A Microcontroller based Door Metal Detector with dual Power Supply, Alarm and LCD display

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Abstract

The design and construction of a micro-controller based metal detector for security and control is presented in this paper. Presently, metal detecting systems are becoming increasingly important for securing lives and properties. This metal detector can be attached to the door or main entrance of an organization, company, office, bank etc where it is desired. For this paper, the metal detector is built in a way that a metal sensor (colpitt oscillator) senses any electrically conducive metal or metallic object brought close to it. The sensor sends the signal to the Peripheral Interface Controller which processes the signal and turns on the driver (a dc motor) connected to the door off or on whereby the door opens or remains closed. Also present is an alarm and a Liquid Crystal Display (LCD) indicating the status of operation of the system. The power supply unit is dual in the sense that the circuit can be powered by electricity or battery and the battery charges when the circuit works with electricity.

Key words: microcontroller, metal detector, Liquid crystal display, alarm

1. Introduction

Metal detectors are used in the food [1], pharmaceutical [2], beverage, textile, garment, plastics, chemicals and packaging industries. Contamination of food by metal shards from broken processing machinery during the manufacturing process is a major safety issue in the food industry. Metal detectors for this purpose are widely used and integrated into the production line [3].

Current practice at garment or apparel industry plants is to apply metal detecting after the garments are completely sewn and before garments are packed to check whether there is any metal contamination (needle, broken needle, etc) in the garments. This needs to be done for safety reasons [4,5].

In civil engineering special metal detectors '*cover meters*' are used to locate rebar. Rebar detectors are less sophisticated, and can only locate metallic objects below the surface. Metal detectors are applicable both in the civilian and military for security purposes. Metal detectors are also used for security purposes in civilian and military applications [6].

The simplest form of a metal detector consists of an oscillator producing an alternating current that passes through a coil producing an alternating magnetic field. If a piece of electrically conductive metal is close to the coil, eddy currents will be induced in the metal, and this produces an alternating magnetic field of its own, if another coil is used to measure the magnetic field (acting as a magnetometer) the change in the magnetic field due to the metallic object can be detected [3,6].

Due to the high level of insecurity in our society, organizations, banks and especially in places where there is high attraction and inflow and out of different kinds of people, the lives and properties of citizens is threaten by other citizens who are well armed with metallic weapons and explosives. The unarmed citizens lives in fear of being attacked or victimize. Except a device that will detect these weapons and explosives carried around by these traitors is produced, our society will continue to live in fear and insecurity.

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2. Methodology

The design of the door metal detector involves two main stages: the hardware and the software.

2.1 The design of the hardware

The hardware consists of the following units namely: the power supply unit, sensing unit, the triggering unit, display unit and the alarming unit.

2.1.1 The power supply unit

The power supply unit is dual in the sense that the circuit can be powered by electricity or battery for places having epileptic electricity supply. The charging unit of the battery is incorporated into the power supply unit to allow the metal detector work even if there is no electricity supply and charge the battery when there is electricity supply. Other units/main components of the system are described below:

2.1.2 Sensory/Oscillator design

The inductance to be used is calculated using

L= $\frac{2.8R^2N}{R+1.11S}$ (1)

Where L is inductance in μH, S is the depth of turn, R represents the radius of coil, while N is the number of turns. For the purpose of this project, the sensor (coil) is desired to be reasonably small. So, radius R and length S is chosen to be 0.04 and 0.004 respectively.

Therefore using the above equation to derive the value of

L when S=0.004m; R=0.04m; N=16 is

$$L = \frac{2.8 \times 0.04^2 \times 16}{0.04 + 1.11 \times 0.004}$$

L = 1.613μH

The frequency of the oscillating discharge current depends on two factors;

- Capacitance of the capacitor to be used
- Self inductance of the coil to be used

To realize the oscillation of 9.34MHz, the oscillatory tank in Figure 1 was considered.

The choice of 10nF and 2.2nF was considered in such a way that their equivalent capacitance when combine with the inductor using equation 1 gives the frequency of oscillation to be 9.34MHz as calculated below.

