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Beat Frequency Oscillator Metal Detector

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The beat frequency oscillator (BFO) metal detector is one of the most rudimentary metal detection systems. It's processed by six analog circuits, one digital circuit, and several basic components. The inductor coil's capacitance, variable by the metal detected, serves as the "input". The headphone jack is the "output", with potentiometers determining tune and volume. This report will demonstrate the process of building the BFO metal detector, applications of learning development, and the extent of which this circuit can be used.

Introduction

The team was given creative freedom to build and report on a circuit. After several ideas, the BFO metal detector was carefully chosen as it exhibited the use of a digital and an analog circuit. The circuit was built on a RadioShack™ breadboard from a grassroots approach—allowing the team to analyze components individually. It was then tested in Multisim™. This entire process yielded knowledge that transcended the previous mini-projects.

Basics

The BFO metal detector (see **FIGURE 1,** page 2**)** uses a total of seven active components. The **NTE618 silicon varactor diode** (D1) functions as an electronic tuner. Given its ability of variable capacitance, the diode tunes the metal detector circuit. The four **2N2222 transistors** (Q1-Q4) amplify the electrical current. The signal is then sent to the **2N5951 JFET transistor** (Q5) which functions as a "control amp" for processing. The **LM386** (IC1), the only digital circuit, is a low-voltage power amplifier [1].

