# Metal Detector By Using PIC Microcontroller Interfacing With PC

Yin Min Theint, Myo Maung Maung, Hla Myo Tun

**Abstract:** This system proposes metal detector by using PIC microcontroller interfacing with PC. The system uses PIC microcontroller as the main controller whether the detected metal is ferrous metal or non-ferrous metal. Among various types of metal sensors and various types of metal detecting technologies, concentric type induction coil sensor and VLF (very low frequency) metal detecting technology are used in this system. This system consists of two configurations_ Hardware configuration and Software configuration. The hardware components include induction coil sensors which senses the frequency changes of metal, a PIC microcontroller, personal computer (PC), buzzer, light emitting diode (LED) and webcam. The software configuration includes a program controller interface. PIC MikroCprogramming language is used to implement the control system. This control system is based on the PIC 16F887 microcontroller.This system is mainly used in mining and high security places such as airport, plaza, shopping mall and governmental buildings.

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## I. INTRODUCTION

Nowadays, Metal detectors have become an essential component in today's society and widely used not only for hobbyists but also for safety purpose. For Safety purpose, Metal detector that used in airport to ensure that there is no dangerous weapon such as knives, guns or any metal objects that could be used as weapons has been brought along by terrorist into the airplane. In technical area, people use metal detector to search for the underground pipe or cable before digging in walls and floors. Besides that, many people enjoy in discovering hidden treasure or valuable metal like gold and silver by using metal detector [1].
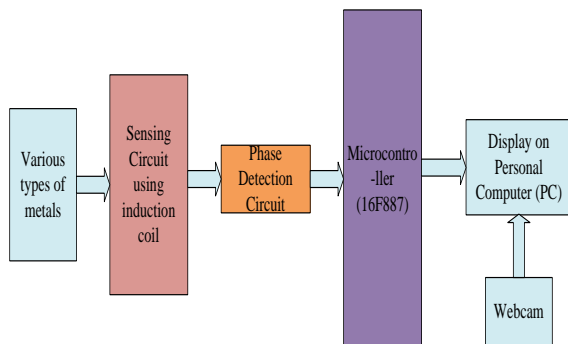


**Figure1.** *Overall block diagram of the system*

In these days, most of metal detectors can only detect metal but not the types of detected metal. And they usually indicate by turning on the alarm or LEDs whenever the metal target is detected. In this system, not only the detected metal target but also the types of metal are indicated on the personal computer (PC) and image records with webcam.

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The types of non-ferrous metal are copper, aluminium, zinc, gold, platinum, bass, bronze and etc... Ferrous metals are all metals which have iron properties. The whole system is controlled by the PIC microcontroller. Figure.1 shows the overall block diagram of the system.

## II. RELATED TECHNOLOGY

Metal detectors' basic operation depends on Ampere's and Faraday's laws. It works on the principle of transmitting a magnetic field and analyzing a return signal from the target and environment. The transmitted magnetic field varies in time. This transmitted magnetic field creates electric current to flow in metal targets. These electric currents are called eddy currents, which in turn generate a weak magnetic field, but their generated magnetic field is different from the transmitted magnetic field in shape and strength. The regenerated magnetic field from the eddy currents causes an alternating voltage signal at the receive coil. Depending on the alternating voltage signal at the receive coil, we can decide whether the metal target is detected or not [2]. Metal detecting sensor is the most essential component in metal detectors. In this system, induction coil sensor is used. Metal detecting capabilities are vary according to coil sensor shapes, sizes and coil configurations. There are three types of coil shapes –

(i)     Round shaped coil
(ii)    Elliptical shaped coil
(iii)   Open-web coil

The most common types of coil configuration are-

(i)     Concentric coil
(ii)    Double-D coil
(iii)   Mono loop coil

There are different types of metal detecting technologies. They are-

1.  Beat Frequency Oscillator (BFO)
2.  Pulse Induction (PI)
3.  Very Low Frequency (VLF)

The Beat Frequency Oscillator (BFO) operates in the range of 100s kHz. The Pulse Induction (PI) operates in the range of 100s Hz and the very low frequency (VLF) operates in the range of 3-30 kHz. Among these technologies, VLF technology is the most popular type of metal detecting technology. In this system, the VLF technology is also used because it has the

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ability to discriminate different metals according to their phase shifting.