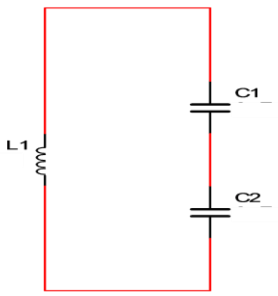

Fig. 1: Oscillatory tank

$C_{eq} = C_1C_2/(C_1 + C_2)C_1 = 10nF$; C_2= 2.2nF

C_{eq} = 1.8nF

Since the oscillator to be used is a Colpitt oscillator,

F = $1/2\pi\sqrt{LC}$ (2)

F= $\frac{1}{2\pi\sqrt{(1.613\times10^{-6}\times1.8\times10^{-9})}}$

F= 9.34× 10^6

F= 9.34MHz

To stabilize the oscillation generated by the oscillatory tank, a C945 transistor was considered.

The slope of a transistor amplifier as we all know is given by;

$$-\frac{1}{R_e} = change\ in\ I_c axis/(change\ in\ V_{ce} axis)$$

$-\frac{1}{R_e}$=$\frac{I_c}{V_{ce}}$

$R_e = V_{ce}/\ I_c$ (3)

I_c (collector continuous current) is at 0.15A for a C945 transistor [7].

Choosing R_e = 10kΩ =R_3

For $\beta = 130$ for C945 transistor,

I_b= I_c/β (4)

I_b=$\frac{0.15}{130}$

$I_b = 1.15mA$

For the voltage across the base of the transistor Q_1:

Resistors that will act as voltage divider will be connected to the base of Q_1 i.e two resistor such that the voltage drop at R_2 is half V_{cc}

$V_{R_2} = \frac{R_2}{R_1+R_2} \times V_{cc}$ (5)

For $V_{cc} = 12v$, $V_{R_2} = 6v$

$\frac{R_2}{R_1+R_2} = 0.5$, let $R_1 = R_2$

$R_1/2R_1 = 0.5$, lets choose R_1=10k, then R_2 =10k

Capacitor C_3 was chosen to serve as ac by pass to R_3 while C_4 is meant to filter or block dc signals, C_3 =4.7nF, C_4= 10nF

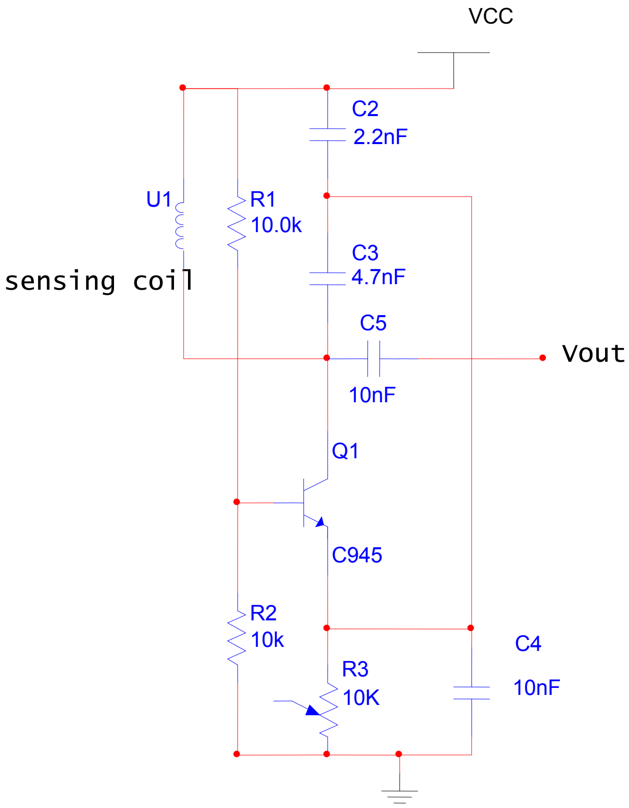

Fig. 2: Sensory unit (colpitt oscillator)

2.1.3 Triggering unit

A shaping circuit that is capable of converting sinusoidal wave to rectangular wave is desired, and to adequately give a low or high output, CD4093 was the choice. CD4093 is a quad 2 input Nand gate Schmitt trigger, but only two Nand gate were required; first for converting the sinusoidal waveform to square and the second for converting the square waveform to either a low or high output.

