Department of Electronic and Telecommunication Engineering

University of Moratuwa

EN2091 – Laboratory Practice and Project

VLF Metal Detector

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Content

Abstract

This project is a handheld metal detector using Very Low Frequency (VLF) technology. It has a special coil system with outer and inner coils and a feedback coil, working together at 5.5 KHz. This helps the detector find different metals, which is useful for security and mining. The design includes circuits for detecting metal properties, and a smart algorithm in a ATMega microcontroller makes it even smarter. Our tests show it can reliably detect Iron, Copper, and Aluminium up to 16 cm deep. It's a practical tool for various situations.

1. Introduction

When electricity flows through a wire, it creates a kind of invisible force field around it. This is a basic rule in physics called Ampere's law. In our Metal detector project, we use this theory. These detectors work because when metal is near, it messes with the force field and we can detect that.

Metal detectors are handy for security and other purposes. They use the fact that when a metal object is close, it affects the force field around the metal detector. This makes a change in the electrical signal, and we can tell there's metal nearby. There are different types of metal detectors, and in this work, we focus on one called Very Low Frequency (VLF). It operates at a certain range and is good for simplifying the design.

Most metal detectors we see today just tell us there's metal around without saying what kind it is. This work aims to change that by making a simple and cheap metal detector that can actually tell us what type of metal it found. It's like an upgrade from the usual metal detectors that just beep when they find something metal.

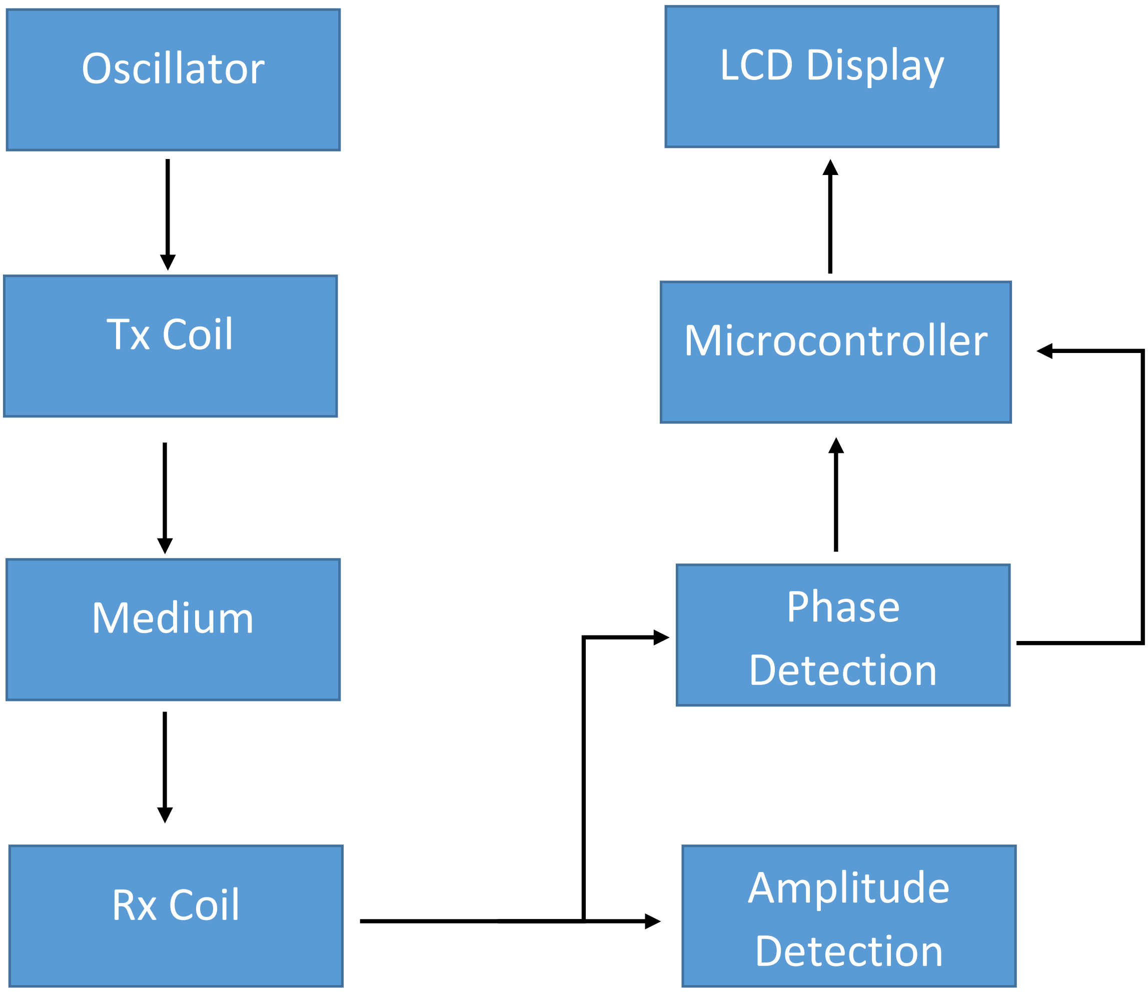
Our design goes a step further, trying to figure out not only if there's metal but also what kind.

