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Microcontroller-Based Metal Detection System with GSM Technology

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Abstract: *In this paper, a Metal Detection System with GSM technology has been presented. The system senses or detects a metallic object and sends an alert message in form of an SMS text to an embedded security GSM number for further actions. The design methodology employed in this work, consist of the following stages: Power Supply Unit , Metal Detectors, Modem for SMS and Call (cell phone), Graphical Liquid Crystal Display (GLCD), Microcontroller and the Multiplexer unit for selecting detector ports. The design specification was strictly followed with series of experimental tests. The results obtained were quite satisfactory. If design is fully implemented in restricted areas like Banks, Airports etc, it would help to detect unwanted dangerous metallic objects like guns or sharp objects carried by suspicious persons; and thereby contributing greatly to the reduction of crime rate.*
Key Words: *Microcontroller-based, Metal Detection System, GSM Technology.*

I. Introduction

Security of lives and property has always been a major concern for a very long time. In the olden days, voodoo practices were very common in protection while in later times, traps made of sharp and harmful objects came into use. In recent times, technology has introduced more sophisticated methods of preventing loss of lives and property such as electronic security systems (alarms). Surveillance is defined as a close watch, especially one kept over a prisoner (Lorimer et al 1995). The emphasis in the above definition is in the clause ‘a close watch.’ At this point, it is important to note that close watch can be kept on virtually everybody and not just prisoners. Several techniques can be employed in executing this close watch and these are embedded in the surveillance technology.

Surveillance Technology is used to scrutinize and sometimes record the actions of others either overtly (openly) or covertly (secretly). It is not the actual technology but its use that brings a technology into this category. Hence sociologists have suggested the term “surveillance-capable technology”.

Consider a situation where an intruder enters an environment with a harmful metal hidden somewhere. A security personnel stationed at the entrance may not find the metal even after searching, due to a number of reasons such as incomplete search. This may eventually lead to loss of property, and even lives because the entire environment will be taken unawares.

With a metal detector, the metal will be automatically detected and an alarm will be raised, but in this case, through a GSM cell phone (Grosvenor, 1998).

There is a power supply unit that supplies power to the metal detectors, microcontroller and the GLCD. A serial data cable interface will be created to establish communication between the microcontroller and the cell phone. The GLCD acts as a means of communication between the user and the metal detection system. A multiplexer under the control of the microcontroller is present and it selects the right metal detector port to be connected to the counter resource of the microcontroller. The microcontroller coordinates all activities in the system. The metal detectors are responsible for recognising the presence of metals. The AT commands compatible modem (cell phone) is used to call or send SMS to a stored phone number when a metal has been detected.

Metal detectors use electromagnetic induction to detect metal. They are used in de-mining (the detection of land mines), the detection of weapons such as knives and guns, especially at airports, geophysical prospecting, archaeology and treasure hunting.

In its simplest form, 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.

II. History

The modern development of the metal detector began in the 1930s. Gerhard Fisher had developed a system of radio direction-finding, which was to be used for accurate navigation. The system worked extremely well, but Fisher noticed that there were anomalies in areas where the terrain contained ore-bearing rocks. He reasoned that if a radio beam could be distorted by metal, then it should be possible to design a machine which would detect metal using a search coil resonating at a radio frequency. In 1937 he applied for, and was granted, the first patent for a metal detector. However, it was one Lieutenant Josef Stanislaw Kosacki, a Polish officer attached to a unit stationed in St Andrews, Fife, Scotland during the early years of World War II, that refined the design into a practical detector. They were heavy, ran on vacuum tubes, and needed separate battery packs (Wikipedia, 2008).

A microcontroller is a single chip that contains the processor (the CPU), non-volatile memory for the program (ROM or flash), volatile memory for input and output (RAM), a clock and an I/O control unit. It is also called a "computer on a chip".

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III. Design

Hardware Design

The hardware consists of Metal Detectors, Modem for SMS and Call (cell phone), Graphical Liquid Crystal Display (GLCD), Microcontroller, Multiplexer for selecting detector ports, Switching devices, Power Supply Unit (fig 1).

The metal detectors are based on the concept of change of inductance of an inductor which is caused by mutual inductance with a neighbouring metal or ferromagnetic material. The diagram is shown in fig 2.