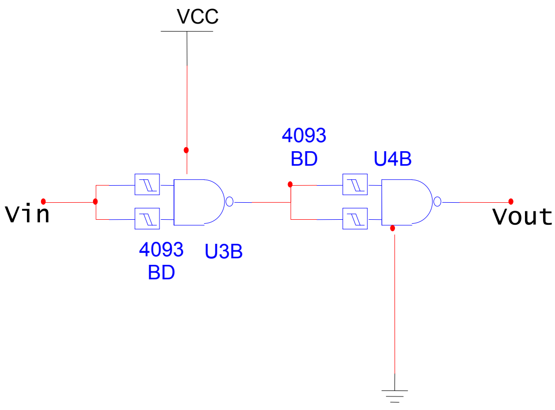

Fig. 3: Triggering unit

2.1.4 Alarming unit

Since the output of the triggering unit is either high or low, a transistor switch arrangement is required to properly power the buzzer.

The high of the CD4093 is equivalent to the V_{cc}. The buzzer is off at high which means that transistor Q_2 is saturated and transistor Q_3 is cut off. At low, Q_2 is cut off and Q_3 is at saturation with $V_{out} = V_{ce(sat)} = 0.2v$.

A buzzer that will produce an alarm is needed when the voltage drop across it is $V_{cc} - V_{ce(sat)}$.

The operation of a transistor in saturation is determined by the value of I_b.

From Figure 4:

$$V_{in} - I_b R_b - V_{be} = 0 \qquad (6)$$

To determine the minimum value of R_b to be used from equation 6,

$R_b = R_5 = (V_{in} - V_{be})/I_{Bmax}$

$I_b = 1.15mA$, for $V_{cc} = 12v$, $V_{be} = 0.7v$ and $V_{in} = V_{cc}$, then

R_b = 9826.1Ω

A resistor of 10k is a good choice for R_b since 10kΩ > 9826.1Ω

Therefore, $R_5 = 10k\Omega$

R_6 is used to limit the current entering the collector of Q_2.

R_6 = 6.8kΩ

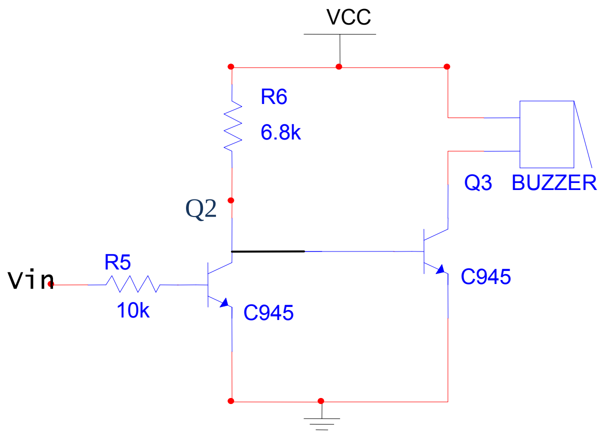

Fig. 4: Alarming Unit

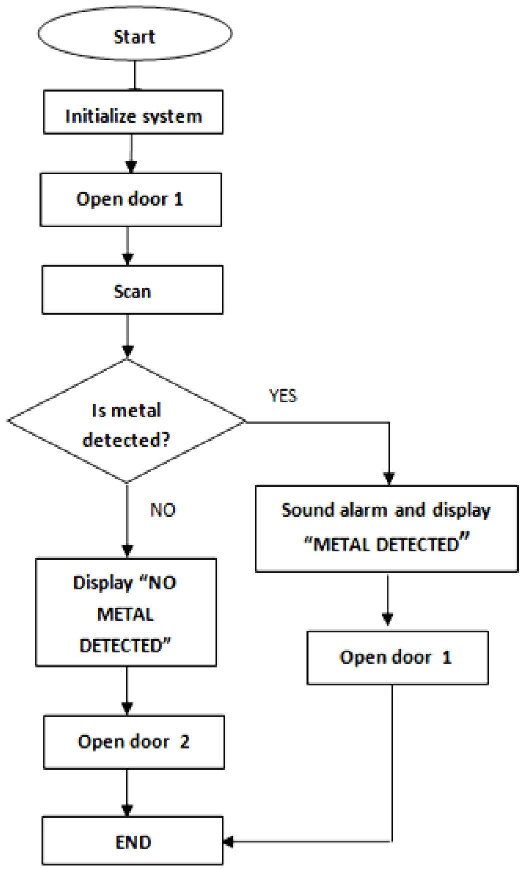

Fig. 5: Flow chart of Microcontroller based metal detector

3. Implementation

Each section/unit making up the system to implement the microcontroller based metal detector using PIC16F877A as the counter were coupled together: the hardware of each section of the circuit were implemented separately and later combined to make a complete system that would be able to accomplish the desired result.