2. Design And Specifications

Our metal detector's coil was made in a similar way, though we wound it by hand in the lab with a different number of turns and wires. However, our circuit and how it works are a bit different. The transmitter part has an oscillator and a coil, while the receiver part has another coil, circuits for detecting size and phase, and a small computer called a ATMega microcontroller with a screen. We set the frequency of the transmitter to 5.5 kHz. Both coils are wound one inside the other, with the transmitter coil on the outer side.

The circuits for detecting size and phase are made using simple filters, amplifiers, and logic gates. Their outputs go to the ATMega microcontroller, which has a program telling it how to figure out what kind of metal is around based on the size and phase. Even though the type of soil can affect how the metal detector responds, our design works well for finding metal buried at shallow depths (up to 16 cm), like anti-personnel landmines. If metal is detected, the ATMega microcontroller shows it on an attached LCD display and even tells you what type of metal it is by comparing the results with what it knows. We also measured and recorded how the size and phase change as the metal gets farther from the coil.

3. Block Diagram



4. Circuit Design & Calculations

4.1 Coil Design

This metal detector uses three coils: one for sending signals (transmitter coil), one for receiving signals (receiver coil), and one to reduce interference (feedback coil).

We wound these coils by hand using different wire sizes (AWG 28 for sending, AWG 30 for receiving and interference-reducing). The feedback coil is wound in the opposite direction to the sending coil, and all coils are wrapped around a plastic cylinder.

The sending coil's inductance (a property related to electrical flow) was measured, including the effect of the feedback coil. To make the coils vibrate at specific frequencies (resonate), capacitors were used: 0.33 RF capacitor for the sending coil at 5.55 kHz and 100 nF capacitor for the receiving coil at 5.2 kHz.

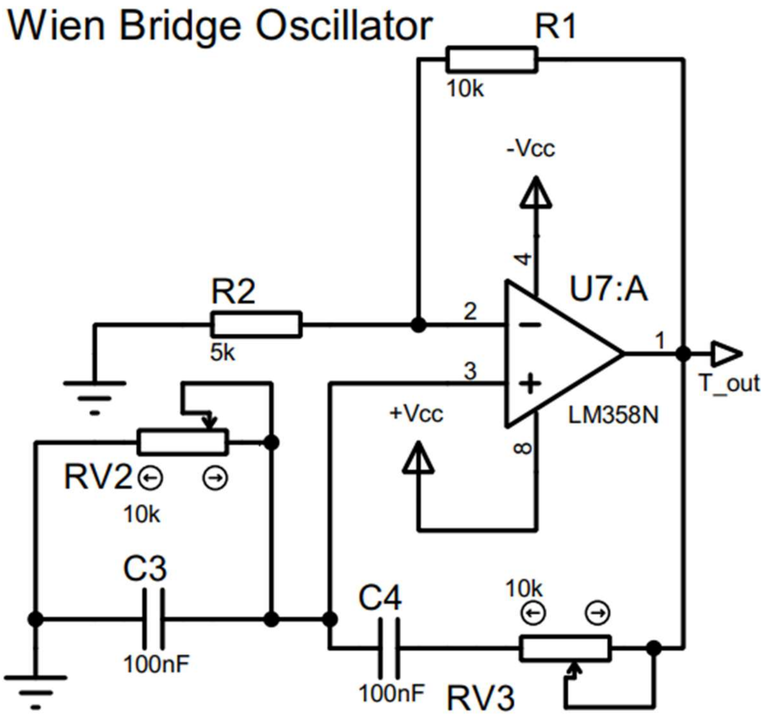
We found the length and turns for the coil as follows.

	Transmitter	Reciever	Feedback
Number of turns	85	275	35
Radius	8cm	4cm	4.2cm

4.2 Oscillator circuit Design

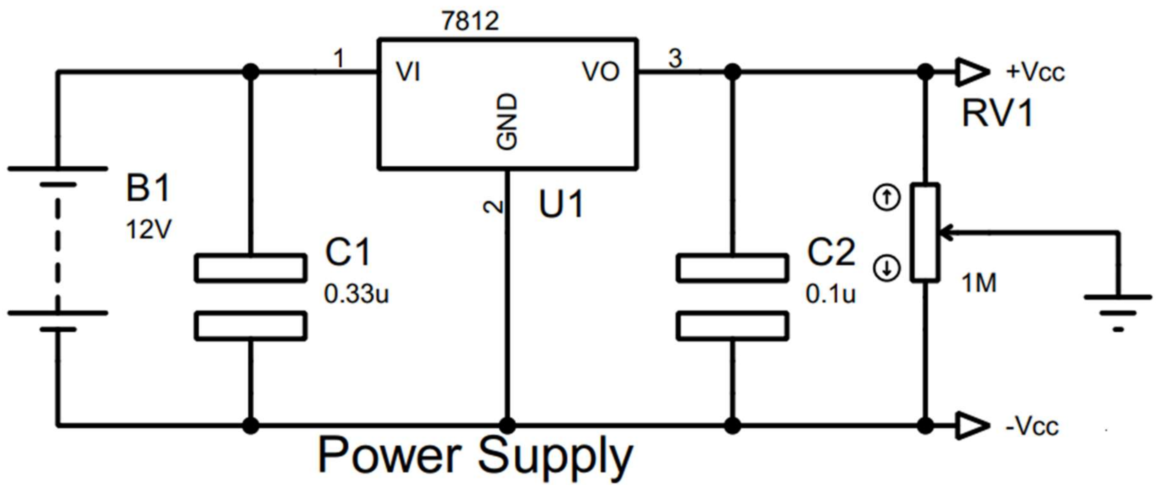
The electronic circuits in this system are designed to function at a specific frequency of 5.5 kHz. To generate this frequency, we used a simple and affordable oscillator called the Wein-Bridge oscillator. Now, in this circuit, they picked specific values for the resistor (R) and capacitor (C) so that the whole setup vibrates or resonates at 5.5 kHz. This vibrating is like a rhythm that the circuit follows.

