Autonomous Robot for Detecting Hazardous Material Underground

by

Liu Hing Hin

Dissertation submitted in partial fulfilment of

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Bachelor of Engineering (Hons)

(Electrical and Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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LIU HING HIN

ABSTRACT

This project mainly focuses on designing a prototype which is able to detect metal made material on the ground and possibly underground. The whole idea is to apply the theory of electromagnetic field which creates a magnetic field around the area and it will response to any metal thus interfere with the radio frequency inside the controller. Over the years, different types of metal detector had been invented. Some of the application maybe used as a hobby to search for gold coin buried in the soil. There is a lot of other application of metal detector such as searching for important and dangerous landmine buried in an old battlefield. In this project, the concept and design may slightly similar with metal detector but it is modified and combines into an autonomous robot. It is designed to detect the material and sent out an alert to the user indicating the dangerous zone. This robot can move around freely without control from anyone. It can help human to scan through a high potential risky area such as old battlefield. Besides that, it can save human resource and time due to the efficiency of a robotic. In this report, the main focus is explaining what a pulse induction metal detector is and how it works.

LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Problem statement

Technology is advancing in a speed of light. Weapon is one of the results of development of technology. Weapon such as landmine is widely used as a “surprise” ambush during wars. However, not all landmines are detonated during the war. Some of the landmines are still lying under a layer of soil even after the war has ended. This will surely put the people who are staying around the previous war zone in great danger. Since landmine is design to detonate based on the pressure applied on it, so it is impossible to detect it without risking a human life on it. Most of the time pets such as dogs are used in detecting this metal material but it is still cruel to risk another living creature. So, the solution is to design a non-living prototype to scan through the suspicious area without risking anyone’s life.

1.2 Objective

The objective of this project is to modify a conventional hand held metal detector into a prototype that can helps in detecting dangerous material such as land mine or metal without taking a single risk of injury. The idea behind the concept is based on the autonomous robotic design combine with a metal detecting sensor. This robotic design is applicable and useful in military which often dealing with landmine.

1.3 Scope of study

The main parts of this project revolving around four aspects which are the metal detector, robot’s mechanical, and programming. All four aspects will be research and develop in different stages in the progress of this project.

Metal detector with induction coil is applying the concept of electromagnetic. When a pulse generated in the coil, a magnetic field will be created in small radius of area. Whenever there is a metal lying around the area scanned, it will interrupt with the magnetic field thus creating a different pulses back to the receiving coil.

Robot’s mechanical parts basically involve all the moving parts namely the wheels. The construction of the robot looks like a remote controlled car which able to travel in normal terrain. The design need no to be complicated due to the simplicity of the robot makes it goes faster and more space to put in the metal detector circuit sensor.

Programming stage will be design based on the language used in PIC microcontroller chip. This chip will act like a brain to the robot and surely control all the function of the robot. So, a set of logical command is very crucial to determine the functionality of the robot.

CHAPTER 2

LITERATURE REVIEW

2.1 Background information

A typical metal detector used for detecting gold coins or landmines consists of a circular horizontal coil assembly held just above the ground. There are a lot of types metal detector designed and created throughout years. There are three famous types of metal detector which is beat frequency oscillator, very low frequency, and pulse induction [1].

2.1.1 Beat Frequency Oscillator (BFO)

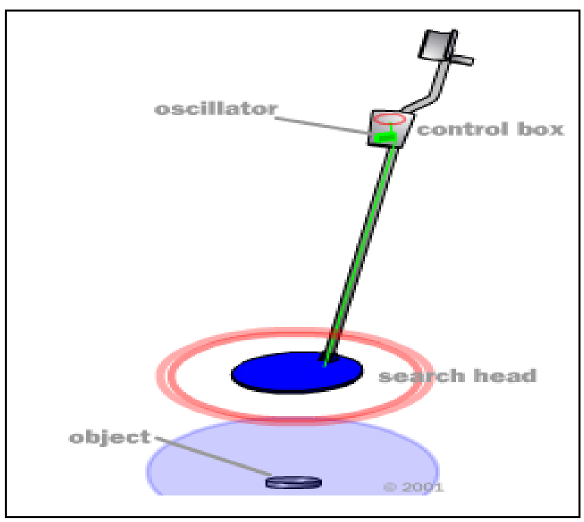

Figure 1: BFO Technology [1]

Beat Frequency Oscillator (BFO) is the most basic way to detect metal. It uses a technology called beat-frequency. There are two coils in this device. One large search coil and a smaller coil located in the control box. Both of the coils are connected to the oscillator that generated thousands of pulses per second. As the pulses travel through the coil, it produces radio waves. If the coil passes over a conductive material, the magnetic field produce by the material interfered with the frequency of the coil in the control box, the beats and duration of the wave changes. This metal detecting device is simple and sold for very cheap price. BFO accuracy and control level is much lesser than Very low frequency and Pulse Induction method [1]. BFO technology is shown in Figure 1.

2.1.2 Very low frequency (VLF)

Very low frequency (VLF), also known as induction balance method is the most common detector technology now. Most of the ready made metal detectors in the market are based on this method. VLF detector consists of two coils, transmitter coil and receiver coil. Transmitter coil is the outer coil loop. Figure 2 demonstrate the VLF technology.

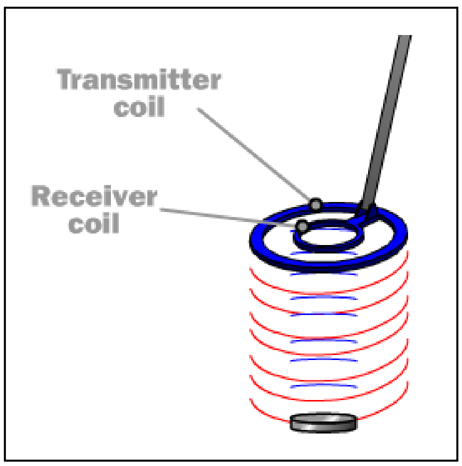

Figure 2: VLF Technology [1]

Current is send thousand of times in a second to the coil. The current will flow in positive and negative direction. The number of times current switched direction is the frequency of the transmitter coil. Receiver coil on the other hand is the inner coil loop. It is also coil of wire which acting like an antenna. It detects and received the frequency coming from the target objects in the ground and amplifies it.

VLF detector utilizes the use of electromagnetic field. The direction of the magnetic field is determined based on the right hand grip rules. The magnetic field produce by the coil is always perpendicular to the direction of the current flowing in the wire. When the polarity of the current changes, it also changes the direction of the magnetic field. So if the coil is parallel to the ground then the magnetic field will constantly changing from towards ground to away from ground. This moving magnetic field can interacts with any conductive material thus causing the material to generate weak magnetic field of its own. This weak magnetic field will be captured by the receiver coil.

The receiver coil is completely shielded from the magnetic field produce by the transmitter coil. However, it is able to receive the weak magnetic pulse from the conductive object. This pulse is amplified and sends to control box to be analyze. [1]

2.1.3 Pulse induction (PI)

Pulse induction (PI) method is less common compare to VLF. Both transmitter and receiver are sharing the same single coil. This technology sends out a powerful but short burst of current to the coil. Magnetic field will be created whenever there is pulses run through the coil. On the second the pulse ends, the created magnetic field will suddenly disappear resulting in a decay of current. PI technology shown in Figure 3.