The modem is a device that interfaces our metal detection system to a remote using the existing telecommunication (e.g. GSM) infrastructure. This modem could be any type compatible with the Hayes AT commands standard.

The GLCD is based on EPSON's S1D15G14 colour LCD driver. A cheaply available source of this LCD is the Nokia 3510i screen. This chip has the ability to realize a stable 12bit colour with onboard LCD driving voltage generation capability. The LCD can be connected to a microcontroller directly via a serial or parallel interface. The package we are using uses the serial interface mode. The controller is capable of driving 104 by 82 pixels at 12bits. A single dot of pixel on the screen corresponds to 4 bits on the DDRAM. The block diagram is shown in fig 3.

This microcontroller is an intelligent manager that coordinates all activities. This includes reading metal detector, communicating with the modem and a user interface via the menu style buttons. The selection of the microcontroller was simply based availability. The ideal processor should be able to handle required throughput of the GLCD, being the most demanding in terms of processing time. This is because of the sheer amount of data to be clocked in every refresh cycle. The block diagram is shown in fig 4.

The multiplexer under the control of microcontroller selects the right metal detector port to be connected to the counter resource of the controller. The multiplexer was "realized" from gates combined together. The realization was done using three NAND gates, three NOT gates and an OR gate. The schematic is shown in fig 5.

Switching devices are devices used for making or breaking circuits. They are of different types namely; toggle switch, rotary switch and push button switch. In this project, we used push button switches.

Four push button switches were used and they serve the following purposes:

Menu Button: When this switch is pressed, the menu is displayed on the GLCD. The menus are; call level (call threshold value), SMS level (SMS threshold value), clear errors, number location SIM.

Zero Button: When this button is pressed, the metal detector coils are zeroed. This is measuring the stable frequency without any metal change. When there is a change in metal level, there is also a change in frequency.

Up and Down Buttons: These buttons are used for scrolling between the menus.

This project requires three voltage levels namely 12V to power the detector, 3.3Vvolts for the GLCD and 5V for the digital logic and the microcontroller. The integrity and quality of the power supply to a great deal determine the stability of components like the microcontroller and a steady image from the GLCD. The voltages are generated from standard three-terminal fixed and variable voltage regulators. The step down transformer takes in an unregulated 220V AC from the wall mains and steps it down to a more manageable 18V. This is in turn rectified by a regular bridge rectifier and filtered with a 1000uf 25V aluminum oxide electrolytic capacitor. The 12V is generated from a 7812 fixed regulator. 5V is generated from 7805 and the 3.3V from the LM317. The circuit diagram is shown in fig 6 (Tocci, 2004; Theraja, 2005)