3.1 Power supply implementation

This unit was the first unit implemented after getting to know the minimum and the maximum voltage, current and power rating of the various sections of the circuit. After which it was first connected on the bread board, to check if it meets the working ability required and finally transferred to a permanent board and soldered.

3.2 Sensory unit

A colpitt oscillator (LC oscillator) was used as the sensor. The coil of the sensor is 8cm (0.08m) in diameter and having 16 turns. After which it was constructed on the bread board and finally soldered on a permanent board.

3.3 Microcontroller unit

This unit was implemented based on the design requirements for the metal detector and the program was written to suit this after which it was burned into the microcontroller chip. The microcontroller controlled the display unit and the opening/closing of the drivers connected to door 1 and door 2. The functionality of this device was first simulated after which it was transferred to a permanent board.

3.4 Display unit

The data-lines of the Liquid Crystal Display were connected to port C of the microcontroller while the control lines were connected to RB0, RB1 and RB2 of the microcontroller. A variable resistor of 10k ohms was also connected to the LCD for controlling the back-light of the LCD.

4. Results

Table 1: Results obtained when tested with metallic objects

Target Metal (Weapon)	Range detected (cm)
Steel	5.0-6.0
Knife	4.0
Handset	3.5
Key	2.0

Table 2: Results obtained when tested with non metallic objects

Target (Non metals)	Response
Book	No alarm
Plastic	No alarm
Wood	No alarm
Ceramic plate	No alarm
Leather bag	No alarm

The Liquid Crystal Display (LCD) which is also controlled by the Peripheral Interface Controller (PIC) indicated 'METAL DETECTED' if an electrically conducive metal was present and entrance to door 2 was denied as the PIC did not activate the driver of door 2. The display also indicated 'NO METAL DETECTED' if an electrically conducive metal was absent and thereby the driver to door 2 was activated and the door opened allowing access into the building.