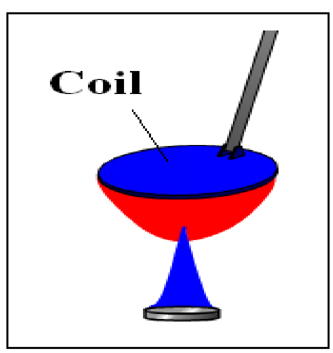

Figure 3: PI Technology [1]

The decay last for only a few milliseconds. This current is referred to reflected pulse. If there is any metal under the detecting coil, the conductive metal will react to the magnetic field created at the coil. Another opposite magnetic field will be created at the conductive metal. Whenever the reflected pulse detected, the magnetic field at the conductive metal will cause the reflected pulse to decay even longer than its usual period. The best example to give easier explanation is echoes. The whole process acts like echoes. If anyone shouts in a empty room, it probably hear only a brief echoes but if the shouts repeated in a room with a few more hard surface such as furniture, the echoes last longer. So the exact same things happened in the PI detector. The “shouts” from the detector causes an “echoes” and it will last longer if there is a metal reflected the “echoes” [1].

In order to compare the duration of the reflected pulse, a sampling circuit is needed. The circuit will works as a comparator, comparing the duration for the reflected pulse to completely decay to the expected duration. If the counts show that it takes a few milliseconds longer then the probability a conductive metal nearby is high. The sampling circuit will react and sends a signal to integrator. The function of an integrator is to amplify and convert the signal to direct current which is the input to the audio circuit. At the end of the audio circuit is a tone generating device such as speaker to indicate the signal.

2.2 Comparison between BFO, VLF and PI metal detector

The comparisons between three types of metal detectors are made based on efficiency, depth penetration capabilities and discrimination accuracy. First of all BFO had the lowest efficiency because setting a search head to work on various frequencies will lower the quality factor. PI detector can penetrate the ground into deeper layer compare to the other two types. However the greatest weakness of PI detectors is lack of reliable discrimination. It means the PI detectors cannot determine what types of metal below its coil. [2]

2.3 Search coil design

In a metal detector, pulse generation happened through the coil. The size of the coil is dependable on the depth and size of the target object. Generally one can say that the maximum detection depth of a coil is approximately five times the diameter and detected object size is five percent of the diameter. Although the assumption is true but it is heavily depend on the situation such as type of soil, humidity and voltage supply. [2]

Search coils can be built on different types of shapes. The most common coil pattern seen is round as in Figure 4, square and elliptical. Although the shape is different but the inductance of coils varies slightly if compared.

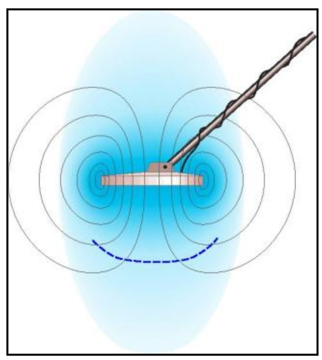

Figure 4: Magnetic field created in a round type coil [2]

When voltage is supplied to the coil via high speed bipolar transistor, the current in the coil will increase until it is limited by the internal resistance of the coil. Based on the facts above, the longer the coil is charging, the stronger magnetic field will be produced. Stronger magnetic field can penetrate deeper in soil but there is a chance for the coil to over-saturated and produces background noise. The noise will affect the accuracy of the detection process. Therefore, most of the search coil design setting the limit of maximum charge time to approximately 250µsec [2].

Apart from the sensitivity, a metal detector should be able to localize the target precisely. The detector may tilt at an angle, exploiting reducing width of detecting limitation as demonstrated in Figure 5 [2].

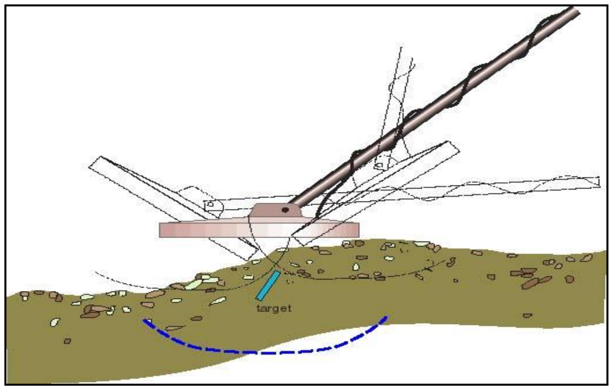

Figure 5: Coil tilt at different angle sensing different level of depth

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

3.1.1 Flow chart of Final Year Project

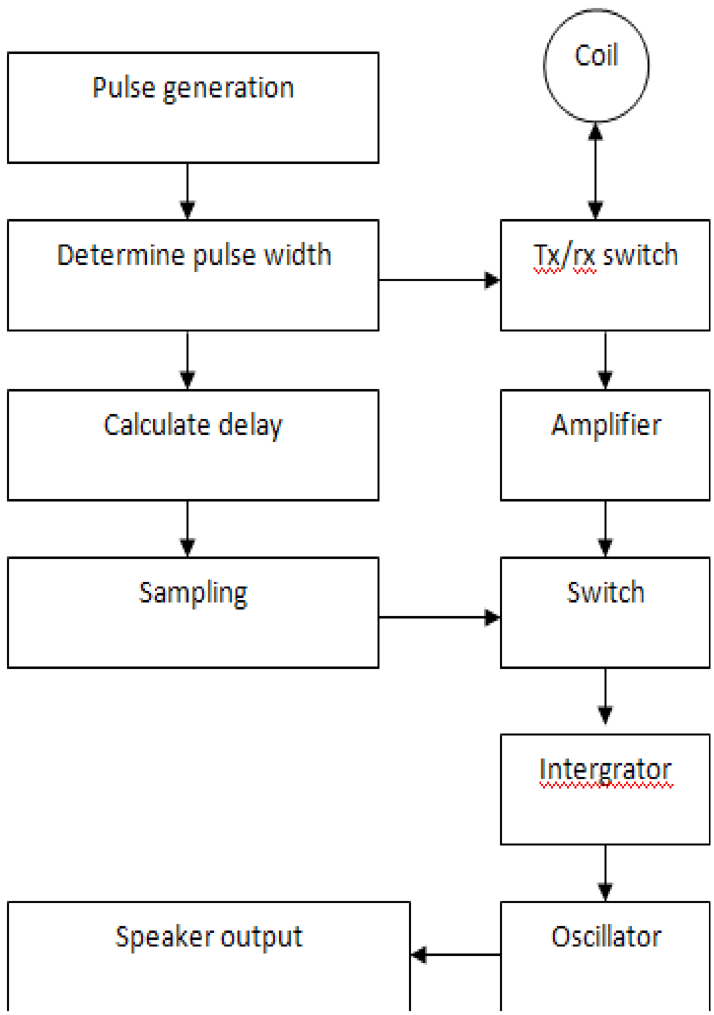

Figure 6: Flow Chart of Final Year Project

3.1.2 Block explaination

Pulse generator

- Generate pulse with certain magnitude and duty cycle by using 555 timers

Calculate delay

- Calculate the delay response of the 555 timer and its decay time

Sampling

- Create a reference decay time pulse based on the theoretical value of capacitor and resistor

Coil

- Turns of wires which act as an electromagnetic transceiver and receiver.

Amplifier

- Amplify the pulse received from the coil

Integrator

- Compare the pulse received from coil with the reference pulse

3.1.3 Theory

Figure 7 is a schematic of pulse 1 metal detector as reference.

