Simulation and Implementation of a Wireless Metal Detector with Variety of Flexible Responses- A Solution to Extensive Security Threats

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Abstract
We proposed a design of a wireless metal detector in this research article. A system is designed which offers a variety of electrical equipments necessary for a privatized metal sensor. The main objective of this research is to provide a mature solution to the recent security threads all over the world by designing a localized wireless metal detection system. Different analysis has been shown graphically in this article. In addition, the system is kept flexible to respond to a security threat e.g. in case of a metal detection. The case study chosen for this article is Pakistan, a country facing extensive threats in the age of globalization.

Keywords*: electrical equipments, extensive security threats, metal detection, wireless metal detector*

1. Introduction

Security is considered to be the key parameter in economical and psychological growth of a country. Pakistan is passing through the most difficult period of its existence when security is becoming the national issue leaving the country isolated from the rest of the world. Insecurity is increasing that much that the people do not feel secure in streets or even in homes [1].

Economic instability is a linked variable to the security of a country. An economically secure country can persue without being threatened from outside. Self sufficiency, per capita income and gross national product is required for security and Pakistan being a developing state is at a disadvantage and hence collapsing security [1]. All Pakistani governments have failed to attain socio-economic quality [2]. For the sake of political and economical stability, security and peace are two prime factors. Corruption and poor governance always have had threats to the internal security of the state. Least security is expanding terrorism and even nuclear attacks which have raised concerns regarding Pakistan atomic program.

There are many horizontal and vertical cleavages in Pakistan which divide people on the basis of religion, cast, creed and status. Many religious groups are conflicting each other on different issues. These cleavages are not only downsizing the Pakistani economy but also causing socio-political instability and hence insecurity [3].

Intolerance, extremism, militancy and terrorism have produced challenges and internal threats to the physical and human security in Pakistan. Corruption and societal crimes are an addition to it. Due to these factors, Pakistan has suffered huge risks and costs in national economy and personal security issues [4]. Only in 2010, there were 1986 terrorists' attacks causing 478 security forces personals and 1,361 civilians lost their lives [4].

2. Methodology

In this paper, the design of a Wireless Metal detector system is introduced based on wireless terminology, which is used to design and evaluate the technical and financial aspects for military and public Surveillance systems. Surveillance Technology is used to scrutinize and sometimes record the action of others either openly or covertly. Various technologies are used in this way and range from the more obvious closed-circuit television cameras (CCTV), tape recorders, and listening devices to devices designed to record computer key strokes and to access remotely the computers of others [5]. In the flow chart Diagram 1st transmitter

Microcontroller transmit the Instruction according to the automatic system of instructions and then information is transmitted to the receiver microcontroller, wirelessly connected to the transmitter Tx which uses Xbee-PRO software. Later, the information goes to the weapon detector circuit which ensures that in case of metal detection, an acknowledgement is sent back to the system for further necessary actions described in experimental work section of this research article. Anyhow, if metal is not detected, then process continues itself uninterrupted. The flow chart completely describing this action strategy is designed and shown in figure 1.
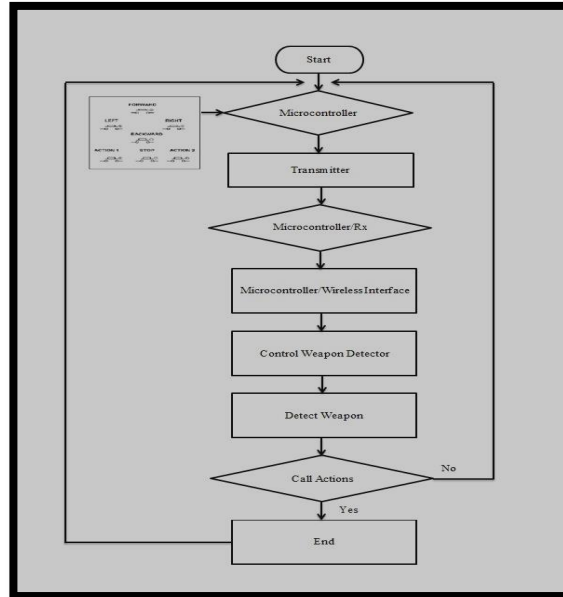

Figure 1. Flowchart

3. Experimental Work

This design is consisted of some sub circuits e.g. Microcontroller interface, weapon detector, transmitter, receiver, flexibilities and actions. The flow chart is designed in the way that if a condition is fulfilled, the flow continues or signal is driven back to the system.