OR

Fig. 6: The displays showed by the LCD

Fig. 7(a): Top view of designed system

Fig. 7(b): Front view of designed system

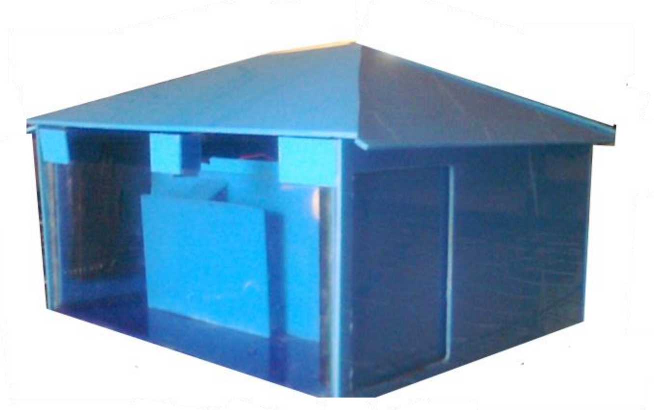

Fig. 7(c): Side view of designed system

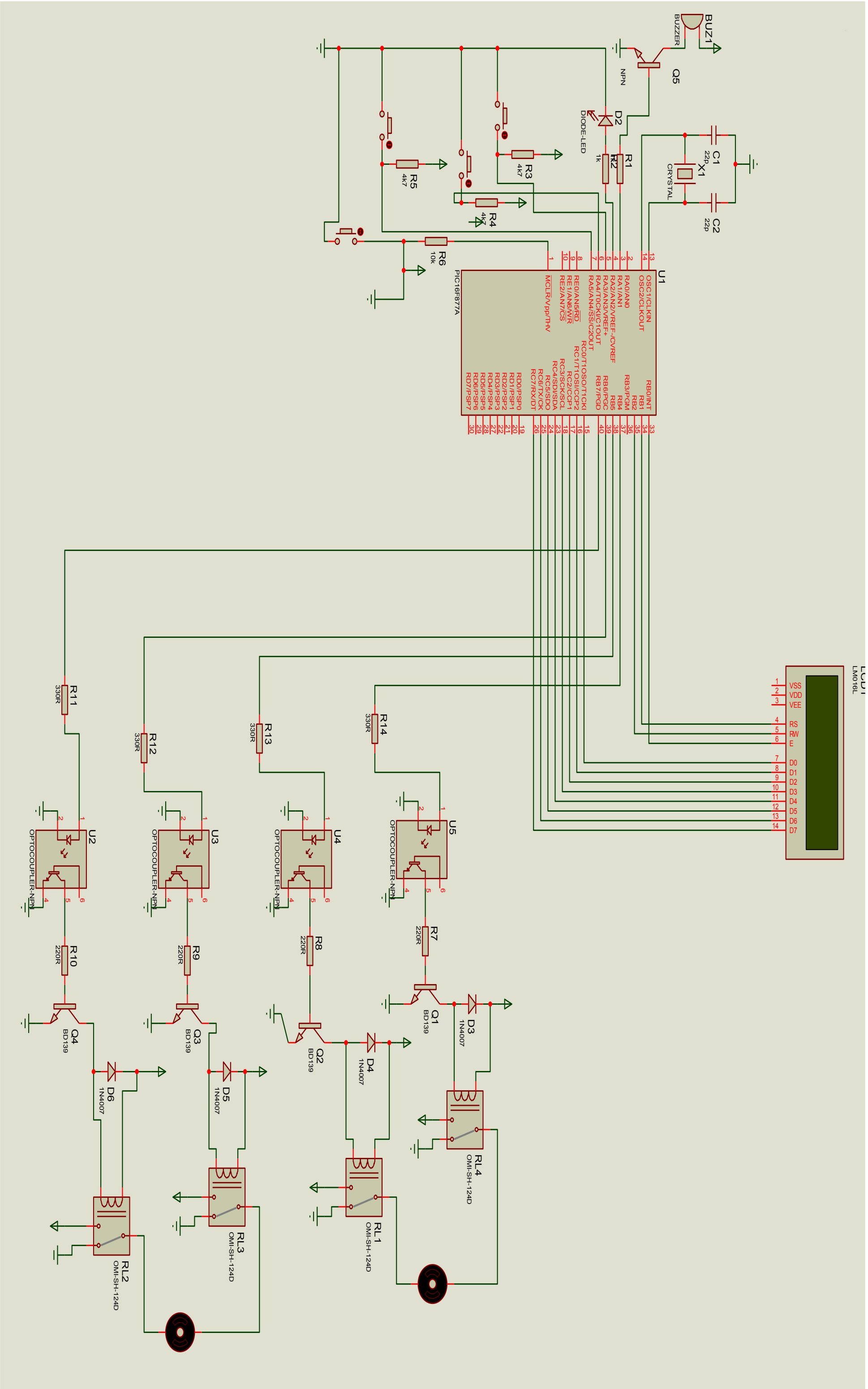

Fig. 8: Circuit diagram of system

5. Conclusion

The design of a device that could detect an electrically conducive metal with the following features was designed and implemented.

- A dual power supply (using both battery and ac mains with battery charging unit incorporated in the power supply unit) in case of power failure.
- Display (LCD indicating "METAL DETECTED'' if there metal or "NO METAL DETECTED'' if no metal is detected)
- Doors (two doors to control the inflow of people in and out, and which will remain closed if a metal (electrically conducive/ferro-magnetic) is detected or otherwise will open if not)
- Alarm (sounds if a metal is detected)

This paper has therefore demonstrated how a metal detector could be designed with some special features as enumerated above. Consequently calculations and assumptions were made for the various choices of components and the circuit designs. Precautions were also taken and tests were conducted under a conducive environment. However, the performance of the individual units that made up the system showed great success. Thus, the objectives of the project was achieved.

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Biography

E.T. Fabiyi has a B.Eng in Electrical and Electronics Engineering from the Federal University of Technology, Bauchi (ATBU), Nigeria and a Masters degree in Microelectronics and Communication Engineering from the Northumbria University Newcastle, England. Her field of specialization includes Microelectronics and wireless communication.

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