## III. SOFTWARE CONFIGURATION

### A. Microcontroller program implementation

In this implementation, it is important to assign the reference value. This reference value is the input voltage of the microcontroller and it is the output of the phase detection circuit when there is no metal detected. And then, it is to get the input voltage value from the phase detection circuit. If the input voltage changes, the metal is detected and the alarm system will be ON. If the input voltage increases when compared to the reference voltage, this metal is non-ferrous metal. If the input voltage decreases when compared to the reference voltage, this metal is ferrous metal. And it will be displayed on the personal computer (PC) using C# GUI. The overall program is implemented by the mikroC language. Figure.2 shows the flowchart of microcontroller program.
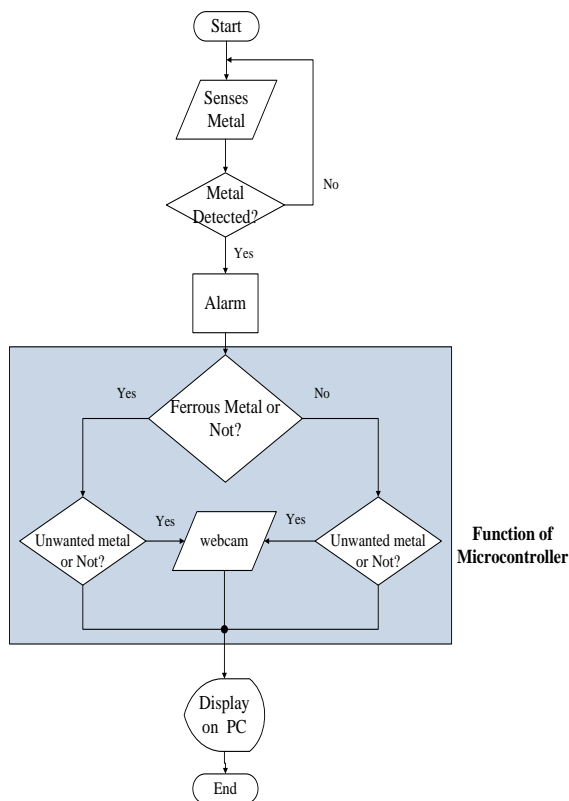


*Figure2. Flowchart of the microcontroller program*

### B. Simulation results

Metal type discriminating system is simulated using PROTEUS SOFTWARE and their results are presented in this system. In simulation software, instead of induction coil sensor, two pulse generators is used to input the frequency to the phase detection circuit. One of these pulse generators is used as the transmitted coil sensor and the other one is used as the received coil sensor. Phase detection circuit determines phase lead or phase lag by comparing two incoming frequencies from two pulse generators. And then phase lead or phase lag value is converted to the appropriate voltage by using active low pass filters. Phase lead means increasing voltage and phase lag means decreasing voltage. A reference voltage is assigned

in the PIC microcontroller program when there is no phase lead or phase lag i.e. there is no output voltage change in the phase detection circuit. The PIC microcontroller discriminates ferrous metal or non-ferrous metal depending on the voltage from the phase detection circuit. Control system for PIC microcontroller is implemented by MikroC program. Table.1 shows defined voltage ranges of different metals.

***Table I***
*Defined voltage ranges of different metals*

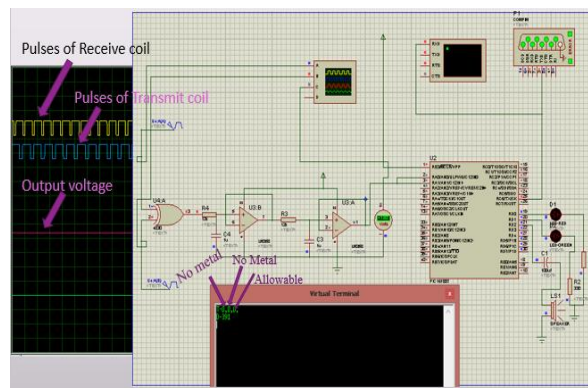| Types of metal | Defined voltage ranges |
|---|---|
| No Metal | 1.90<Vref<1.95 |
| Ferrous Metal | V<Vref |
| Non-Ferrous Metal | V>Vref |
| Disallowable for Non-Ferrous Metal | 2.10<V<2.15 |