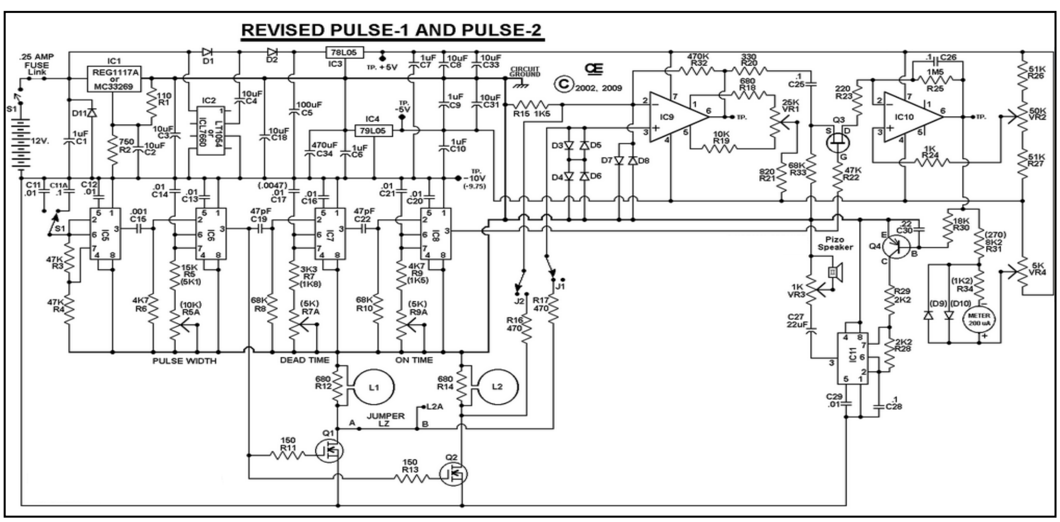

Figure 7: Schematic of Pulse Induction Metal Detector [3]

I. Pulse generation and sampling

The circuit consist of five 555 timers. Four of the timers are interconnected. The first timer is in astable configuration in order to provide a constant clock for the rest of the timers. The rest timers connected in monostable configuration to give a one shot characteristic. The function of the set of timers is to control the width of the signal going into the coil. Besides that, delay time also take into consideration for the circuit to wait reflected pulse to decay. A sample time was set in order to do comparison to the reflected pulse. Different value of pulse width can be obtained by changing the value of capacitors and resistors. The calculation is shown in the result.

II. Power supply

The main power supply for the circuit will be 12V source. The power supply is regulated by REG1117A to reduce the voltage down to about 3V. LT1054 provide -10V to the 555 timers. There are also negative and positive voltage regulator, 79L05 and 78L05. These regulators convert the voltage to +5V and -5V and supply it into JFET input operation amplifier, LT081.

3.2 Tools and Equipments

In this project, there are different methods used to gather all the information needed such as:

- Internet browsing
- Reference book
- IEEE Journals and papers
- Pspice (simulation)

I. Internet browsing

Internet browsing is the most common method used now to find any related information. The convenience provided by the university by implementing high speed internet connection makes the process even easier. In this project, a lot of researches have done using the information from internet. These matches are referring to similar metal detecting projects. There are a lot of ideas provided by people around the world regarding metal detecting projects and they are willing to share all the ideas and information online. Google used as the medium to search all the ideas. Google allows users to enter the key word such as “metal detector” in order to find all the related information which contains the key word. From here, users can browse through all provided link and slowly eliminate the less useful links. Finally, lists of useful websites are taken as reference to this project.

II. Reference book

Reference book is the most direct way of getting all the information related to specific topics. In this project, a reference book used such as Microelectronic Circuits as guidance. Most of the theories and calculations are referring to the text book.

III. IEEE journals and papers

IEEE website provides a lot of journals and paper regarding different topics. Universiti Teknology PETRONAS (UTP) is one of the subscribers to the society thus every student in UTP can easily get an access to the journals and papers without paying the amount of money. A few of the papers got from the library such as “Autonomous Metal Detector robot”[4], “ALIS”[5], and “Sensitivity map for metal detector design”[6]. All papers provide different types of information regarding the design of project’s prototypes.

IV. Pspice (simulation)

After all the necessary information is gathered, a simulation done based on the circuitry found. A software named Pspice used to do the circuit simulation. However, the version that available for this project is a student version. There are some limitations for a student’s version for example 50 parts limitation in a simulation circuit and some of the electronics parts are not found in the student’s version. The simulation is done using all the available parts only.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Simulation and lab testing

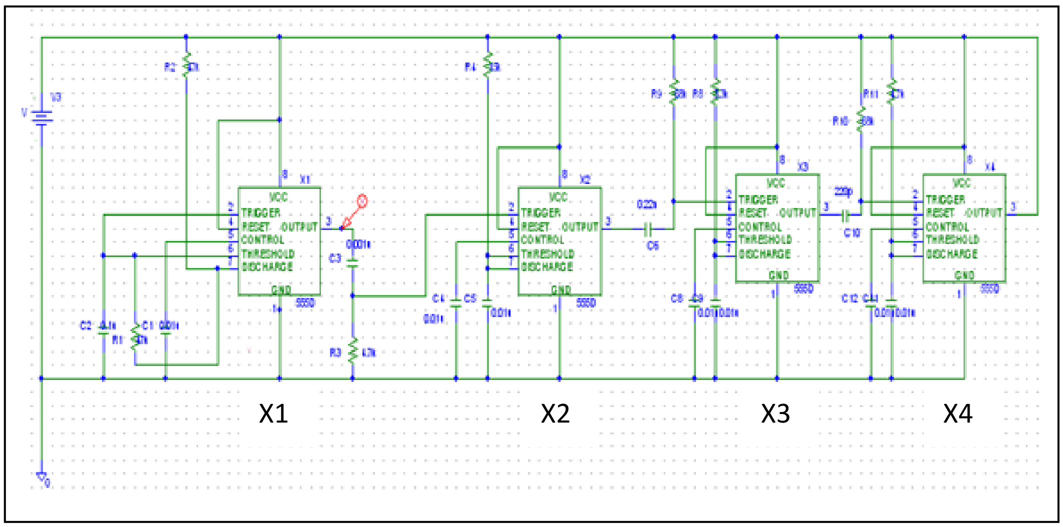

Figure 6: Schematic Diagram for 555 timers

Schematic diagram build in Pspice shown in Figure 8 to simulate the output from each 555 timer. The components used are four 555 timers, capacitors and resistors. The output from this circuit will fed into two different operation amplifier to make comparison with the reflected signal from the coil. 555 timers provide pulses needed to fed into the coil. The output of the first 555 timer (X1) is calculated based on the astable configuration. Astable configuration produced square wave and the duration of low and high states is different based on the value of capacitor can resistor. The time period of high states is calculated using Equation (1).

$$\mathrm{T_H} = 0.693 \times \mathrm{C} \times (\mathrm{R_1} + \mathrm{R_2}) \quad (1)$$

$$T_H = time\ when\ signal\ is\ high$$

$$C = Capacitor\ value$$

$$R = Resistor\ value$$

Substitute capacitor, R_1 and R_2 value to 0.1μF, 47kΩ and 47kΩ respectively into Equation (1) to calculate the time period when signal is high.

$$\mathrm{T_H} = 0.693 \times \mathrm{C} \times (\mathrm{R_1} + \mathrm{R_2})$$

$$\mathrm{T_H} = 0.693 \times 0.1\mu \times (47k + 47k)$$

$$\mathrm{T_H} = 6.51 \times 10^{-3}\ s = 6.51ms$$

The time period of low states is calculated by using Equation (2).

$$\mathrm{T_L} = 0.693 \times \mathrm{C} \times \mathrm{R} \quad (2)$$

$$T_L = time\ when\ signal\ is\ low$$

$$C = Capacitor\ value$$

$$R = Resistor\ value$$

Substitute capacitor and R_2 value to 0.1μF and 47kΩ respectively into Equation (2) to calculate the time period when signal is low.

$$\mathrm{T_L} = 0.693 \times \mathrm{C} \times \mathrm{R}$$

$$\mathrm{T_L} = 0.693 \times 0.1\mu \times 47k$$

$$\mathrm{T_L} = 3.25 \times 10^{-3} s = 3.25ms$$

A graph is plotted using the simulation presented in Figure 9. X-axis in Figure 9 is voltage level in volt while the Y-axis is time in miliseconds. From the graph shown in Figure 9, the time period for signal high which is 10V is 6.51ms and the time period for signal low which is 0V is 3.2ms.

