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Hardware Implementation of a Vibrating Sample Magnetometer Circuitry

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ABSTRACT

In this paper we present hardware implementation of electronics circuit associated with the sample vibrator which is the subsystem of vibrating sample magnetometer (VSM). Sample vibrator is an important part of the VSM which is build to fulfill the principle requirements that is pure sinusoidal vibrations of constant frequency and stability of vibration amplitude of the signal. The VSM is suitable for the study of magnetic properties of materials in high magnetic fields. The system is tested using Digital Storage Oscilloscope (DSO).

Keywords- VSM, magnetic properties, magnetic field, DSO.

1. INTRODUCTION

A VSM is used to measure the magnetic behavior of magnetic materials. The Vibrating Sample Magnetometer (VSM) is based upon Faraday's law, according to which an electromotive force (emf) is induced in a conductor by a time-varying magnetic flux. In VSM, a sample magnetized by a homogenous magnetic field is vibrated sinusoidally at small fixed amplitude with respect to stationary pick-up coils. The resulting field change inside the pick-up coils (detection coils), induces voltage and from measurement of this voltage the magnetic properties of sample deduced [1]. A second voltage is induced in a similar set of reference coil by a reference sample which may be a small permanent magnet an electromagnet. Since the sample and reference are driven synchronously by a common member, the phase and amplitude of the resulting voltages are directly related. The known portion of the voltage from reference coil, phased to balance the voltage from detection coil, is then proportional to the magnetic moment of the sample. By this procedure the measurements can be made insensitive to changes of vibration amplitude, vibration frequency, small magnetic field instabilities, magnetic field nonuniformity, amplifier gain, or amplifier linearity. So the associated electronic circuits with sample vibrator serve the function of a null detector [2, 9].

Schematic diagram of a vibrating sample magnetometer shows in figure 1 [5]. Where vibration unit or sample vibrator consists reference coil is used to provide vibration at constant frequency to the sample holder. Sample is fixed to the end of the sample holder.

The sample vibrator is main subsystem of VSM which is built to fulfill the following principle requirements: (i) Pure sinusoidal vibrations of constant frequency; (ii) Stability of vibration amplitude under load variation and friction. For controlling the vibrator an electronic circuit has been designed [1].

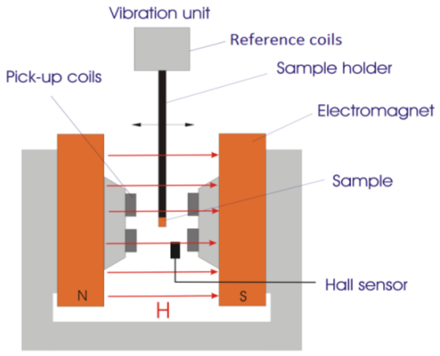

Fig.1: Schematic diagram of a vibrating sample magnetometer

Different types of magnetometers have been developed and are now commercially available .The first VSM was designed and constructed by Professor Simon Forner of the Massachusetts Institute of Technology, USA [2]. Since then, vastly improved versions of VSMs have been developed by various manufactures and are now commercially available. They have been extensively reviewed by Foner [3, 4]. These all types of magnetometer consists electronic system which is manually operated and also required lots of time and cost for fabrication of different type of electronic component of the circuit. Therefore, much attention was paid to make design and tested the circuitry associated with VSM for controlling the frequency and amplitude of the sample vibrator [1] by using digital storage oscilloscope [8].

2. ELECTRONIC CIRCUIT ASSOCIATE WITH SAMPLE VIBRATOR

The functions of the associated electronic circuits are: (1) to permit accurate calibration of the signal output obtained from the detection coils, (2) to produce a desire sine wave signal with 20-170 Hz directly related to the input and, (3) to provide sufficient amplification for high sensitivity operation. These functions can be performed by a variety of circuits. The block diagram of the vibrator electronic circuit is shown in figure 2. Description of individual parts and their features are given below:

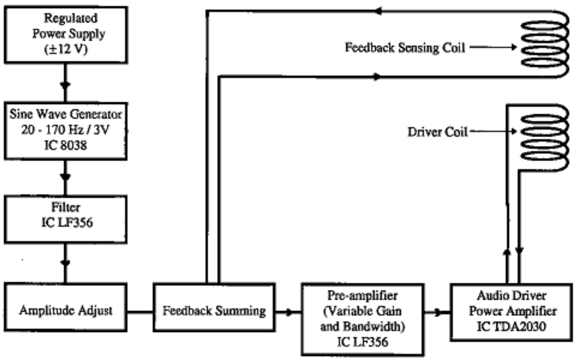

Fig. 2: Circuit Block Diagram

3.1 Sine- Wave Generator

It requires adjusting variable frequency range between 20-170 Hz. The output of sine wave generator is feed into the sine wave filters for phase shifting and to obtain desired shape.

3.2 Sine-Wave Filter

This circuit generates a desired low noise signal by passing through low pass filter and attenuate (reduces the amplitude of) signals with frequencies higher than the cutoff frequency. Second filter is use for generate same phase signal which phase shifted from first filter in order to maintain same phase. Buffer is use to reduce the loading effect. Biasing of four diode bridge act as a phase sensitive detector. It is used to match the phase and amplitude of velocity signal from pick up coils with the reference signal. A lock in amplifier (LIA) is connected to the detection coils in differential input mode. For operation at 80 Hz reference frequency using bandwidth as well as line (50Hz) filters, a pre-filter and post filter give the maximum noise reduction.

3.3 Preamp and Power Amplifier

A preamplifier is used as a high gain amplifier to prepare a small electrical signal for further amplification or processing and reduce the effects of noise and interference. It is used to boost the signal strength to drive the cable to the main instrument without significantly degrading the signal-to-noise ratio (SNR). The second amplifier is typically a power amplifier. The preamplifier provides voltage gain (e.g. from 10 milli volts to 1 volt) but no significant current gain. The power amplifier provides the higher current necessary to drive loudspeakers attach through reference coil or driver coil which is connected to sample vibrator to provide vibration.

3. EXPERIMENTAL ARRANGEMENT

The basic hardware circuit of VSM is shown in figure given below. Fig. 3 shows circuit diagram of function generator IC8038 act as a sine wave generator. For getting desired shape it feeds to sine wave filter. Fig. 4 shows circuit diagram of LM 741 is use as a low pass filter to attenuate (reduces the amplitude of) signals with frequencies higher than the cutoff frequency. Than this signal go to next filter which is use for generate same phase signal which phase shifted from first filter in order to maintain same phase. Fig. 5 shows circuit diagram of pre and power or audio amplifier. LM 741 used as pre amplifier which is used as high gain amplifier to prepare a small electrical signal for further amplification or processing and reduce the effects of noise and interference. It is used to boost the signal strength to drive the cable to the main instrument without significantly degrading the signal-to-noise ratio (SNR). Here power amplifier TDA 2030 provides the higher current necessary to drive loudspeakers which is connected to the terminal in the circuit.

