The number of turns in the coil, in this case, is 150. The wire is wound around the ferrite core, ensuring each turn is evenly spaced and tightly wound. The number of turns contributes to the sensitivity and detection range of the PIMD system. Generally, a larger number of turns can enhance sensitivity but may also increase resistance and reduce the detection range.

The wire diameter of 0.3mm determines the thickness of the wire used to form the coil. It is an important parameter that affects the electrical resistance and conductivity of the coil. Thinner wires with smaller diameters can provide higher sensitivity and lower resistance, while thicker wires may offer increased durability and handling.

The combination of a ferrite core with 150 turns and a 0.3mm wire diameter indicates the specific construction of the coil in the PIMD system. The ferrite core enhances the coil's inductance and magnetic field concentration, improving its sensitivity and performance in detecting metallic objects.

It is important to consider these specifications and the use of a ferrite core during the assembly and winding process to ensure the coil is accurately constructed and capable of generating and detecting the desired electromagnetic fields for effective metal detection.

Please note that the specific design and dimensions of the coil can vary based on the requirements of the PIMD system, including the desired sensitivity, target detection depth, and discrimination capabilities. Other factors such as the coil's size, shape, and material composition may also influence its performance.

4.3. Pictures:

4.3.1. Circuit Diagram:

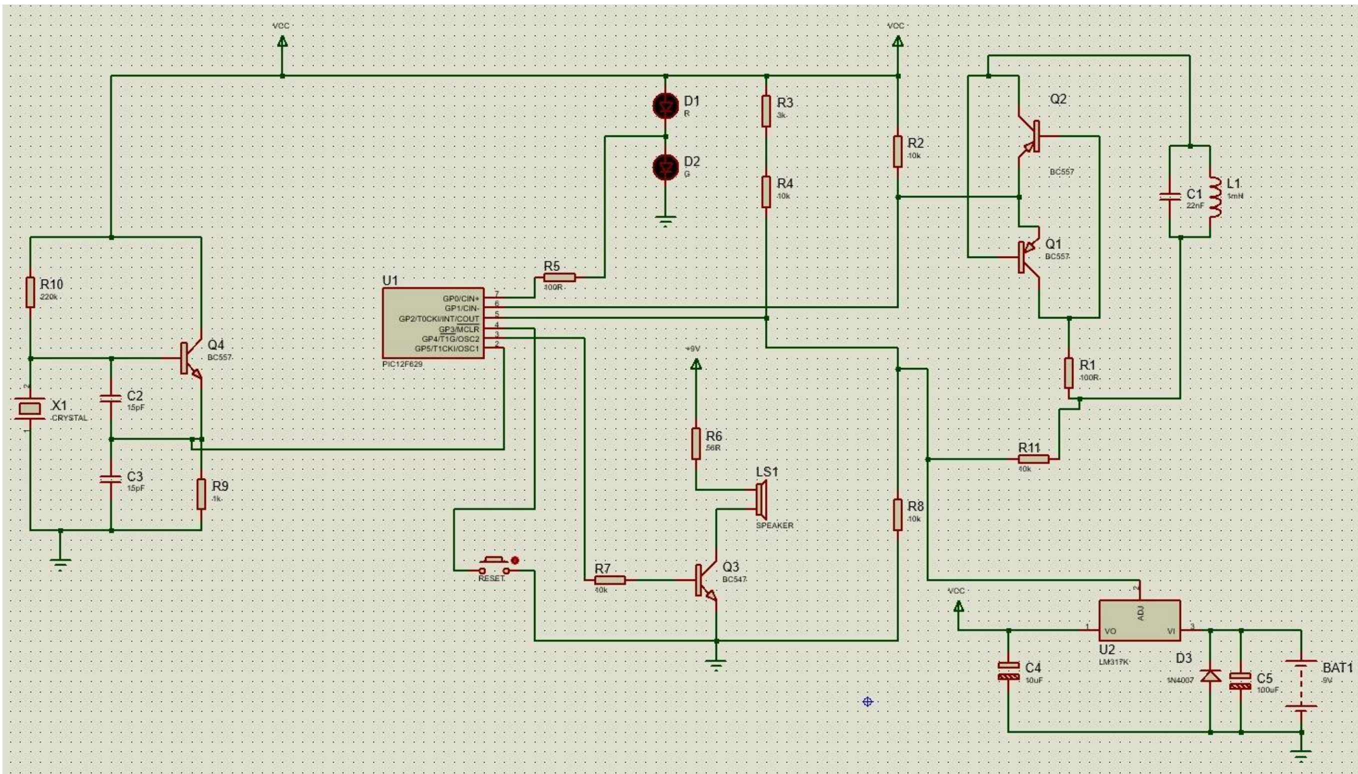

Figure 4.1. Circuit Diagram of PIMD.

4.3.2. Hardware Implementation:

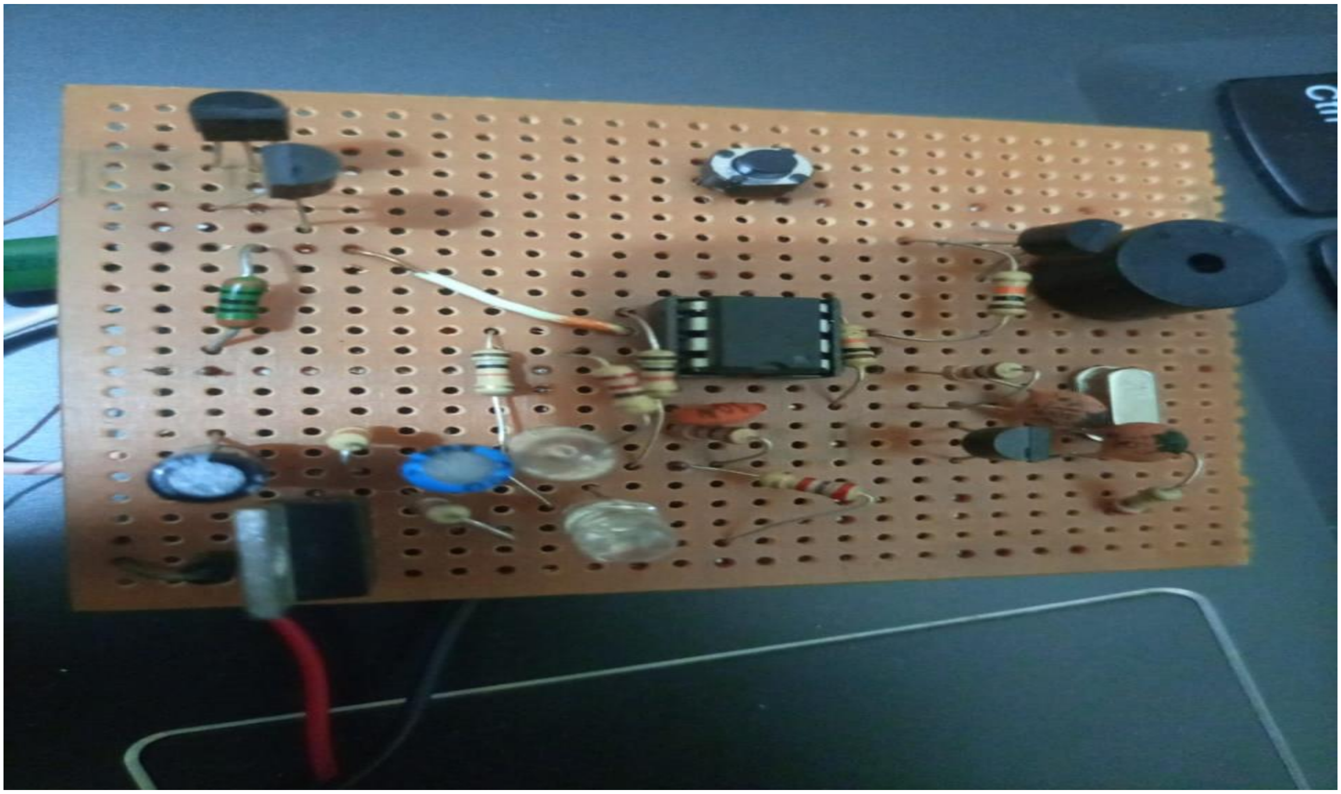

Figure 4.2. Hardware of PIMD.

