Journal of science, education and technology
Volume 1 Number 2

April 2008
ISSN 1596 9770

Design, Construction and Characterization of Metal Detector Device

J. A., Ezenwora,
Department of Physics Federal University of Technology, Minna.

Abstract

A metal detector device based on Beat Frequency Oscillator (BFO) was designed, constructed and characterized in this research work. The device comprises basically of two modules; the transmitter and receiver module. The transmitter module is a resonant inductor-capacitor (LC) circuit oscillator based on Colpitts oscillator while the receiver module comprises; tuning circuit, demodulating unit, preamplifier the amplifier and load. The receiver oscillator, turning circuit is synthesized with a tapped inductor cored with a ferrite rod and a variable capacitor of 500PF. With this configuration the receiver oscillator can be made to oscillate at close radio frequency (RF) to that of the transmitter and hence interference occurs to produce an audible note. This audible note is demodulated by the demodulator; IN 133 germanium diode and passed to the preamplifier; two matched complementary pair of transistors C9013 and A733. LM386 OP-amp with its gain set at 200 performs the final amplification and drives directly the load; 8 Ohm (Ω) speaker. When a metal object is brought near the transmitter inductor (search coil) it modulates this audible note; it will fall for ferrous metal and rise for non-ferrous metal. The device has been successfully tested and it worked.

Introduction

A metal detector device or system is an electronic device that can detect the presence of any metallic substance within its field of operation. There are varieties, a variety that arises from choice of circuit design. Broadly speaking, however, their modes of operation are similar in that they involve modulation by metallic substance of signal produced from an oscillator circuit.

The research work makes use of two frequency oscillator circuits for its operation. The operation of the circuit depends upon adjusting one of the two radio frequency oscillators so that the two oscillates at nearly the same frequency and interferes with each other to produce a low frequency audio note that is heard in the speaker. This note is caused by the two radio frequency circuits "beating together," and for this reason, the circuit is known as a "Beat Frequency Oscillator" (BFO). Should a metal object come close to the search coil (the coil of the first radio frequency Oscillator), there is a change of beat frequency. For certain settings of the circuit, the note will fall for ferrous (iron-like) objects and rise for non-ferrous objects such as coins. This distinguishable property makes this particular circuit unique, uniqueness that informed its choice of design.

Rationale of Project Work

Human beings can be considered a part of a nation's natural resources. Like other natural resources, human resources must be developed and conserved if a nation is to survive and flourish. Human resources can be developed (human capacity building) through education and training. The goal of publicly supported educational systems is to provide a means for each person to develop his capabilities. But also important in human development are the roles played by family, church, and other social institutions.

Human resources can be conserved by reducing or eliminating conditions that waste and destroy human talent and productivity. Among these conditions are disease, disability, malnutrition, unemployment, crime, poverty, overpopulation, and war.

Human resources are wasted when people cannot find jobs suitable for their abilities

April 2008
ISSN 1596-9770

(underemployment) – or any job at all (unemployment). The cause of unemployment may be lack of education or lack of motivation. Large-scale underemployment and unemployment are generally caused by a weak economic system (as in an underdeveloped country) or a depression. Crime represents another waste of human resources, both in the regard to the criminal and victim. And society's fight against crime absorbs efforts that might other wise be turned to productive activities. These wastes are interrelated – lack of suitable employment causes poverty and poverty breeds crime.

A nation cannot fully develop and conserve its human resources if her vast majority cannot obtain adequate food, health care, shelter, employment, and education.

Perhaps the greatest waste of all is war, in which one country, tribe or any other group is bent on literally destroying the human resources of another

This research work was borne out of a true war experience in which there was a huge waste of human resources through Land mines usage in arms conflict. Interestingly, Civilians who represent greater number of human resources are worst hit because they lack the capacity to detect these land mines in their farms, on the way to their different places of work during and after conflict time. As a result they get killed or maimed for life preventing them from developing their capability-a huge waste of human resources. This particular metal detector device is apt for checking this menace as it can permit the extension of the search coil to a reasonable distance from the holder and hence allows the mines to be detected before stepping on it.

Moreso, in the area of security, metal detector device is fast becoming a house hold device in checking crime. In our nation today almost, if not all that we have are imported at the cost of our resources and its attendant consequence of dumping. This design offers a choice of variety as it can differentiate between ferrous and non-ferrous metal and also offers a way forward in our technological advancement, creating jobs when mass produced and fashioning our own customized technology that will suit our peculiar need instead of perpetual dependence that continue to negatively affect our economy and human capacity building.

In addition, since this device can also detect coins, metallic bric-a-brac, lost metallic items, position of hidden nails in second hand timber or trace the path of water pipes under the ground, conduit path in walls e.t.c., it will enhance the work of archeologist, carpenter, engineer and other professionals thereby enriching their capacity.