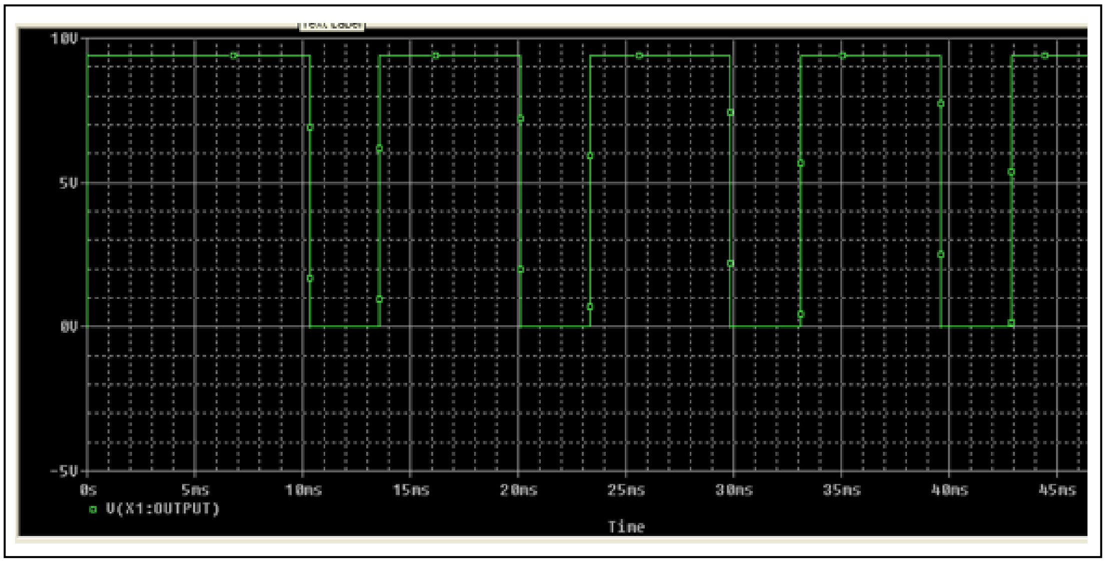

Figure 7: Pspice Waveform of Output X1 Timer

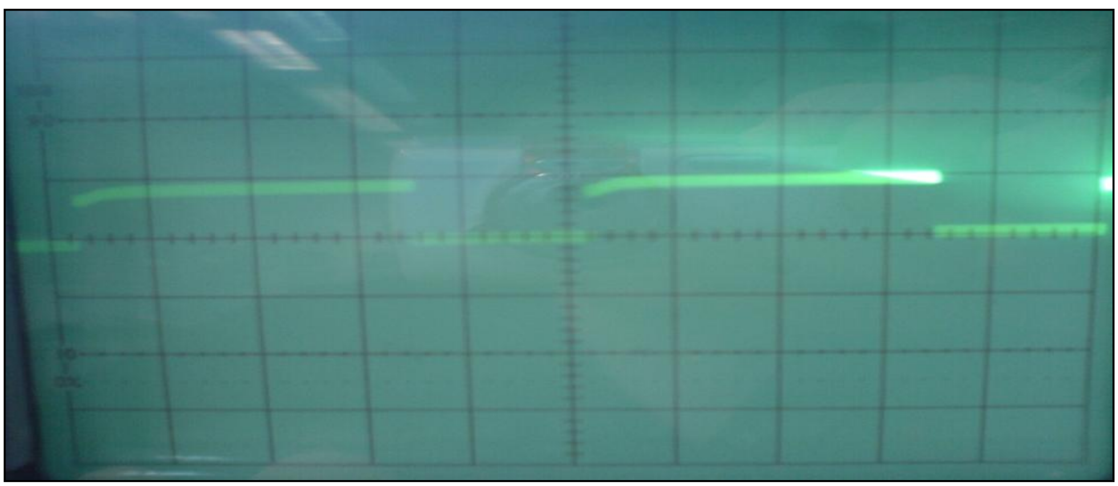

Figure 8: Experimental result from output X1

Experimental result from output of first 555 timer is shown in Figure 10. Voltage per division (volt/div) used is 10 volt. Time per division (tim/div) used is 2 milisecond. The result in Figure 10 showed that the time period of high signal (10V) is 6.4ms and the time period of low signal (0V) is 3.2ms. Comparison is summarized in Table 1.

	Time period	
	Signal High, 10V	Signal Low, 0V
Simulation value	6.51ms	3.2ms
Calculated value	6.51ms	3.25ms
Experimental value	6.40ms	3.20ms

Table 1: Comparison of time period between simulation, calculated and experimental value

From Table 1, the error percentage is calculated based on the calculated value and experimental value using Equation (3).

$$\text{Error percentage}, \% = \frac{\text{Calculated value} - \text{Experimental value}}{\text{Calculated value}} \times 100\% \qquad (3)$$

Error percentage for the time period of signal high calculated using Equation (3) shown as below:

$$\text{Error percentage}, \% = \frac{6.51 - 6.40}{6.51} \times 100\%$$
$$\text{Error percentage}, \% = 1.68\ \%$$

Error percentage for the time period of signal low calculated using Equation (3) shown as below:

$$\text{Error percentage}, \% = \frac{3.25 - 3.20}{3.25}$$
$$\text{Error percentage}, \% = 1.53\ \%$$

The result from error percentage calculation showed that the error is neglect able and the actual 555 timer is working perfectly. It provided an accurate signal to the other 555 timers and also controls the input to the coil.

Second and third 555 timer (X2 and X3) is simulated, the result was not able to provide any result due to the incomplete of the circuit simulated in Pspice. The incomplete simulation is due to the limitation set at the student version of Pspice. The timer is constructed in monostable configuration. A monostable configuration can produced a single output pulse when triggered. It generates stable low states but a temporary high state. The time period can be calculated based on Equation (4).

$$T = 1.1 \times C \times R \quad (4)$$

$$C = \text{Capacitor value}$$

$$R = \text{Resistor value}$$

Substitute capacitor value and resistor value with 0.1μF and 15Ω respectively into Equation (4) to calculate the time period for the monostable configuration.

$$T = 1.1 \times C \times R$$
$$T = 1.1 \times 0.1\mu \times 15\Omega$$
$$T = 1.65 \times 10^{-6}\ s\ = 0.165ms$$

Experimental result from output X2 is shown in Figure 11. The voltage per division (volt/div) used is 5V and the time per division (tim/div) set to 0.05ms. From the observation, the time period of the momentary high state is approximately 0.15ms and the voltage is 10V. The result comparison of both calculated value and experimental value is shown in Table 2.