***Figure3.*** *Simulation result when searching the metal target*
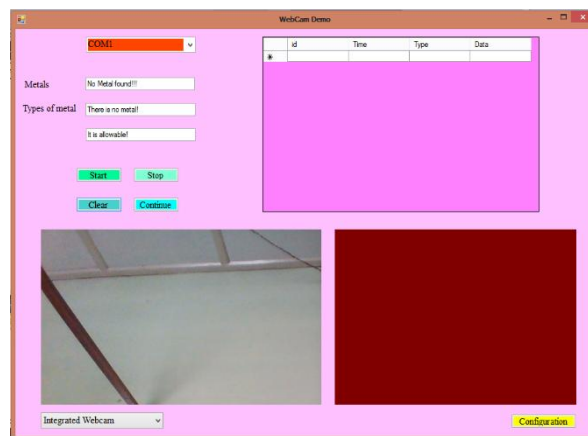


***Figure 4.*** *C# GUI result when searching the metal target*

Figure.3 and Figure.4 show the simulation result and C# GUI result when there is no metal. When no metal detecting, there is no increasing voltage or decreasing voltage but still the reference voltage. So, the PIC microcontroller is informed on

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personal computer (PC) that there is no metal. Figure.5 and Figure. 6 show the simulation result and C# GUI result when non-ferrous metal is detected. In this case, pulse width of the pulse generator as the receive coil sensor is greater than the pulse width of the pulse generator as the transmit coil sensor. So, the phase difference between these two signals is phase lead. And then, the increasing voltage is inputted to the PIC microcontroller. PIC microcontroller determines that it is non-ferrous metal and informs this message on personal computer (PC). At the same time, buzzer is activated and the green LED is ON.
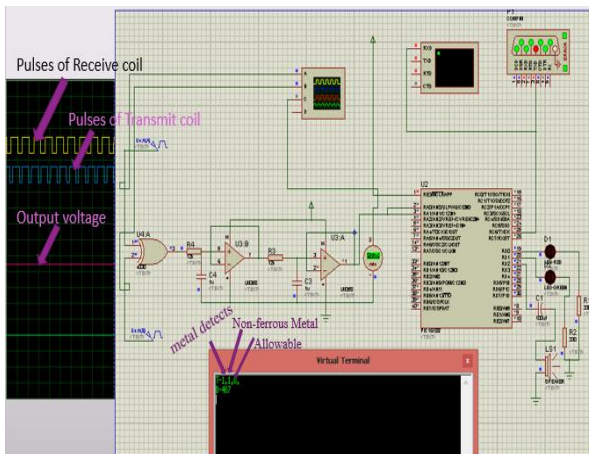


**Figure5.** *Simulation result when the detected metal is non-ferrous metal*
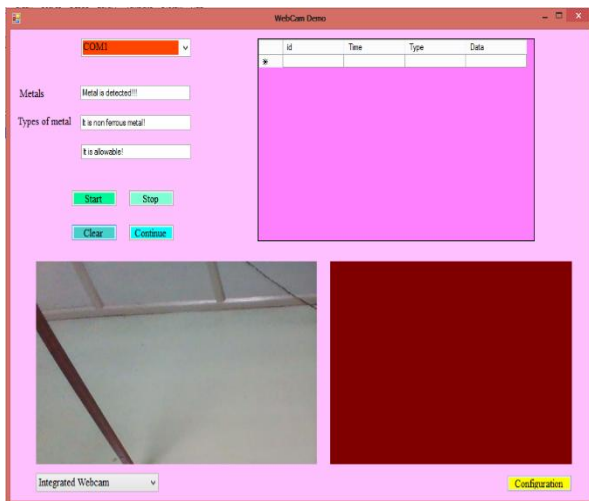


**Figure 6.** *C# GUI result when the detected metal is non-ferrous metal*

Figure.7 and Figure.8 show the simulation result and C# GUI result when ferrous metal is detected. In this case, pulse width of the pulse generator as the receive coil sensor is less than the pulse width of the pulse generator as the transmit coil sensor. So, the phase difference between these two signals is phase lag. And then, the decreasing voltage is inputted to the PIC microcontroller. PIC microcontroller determines that it is ferrous metal and informs this message on the personal computer (PC). At the same time, buzzer is activated and the red led is ON.
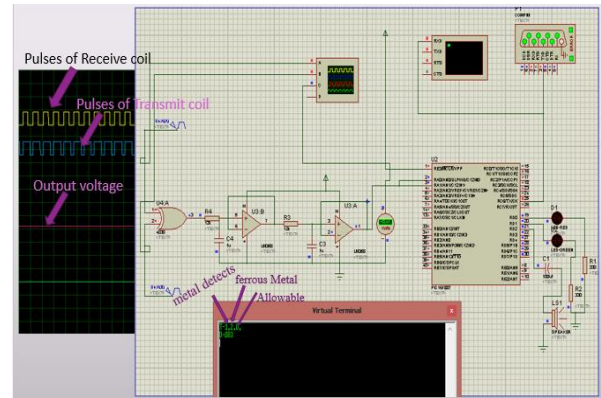