Construction of Detecting Coil:

The idea of detecting coil construction was taken from [9]. The inductor forming the oscillation circuit in the metal detector is realized by wounding a 26SWG wire around an 22cm air core 14 times.

Capacitor, C=10nf
Number of turns, N=14
Diameter of the coil, D=22cm
Radius of the coil, r=D/2=11cm
Length of the coil, l=7.4cm=0.074m
The cross-sectional area of the coil, which is circular, is given by,

$$A=\pi r^2 \tag{1}$$

$$A=\pi \times 11^2 = 380.13 cm^2 = 0.038013 m^2 \tag{2}$$

In accordance with electromagnetic theory, the inductance of an inductor is given by

$$L=N^2 \mu A/l \tag{3}$$

Where μ is the permeability of the coil $\mu=4\pi \times 10^{-7}$

$L=\dfrac{14^2 \times 4\pi \times 10^{-7} \times 0.038013}{0.074}=1.265\times 10^{-4}$

$\omega = \dfrac{1}{\sqrt{LC}}$; But $\omega = 2\pi f$

$f = \dfrac{1}{(2\pi\sqrt{LC})}$ (4)

$C_{eq}=C^2/2C$

$C_{eq}=10^2/2 \times 10 \text{ nF} = 5\text{nF}$

The frequency of oscillation is approximately 200 KHz.

Transmitter:

In the transmitter section, not only we can control the rotation of the metal detector motor but also we can initiate modification 1 and modification 2 if necessary. When metal will be detected, a buzzer indication will be received at transmitter side. Figure 2 shows the implemented transmitter circuit for this research article. PIC16F877A was used as a transmitter.
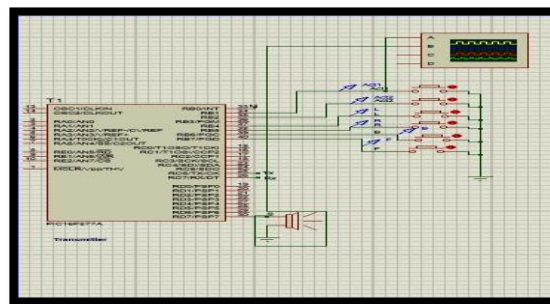

Figure 2. Transmitter

Receiver:

When motor rotation instructions from the transmitter side are launched to the receiver, the receiver acts accordingly and motor is rotated in all directions, looking for a suspect containing metal. The designed circuit for the receiver is shown in figure 3.
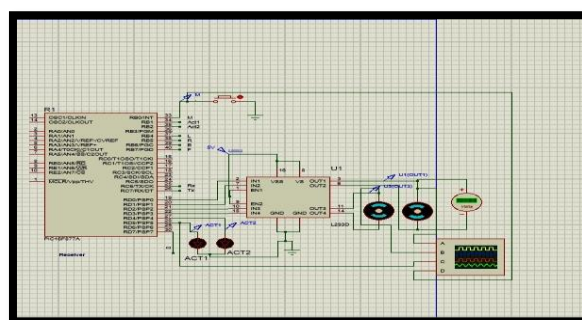

Figure 3. Receiver

In this waveform when motor start according to the transmitter Instructions. A motor is used to control the rotation of the metal detector assembly accordingly to the user instruction. Figure 4 shows the rotation of the motor.
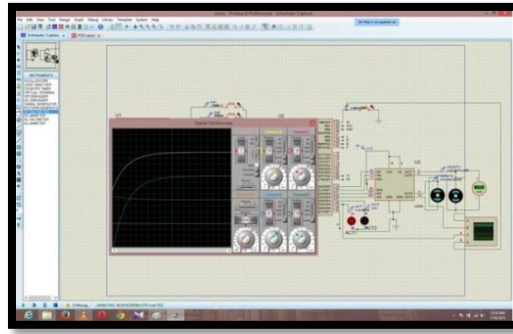
Figure 4. Motor start

Weapon detector:

