Cost Effective Beat Frequency Oscillator Metal Detector

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Background

Beat Frequency Oscillator (BFO) metal detectors use LC oscillators to detect metal by measuring change in oscillation frequency. Obsolete BFO detectors used analog signal change measured with the human ear. With microcontrollers it is possible to analyze BFO signals with greater precision using an ADC. BFO detectors use high operating frequencies, approximately 100kHz apposed to very low frequency (VLF) detectors, approximately 10kHz. The higher the operating frequency the more apparent soil mineralization becomes. This is necessary when hunting for minerals such as gold and copper nuggets. The combination of high frequency and digital signal processing creates a cost-effective detector that detects coins and different mineralization patterns.

Objectives

- Build a quality cost effective product
- Combine digital signal processing with older BFO technology
- Detection of coins with minimal interference
- Detection of soil mineralization

Software

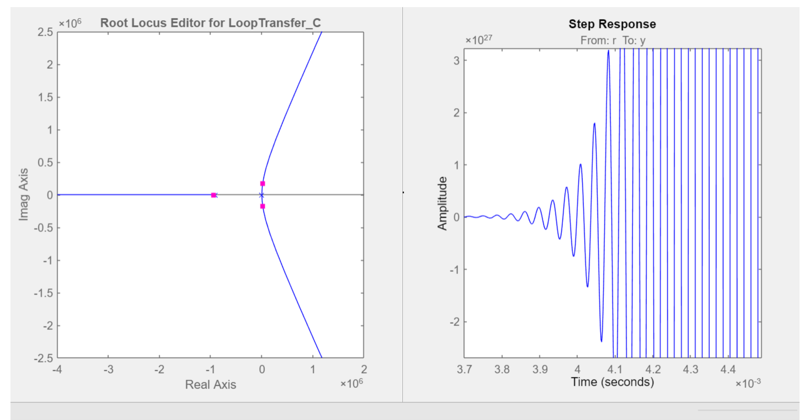
The function voltpeak maps 0-5 volts using Atmega328p's 8-bit ADC, mapping input voltage to integers from 0-255. The peak of every 100 samples is returned every 200 microseconds.

Calibrating the detector uses a function automatically called when the device is activated. This places a break in the code for 33 seconds calling the voltpeak function.

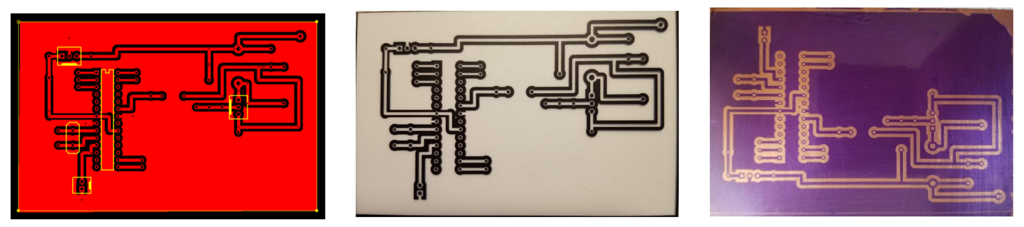
Int main function calls the calibration function then subtracts 2. A while loop then runs one of two settings, pinpoint or search mode. Pinpoint mode outputs sound when metal is detected. Search mode silently displays signal change on the IC2 in relation to the target.

Hardware

- Coupled Colpitts oscillator operating at 174kHz with Poles at $\pm(1.05 * 10^6)j$



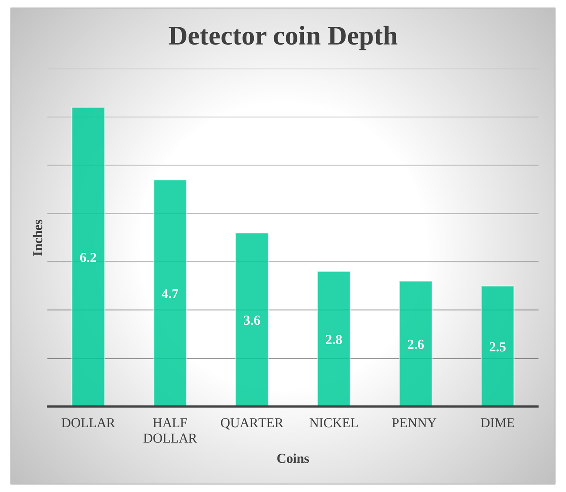
- Voltage regulator circuit for 5-volt microcontroller supply.
- AA 12-volt oscillator supply battery pack
- 3D printed 8in water resistant search coil with 860uH inductance and shielded RCA cable leads
- Chemically etched circuit board utilizing photolithography