**Figure7.** *Simulation result when the detected metal is ferrous metal*
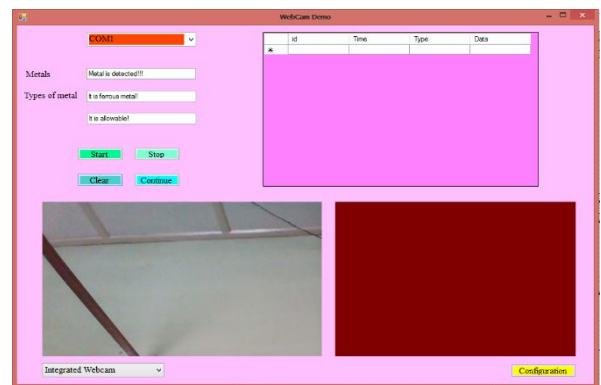


**Figure 8.** *C# GUI result when the detected metal is ferrous metal*

Figure.9 and Figure.10 show the simulation result and C# GUI result when disallowable non-ferrous metal is detected. In this case, pulse width of the pulse generator as the receive coil sensor is greater than the pulse width of the pulse generator as the transmit coil sensor. So, the phase difference between these two signals is phase lead. And then, the increasing voltage is inputted to the PIC microcontroller. PIC microcontroller determines that it is non-ferrous metal and this non-ferrous metal is disallowable metal according to the defined voltage ranges and then informs this message on personal computer (PC) and captures the object by using webcam. At the same time, buzzer is activated and the green LED is ON.
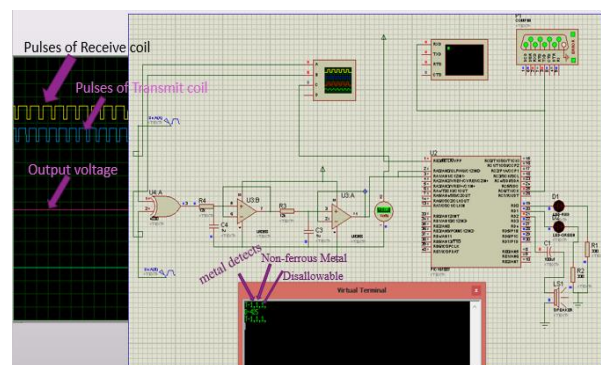


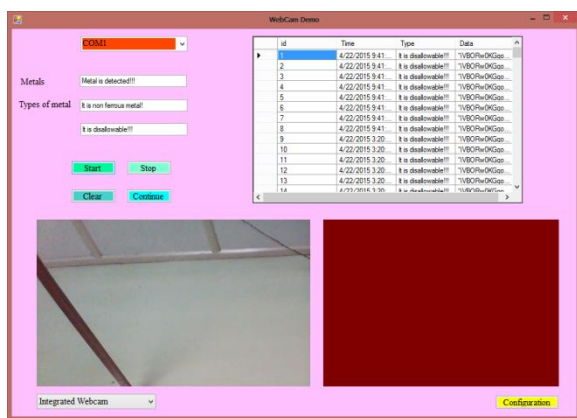**Figure 9.** *Simulation result when the detected metal is disallowable non-ferrous metal*

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**Figure 10.** *C# GUI result when the detected metal is disallowable non-ferrous metal*

## IV. HARDWARE CONFIGURATION

### A. Oscillator Circuit Design
4.86 kHz frequency range is designed to operate the transmitter circuit. For low frequency, oscillator based R-C circuit can be used. In this system, Wien Bridge Oscillator, one of R-C oscillator circuit is used. The dual power supply for this circuit is designed as ±9V. Figure. 11(a) and Figure. 11(b) show Wien Bridge Oscillator circuit.