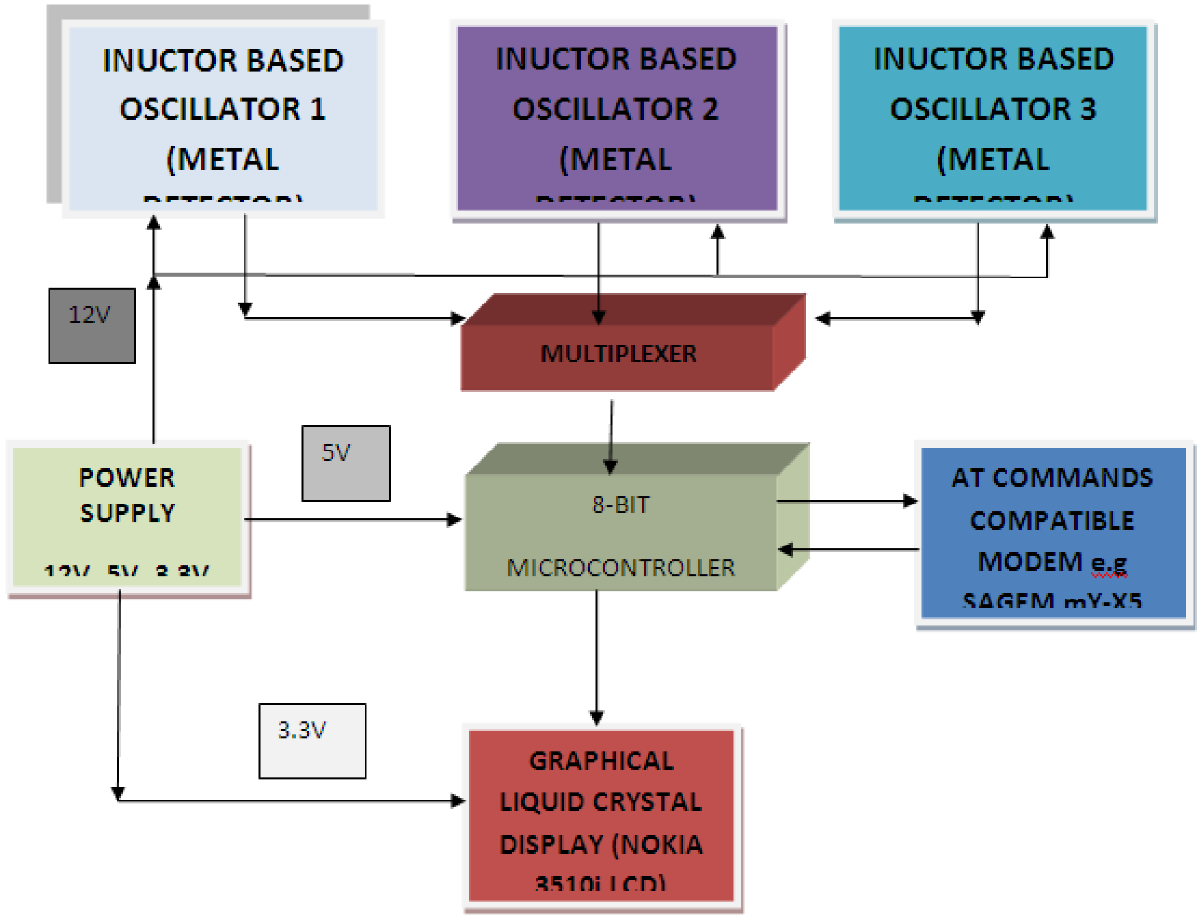

Fig 1: Block Diagram of the Hardware

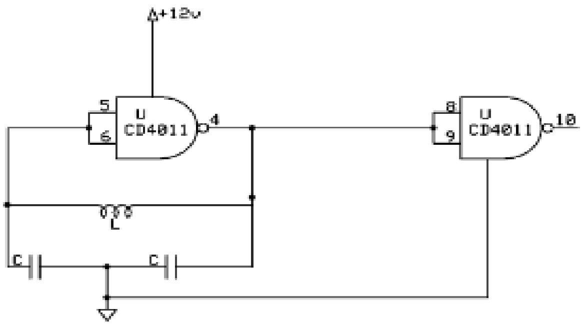

Fig 2: Metal Detector Schematic

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,

$A = \pi r^2$, A = $\pi \times 11^2 = 380.13cm^2 = 0.038013m^2$

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

L= $N^2 \mu A/_l$. Where µ is the permeability of the coil

$\mu = 4\pi \times 10^{-7}$, L= $\frac{14^2 \times 4\pi \times 10^{-7} \times 0.038013}{0.074} = 1.265 \times 10^{-4}$, $\omega = 1/(\sqrt{LC})$; but $\omega = 2\pi f$ (Alexander, 2000).

$f = 1/(2\pi\sqrt{LC})$, $C_{eq} = C^2/_{2C}$, $C_{eq} = 10^2/_{2} \times 10\, nF = 5nF$

$Therefore\ f = \frac{1}{2\pi \times \sqrt{(5 \times 10^{-9} \times 1.265 \times 10^{-4})}} = 200119.71Hz \approx 200kHz$