- Atmega328p microcontroller circuit with IC2, speaker, input pushbuttons, and on-board flash capability
- Custom designed 3D printed enclosure and accessories

Results

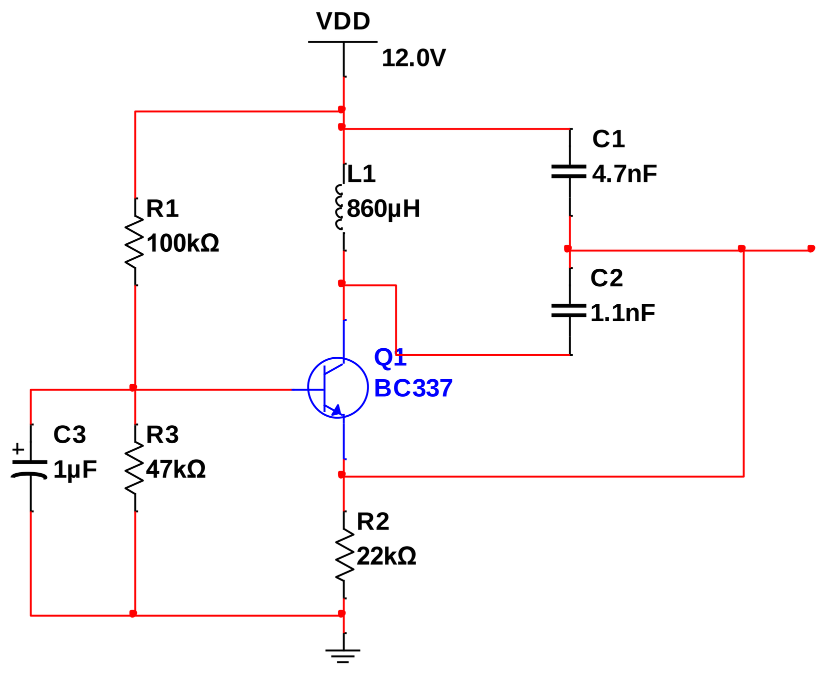
The metal detector performs correctly with depth detection slightly below calculated output. This is because of internal resistance of the cables and circuit board. The frequency change was too unstable with the given capacitor's low quality to accurately measure small frequency change. This made it hard to realistically measure soil mineralization change.



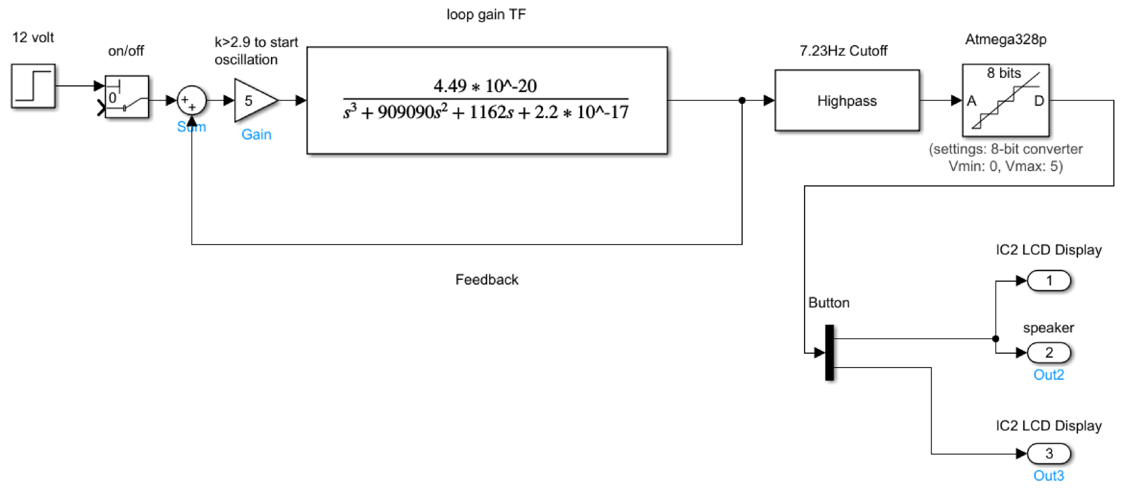
Coin Type	Weight	Composition
Dollar	25.84g	90% Au 10% Cu
Half Dollar	12.27g	90% Au 10% Cu
Quarter	5.62g	75% Cu 25% Ni
Nickel	4.97g	75% Cu 25% Ni
Penny	2.55g	95% Cu 5% other
Dime	2.28g	91% Cu 9% other