Electromagnetic induction is the well known phenomenon used to detect the metals. Keeping in view the extensive security threats, world is facing today; metal detectors are widely used in facilities like airports, halls, universities and important buildings. Industrially, metal detectors are also used widely to detect steel reinforcement bars in concrete etc [7]. A metal detector circuit is implemented in Protius 8.0 and is shown in Figure 5.
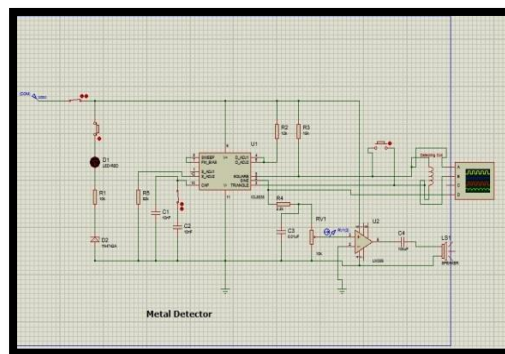

Figure 5. Metal detector

Metal detector circuit shown in Figure 5 was implemented in Proteus 8.0 and results were recorded in reset condition. In this research article, reset state demonstrates that the system has just started working and no metal or weapon is detected yet. The results grabbed out of this metal detector circuit at reset state are shown in Figure 6.
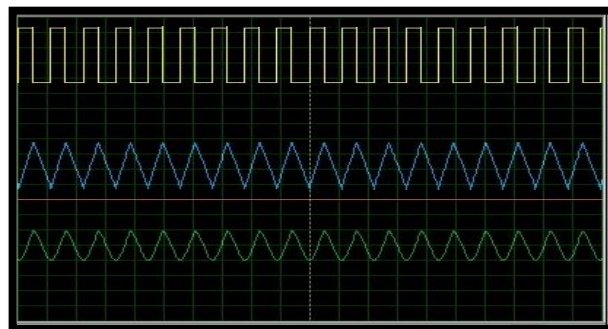

Figure 6. Metal detector reset condition

In this result, the Yellow Square wave and Blue Triangular wave are attached to the detecting coil and the Green Sine wave is affiliated with the output i.e. a buzzer being fed by an amplifier. In case if metal is not detected, the amplifier remains off and buzzer is not alarmed.

Modifications/actions:
When metal is detected and a buzzer is ignited, transmitter is informed to perform several modifications/ actions. In this research article, two modifications are introduced and are demonstrated as follows:

Modification 1:
In this research paper, modification 1 is affiliated with the surveillances, as if metal contained person is keeping to go in secret facilities i.e. red zones etc., then the transmitter will be asked to record the activities of the suspect through a camera. The motion of camera is shown below in pink waveform, which will be treated as a first warning to the suspect.
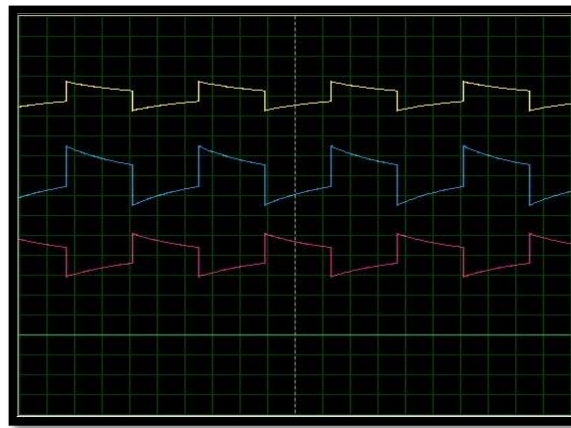

Figure 7. Action 1

Yellow and blue waveforms are affiliated with the motor motion and are also connected to the camera motion. Transmitter basically takes the instruction from metal detector and is responsible of initiating the modification 1 as well as modification 2.

Modification 2:
The modification 2 is affiliated with the modification1 as if the person keep entering the important facilities even after modification 1 then modification 2 can be initiated through the transmitter and this modification will be used to neutralize the weapon contained person. In the figure 8, green waveform shows an AC waveform which could be operated to start a neutralizer. Anyhow, modification 2 will be considered as a second warning. Modification 1 is switched off once modification 2 is initiated and it is shown in Figure 8 which shows the pink waveform of Figure 7 switched off.
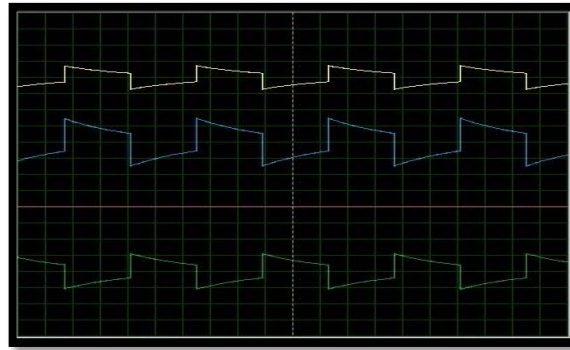
Figure 8. Action 2

The yellow and the blue waveform shows the motor motion and the green waveform used for neutralizing the weapon contained person.