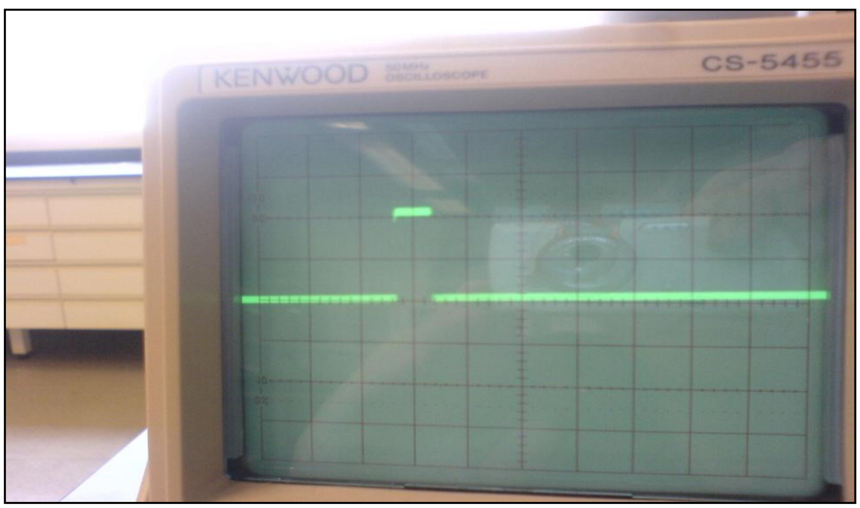

Figure 9: Experimental result from output X2

	Time period
	Signal High, 10V
Simulation value	-
Calculated value	0.165ms
Experimental value	0.150ms

Table 2: Comparison of time period between calculated value and experimental value.

From Table 2, the error percentage is calculated based on the calculated value and experimental value using Equation (3).

$$\text{Error percentage}, \% = \frac{\text{Calculated value} - \text{Experimental value}}{\text{Calculated value}} \times 100\%$$

$$\text{Error percentage}, \% = \frac{0.165 - 0.150}{0.165} \times 100\%$$

$$\text{Error percentage}, \% = 9.0\%$$

From the result of error percentage above, the value of 9.0% is acceptable and the 555 timer circuit is working accordingly. It produced a suitable signal to feed into the coil.

4.2 Lab demonstration

Second part of the result is based on the experiment and circuit testing in the lab. It is different from the simulation in Pspice because it is a complete pulse generating circuit which consists of four 555 timers, capacitors and resistors. Experiment done in the lab is shown in Figure 12. The input of the oscillator is connected to the pin3 of the 555 timers which is the output from 555 timers respectively. The purpose of testing this part of the circuit in lab is because it is the most important part which provides the appropriate signal to the coil. It must be fully tested and make comparison with the theoretical value in order to ensure the accuracy of the waveform.

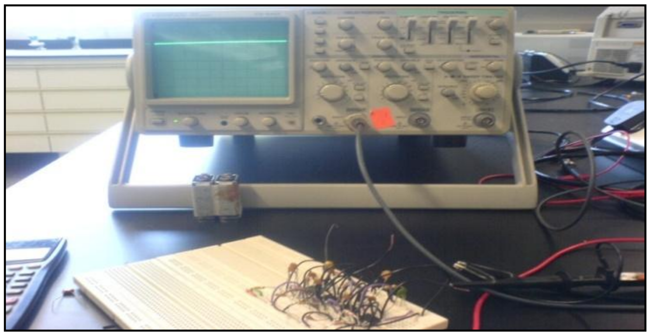

Figure 10: Experiment setup in Lab

4.3 Coil design

A testing coil is produced. The shape of the coil is round with a diameter of 10.16cm (4 inches) as shown in Figure 13. It is made of 30 turns of stacked copper wire. This is not an ideal coil design due to the inconsistency of the stacked arrangement of the copper wire. The facilities in the university restricted the construction of a proper flat coil thus a testing coil is produced for testing and study purposes only. Insulated type of wire is used in this project. It is a type of wire where it has a layer of insulation material covered around the surface of the wire. All the wires used in the industry had this insulation layer to prevent any short circuit between wires. In this project, the insulation layer had been removed for a few centimeters from both end of the wire. This had enabled the voltage flow within the conducting copper layer. The resistivity test has also shown that both end of the coil is connected. It can conduct voltage within the insulation layer without getting short circuited with the stacked wire.

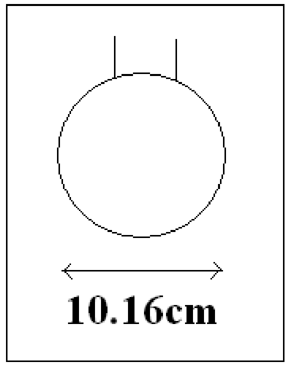

Figure 13: Illustration of round shape coil

Figure 14: Insulated copper coil

A testing coil is shown in Figure 14. It is a 30 turns of copper wires in stacked up arrangement. The testing coil did not expect to provide the exact magnitude of magnetic pulses needed for a deep metal detecting. The coil was built by hand thus the orientation and arrangement is not perfect.

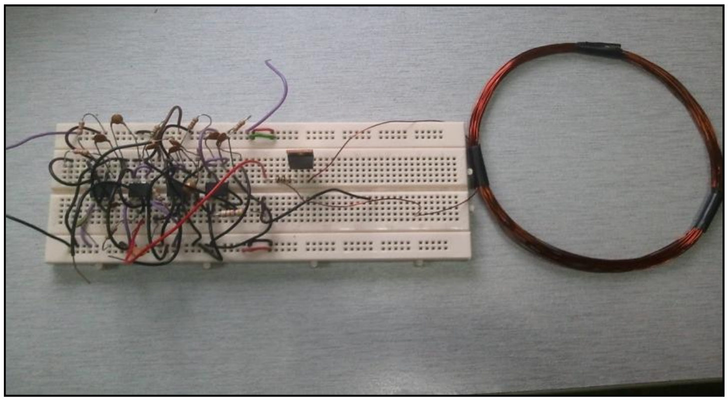

Figure 15: Pulse generation circuit and coil

Pulse generation circuit and coil is connected as shown in Figure 15. The pulse generation circuit is providing the needed signal for the coil. The 555 timer is expected to provide one shot pulse every cycle to test the coil as shown in Figure 11 earlier. When the reflected signal from the coil is same as the sending signal then the circuit remained its usual operation without giving out any alarm or warning sound.