4.3.3. Ferrite Coil:

Figure 4.3. Ferrite Coil of PIMD.

4.3.4. Battery:

Figure 4.4. 9v Battery of PIMD.

4.4. Output:

In the output section of the Pulse Induction based Metal Detector (PIMD) system, various components are employed to provide visual and audible indications when a metal object is detected. Additionally, connecting an oscilloscope to pin 5 of the microcontroller allows for the observation of frequency changes when a metal object is in proximity to the coil.

When a metal object is detected by the PIMD system, the following actions occur:

4.4.1. Buzzer Activation:

A buzzer is connected to the microcontroller's output pin (e.g., GPIO). When a metal object is detected near the coil, the microcontroller sends a signal to activate the buzzer. The buzzer emits an audible sound to alert the user of the metal detection.

4.4.2. LED Indication:

LEDs (Light-Emitting Diodes) are connected to the microcontroller's output pins (e.g., GPIO). When a metal object is detected, the microcontroller sends signals to turn on the LEDs. The illuminated LEDs provide a visual indication of the metal detection.

4.4.3. Oscilloscope Connections:

An oscilloscope can be connected to pin 5 (or any suitable pin) of the microcontroller. Pin 5 is configured to output a signal that represents the frequency changes detected by the coil. When a metal object is placed near the coil, it alters the inductance, affecting the oscillator's frequency. The oscilloscope displays the waveform of the frequency changes, allowing for further analysis and observation.

This combined approach of using a buzzer, LEDs, and an oscilloscope enhances the user experience and provides multiple ways to detect and analyze the presence of metal objects. The audible sound from the buzzer, the illuminated LEDs, and the visual representation on the oscilloscope all contribute to the effectiveness and usability of the PIMD system.

It is important to ensure proper wiring and appropriate circuitry to connect the buzzer, LEDs, and oscilloscope to the microcontroller. The specific pin assignments and connections may vary based on the chosen microcontroller model and the electrical specifications of the components used.