4. Results and Analysis

Different parameters are taken into account when it is required to analyze such system design. In this research, different key parameters including Analogue analysis between searching coil and buzzer amplifier, Dc Transfer Curve Analysis, Digital analysis, Transient Analysis, Conformance Analysis, Dc Sweep Analysis, Interactive Analysis etc. are enclosed.

4.1. If Metal is not Detected

Yellow Square wave and Blue Triangular wave attach to the detecting coil and the Green Sine wave connected to the buzzer through an amplifier. When no metal\weapon is detected then amplifier circuit remains switched off and no buzzer is activated. The results are shown in figure 9 if metal is not detected.
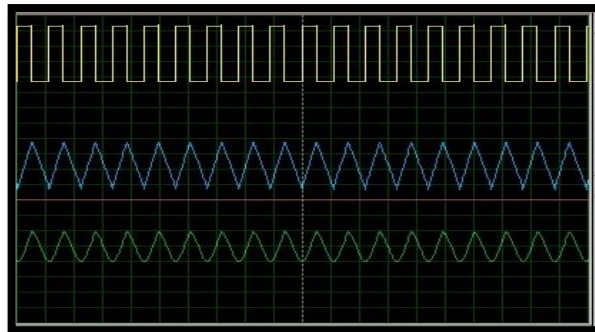

Figure 9. Metal not detected

Yellow and blue waveform affiliated to the searching coil of Metal detector and the green waveform is affiliated to the amplifier section of the buzzer its represent the normal condition of the metal detector.

4.2. If Metal is Detected

When metal is detected then an interrupted signal is generated. Motor is provoked to stop rotating and the results are compiled and shown in figure 10. As it is stated that motor rotation is forced to stop in case of a metal detection, so the Figure 11 shows the motor rotation.
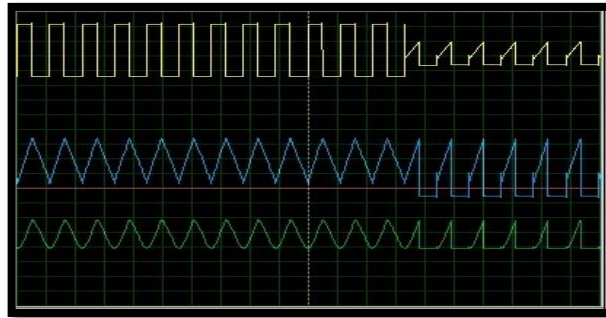
Figure 10. Metal detected

When metal is detected the motor stops the rotation and Green wave is the Metal detected wave to represent that a metal is detected in Figure 11.
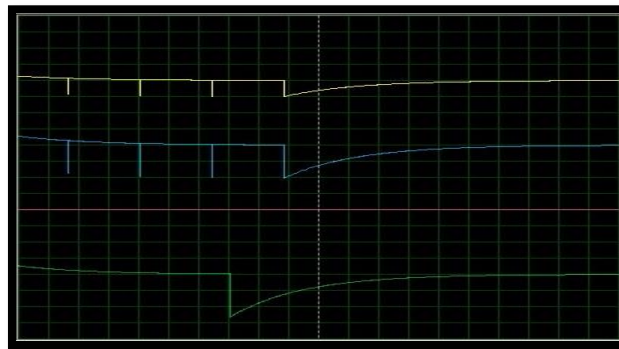

Figure 11. Metal detector motor stops

When metal was detected receiver section, which is working as transceiver; sends the instructions to the transmitter section to ignite the buzzer indication which shows that metal is detected and a suspect is found. Figure 12 shows the buzzer indication exactly when motor stops its rotation.