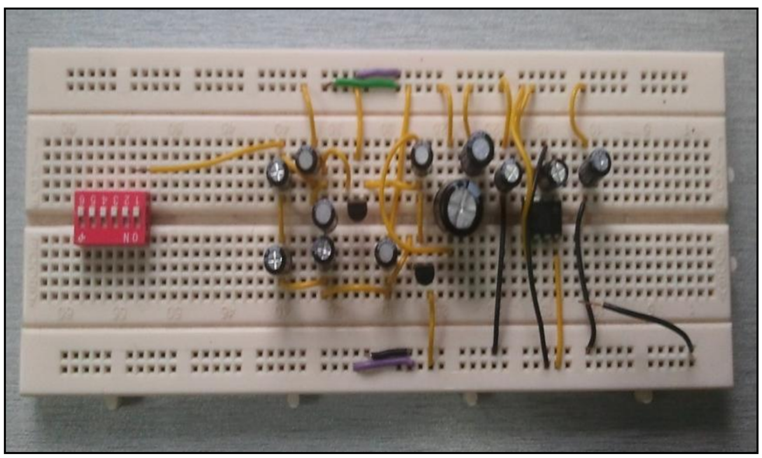

Figure 16 Power supply circuit

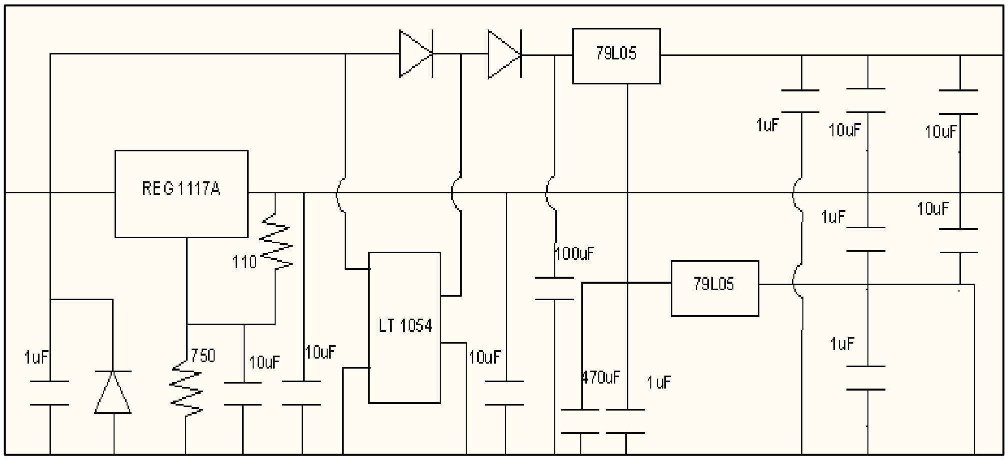

Figure 17: Schematic diagram of the power supply circuit

Power supply circuit is shown in Figure 18. The value of the capacitors and resistors used are shown in the Figure 17. The function of all the components in the circuit are design to convert the 12V input source voltage into different level voltages based on the various requirements of the other components in the complete circuit. REG 1117A is function to regulate the voltage down to approximately 3V from the 12V voltage source. LT1054 used to provide -10V for the 555 timers. 79L05 used to convert the voltage into +5V for the JFET input operation amplifier.

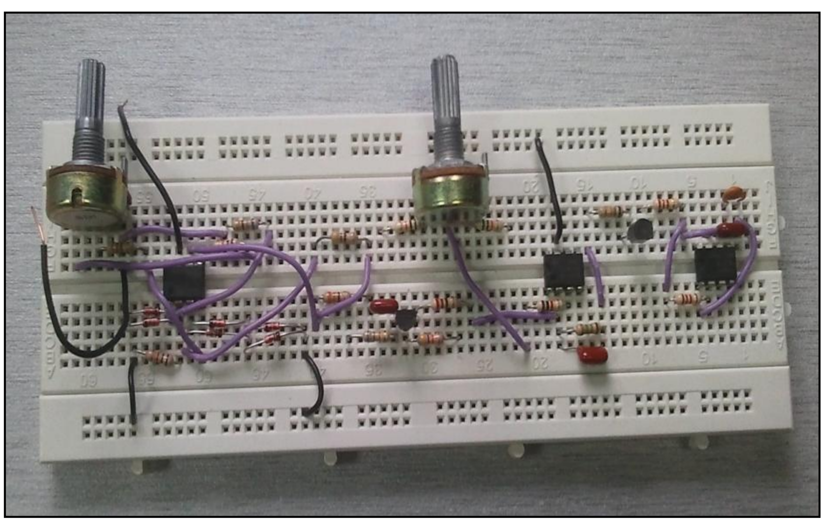

Figure 18: Integrator circuit

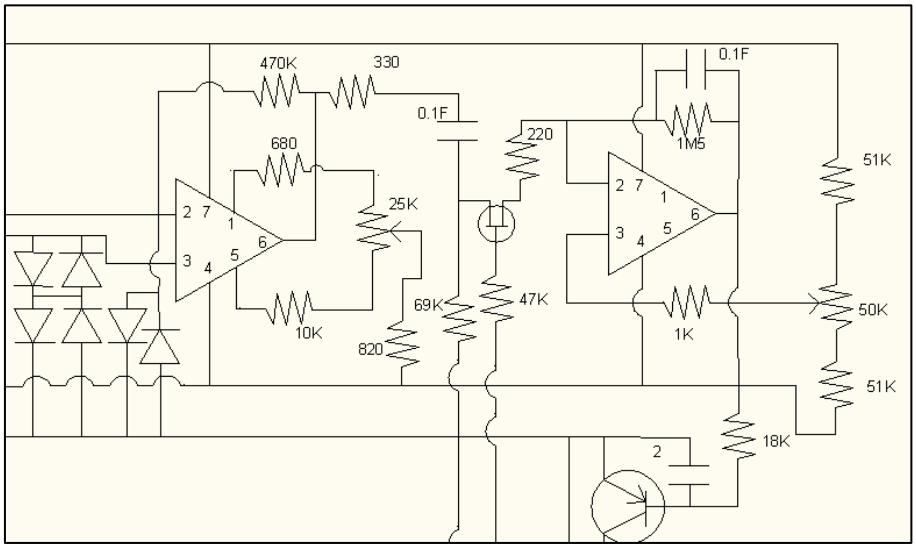

Figure 19: Schematic diagram of integrator circuit

Integrator circuit is shown in Figure 18. All the component values are shown in Figure 19. There are two important components in this circuit which is the TL081 which is an operation amplifier. The function of both TL081 is to receive the signal from the testing coil and further compare it with the predetermined value of signal provide by the other 555 timer in the circuit. The rheostat in the circuit used to adjust the predetermined value of the 555 timer.

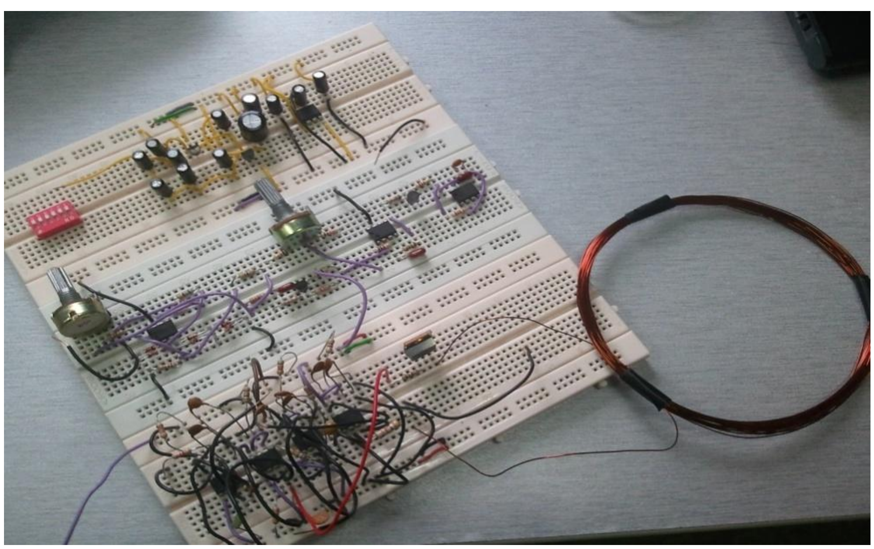

Figure 20: Overall complete circuit

Complete circuit shown in Figure 20 with three different modules combines into whole circuit. The actual circuit then built on the PCB board shown in Figure 21 to minimize the space consume. The complete soldered circuit is shown in Figure 22. This circuit is provided with 12V voltage source from a series of batteries.