Additionally, we used two other resistors to make the circuit stronger or amplify the signal. The power to run all these circuits comes from a 9V battery. And for circuits that need a slightly different version of that power, they used a device called an LM7805 voltage regulator circuit.



4.3 Regulator circuit

We are using two 3.7V Li-Po batteries to power the cicuit and from the regulator it is decreased to 7V.

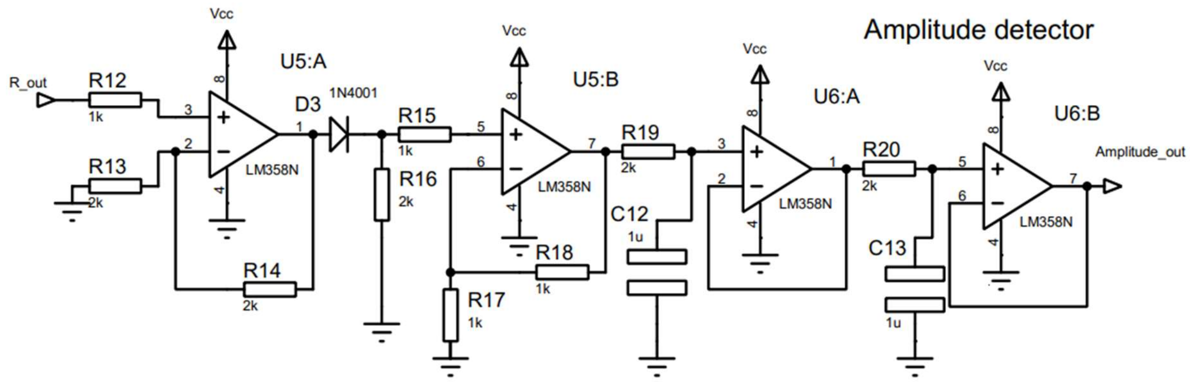


4.4 The amplitude detection

The part of the metal detector that checks how strong the signal is has a few pieces in it. First, there's a buffer that keeps the signal steady. Then, there's something that only looks at the positive part of the signal, ignoring the negative part.

After that, there's a thing that makes the signal stronger, like turning up the volume. Following that, there's another part that makes sure the signal is in a steady form, kind of like making it smooth and constant. All of this is set up to work at a specific speed, kind of like a rhythm.

Finally, the result of all this work, called the DC output, goes to a special place in the metal detector called the ATMega analog port. It's the brain of the detector, and it uses this information to figure out if there's metal around.

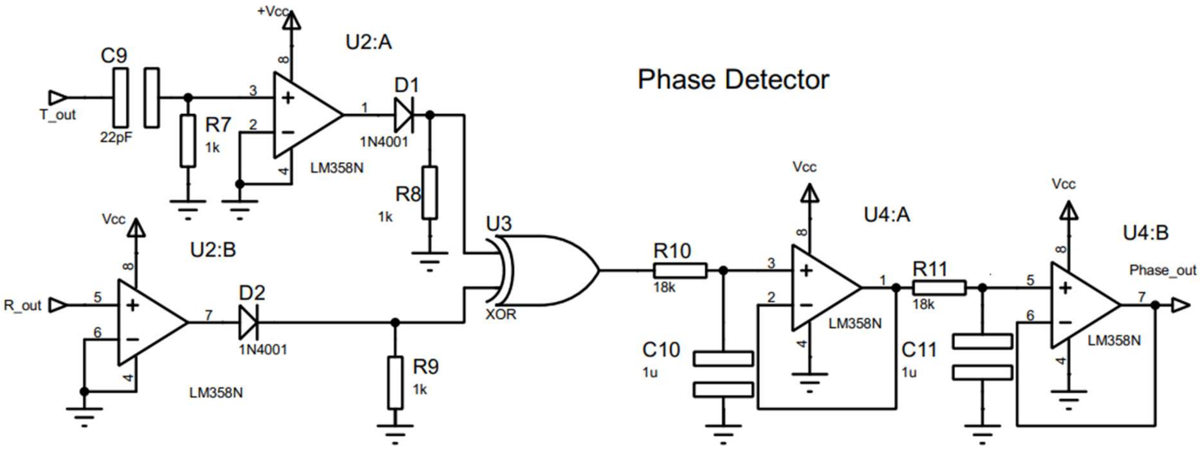


4.5 Phase Detection Circuit

This part of the metal detector works like a detective, trying to understand the timing difference between its own signal (the one it sends out) and the signal it receives.

In the first step, it takes the incoming and local signals (like the signals from the metal detector and the signals it generates itself) and changes them into a kind of simple digital signal, like turning them into on-and-off signals. Then, it uses a special gate (XOR gate) to figure out the timing difference between these signals.

After that, there's a kind of filter that smoothens things out, converting this timing difference into a steady level. It's like making sure the information is clear and easy to understand. This filtered result goes to another part of the metal detector (called the second ATMega analog input), and the metal detector's brain uses it to figure out the phase shift, kind of like how much the timing is off. It's all about measuring the area under the signal to understand this timing difference.

