Stony Brook University
College of Engineering and Applied Sciences

Institute for STEM Education

Metal Detector

Student Lab Guide

Engineering Teaching Laboratory

Name_____ Date_____

Lab Partner(s)_____

NEW TERMS

Electric Circuit: Electric circuits are paths for transmitting electric current, or moving electricity. Such circuits allow electricity to be used to provide power to lights, appliances, and many other devices

Capacitor: a device used to store electric charge. It is similar to a battery except it stores energy instead of providing new energy. These are used to amplify power supplies and filter out electronic ripples.

Resistor: a device that is designed to resist the passage of an electric current.

Transistor: a semiconductor device that can be either used as an amplifier of a signal or as a switch. It has three terminals: input, output, and control.

Printed Circuit Board (PCB): a board that mechanically supports and electrically connects electronic components using conductive tracks, pads, and other features etched into the nonconductive board in copper. Components are generally soldered onto the PCB.

Potentiometer: a potentiometer can act as a variable resistor. The value of its resistance can change with moving its shaft.

Battery: a battery will supply the voltage needed to power the circuit.

Electromagnetic coil: is a conductor that is a wire shaped into a coil. They are used in applications where electric current interact with magnetic field.

Diode: is a semiconductor device that allows the flow of current in only one direction. In this project t, we are using Zener diode which allows the current to flow in one direction. However, when the voltage across the diode exceeds the Zener voltage the current can flow in the reverse direction.

Light emitting diode (LED): is a diode that emits light when a suitable voltage is applied to it. In the design the LED goes on, once metal is detected.

Buzzer: is an audio signaling device, the beeps when a certain voltage crosses it.

Transistors (TR): a semiconductor device that is used either as a switch or an amplifier.

Terms to be familiar with:

Circuits
Series
Parallel
Voltage
Electricity
Conductors
Insulators
Oscillation
Electromagnetism

INTRODUCTION

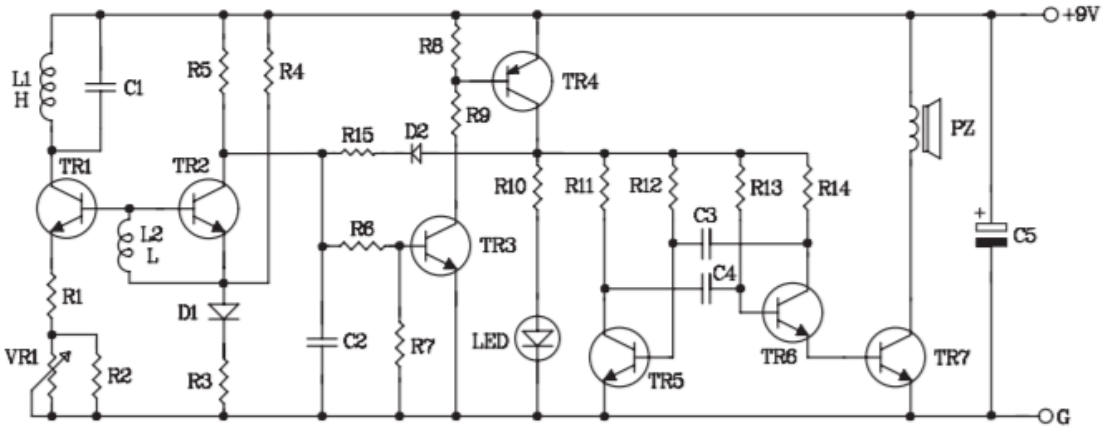
Metal detectors are devices that were first practically used in the early years of World War II. They are used for different reasons. One can find them at the airport for security screening of airline passengers or at the food packaging industries to ensure that the packaged food is free of any metal. Metal detectors could also be used as a hobby such as coin shooting.

To understand how a metal detector works, one should understand how electricity and magnetism interact together. Electricity is the flow of electrons. Each electron is surrounded by electric field. When an electron moves it creates another field called the magnetic field. Magnetic fields cannot be produced from a stationary electron. Now, the question is, can we produce an electric field from a magnetic one? The magnetic field produced by moving charges can induce a change which results in electricity.