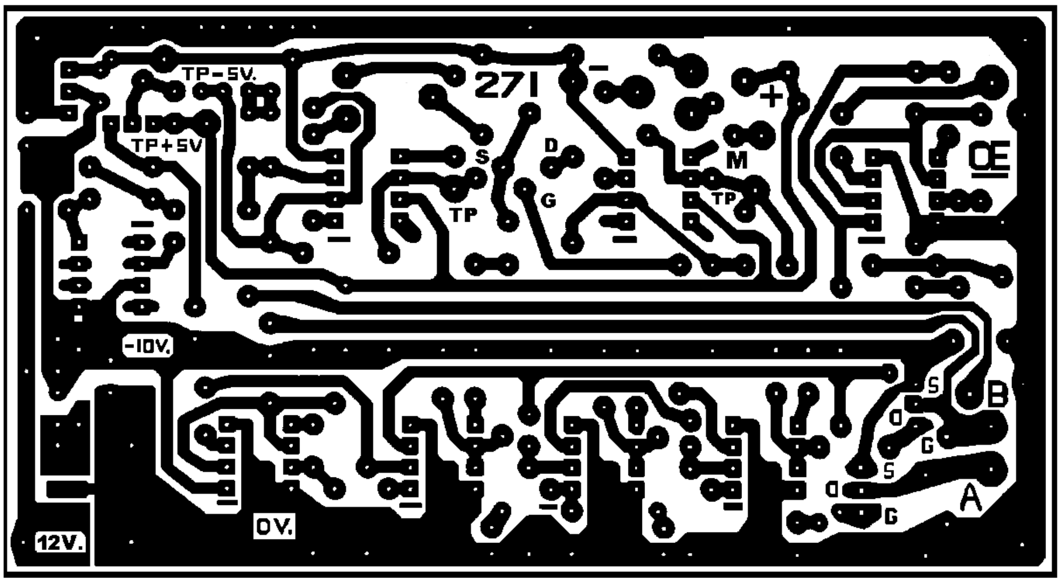

Figure 21: PCB design

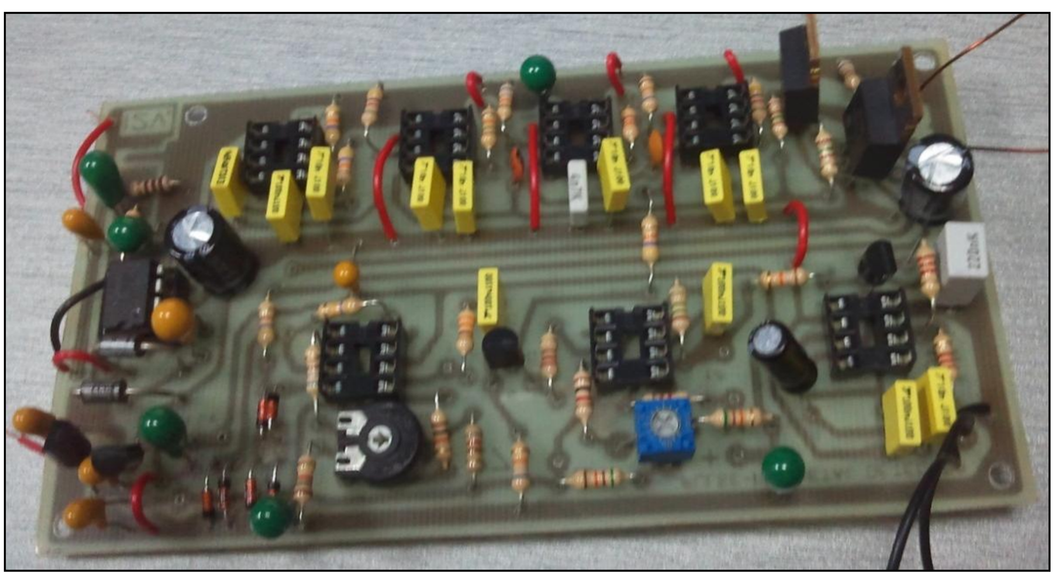

Figure 22: Circuit build on PCB board

4.4 Robot construction

The motor implemented in this project is twin gear motor from Tamiya. It can operate two wheels separately by using two DC motors. The front wheels are designed to be free wheels. Figure 23 showed the gears, wheels and chassis of the robot.

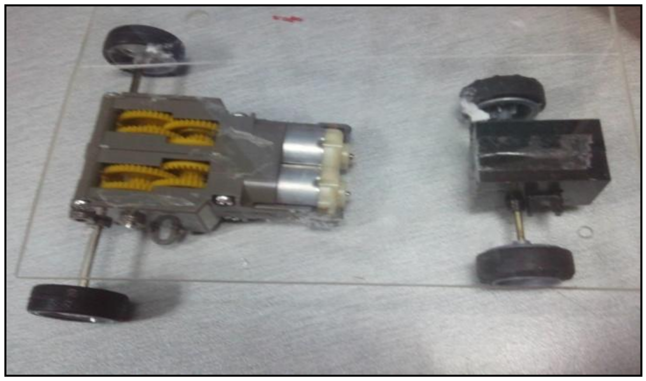

Figure 23: Twin gear motor

The motor is connected to the Programmable Interface Controller microcontroller through a L239 motor driver. Voltage regulator 7805 used to regulate the power supply into 5V. The regulated 5V is supply to PIC and also the motor driver L239D. 24MHz clock is used for the PIC. The circuit of PIC is shown in Figure 24. All the soldering connection is done under the board.

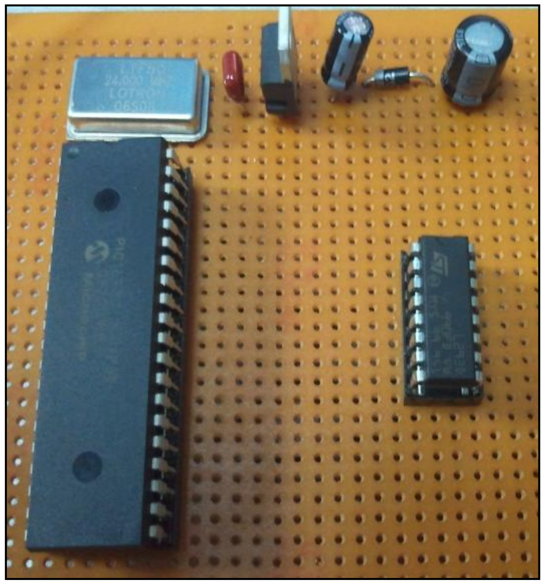

Figure 24: PIC, L239D, and voltage regulator

Coding for PIC programming is presented in Appendix A. The code demonstrates that when input D0 received low (off) from the sensor, it will give high to output pin RB1 and RB3 to enable the motor to move forward. When the sensor activated and send signal high (on) to the PIC, then the motor will stop because RB1 and RB3 is off. Simulation is shown in Figure 25 and Figure 26.