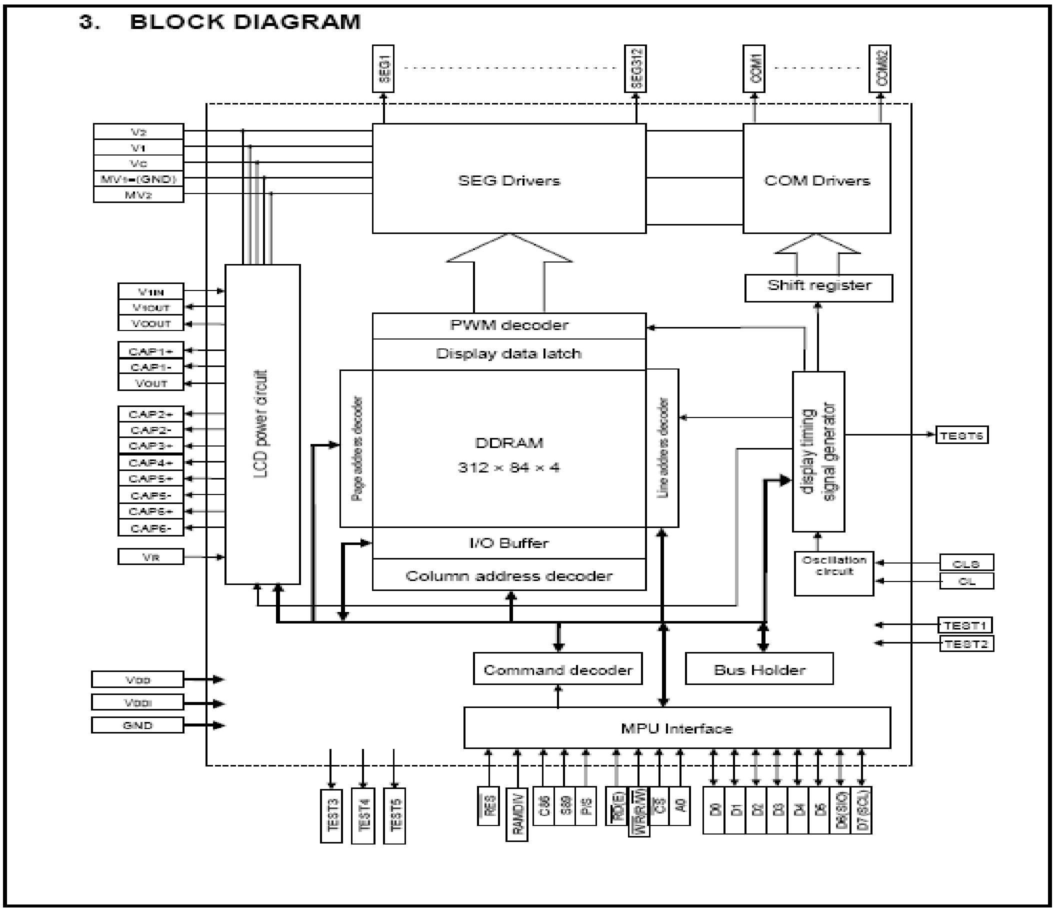

Fig 3: Block Diagram of GLCD

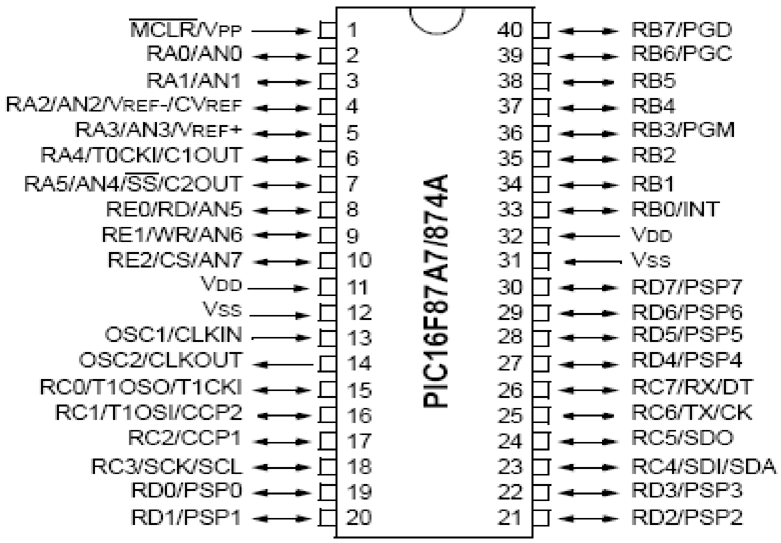

Fig 4: Pin Diagram of the Microcontroller

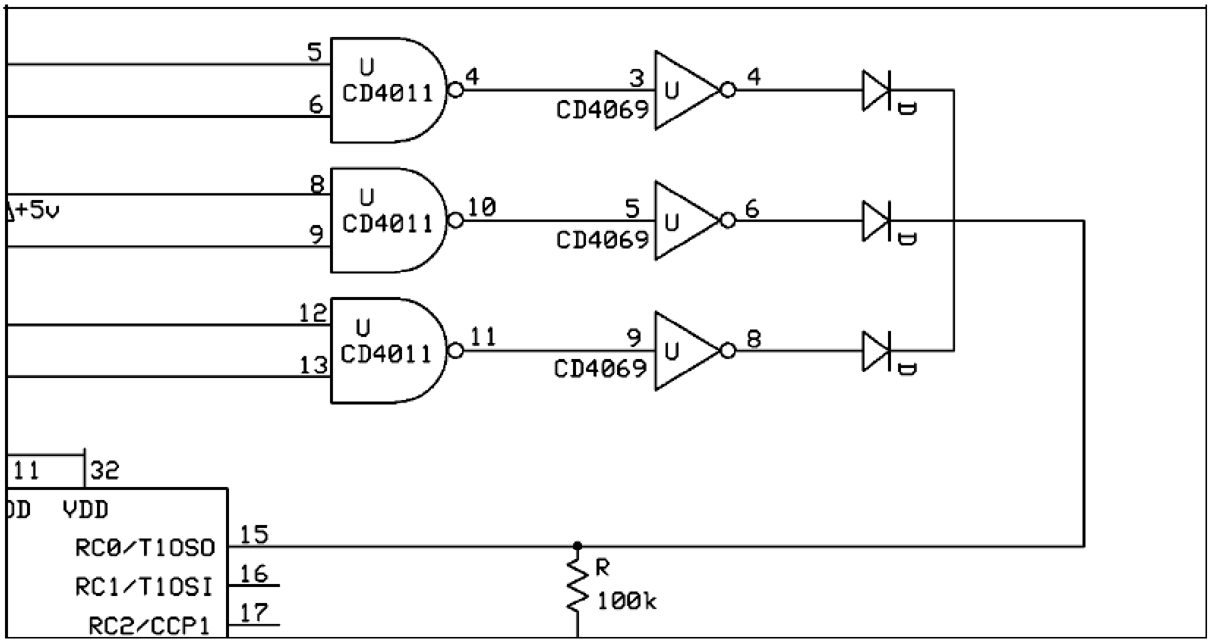

Fig 5: Diagram of Multiplexer with Three Channels

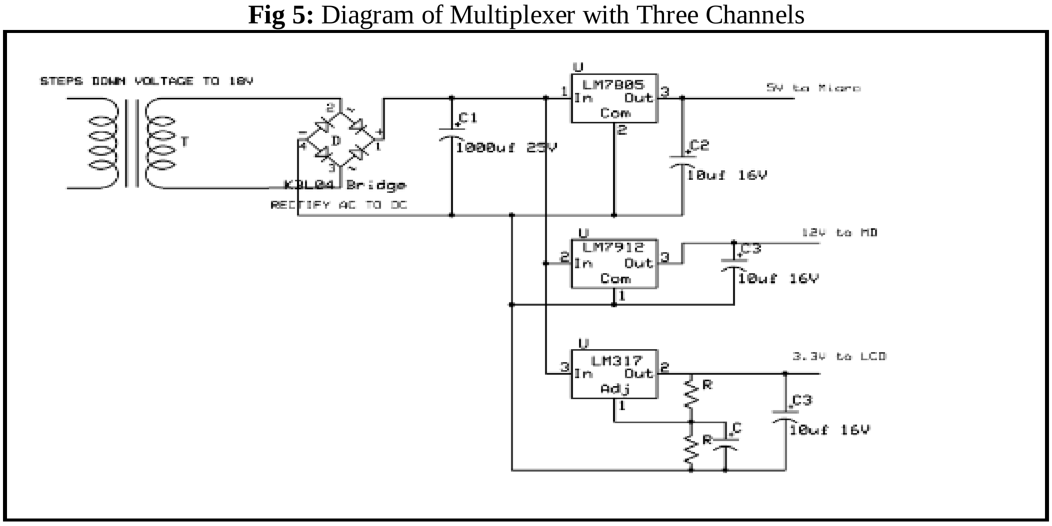

Fig 6: Circuit Diagram of the Power Supply Unit

The DC power supply produces a steady and regulated flow of voltage to all components of the system except the GSM phone. Fig. 7 shows a block diagram of the component parts and stages of the power supply system.