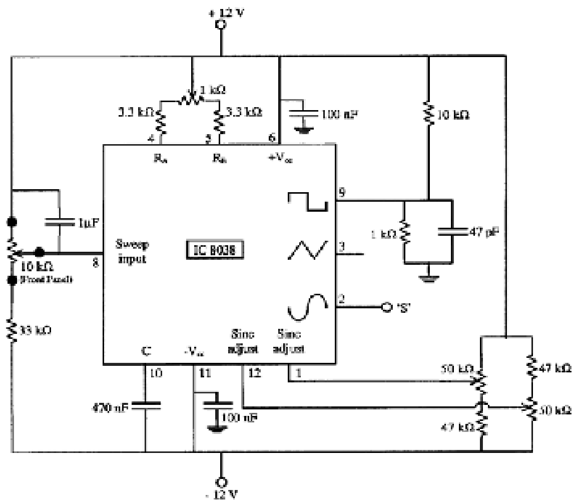

Fig.3: Basic circuit diagram of Sine Wave Generator

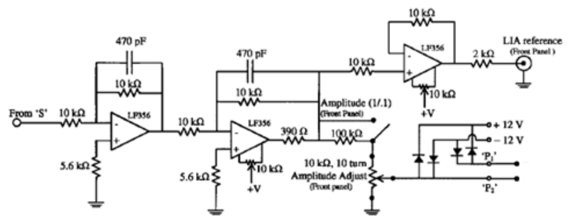

Fig. 4: Basic circuit diagram of Sine Wave Filter

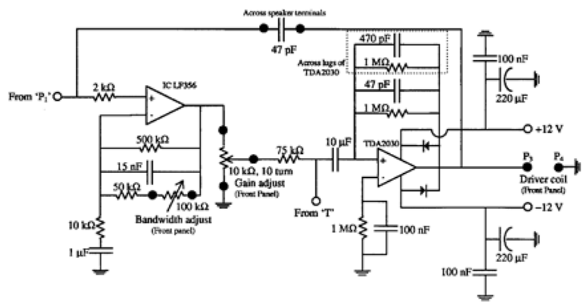

Fig. 5: Basic circuit diagram of Pre-Power Amplifier

An elaborate electronic circuit has been designed for controlling the vibrator's frequency and amplitude. The experimental set up is shows in figure 6. It is constructed using locally available components. Here we use 15 volt power supply. DSO is use for detection of signal at output of various ICs which is used in this circuit. Multimeter is used to check the continuity at the different nodes.

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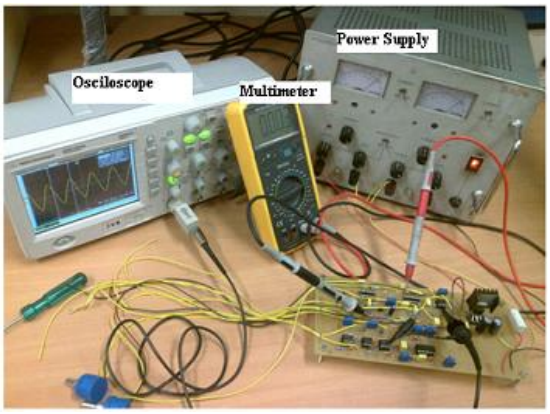

Fig. 6: Hardware circuit design with some measurement devices and power supply

The hardware implementation of the system has been done by using the commercially available Integrated Circuits (ICs) in combination with the discrete components. We have designed and tested (i) the sine wave generator (ii) the sine wave filter (iii) the pre amplifier (iv) the audio amplifier. Then we cascaded all the blocks together to design the complete circuit block of the VSM circuitry.

4. RESULTS

To control the vibratory frequency and amplitude we have design an electronic circuit in which various IC's is used to generate sine wave of desired frequency and amplitude. For this various stages or experimental results are shown below.

Stage 1: Output of Sine wave Generator shown in fig. 7 which shows the sine wave signal of 80 Hz. It is generated from the sine wave generator IC8038. Output is check at pin number 2. For getting desired shape it feed to the next stage.

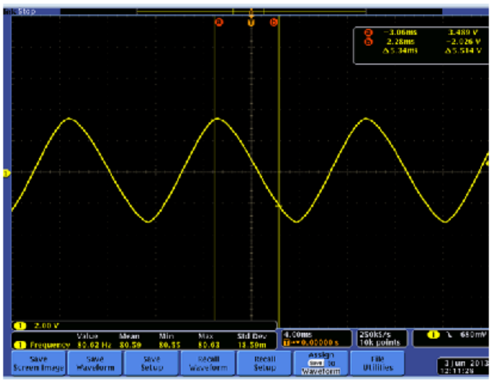

Fig. 7: Sine Wave Generator Output

Stage 2: Output of IC LM 741, sine wave filter shown in fig. 8. Where output of two filters showing 180 degree phase shift to maintain phase with input signal. Fig. 9 shows the output of buffer generated at same frequency of 80 Hz. It is use to reduce the loading effect.