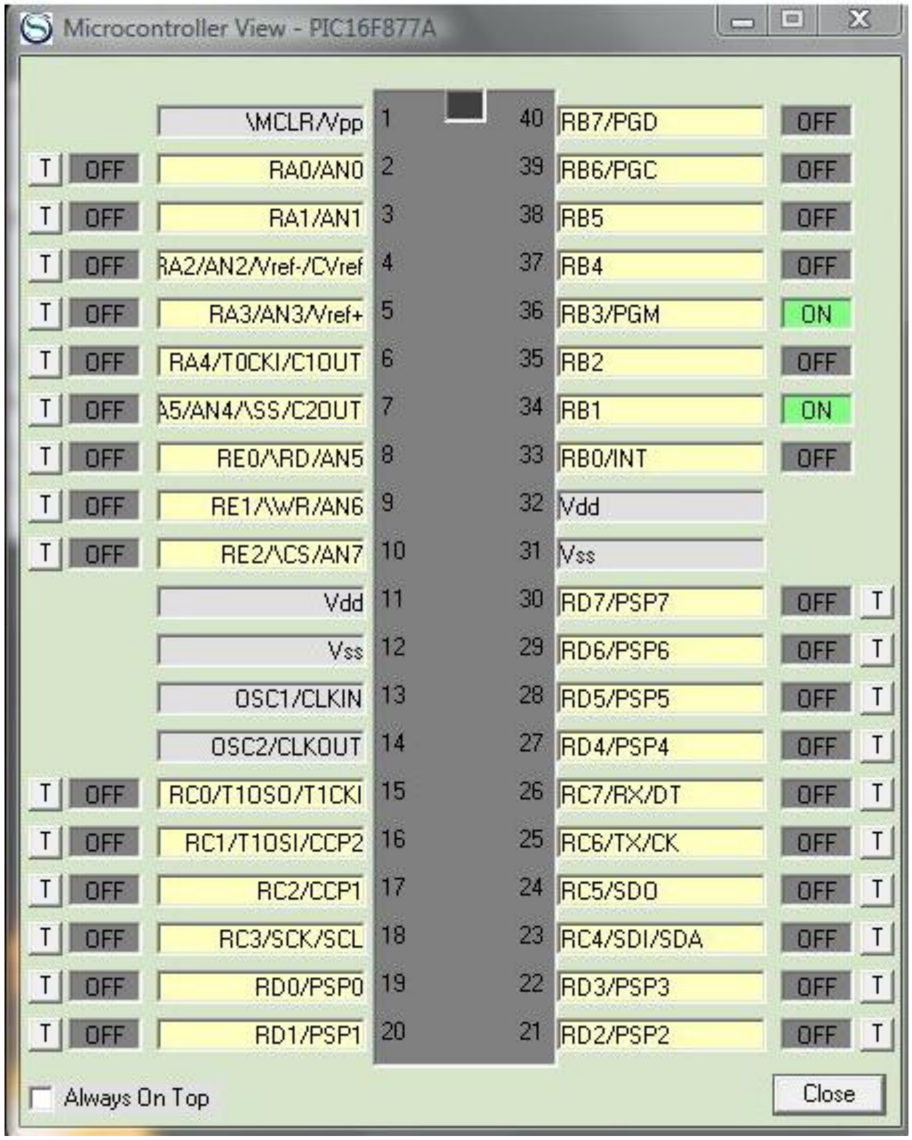

Figure 25: Simulation result when sensor D0 is off

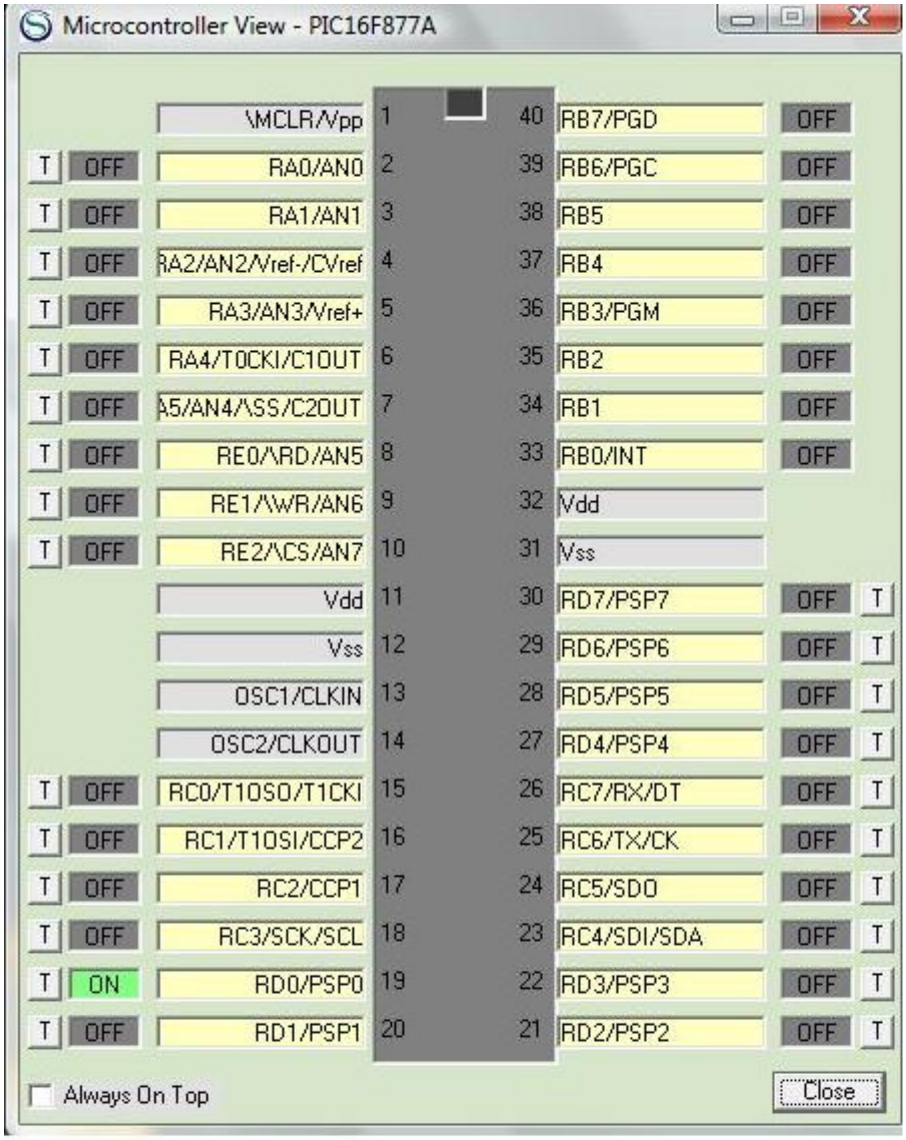

Figure 26: Simulation result when sensor D0 is on

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main focus of this project is to design and build pulse generating circuit of the whole complete metal detecting circuit. The first implementation is simulation using Pspice. Pspice simulation has its limitation due to the version. So the circuit is simulated separately and hoping to get the similar result by simulating each part individually. During the simulation, the waveform shown for first timer is acceptable but there is an error during the simulation of second timer. The waveform should be astable and monostable configuration respectively. Regardless the simulation results, a real lab demonstration is carried out using a breadboard implementation of the circuit. By providing 10 volts as testing voltage, waveforms shown on the oscilloscope are satisfied. The output of every 555 timer satisfies the theoretical value as well. This had proven that the schematic is workable and there is need of changes in the way of simulating in Pspice. The output at the X2 will be feed into the coil later at the progress of the project. At the moment, 555 timer with a combination of astable and monostable configuration is proven to be able provide the desired waveform suitable to feed into the coil.

The second stage of the project is building the testing coil to generate electromagnetic pulse. The pulse generated reflected on the metal material and create a reflected pulse with different pulse wave. A proper flat coil must be use in order to create a perfect electromagnetic pulse but the facilities in UTP is not avaible to perform the task. So, a testing coil is used for testing and study purpose only.

Finally, the circuit and coil is mounted on a chassis complete with gears and motor. The motor is control by PIC by using the input from the main circuit. In this project, the control of the motor is simplified to move forward and stop only.

5.2 Recommendations

In order for the metal detector to work perfectly, a proper coil is needed. A flat coil is very good to serve the purpose. Flat coil is a coil with copper wires arranged in spiral form without wires stacking on each other. It has wider area of surface and the pulse generated is equally distributed.

The control of the motor can modify to perform more complicated task such as remote control. This task is not perform in this project is due to the complexity and insufficient time.

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APPENDICES

APPENDIX A: PIC Programming Code

```
#include <16F877a.h>

#fuses HS,NOWDT,NOPROTECT,NOLVP,NOPUT,NOBROWNOUT,NODEBUG

#use delay(clock = 24000000)   //24MHz

unsigned int inval;

void main (void)

{   set_tris_d(0x01); //port d LSB set to input

   set_tris_b(0x00); //port b all set to output

   while(1)

   {       inval=input_d();   //check the input from port D

         if(inval==0x01)

         {           output_high(PIN_B1);    //B1=1 B2=0 B3=1 B4=0

            output_low(PIN_B2);     //to enable the robot move forward

            output_high(PIN_B3);

            output_low(PIN_B4);        }

         else if (inval==0)

         { output_low(PIN_B1);     //all set to 0

            output_low(PIN_B2);     //to halt the wheel.

            output_low(PIN_B3);

            output_low(PIN_B4);        }

   }

}
```

APPENDIX B: Schematic Diagram Of Pulse Induction Metal Detector.