Our circuit design today implements the theory above to detect metals. A metal detector contains a coil of wire known as the transmitter coil. When electricity flows through the coil or inductor, a magnetic field is created all around it. Moving the detector around will create a magnetic field around the detector. If the detector is moving around a metal object, the electrons inside the metal will move differently. This as a result produces a magnetic field around the metal. So, when you move a metal detector over a piece of metal, the magnetic field coming from the detector causes another magnetic field to appear around the metal. The second magnetic field produced by the metal affects the detector and cuts through its receiver coil.

As we said above, a changing magnetic field produces electricity. Electricity will be produced on the receiver side of the coil in the detector and produces a sound through a speaker. The closer the detector moves toward the metal, the stronger the magnetic field created by the transmitter coil (from the detector) is produced. As a result, the magnetic field produced from the metal is stronger and the induced electricity through the speaker will be higher producing a louder noise.

Figure 1. The Metal Detecting Circuit

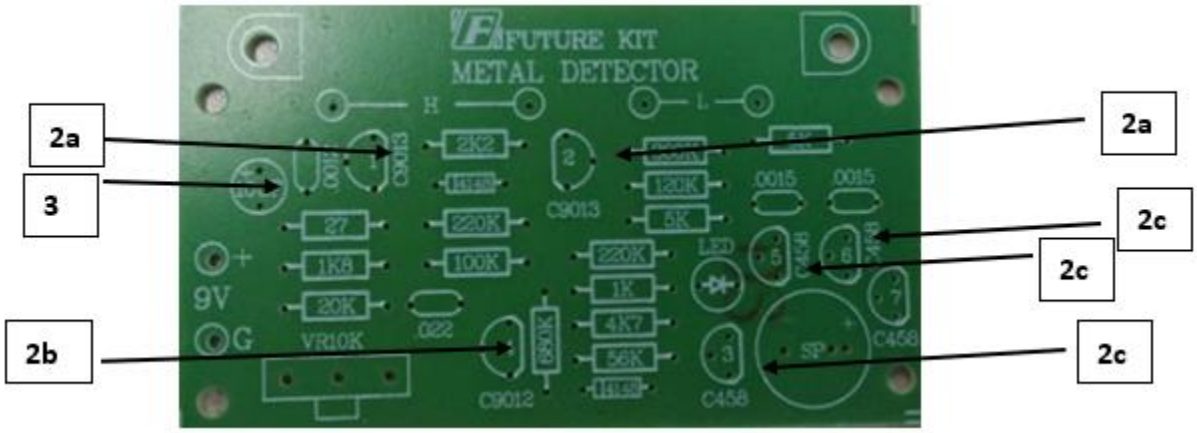


PROCEDURE

A) Orientation Critical

The following components must be installed in a particular direction. After installing the component, solder it down and trim the leads if necessary.

1. Place the circuit board as shown. **The green board with the white text must be on the side facing you.** All of the components must be installed on this side of the board. The terms 'right', 'left', 'top', and 'bottom' refer to the board in this position.

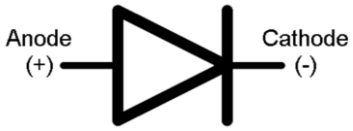


2. Install the transistors first: each transistor has a specific number associated with it **(C9012, C9013, and C458).** It is printed on the part itself. It can be hard to read. So please read it carefully. **Look at figure 2 for assistance.**
    a. Install TR1 & TR2 in the **C9013** position on the board. **ATTENTION:** the transistor should be installed in a way where it follows the drawing on the board
    b. Install transistors TR4 in **C9012** position on the board.
    c. Install TR3, TR5, and TR6 in **C458** position on the board.

3. Install the dielectric capacitor. The longer wire goes to the + sign pad in location 10µF on the board.

4. Install the buzzer PZ. The + sign on the buzzer should be aligned with the+ sign on location SP on the board.

5. Install LED with the shorter wire going into the tip of the triangle (cathode side) and where the longer side goes to the end of the triangle (anode side).