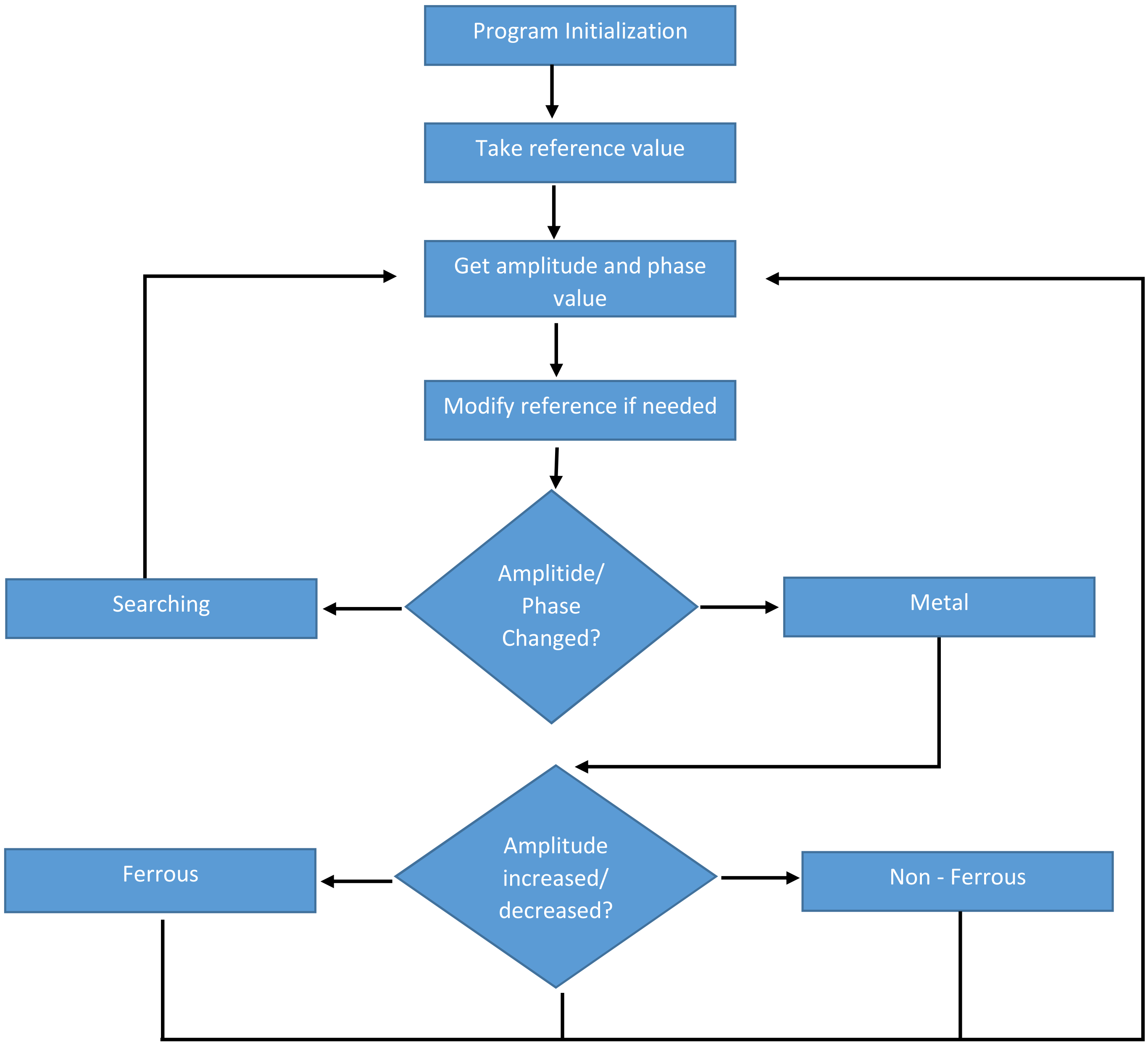


4.6 ATMega Programming

In this design, we used an ATMega. The programming language we used is C. This microcontroller takes in the levels from both the amplitude and phase detection parts, converts them into digital information using something called an analog-to-digital converter (ADC), and then does some analysis based on the program it has inside.