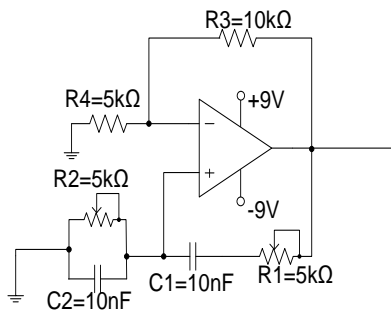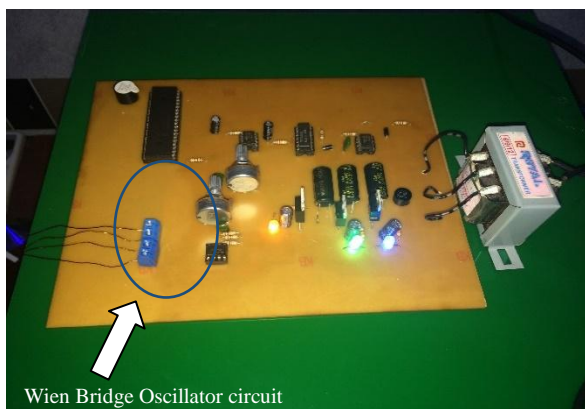**Figure11(a).** *Wien Bridge Oscillator circuit diagram*



**Figure11(b).** *Wien Bridge Oscillator circuit*

### B. PIC microcontroller
PORTC pin 25 is connected to the personal computer (PC) via RS232 PIC to PC serial cable cord on which is informed that the target metal is detected and the detected metal is ferrous

or non-ferrous. PORTD pin 5 is connected to buzzer and PORTD pins 19 and 20 are connected to LEDs. PORTA pin 1 is connected to the phase detection circuit which is inputted the voltage level as the signal from the induction coil sensor. Pin 11 and pin 32 are power supply pins and the supply voltage is +5V. The ground pins are 12 and 31. Figure.12 shows PIC16F887 microcontroller pins assign.
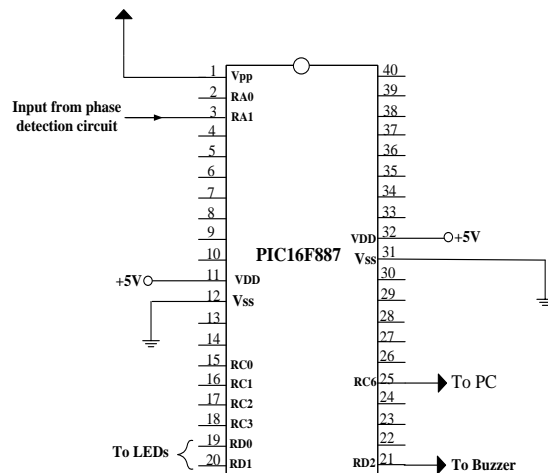


**Figure12.** *PIC16F887 microcontroller pins assign*

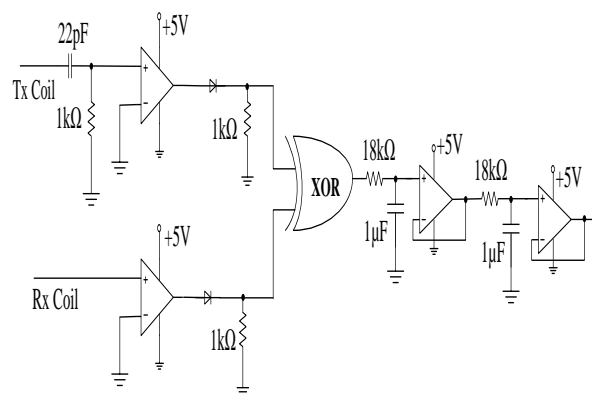### C. Phase Detection Circuit Design



**Figure13(a).** *Phase detection circuit diagram*
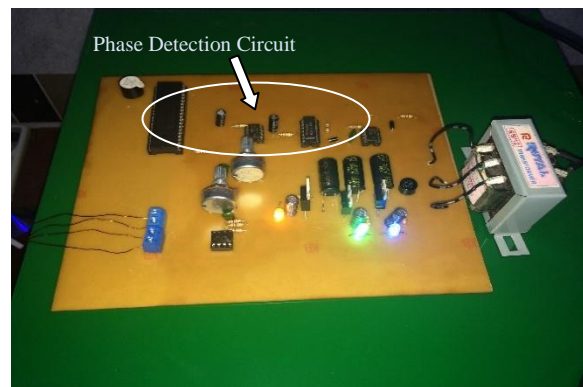


**Figure13(b).** *Phase detection circuit*

Figure. 13(a) and Figure. 13(b) show Phase Detection Circuit Diagram and Phase Detection Circuit respectively. A phase