Design and Construction

The metal detector device is configured in two major modular schemes: transmitter and receiver modules. The receiver module is sub-divided into; tuning circuit, demodulating unit, preamplifier, amplifier and load. Design consideration was also taken, as is with any electronic system in the area of power supply.

Power Supply Design Considerations

The Considerations here are based on the electrical parameters of the active elements-transistors and amplifier, most especially the LM386 amplifier.

The quiescent power drain is only 36 miliwatts when operating from a 9volt supply, making the LM386 ideal for battery operation (National Semiconductor, 2007: Tooley, 1993; Tokhiem, 2004;). Based on these, 9 volt battery was chosen since it also met the requirements of the transistors. Battery operation is best suitable for portability and outdoor use.

Design of Transmitter Module

April 2008
ISSN 1596 9770

The heart of the transmitter module is a resonant circuit based on Colpitts oscillator. The circuit is a type known as resonant feed back oscillator, as can be seen in Fig. 1; positive feed back is provided by a connection between a tapped capacitive divider and the emitter of the transistor. Oscillation is generated in the tuned circuit of the collector, formed by the inductor L_1 and two capacitors C_2 and C_3 arranged in series. A fraction of the voltage in this circuit is fed back to maintain the oscillation. C_1 is a decoupling capacitor and ensures that the base of transistor (Tr_1) is effectively grounded for feed back signals. In order to ensure that the signal which is fed back is in the correct phase with the input signals, the capacitor is "tapped" (C_3). It can be shown that the resonant frequency of the Colpitts oscillator is given by:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad 1$$

But in this case C is the equivalent capacitance of C_2 and C_3 which is given by

$$\frac{1}{C} = \frac{1}{C_2} + \frac{1}{C_3} \qquad 2$$

An important condition for oscillation to occur in the colpitts oscillator is that C_2/C_3 must be greater than the ac current gain of the transistor. Actually, there is also another condition for oscillation to occur which depends upon the electrical properties of the inductor. However, one may generally assume that if C_2/C_3 is about 10/1, the circuit will oscillate (Horowitz and Hill, 1995; Faisher, 1991; Warnes, 1998).

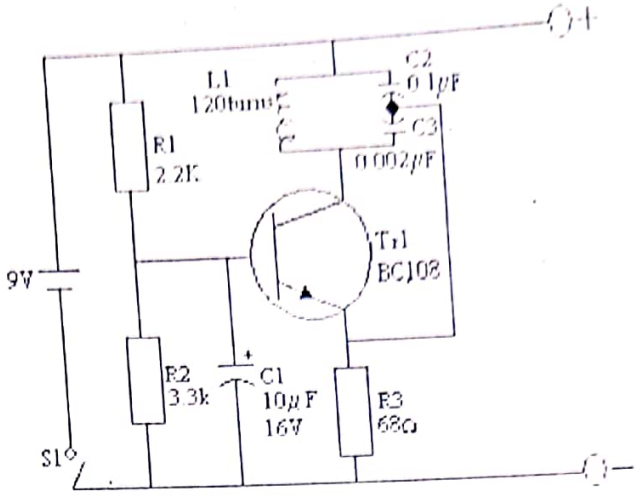

Fig 1 Transmitter Module

Design of Receiver Module

Tuning and Demodulation Unit

Since the transmitter frequency is within the medium wave band, a medium wave coil was chosen as the receiver inductor, L_2 (See Fig. 2) cored with ferrite rod which possesses spontaneous magnetism. This cored inductor, L_2 together with variable capacitor, VC_1 forms the receiver oscillator and hence the tuning circuit. The amount of magnetization of ferrite can change rapidly, so it is able to respond readily to rapid changes of radio frequency signal (Sparks, 1978). With the aid of VC_1, the electromagnetic system formed by VC_1 and L_2 can be made to resonate at different frequencies within the medium wave band and hence at close frequency of the transmitter to produce an audible note that would be demodulated.

The demodulating unit is IN133 germanium diode which was chosen because of its high sensitivity over silicon diodes. The capacitor C_4 assists the one direction of the diode and resistor R_4 form its discharge path (Bartelt, 1997; Floyed, 2002; Bishop *et al*, 1994).

ISSN 1596-9770

Journal of science, education and technology
Volume 1 Number 2

Preamplifier and Amplifier

The two pre-amplifier transistors, Tr_2 and Tr_3 are both silicon type NPN and PNP respectively and they form what is known as a complementary pair (See Fig. 2). The audio signal from the demodulator (detector) circuit is impressed on the steady voltage, which biases the base-emitter junction of Tr_2, by means of the coupling capacitor C_5. The base bias for Tr_2 is obtained by means of the feed back resistor R_8. Infact, R_8 in this circuit provides what is known as negative feedback, since the signal at the emitter of Tr3 is 180 degrees out of phase with that at the base of Tr_2.

