Concept Evaluation For Ferro-Magnetic Detector For Patient Safety

Nitin Jadhav[1], Ulhas Patil [2], Prabhakar Bhadange[3]
[1]Dept of E&TC
[2]HOD, Dept of E&TC
[3]Manager, R&D
[1, 2] Sir Visvesvaraya Memorial Engineering College Nashik, India
[3]Sivananda Electronics Pvt Ltd Nashik, India

Abstract- *The aim of this paper to verify design concept for implementation of Ferro-guard detector for patient safety. The paper revolves around the basic fundamental concept of technique for detecting the presence of ferromagnetic material under the presence of artificial magnetic field (MRI machines). We propose to use the Earths magnetic field for detection of Ferro-magnetic material with the patient. The core intelligence of the system lies in the Passive sensor coils (inductive sensor coils) which would be designed in such a way, that we can pick up the change in earths magnetic field due to presence of Ferro-magnetic material. The system will be installed at the entryways of MRI machines to provide additional level 2 safety for detection ferromagnetic materials for people entering in the scanning Room/Area. This will potentially reduce the number of accidents caused to negligence of the staff /People carrying the ferromagnetic material knowingly or unknowingly .*

Keywords- Ferro-gaurd , Ferromagnetic detectors , Low cost, Logic control unit,Infrared(IR)

I. INTRODUCTION

A ferromagnetic detection system (FMDS) is available for use in the MRI environment. There are various configurations of the FMDS which exists it can come in a portable system, in a pillar, or as a handheld version. The devices are specially designed to detect ferromagnetic objects. In addition, discard other materials such as aluminum, copper, which come under non-ferromagnetic category.

As an example the FMSD will detect a steel gas cylinder and will alarm for its risk for taking inside the MR scanner zone, while will not generate the alarm for non-ferromagnetic material.Hence as the name suggest Ferro-guard , it selectively filters /generates alarms for ferromagnetic materials and keeps silent for non-ferromagnetic materials

The hazard of Missile effect which essentially means , the rate at which the MR magnet bore pull the ferromagnetic objects towards itself is so intense that it replicates a missile. Under such condition, the damages are enormous and by the time, the person handling is virtually unware and has no time to react. The proposed system will drastically bring down the accidents by providing additional checks along with the manual check or declarations happening before the MR scan of the patient.

II. SYSTEM SPECIFICATION

Following are the proposed system level specification:

- Electronic hardware should be able to operate for a typical 230 V AC 50 Hz mains or 12V battery system
- Maximum current consumption /12mA
- Easy to install and maintain

III. MODELLING AND SYSTEM DEVELOPMENT

The essential parts from system implementation point of view are as follows:

- Passive Sensor Coil
- Amplifier stages
- Filter stages
- I-V convertor
- Logic control unit
- Sensitivity selector
- IR- sensors
- Power supply
- Alarm indicator
- Buzzer driver

A. System Block Diagram

“Fig 1” shows the basic block diagram

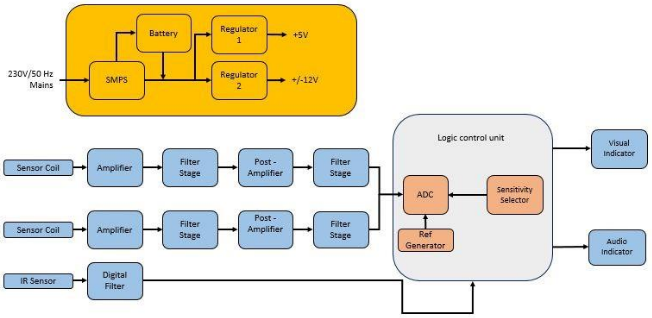

Fig. 1. System Level Block Diagram

B. Passive Sensor Coil

These sensors are coils of wire wound on ferrite cores. Induction coils measure the rate-of-change of magnetic field, not the field itself. Therefore, they intrinsically reject static magnetic fields without the need for a filter. Their sensitivity depends upon the detailed design but they are intrinsically similar to an AMR sensor in both sensitivity and cost. The design approach we would take is to use air-cored induction coils. The design follows the fundamental law of induced voltage as mentioned in Equation 1