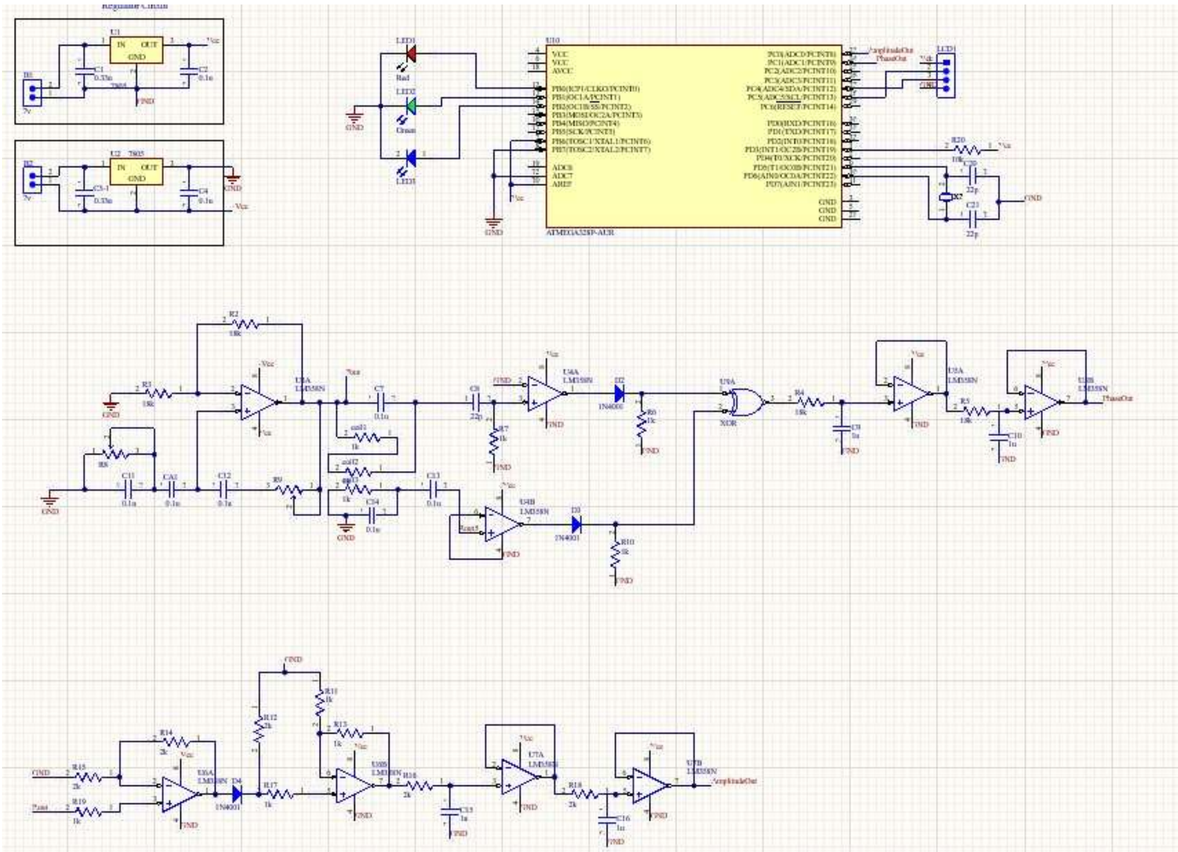
If there's a change in the amplitude or phase, the program can detect the presence of metal. It can even figure out what type of metal it is, like iron or non-ferrous metals such as copper or aluminum, and then show this information on a display screen.

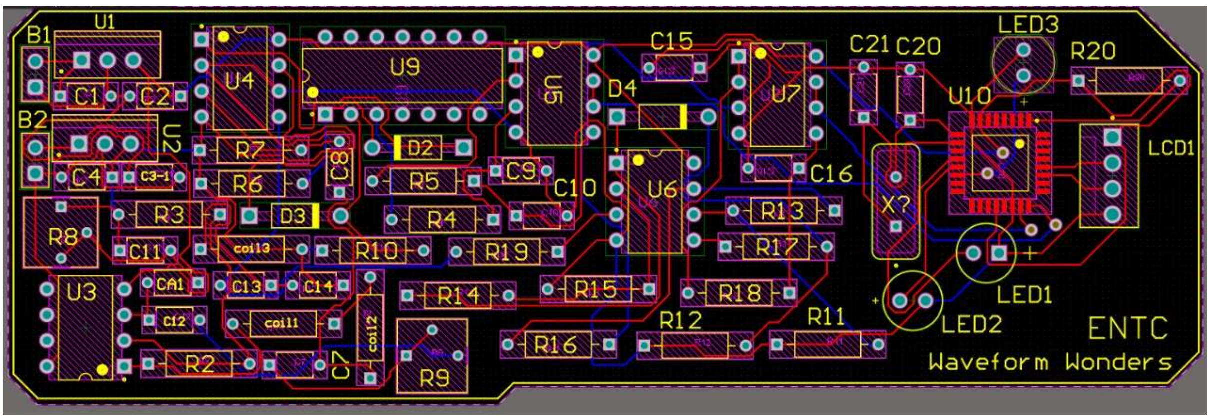
Flow Chart of the Program



5. PCB Design

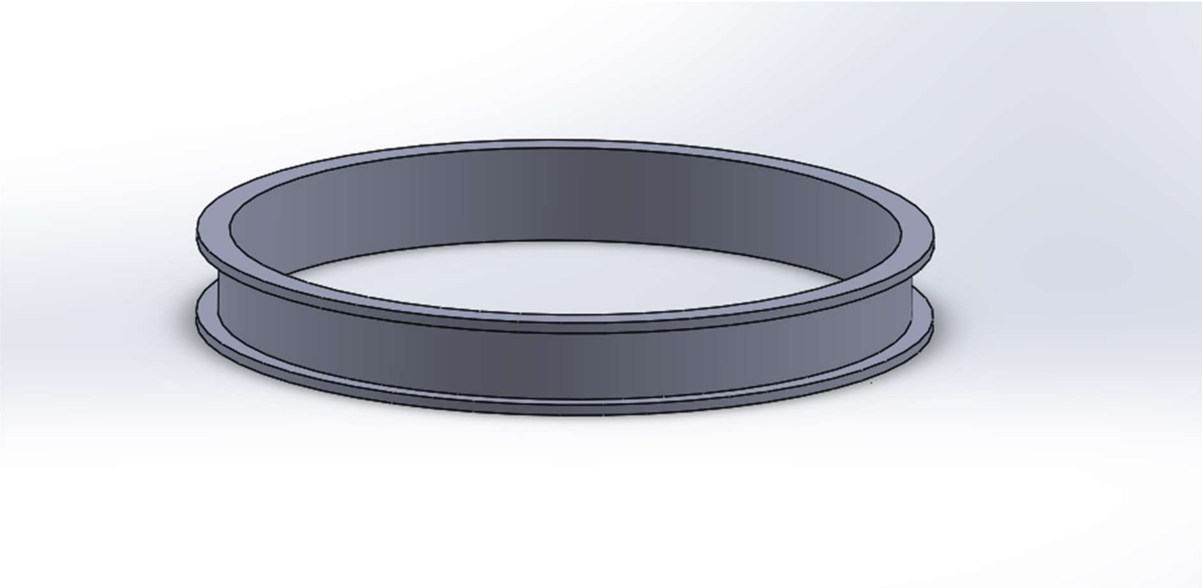
We used Altium design software to design the PCB for this metal detector. We used it because it is easy to use and have many advanced features for designs and it is a recommended software. OurPCB has one circuit design.