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detector generates a voltage proportional to the difference in phase between two signals. In this circuit design, phase detection circuit is designed by the Exclusive OR: HEF4030. 0° and 180° are the two extreme values of an XOR gate based phase detector. If the phase difference of the input signals decreases, the average voltage of the output signal also decreases. If the phase difference of the input signals increases, the average voltage of the output signal also increases. On the other hand, the width of the positive pulse of the output signal changes proportionally to the phase difference of the input signal. So, the average output voltage is directly proportional to the phase difference of the input signal if the phase difference is between 0° and 180°. Then, to get the average voltage without noise, the output voltage is passed through the active low pass filter. The formula for the output voltage is

$$V_{out} = (V_{dd}/180) * \Delta\Phi$$

Where,

$V_{out}$= Average output voltage
$V_{dd}$ = Supply voltage of the XOR gate
$\Delta\Phi$ = Phase difference in degrees ( ° )

## D. Induction Coil Sensor Design

In this system, concentric coil design is used to sense the metal target. It has transmit coil, receive coil and feedback coil. Transmit coil and receive coil are wound in the same direction but the bucking coil is in the reverse direction of these two coils and wound over the receive coil to cancel the external noise of the transmit coil. An AWG 28 is used for the transmit coil and feedback coil. An AWG 30 is used for the receive coil. Figure.14 shows the induction coil sensor. To calculate the coil inductance, the following equation is used in this system.

$$L = \frac{0.8(R^2 \times N^2)}{6R + 9l + 10D}(\mu H)$$

Where,

R= radius (in inches)
N= turns
L= length (in inches)
D= Depth (in inches)



**Figure14.** *Induction coil sensor*

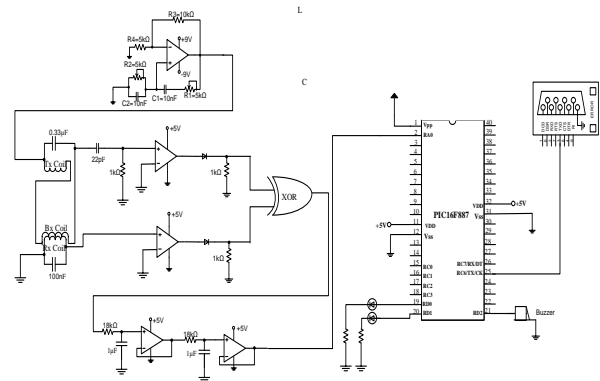## E. Circuit Description



**Figure15.** *Overall circuit diagram of the system*

Figure.15 shows the overall circuit diagram of the metal discriminating system by using PIC 16F887 microcontroller. In this system, there are three parts: the input, the processing and the output. It is composed of power supply, sensing circuit, phase detecting circuit, microcontroller, personal computer (PC), light emitting diode (LED) and buzzer. PIC 16F887 microcontroller is used to control the overall system. The sensing value from the sensing circuit is inputted to the phase detection circuit. The sensing value is the frequency coming from the metal. The frequency changes are depended on the various types of metals. And then, the frequency changes is inputted to the phase detection circuit. Depending on the output voltage from the phase detection circuit, the microcontroller determines whether the detected metal is ferrous metal or non-ferrous metal and it is displayed on the personal computer (PC). In this system, buzzer is used to alarm that the metal is detected. In the case of LEDs, two LEDs: green and red are used to notify that the metal is ferrous or non-ferrous. If the discriminated metal is prohibited metal, the webcam will capture this type of metal.
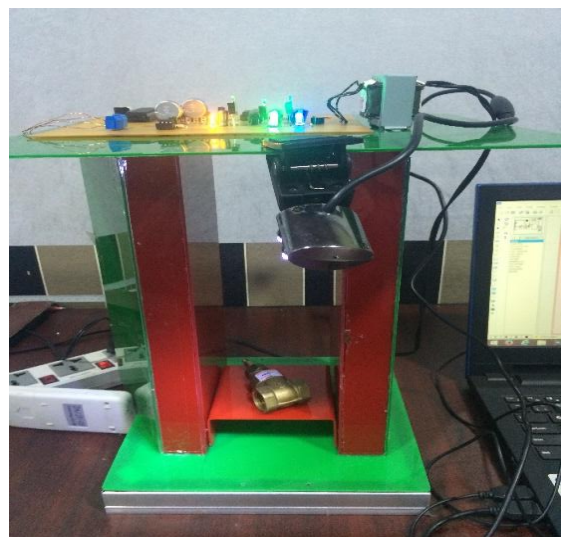
## F. Hardware Results