Negative feed back is used in amplifiers of this sort in order to increase the input impedance of the first stage, which allows the amplifier to be used with high impedance signal source. Also the output impedance is reduced, allowing the amplifier to be more effective in passing the amplified signal into a low impedance load.

The gain of the circuit is improved by means of C_6, this capacitor feeds back a proportion of the output signal to the top end of R_6 and this signal is in phase with that at the collector of Tr_2. Thus the voltage at the top of R_6 follows the voltage at the bottom, with the result that the current due to the signal is very small; R_6 has effectively been increased for signals, and this improves the gain of the amplifier. The technique is known as "boot-strapping" (Horowitz and Hill 1995, Tooley, 1993; Warnes 1998).

The amplified output from the pre-amplifier is fed into the final amplifier; LM 386 OP-amp I.C. by means of coupling capacitor C_7. The I.C. amplifier is wired as shown in Fig. 3 to produce a gain of 200. This further amplifies the signal that drive directly the load; 8ohm speaker (National Semiconductor, 2007).

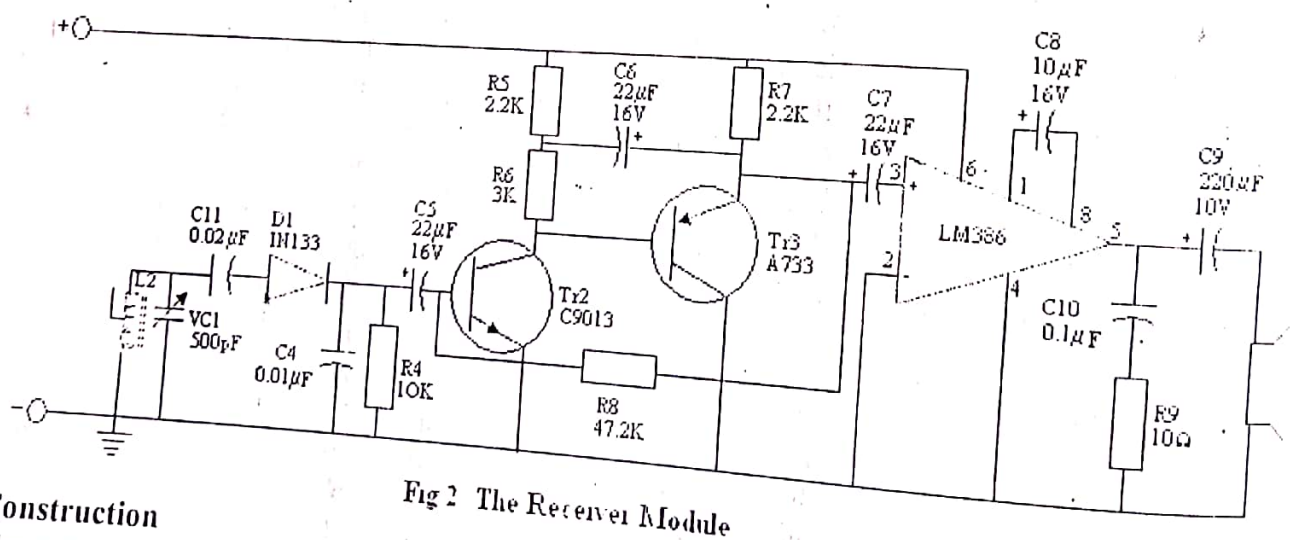

Fig 2 The Receiver Module

Construction

The complete circuit diagram of the metal detector device is shown in Fig. 3. The components are mounted as shown and wired on a vero board. This board contains drilled holes and interconnections for all the components; the inductors L_1 (Search coil which consists of about 120 turns of 28 s.w.g enameled copper wire wound on a hollow plastic hose of 11cm in diameter) and L_2, the compression capacitor VC_1, the on-off switch S_1 and 9Vdc battery that powers the circuit to drive an 8ohm, 0.25 watts speaker