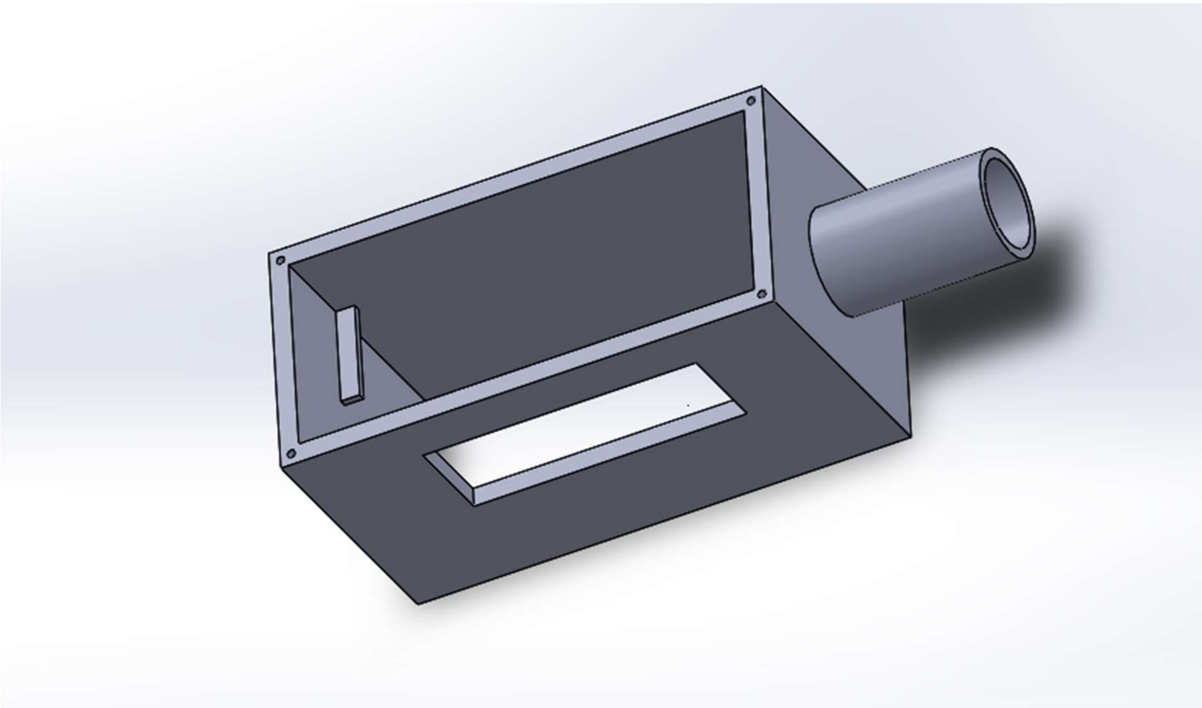


6. Enclosure Design

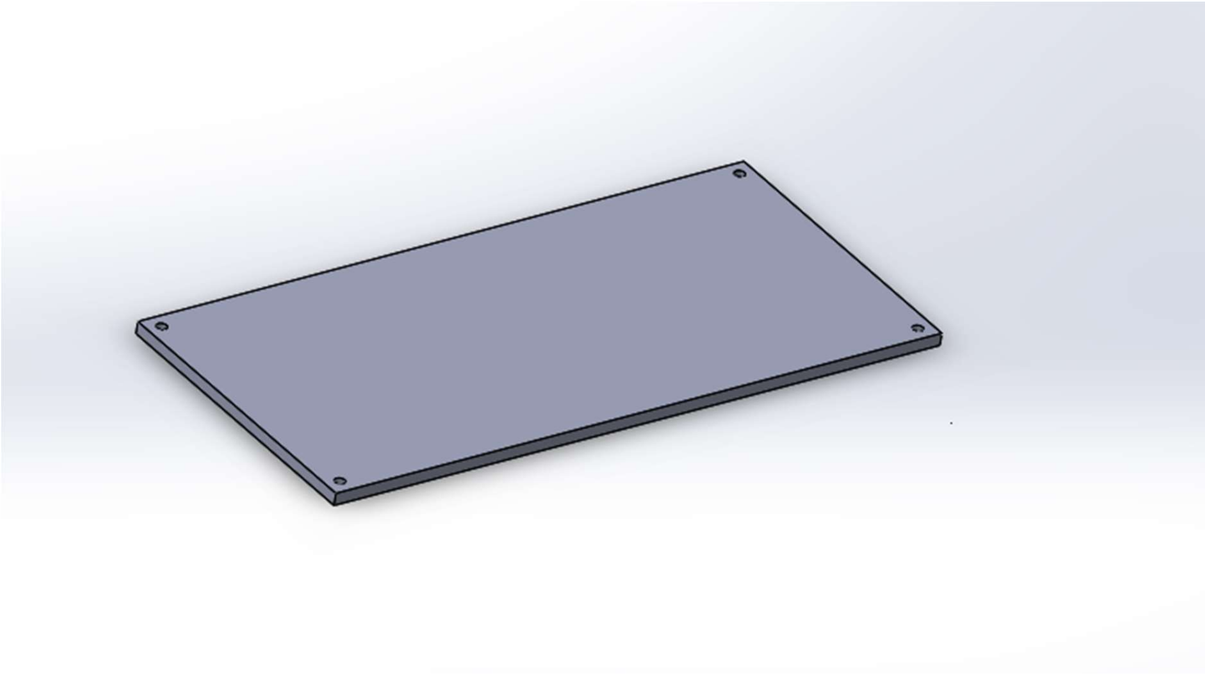
We used Solid works software to design the enclosure for this metal detector. We used it because it is easy to use and have many advanced features for designs and it is a recommended software. Our enclosure has two parts. One for cover the circuits and other part for coil side. And we connected it using a wood stick.