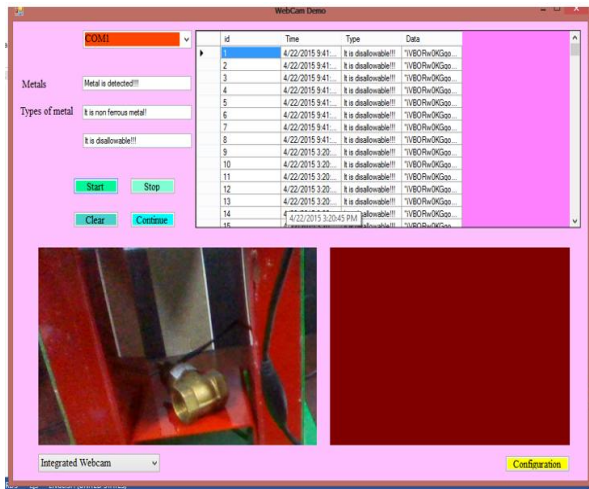**Figure 16(a).** *System model for walkthrough metal detector*

**Figure 16(b).**C# GUI of personal computer (PC) for the walkthrough metal detector
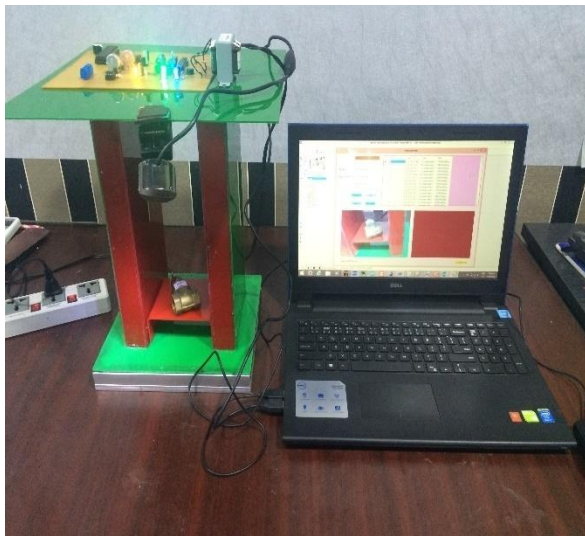


**Figure 16(c).** System model for walkthrough metal detector with personal computer (PC)

Figure.16 (a), Figure.16 (b) and Figure. 16(c) show thesystem model for the walkthrough metal detector with personal computer. In this system, various types of metal such as iron, copper, aluminum, gold and platinum can be sensed by the induction coil sensing circuit. And the maximum distance that the coil sensor can sense is about 8cm to 9cm. The buzzer is activated whenever the metal is detected. When the ferrous metal is detected, the red LED is ON. In the case of non-ferrous metal, the green LED is ON. And this message is also displayed on the personal computer (PC). Moreover, if the detected metal is disallowable metal, the webcam will capture this object. By this way, the security personal can get the photo records from this type of metal detector.

## V. CONCLUSIONS
In this paper, this system is implemented by the VLF technology. And the induction sensor is designed by the concentric design. It is mainly used in airports, shopping mall, plaza and governmental buildings. It offers an effective way to improve the security of citizens and government. And metal detector using metal-type discriminating system can find the prohibited metal easier than other metal detectors. This system also supports the security personnel to find the dangerous metals more easily.

## ACKNOWLEDGEMENT

### REFERENCES
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[2]  http://www. The basic theory of metal detector.com

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[4]  http://homepage.ntlworld.com/moonshadow New_Folder/metal_detectors.htm

[5]  http:// Geotech- Projects/Coils coils and coils.htm

[6]  http://en.m.wikipedia.org/wiki/Phase_detector

[7]  http://www.ebinger.org/metal