Image 1: Coin detection depth variance dependent on coin size
Image 2: Measured coin weight and chemical composition

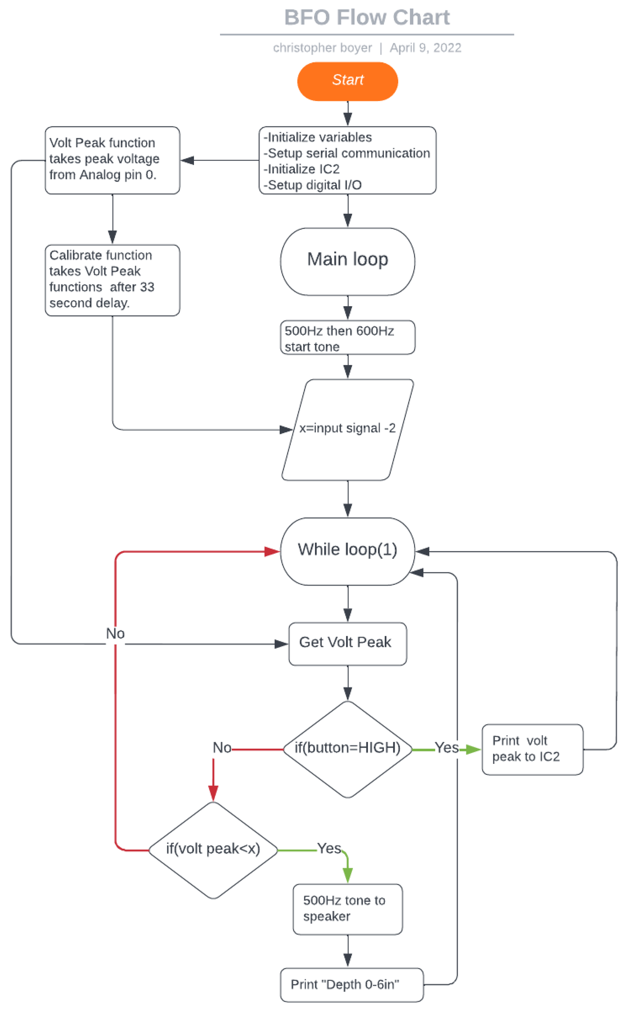
Colpitts Oscillator Circuit



Hardware Diagram



Software Diagram



Conclusions

- Learned how to build transistor based Colpitts oscillator, op-amp based Colpitts oscillator, and Hartley oscillator
- Calculated oscillator impedance, loop gain, and parameters necessary to start oscillation
- Designed 3D printed parts in SOLIDWORKs environment such as screws, search coils, and circuit enclosures
- Utilized material from ECE 603 Electromagnetics to calculate magnetic field of inductor
- Used MP Lab to flash different microcontrollers taking the FFT of different signals using C code
- Prototyped FFT software and analog signal mapping using Arduino
- Hand wound inductors, measuring change in inductance compared to calculated values

Next Steps

- Implement DSP PIC microcontroller for faster frequency processing
- Use VLF technology to measure phase shift instead of frequency change
- Integrate multifrequency technology into design for improved target accuracy
- Weatherproof design for all terrain
- Surface mount circuit board components for smaller size and efficiency

References

Advisor Prof: Nicholas Kirsch

Collaboration with Prof: Michael Carter

Software: Shapr3D, MATLAB, Multisim, ExpressPCB, Arduino, MPLAB X

Text: Microelectronic Circuit Design: Jaeger Blalock, Engineering Electromagnetics: William H. Hayt, Jr. John A. Buck

URL:

https://www.seas.upenn.edu/~ese319/Lecture_Notes/Lec_19_Colpitts_Osc_09.pdf

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