Figure 12. Buzzer ignition

Analogue analysis:
For a transient analysis we need an Analogue type graph power. Here A,B Are the coil terminal and (D) is the amplifier Buzzer terminal. Figure 13 shows the analogue analysis.
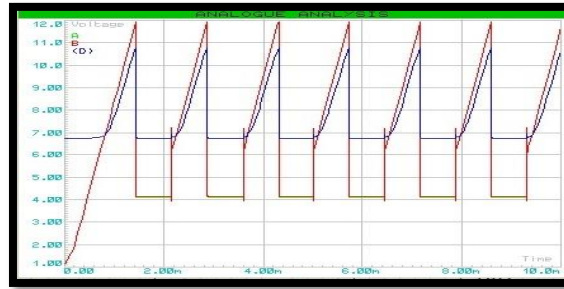
Figure 13. Analogue analysis

Dc Transfer Curve Analysis:
      The DC transfer curve analysis for the designed system is shown in Figure14.

Figure 14. DC transfer curve analysis

Transient Analysis:
      The transient analysis portion of Spice computes the transient output variables A, B and (D) as a function of time over a user- specified time interval. The transient analysis of this system is shown in Figure 15.
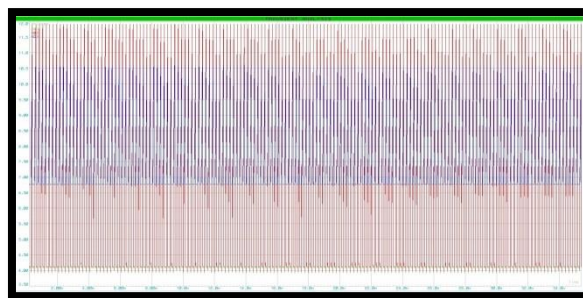

Figure 15. Transient analysis

- **Main Circuit Simulation result:**
      In the results we use U1 (out1), U3 (out3), is the Motor output Terminal. M is used for the metal detecting purposes and ACT 1, 2 is the actions as well as modification push Button.

- **Conformance Analysis:**

A conformance analysis compares one set of digital simulation results against another. The conformance analysis of the system was recorded and shown in Figure 16.
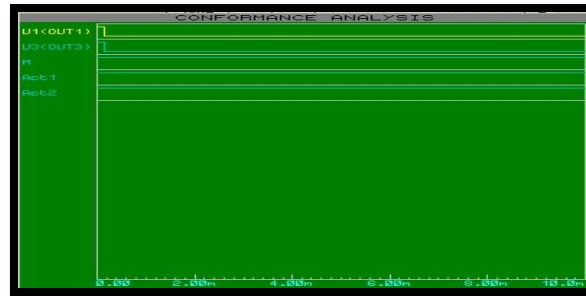

Figure 16. Conformance analysis

Dc Sweep Analysis:

A DC Sweep graph displays a series of operating point values against the swept variable. The DC sweep analysis is shown in Figure 17.

Figure 17. DC sweep analysis

Digital Analysis:

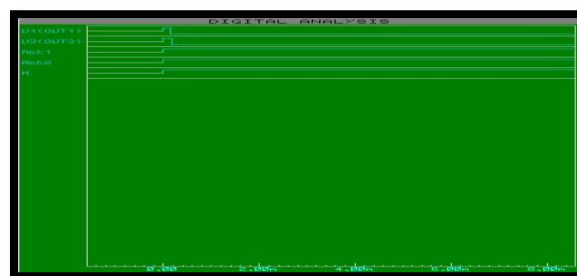The most advanced form of transient analysis is DC analysis which is shown in Figure 18.

Figure 18. Digital analysis

Action 1,2 and metal detector is always on high state.U1(out1),U3(out3) in low state its change its state corresponding to the transmitter instruction right, left, backward, forward in all direction and also actions
.

5. Conclusions

Metal detectors have been used in past but with limited operational usage for the reason that technical issues were too much concerned. Now days, metal detectors are essential for the facilities like parking areas, shopping malls, airports and train stations. In this research article, we proposed and implemented a metal detector design using available resources and found the design accurate and up to the requirements. This design is implemented wirelessly. We do not need to touch metal detector with the body of a suspect but just wirelessly transmitting electromagnetic waves. As far as ranges are concerned, the range of metal detector is seven feet. The range of Xbee- PRO in non urban areas is up to 1 km while 300 feet in urban areas.

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