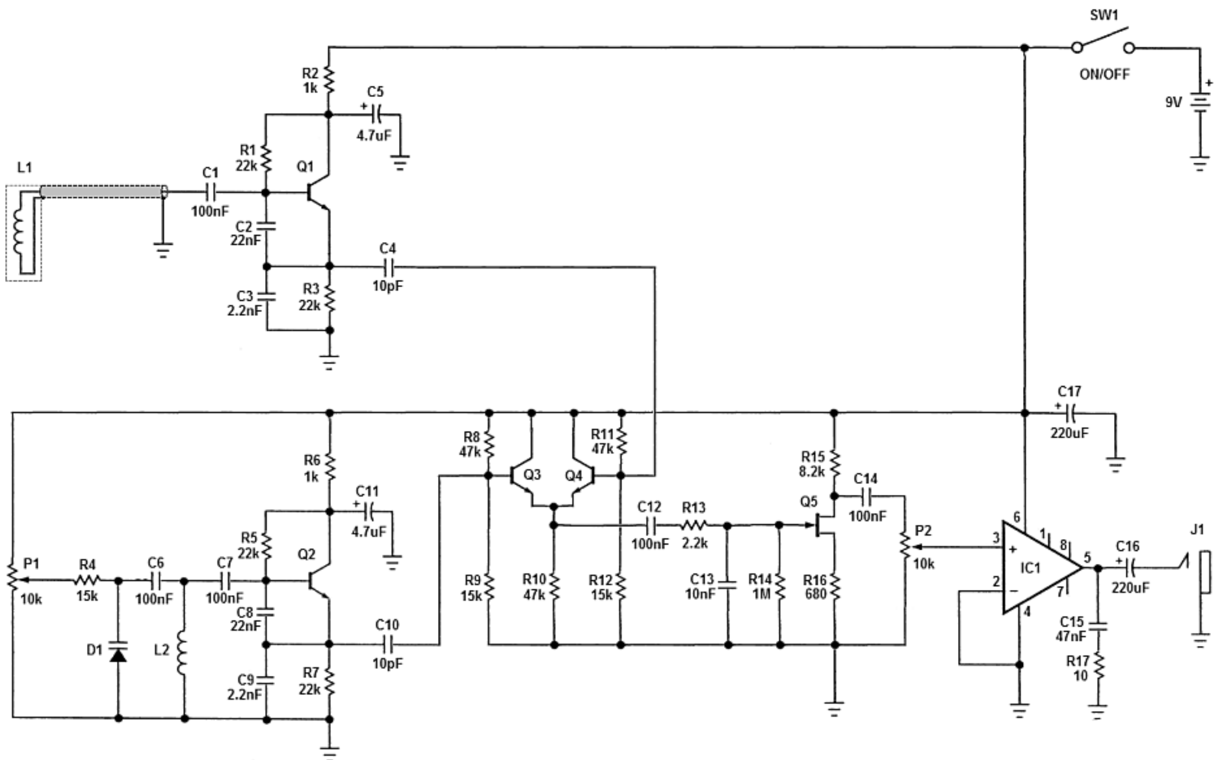

FIGURE 1 *BFO metal detector schematic diagram*

Analysis

Like all metal detectors, it uses metal coils to help recognize both the proximity of the metal as well as the type of metal with enough research. How this works is by running a current through these coils. When the coil is charged, the shape of the charged coil creates a magnetic field that flows through the center of the coils, out around then back into them again. This electromagnetic field is what reacts to nearby metals. When the field comes in contact with another metal, that metal then creates its own electromagnetic field that flows opposite to the field created by the coils. That opposing field in turn decreases the inductance of the original metal coils. All of the different kinds of metal detectors process and measure this change in some way, but we will concentrate on how that is specifically done in a beat frequency oscillator.

The beat frequency oscillator metal detector essentially creates a coil with an inductance within the circuit that is kept constant. The inductance of the coil next to the metal is compared to that of the internal coil. The difference is then translated into an audio output that changes relative to the size of the difference in inductances.

The coil with an inductance held constant is called the reference coil, while the coil that detects metal is called the search coil. The detector depends on the difference between the inductances of the two coils to function correctly; so when there are no metals nearby, the inductance of the two coils should be equal to each other. Of course this probably will not hold true when the circuit is first built. Every measurement tool needs calibration of some sort when it is first built. To do so in this particular circuit, we must use the P1 potentiometer. It is there to alter the pulses going into the coil and thus alter the inductance. Calibrating is a matter of changing the resistance until the reference coil's inductance is equal to that of the search coil when there are not any metals close by. Empirically, it is almost impossible for both coils to have identical inductances, but it can be close enough so that any change in inductance is readily noticed through the audio output.

Though it is the inductance that is directly affected by nearby metals, it is not directly measured within the circuit. In the diagram below you can see that both coils are connected to transistors (Q1 and Q2) each surrounded by RC configurations. Those sections of the metal detector circuit are called the buffers. The buffers turn the inductance into an oscillating signal using the RC circuits. Those two signals from the coils are then compared in what is called the mixer.

Lessons Learned

The project gave the team freedom, and this freedom gave better insight into the design process than previous assignments. For example, the BFO schematic diagram didn't have directions of where to place wiring or components. It was new territory to go from the diagram to the breadboard and this project permitted some team members to finally understand this link of knowledge representation.

To capitalize on the potential knowledge this project presented, the team followed a concept used by Thomas Edison [2]. Creative mind-power explored how modifying the circuit would make it more beneficial, or used within a capacity for other implementations while serving the same function. As far as varying component values, the obvious first question was: What will happen if we change the size of the searching coil? A smaller coil would be ideal for find smaller targets, contrariwise to a large coil's efficacy for a deeper depth or larger targets.

Testing

To test our circuit, we used the most readily available metal objects we had without considering its theoretical strength or sensitivity. So we initially tried to use coins to be detected. This testing yielded a success rate of only 12.5%. The second time we tested the metal detector on the metal part of the chairs and it worked every time. The reason our results were as such was due to the fact that the beat frequency oscillator metal detector we tried building is meant to only find large metal objects at a close range.

Some Applications

The circuit built can also serve several other functions. For example it can serve as a pipe locator if you are trying to dig in your backyard without hitting important pipes. It can also be used in vending machines not only to determine whether coins inserted were metal, but also depending of the specific feedback from the coin, what kind and size that metal coin is. Another application that this circuit can serve in is in airport security in trying to find concealed metal objects that are not meant to be transported in an airplane.

Conclusion

In this last project the team was able to use all the things that were learned in throughout the semester. Our team working skills were improved in the way that we were able to communicate more efficiently and complete the project in a manner that was enjoyable for all parties. The team was able to learn how a breadboard works while trying to connect the circuit by trial and error. Our understanding of Multisim™ improved greatly due to the fact that this circuit required more components that were not easily accessible. The last thing the team was able to learn was the design process with the use of the metal detector. The desire for our circuit to be cost-effective and simple was always kept in mind because those qualities are two of the main considerations in the engineering design process.

References

[1] http://www.hobby-hour.com/electronics/s/bfo-metal-detector.php

[2] http://www.creativethinkingwith.com/Thomas-Edison.html