$$V_i(t) = NAdB(t)/dt(1)$$

Suppose we measure the Field B is periodic with period T=(1/f), After integration between two zero crossings *t1* and *t2*
Z *t2*

$$V_i(t) = NA \cdot \delta B = NA(B_{max} - B_{min}) \quad (2)$$

*t*1

because B reaches its maximum and minimum values at the time When $V_i(t)$ goes through zero. The arthmetic mean value of the induced voltage will be :

$$V_{mean} = \frac{2}{T}\int_{t1}^{t2} V_i(t)dt = 2fNA(B_{max} - B_{min}) \quad (3)$$

because we know that V_i has no DC component, usually $B_{max} = -B_{min}$ and if the coil is cylindrical and had the mean diameter of d_m, them :

$$V_{mean} = 4fNAB_{max} = fN\pi d_m^2 B_{max} \quad (4)$$

if B is the sine wave, we can write the peak(maximum) value of the incuded voltage

$$VP = 2\pi \cdot fNABmax = Nd2mfBmax\pi 2/2 \quad (5)$$

The coil Dc resistance can be calculated as :

$$R_{DC} = 4\rho Nd_m/d_w2 \quad (6)$$

Where ρ is the coil specific resistivity ,$d_w$is the wire diameter, and $d_m$is the coil mean diameter.

C. Current to Voltage & Amplifier Stage Fig 2 shows the I to V converter The Coil is in current

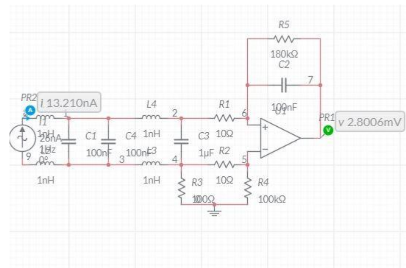

Fig. 2. I to V converter Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

mode and is simulated by including a current source as show in Fig 2 . L1 and L2 are the filter choke. L3 and L4 along with C1 and C2 form the filter circuit. R5 and R1 form the gain factor. The Output is proportional to the product of gain with input current. Fig 3 shows the output waveform of I-V stage.

Fig. 3. Current to Voltage and Amplier Stage I Simulation Circuit Waveform Courtesy SIVANANDA ELECTRONICS Reprinted By
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• The Gain Stage 1 will follow the equation of :

$$V_{Out} = G \cdot I_{in} \qquad where \quad G = \frac{R_f}{R_i} \quad (7)$$

Where $V_{Out}$is the ouput voltage proportional to the product of G and I_{in}

D. Amplifier stage II

As we very well know the gain stage is required to bring the signal in the dynamic range of the ADC of the microcontroller so that the signal can be measured . The fig 4 shows the simulation circuit for second gain stage.

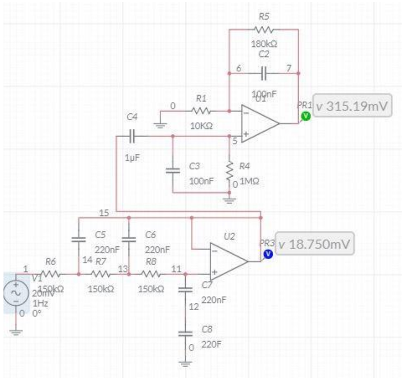

Fig. 4. Second Gain Stage Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

- The Amplifier will follow the equation of :

$$VOut = G \cdot Vin \quad where \quad G = 1 + \frac{R_f}{R_i} \qquad (8)$$

- The capacitor at the non inverting input serves as a Zero DC input .