6. Install the two Zener diodes in location 14148 on the board.

B) Value Critical

The rest of the components can be installed either way around, but you must be very careful to install the right component in the right holes. Check the resistor color codes carefully and ask for assistance if you are not sure Also, the different capacitor values may look very similar.

Both C1 and C2 capacitors are orange ceramic. Read the values on them before installing and soldering them. If you cannot identify which one is which **ask for assistance**.

1. Install capacitor C1 in 0.0012µF location board.

2. Install capacitor C2 in 0.0022µF location on the board.

3. Install, C3 & C4, the green capacitors in the 0.0015µF location on the right of the board.

4. Now install the Resistors. Install each resistor in the right spot according to its value. To know the value of a resistor you need to read its color. **The table** below has both the values and the color codes of the resistors for this design. For example R11 has 5kΩ value and a color code of green-black-red-gold. Locate this resistor and put it in location 5kΩ on the board.

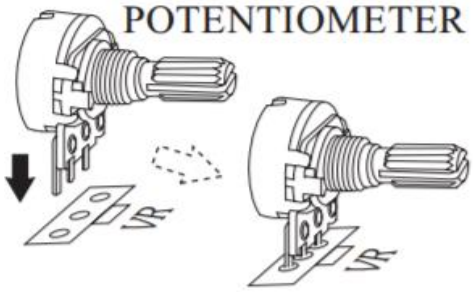
Resistors	Value	Color code
R1	1.8kΩ	brown-gray-red-gold
R2	20kΩ	red-black-orange-gold
R3	27kΩ	red-violet-black-gold
R4	2.2kΩ	red-red-red-gold
R5	220kΩ	red-red-yellow-gold
R6	220kΩ	red-red-yellow-gold
R7	56kΩ	green-blue-orange-gold
R8	100kΩ	brown-black-yellow-gold
R9	4.7kΩ	yellow-violet-red-gold
R10	1kΩ	brown-black-red-gold
R11	5kΩ	green-black-red-gold
R12	120kΩ	brown-red-yellow-gold
R13	300kΩ	orange-black-yellow-gold
R14	5kΩ	green-black-red-gold
R15	680kΩ	blue-gray-yellow-gold

Note: Any resistor value that has a decimal is written as the following: R1 for example is 1.8kΩ, on the board it is 1k8 location. Similarly, R4 is 2.2kΩ. On the board, R4 is 2k2 location.

C) Orientation Critical

The following components must be installed in a particular direction. After installing the component, solder it down and trim the leads if necessary.

1. Install the potentiometer in the VR10k location on the board. Please refer to the figure below for orientation.



2. Install the coil the way shown in the figure below. Connect the outer copper wires of the coil to the must outer circles and the inner wires to the inner circles as shown below:

3. Install the battery connector as shown in the figure below. Solder the red wire to the + sign and the black wire to G.

D) Project Testing

Now it is time to test the design. After energizing the circuit, turn the volume clockwise. LED1 will turn on simultaneously with the sound of the dynamic buzzer. Gradually turn the volume anticlockwise until LED1 turns off and the sound stops. This indicated that the circuit is ready for use. However, adjustment shall be done far from metallic object.

Test your design near a metal and nonmetal objects and note the difference. Also test the design at a different distance from the metal. Is the sound of the speaker louder or lower when the detector gets closer? Can you provide an explanation for this behavior of the design?

Please go to the test station to test if your metal detector is working. Make sure to ask the teacher for assistance and guidance in testing the design.


FUTURE KIT
METAL DETECTOR
H
L
C9013
B10K
9V
.022
C9012
C458
Photo by bangkoktoshop.com

Questions:

1. What is an electromagnetic coil and how does it work?

_____
_____
_____

2. What is electromagnetism?

_____
_____
_____

3. What does electromagnetic induction mean? How does it happen?

_____
_____
_____

4. Explain in words or through an illustration how a metal object triggers your device.

_____
_____
_____

Think like an engineer- Questions & Discussions:

1. Besides cost, what are other potential issues with materials and design to be considered?
2. Do you think engineers have to make important tradeoffs between costs, environmental considerations, and other issues?
3. Are there any other improvements to this design that you would employ?