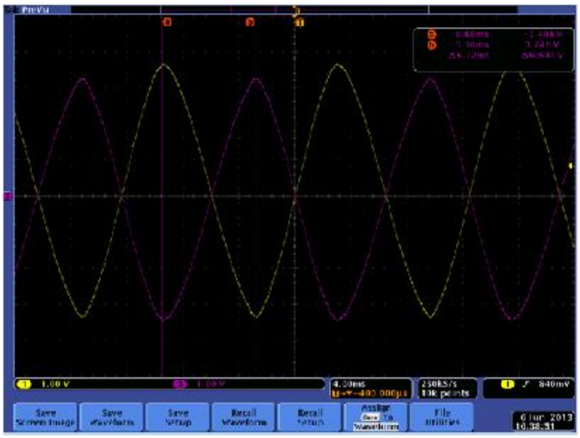

Fig. 8: Sine Wave Filter Output

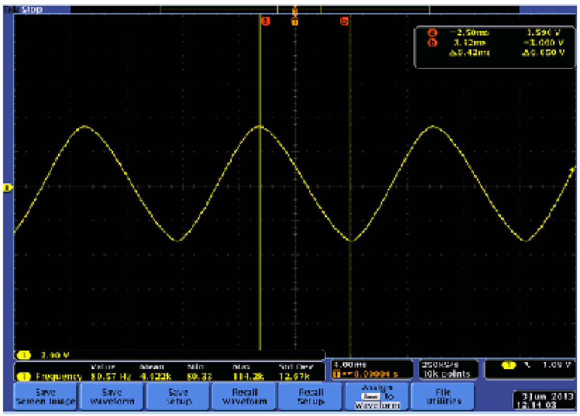

Fig. 9: Output of Buffer

Stage 3: Fig. 10 shows the output of pre amplifier. Here we get sine wave of 80 Hz frequency with proper shape with maximum noise reduction.

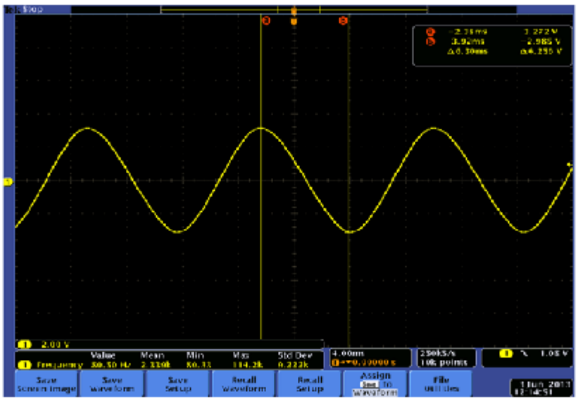

Fig. 10: Pre- Amplifier Output

Stage 4: Fig. 11 shows the output of IC TDA 2030. Power amplifier generates sine wave with higher amplitude to drive loudspeakers which is connected to the terminal in the circuit.

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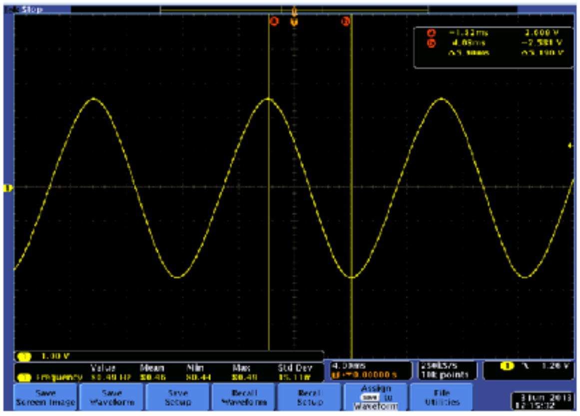

Fig. 11: Power Amplifier Output

5. CONCLUSION

Experimental observational testing of various modules of electronic circuit of sample vibrator of Vibrating Sample Magnetometer such as actuator frequency and amplitude are found to close agreement with our theoretical value with some percentage variation. The signal is observed in various frequency and voltage level to generate proper sine wave of desired frequency and amplitude. Implementation of electronic circuit tested successfully with the help of DSO. For operation vibrator frequency is kept around 80 Hz as well as sine wave filter which gave maximum noise reduction and also minimize interference from 5 Hz A.C. line noise.

6. ACKNOWLEDGEMENTS

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