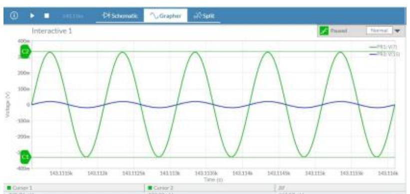

Fig. 5. Gain Stage II Simulation Circuit Waveform Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

E. Filter Stage

The configuration used for the Filter design is a 3^{rd}order Sallen-key Low pass filter. Fig 6 shows Sallen-key Low Pass Filter The values of filtering components are selected such that

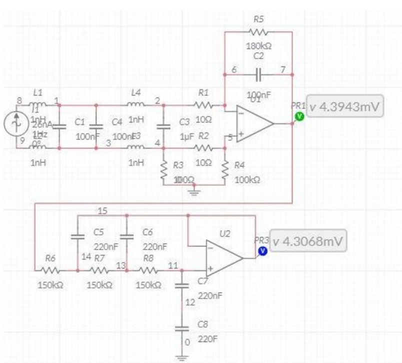

Fig. 6. 3^{rd}order Sallen-key Low Pass Filter Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

we get cut-off frequency at close to 10Hz. The op-amp is used in the unity gain configuration. The filtered signal is feed to the next stage . The next stage is the gain stage.

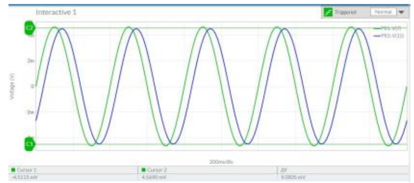

Fig. 7. Filter Stage I Simulation Circuit Waveform 1Hz Input Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

F. Comparator & Digital Filter

The comparator stage essentially compare the input signal from the gain stage II with the reference. The comparators are used in Inverting and Non-inverting configuration as the input is a Sinusoidal waveform. It is a Sine to square waveform converter. Fig show the simulation circuit. The square waveform input is feed to the digital filters. This filter stage is used to filter out any high frequency components. The output of the

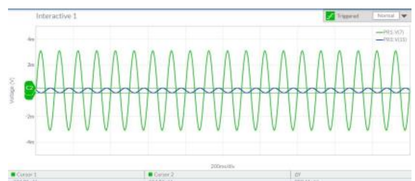

Fig. 8. Filter Stage I Simulation Circuit Waveform 10Hz Input Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

comparator stage will be given to the logic control unit. Based on the S/W implementation and strategy the output of Buzzer (Audio) and Lamp (Visual) indication will be provided.

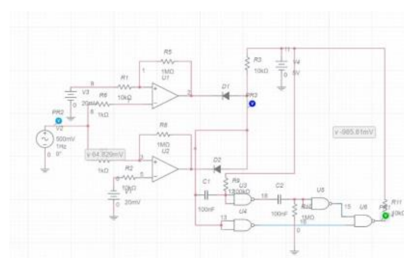

Fig. 9. Comparator Stage And Digital Filter Simulation Circuit Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

Fig. 10. Digital Filter Input(1Khz) Output Waveforms Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

Fig. 11. Digital Filter Input(10Khz) Output Waveforms Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

IV. CONCLUSION

With the proposed design approach, we can see that, detection of Ferro-magnetic material can be achieved using passive

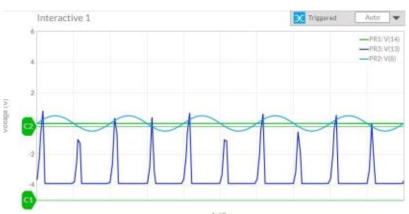

Fig. 12. Digital Filter Input(1Mhz) Output Waveforms Courtesy SIVANANDA ELECTRONICS Reprinted By Permission

Induction coils. Though the earths magnetic field strength is extremely low (varies between 26-40 nT) with proper signal conditioning and filtering circuits rate of change of magnetic field can be captured into measurable current and voltage and feed to Logic control unit for further processing. From the above simulation results we see, the system is practical to be implemented, fine-tuning of components values would be required based on the actual circuit behavior. Further optimizations of the circuit is possible once the Microcontroller (Logic control Unit) is interfaced.

V. ACKNOWLEDGMENT

I owe my deepest gratitude and indebtedness to my highly respected and esteemed guide Prof. U.V.Patil ,Department of Electronics & Telecommunication Engineering, Sir Visvesvaraya Memorial Engineering College,Nasik (Maharashtra) and Mr. PrabhakarBhadange ,Manager R&D Sivananda Electronics Pvt Ltd for being a continuous source of inspiration, guidance, sincere criticism and regular feedback on my advancement each week I was able to learn and improve upon my working strategy and thus, enhance my approach during this piece of work. It was because of thier stimulating suggestions and comments that I could identify the right topic and always keep in the right track.

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