April 2008
ISSN 1596 9770

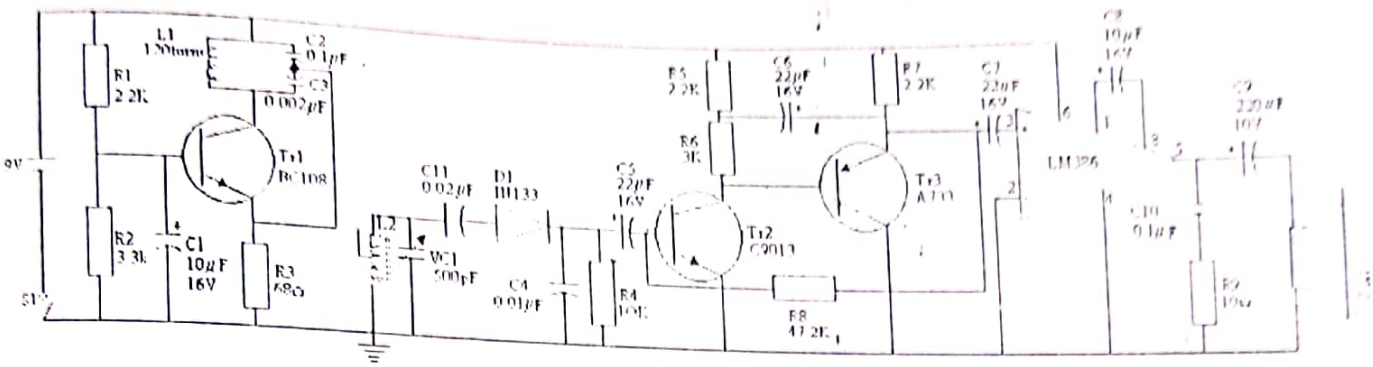

Fig 3 Complete Circuit Diagram of The Metal Detector

Testing and Discussion of Results

The transmitter was first tested with a separate radio receiver. A whistling (low audio) note was heard at different frequency levels – 680KHz, 1000KHz, 1300 KHz etc. on the receiver set. But at 1000KHz level, the note seems to be most stable, loudest and with minimum interference and noise. This testing method was used as improvise to ascertain the operating frequency range of the transmitter because there was no inductance meter to determine the value of inductance, L in equation 1. Based on this, a medium wave receiver was designed, constructed and tested. And, it was able to receive a local medium wave radio station loud and clear. The two modules; transmitter and receiver modules were later coupled together and tested and the result was satisfactory.

Device Operation

The operation is such that when the device is switch on the two radio frequency oscillators are immediately activated, and upon adjusting the receiver oscillator through VC_1 so that the two oscillates at nearly the same frequency within the medium wave band, a low frequency audio note is generated as a result of the two radio frequencies "Beating together". This audio note is detected by the demodulator and passed on to the pre-amplifier that amplifies it to a reasonable value before passing it to the final amplifier which amplifies further such that the audio note is heard loud and clear from the speaker. Should a metal object come close to the search coil (the transmitter coil), there is a change of beat frequency due to modulation by the metal object. For certain setting of the circuit, the note will fall for ferrous objects and rise for non-ferrous objects.

The device is particularly useful in the area of security. As was mentioned earlier, it can detect land mines, buried or hidden arms. In addition, since this device can also detect coins, metallic bric-a-brac, lost metallic items, position of hidden nails in second hand timber or trace the path of water pipes under the ground, conduit path in walls e.t.c., it will enhance the work of archeologist, carpenter, engineer and other professionals thereby enriching their capacity.

Conclusion

In Conclusion, the design and implementation of metal detector device was successful using available components. In depth understanding of circuit theory and the electrical characteristics of these components ensured the satisfactory and efficient performance of the system.

Recommendation

Since the feasibility of the product arising from this project work has been demonstrated and owing to the importance

April 2008
ISSN 1596-9770

and need for metal detector system in our lives today, it is pertinent for developing countries like ours to establish indigenous electronic industry to enable us develop our capabilities and build our human capacity. In so doing, we will increase our Gross Domestic Product (GDP), create jobs, and build a strong economy to enable us develop and conserve our human resources if we must flourish as a nation.

References

Bartelt, T. L. M. 1997. Industrial Electronics, Delmar, a division of Thompson learning Inc., Albany, New York.

Bishop, O. N., Anyanwu, I. J. and Olopade, O. L. 1994. Basic Electronics (2nd ed.). MacMillan Publishers, London.

Faisher, W. L. 1991. An Introduction to Modern Electronics (1st ed.). Hamilton Printing Company, U.S.A.

Floyed, T. L. 2002.Electronics Devices (6th ed.). Paerson Education Ltd., Singapore

Horowitz, P. and Hill, W. 1995. The Art of electronics (2nd edition). Cambridge University Press, London.

National Semiconductor, 2007. Datasheet, Packaging, Samples and Pricing. In www.google.com, Page 1 3.

Sparks, R. A. 1978. Electronics (2nd ed.). Hutchinson and Co. London.

Tokhiem, R. L. 2004. Digital Electronics: Principles and Applications (6th ed.). Tata McGraw-Hill Publishing Company, New Delhi.

Tooley, M. 1993. Electronic circuit Handbook: Design, Testing and Construction, Butterworth and Heinemann, London.

Warnes, L. A. 1998. Electronics and Electrical Engineering: Principles and Practice (2nd ed.). Palagrave Publishers, New York.