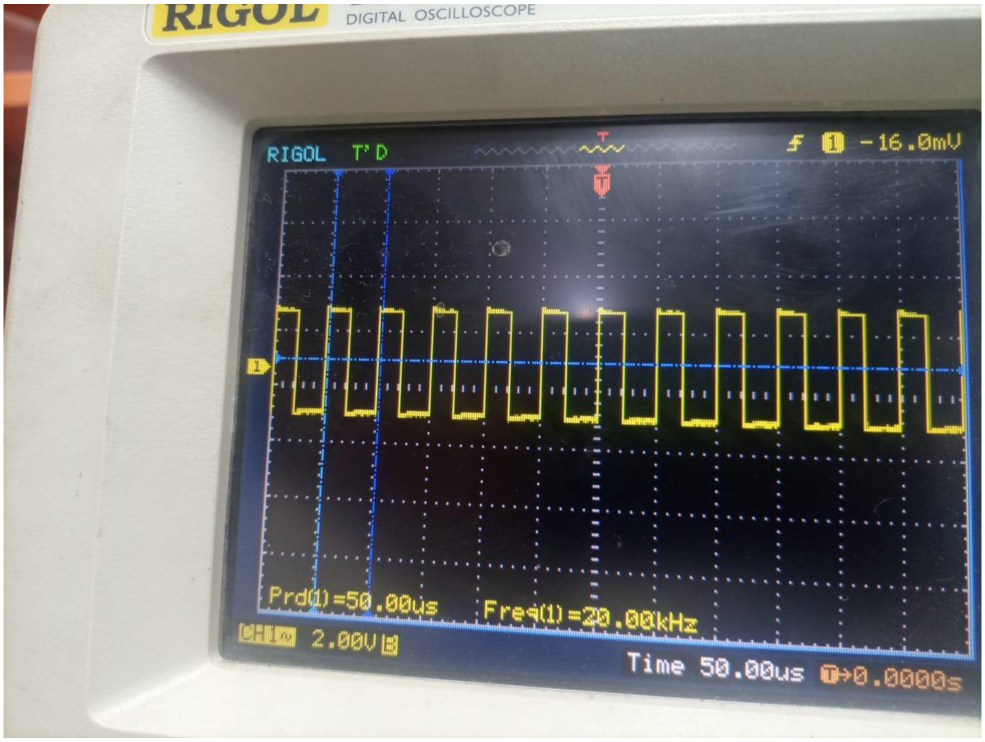

Figure 4.5. Output without Metal.

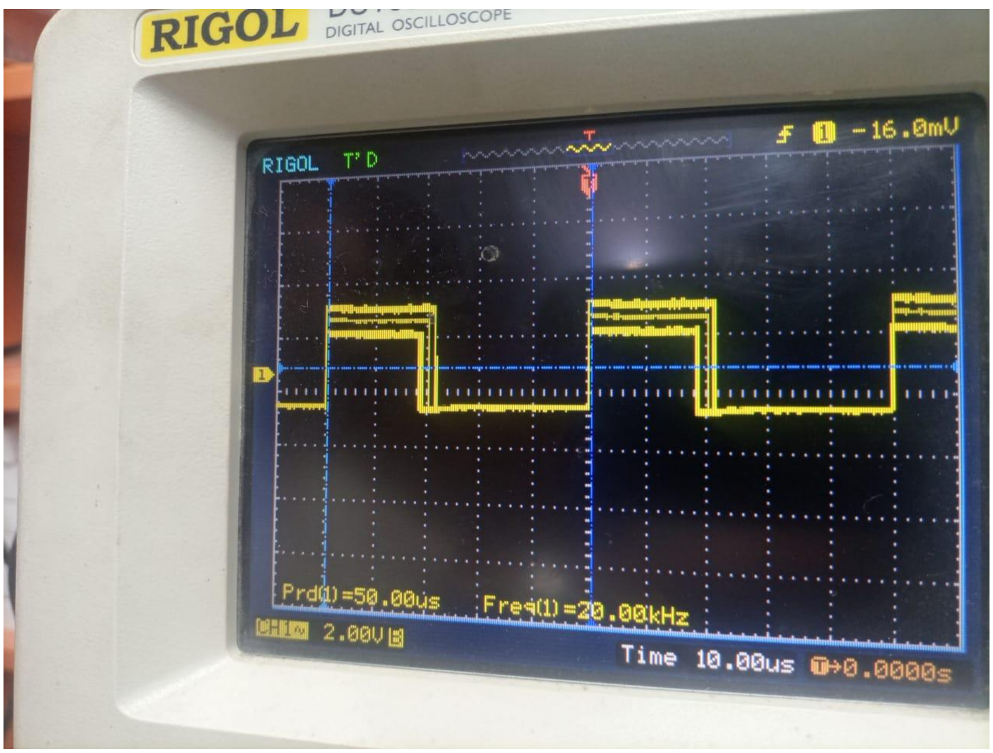

Figure 4.5. Output when Metal Detected.