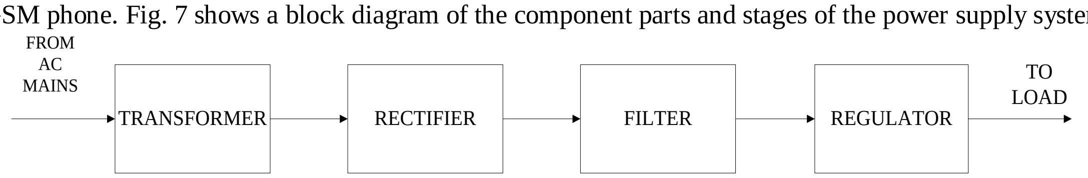

Fig 7: Block Diagram of Power Supply Unit

Transformer: The transformer is an electrical device that transforms energy from one circuit to another by magnetic coupling with no moving parts. A transformer comprises two or more coupled windings or single tapped winding and in most cases, a magnetic core to concentrate magnetic flux. Transformers are used to convert between high and low voltages, to change impedance, and to provide electrical isolation between circuits.

If a time-varying voltage, V_p is applied to the primary winding of N_p turns, a current will flow in it producing a magneto-motive force (mmf). Just as an electromotive force (emf) drives current around an electric circuit, so mmf drives magnetic flux through a magnetic circuit. The primary mmf produces a varying magnetic flux Φ_p in the core, and with an open circuit secondary winding, induces a back electromotive force in opposite to

V_p. In accordance with Faraday's law of induction, the voltage induced across the primary winding is proportional to the rate of change of flux.

$Vp = Np\frac{\partial \Phi p}{\partial t}$ and $Vs = Ns\frac{\partial \Phi s}{\partial t}$. Where,

V_p and V_s are the voltages across the primary and secondary windings.

N_p and N_s are the number of turns in the primary and secondary windings.

$d\Phi p/dt$ and $d\Phi s/dt$ are the derivatives of the flux with respect to time of the primary and secondary windings.

For the primary and secondary windings to be perfectly coupled, $\Phi p = \Phi s$. Substituting and solving for the voltages shows that,

$\frac{Vp}{Vs} = \frac{Np}{Ns}$ .Where, Vp and Vs are voltages across primary and secondary respectively.

Np and Ns are the number of turns in the primary and secondary respectively.

However, in this project, a 50Hz 220V/18V, step-down transformer is used. Thus, the ratio of the primary windings to the secondary winding is approximately 12:1.

Rectifier: The rectifier is an electrical device comprising one or more semiconductor devices (such as diodes) or vacuum tubes arranged for converting alternating current to direct current. When one diode is used to rectify AC (by blocking the negative or positive portion of the waveform) it is called a rectifier. The difference between the term diode and the term rectifier is merely one of usage. For example the diode retains its name when used in DC to block flow of current. Fig.8 shows a typical sinusoidal measuring.

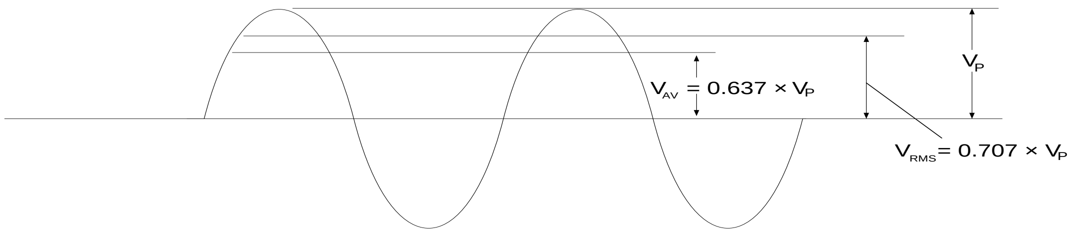

Fig 8: Measuring sinusoidal alternating current

A little algebra can be used to relate root mean square (rms) values to average values:

$$Vav = 0.637 \times Vp \quad (1)$$

$$Vrms = 0.707 \times Vp \quad (2)$$

From 2, $Vp = \frac{Vrms}{0.707}$ (3)

Substituting the RHS of (3) and (1)

$$Vav = 0.637 \times \frac{Vrms}{0.707} = 0.9 \times Vrms$$ (For Full-wave cases)

$$Vac = \frac{0.9}{2} \times Vrms = 0.45 \times Vrms$$ (For Half-wave cases)

In this work, a full-wave rectifier (bridge rectifier) was used.

Filter: A filter is a circuit used to remove AC components from pulsating DC just after rectification. There are several filtering techniques used in electronic power supply circuits. In this work, a capacitive filter was used.