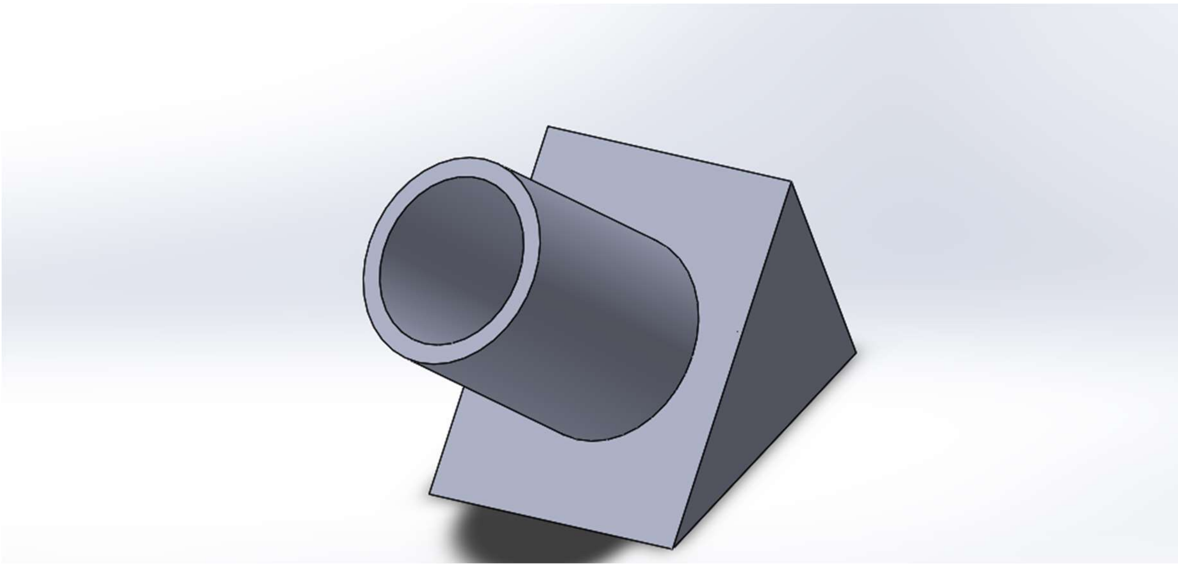
Coil stand



PCB Enclosure



PCB enclosure lid

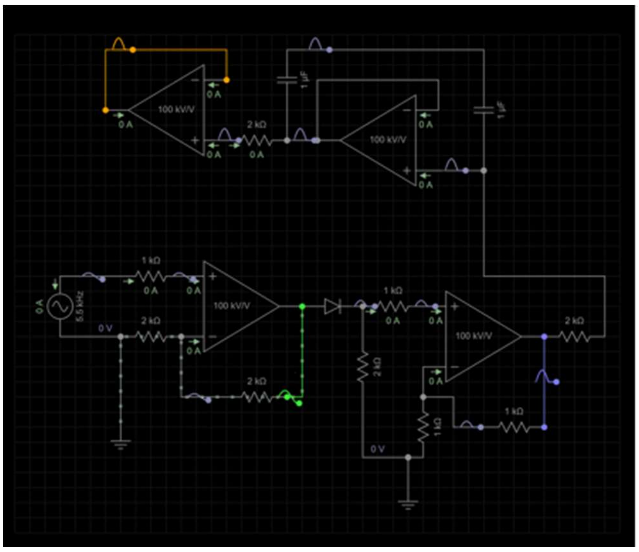


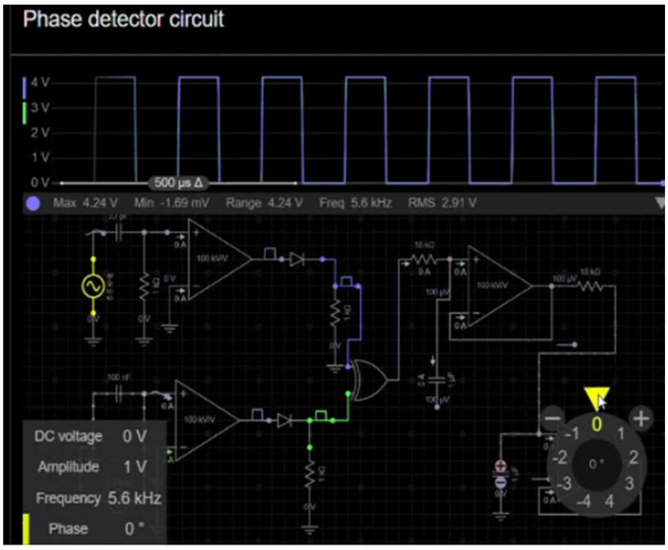
Stick stand

7. Testing and Simulations

We used a program called Everycircuit for simulating our circuits. We chose this software because it helps us see voltage and current waveforms more easily. Before making the actual circuit on a printed circuit board (PCB), we first tested it on a breadboard. This step-by-step process helps us understand how the circuit works and ensures that it behaves as expected when we eventually build it in real life

Simulation results



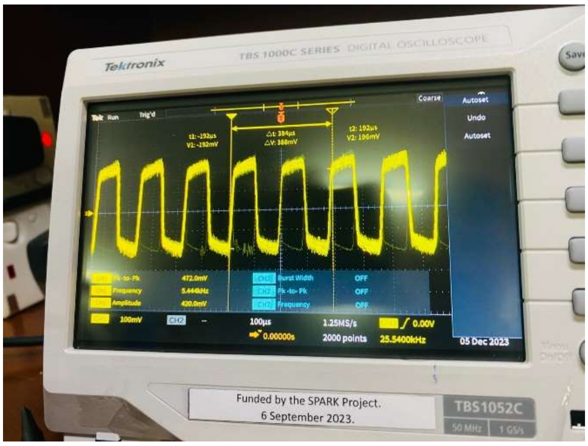


Amplitude detector

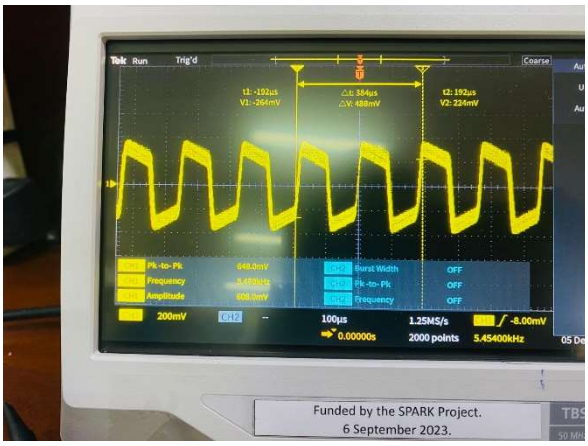
Phase Detector

8. Results

We got some important information while checking our circuit in the lab. We used special tools like an oscilloscope to see the wave patterns and a multi meter to measure the amounts of voltage and current. These details help us understand how well the circuit is working during our tests.

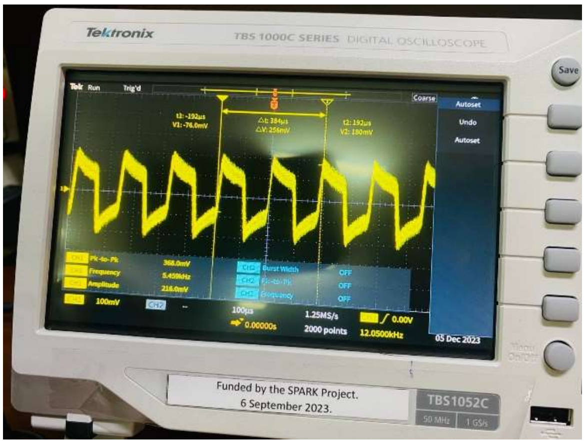


Reference amplitude



Amplitude increased

Nonferrous metal



Amplitude decreased. Ferrous metal

Final Product Appearance

9. Conclusion

In conclusion, the project not only enhanced our understanding of electromagnetic principles and circuit design but also provided valuable insights into the practical challenges associated with metal detection. We successfully navigated issues such as signal interference and calibration, refining our problem solving skills in the process. The project has not only met academic requirements but has also laid the foundation for further exploration and development in the realm of metal detection.

10. Future works

1. Enhanced Sensitivity and Discrimination
2. User Interface Improvements
3. Wireless Connectivity

10. Contribution of Group Members

Thamirawaran.S 210629A	Circuit Design, Simulation, Finalizing
Thennakoon T.M.K.R 210642G	Enclosure designing, Testing and debugging
Shamal G.B.A. 210599E	Breadboard implementation, Testing and debugging
Niroshan E. M. A. R 210433R	PCB designing, Testing and debugging

12. References

[1] Corson, D. R., & Lorrain, P. (2018). Introduction to Electromagnetic Fields and Waves. Wiley.

[2] Hibey, C. R., et al. Design and Performance of a Very Low Frequency Metal Detector. IEEE Transactions on Geoscience Electronics.

[3] The Demining Research Group. Metal Detector Handbook for Humanitarian Demining.