4.4. Code:

```
// PIC12F629 Configuration Bits
#pragma config FOSC = INTRCIO // Internal oscillator, port functions on RA4/RA5
#pragma config WDTE = OFF    // Watchdog Timer disabled
#pragma config PWRTE = OFF   // Power-up Timer disabled
#pragma config MCLRE = OFF   // MCLR pin function is digital input
#pragma config BOREN = ON    // Brown-out Reset enabled
#pragma config CP = OFF      // Program memory code protection disabled

#include <xc.h>

#define THRESHOLD 500      // Adjust this threshold according to your requirements

void main(void) {
   TRISIO = 0b00001001;   // Set GP0 and GP3 as inputs for frequency measurement and reset
button
   GPIO = 0;              // Initialize GPIO pins

   unsigned int previous_time = 0;
   unsigned int current_time = 0;
   unsigned int frequency = 0;

   // Set buzzer and LEDs as outputs
   TRISIObits.TRISIO4 = 0;  // Buzzer (GP2) as output
   TRISIObits.TRISIO0 = 0;  // LED1 (GP4) as output
   TRISIObits.TRISIO0 = 0;  // LED2 (GP5) as output

   // Turn off buzzer and LEDs initially
   GP4 = 0;  // Buzzer off
   GP0 = 0;  // LED1 off
   GP0 = 0;  // LED2 off

   // Main loop
   while (1) {
      // Check for reset button press
      if (!GP2) {
         // Reset button pressed, perform necessary actions
         // ...

         // Turn off buzzer and LEDs
         GP4 = 0;  // Buzzer off
         GP0 = 0;  // LED1 off
         GP0 = 0;  // LED2 off

         // Reset the microcontroller
         asm("RESET");
```

```
        }

        // Measure frequency
        while (GPIO & 0x01) {}  // Wait for the input signal to go low
        while (!(GPIO & 0x01)) {}  // Wait for the input signal to go high
        current_time = TMR0;  // Get the current timer value
        frequency = (current_time - previous_time) * 2;  // Calculate the frequency
        previous_time = current_time;  // Update the previous time

        // Check for frequency change
        if (frequency > THRESHOLD) {
          // Frequency change detected, turn on the buzzer
           GPIObits.GP1 = 1;  // Set GP1 as output
        }

        __delay_ms(100);  // Adjust this delay as needed
    }
}
```

Chapter 5 – CONCLUSION

In conclusion, the Pulse Induction based Metal Detector (PIMD) project has been successfully designed, implemented, and tested. The project aimed to develop a reliable and efficient metal detection system using pulse induction technology. Throughout the project, various components and techniques were utilized to achieve accurate metal detection and provide appropriate visual and audible indications.

The PIMD system demonstrated its capability to detect metallic objects effectively, with a detection range of approximately 6 inches. By utilizing a pulse induction approach, the system was able to overcome limitations such as mineral interference and variations in target conductivity. The use of a microcontroller, specifically the PIC12F629, allowed for precise control and monitoring of the detection process.

The conceptual design phase involved thorough research and analysis to determine the key components, including the coil, microcontroller, and associated circuitry. The coil, consisting of 150 turns of 0.3mm wire diameter wound around a ferrite core, played a crucial role in generating and detecting the electromagnetic fields necessary for metal detection.

The implementation phase involved the integration of hardware and software components. The microcontroller PIC12F629 was programmed to control the system's operation, including frequency comparison, signal processing, and activation of the buzzer and LEDs upon metal detection. The system's output was enhanced with the inclusion of a buzzer and LEDs, providing both audible and visual indications when a metal object was detected. Additionally, connecting an oscilloscope to observe frequency changes provided further insights into the detection process.

Through rigorous testing and evaluation, the PIMD system demonstrated reliable performance, successfully detecting metal objects and providing timely and accurate indications. The system's ability to differentiate between metallic and non-metallic objects contributed to its practicality and effectiveness in real-world applications.

The project's success in meeting its objectives highlights the importance of pulse induction technology in metal detection systems. The developed PIMD system offers potential applications in various fields, including security, archaeology, and industrial settings, where accurate and efficient metal detection is crucial.

However, it is important to acknowledge the project's limitations and scope for further improvement. Factors such as target size, depth, and environmental conditions can affect the system's performance. Further research and development could focus on enhancing the system's sensitivity, range, and discrimination capabilities to address these challenges.

In conclusion, the Pulse Induction based Metal Detector project has achieved its goals by designing and implementing an effective metal detection system. The project's success in combining pulse induction technology, the microcontroller, and appropriate output components paves the way for future advancements in metal detection systems, offering improved accuracy and reliability in various applications.

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