Regulator: Various kinds of regulators are used for voltage regulation in electronic power supply circuits. IC regulator units contain the circuitry for reference source, comparator amplifier, control device and overload protection all in a single IC. IC regulators provide regulation of a fixed positive voltage, fixed negative voltage, or an adjustably set voltage. For this project, a three terminal IC regulator unit providing regulation of a fixed positive voltage is used.

Various models of IC voltage regulators exist by virtue of the regulation provided. So, positive voltage regulators in 7800 series include 7805, 7806, 7808, 7810 and so on. In this project, we used 7805, 7812 and LM317 since 5V, 12V and 3.3V are required to power the metal detectors, microcontroller and GLCD respectively.

Software Design

The software running on the microcontroller was edited compiled and programmed using Mikrobasic V5.03 integrated development environment. It features a basic-like syntax and a large library for commonly used peripherals. The programming style is basically a procedural structure with an element of multitasking used in setting MODEM_DETEC flag (a flag used to signify modem detection). Two user-defined pre-compiled libraries namely ATLIB.PBAS and NOKIA_3510i_LCD.pbas were used to communicate with the Modem and GLCD respectively. The code consist basically of four routines namely (Mikro Elektronika ,2007; Anon, 2008)

1. Initialization
2. Metal Find
3. Modem Communicate
4. User Interface

Each of this procedure handle unique aspects as hinted by their names by calling many other set of functions. The flow chart for the software design is shown in fig 8.

IV. Testing And Results

A scenario was created with a metallic objects brought close to the operational range of the microcontroller-based metallic detector. It was strongly observed that the metallic object was detected by the constructed device and the microcontroller sent a message through a data cable to GSM cell phone representing a stored security number for necessary action . The data cable acts as an interface between the microcontroller and the cell phone, there is also an interface between the microcontroller and a Liquid Crystal Display (LCD). Sending this message to the stored security number was made possible by use of a high level language with the help of a compiler. The programming language used is known as mikrobasic. Test was repeated several times and the results obtained were very satisfactory.

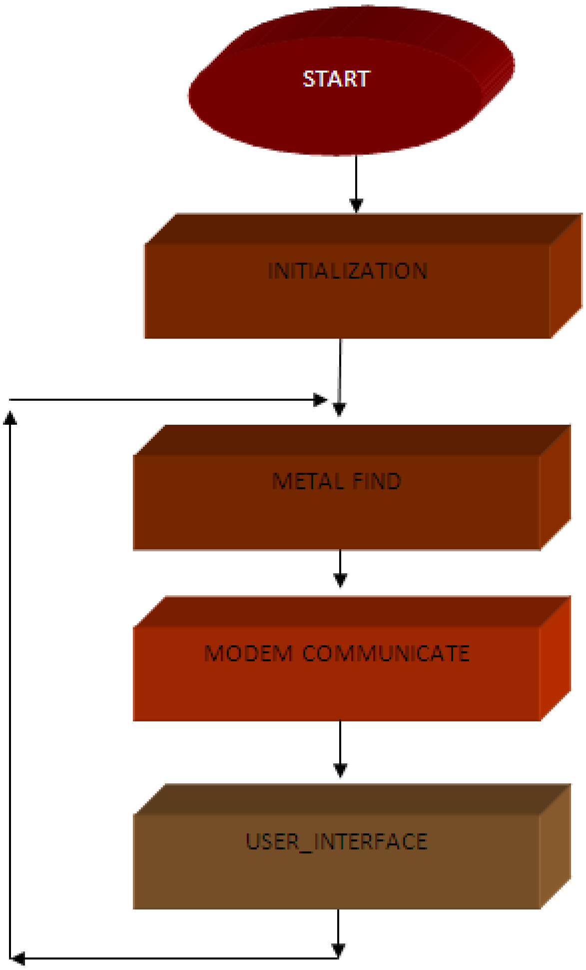

Fig 9: Flow Chart for the Main Software

V. Conclusion

A metal detector controlled by a microcontroller with GSM technology been designed .With minimal cost, a microcontroller based metal detection system with a GSM modem can be constructed with an efficient performance. If the GSM phone must be put into another use beside its initial use (especially in domestic cases), it is recommended that the interface between the microcontroller and GSM phone be wireless .

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