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DESIGN OF DRIVE FOR OVERHAUSER MAGNETOMETER

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Abstract: The drive is used to operate and control the overhauser magnetometer and produce the proton precession signal. It is used to deflect the increased proton magnetization into the plane of precession and after the deflection pulse, the frequency measurement is done. And, while the existing deflected magnetization is processing and being measured, a new one is being created by the Overhauser effect. After the frequency determination has been completed, we can apply another 90degree pulse and continue the measurements faster than would be possible with the classical proton magnetometer.

Keywords: Amplifiers, DC polarization , Impedance matching, Microcontroller, Proton precessions, PLL, Sensors.

I. INTRODUCTION

A **magnetometer**is an instrument that measures magnetism: either the **magnetization** of magnetic material like a ferromagnet, or the **direction, strength, or the relative change of a magnetic field** at a particular location. A compass is the simple example of a magnetometer, one that measures the direction of an ambient magnetic field. Magnetometers are widely used for measuring the **Earth's magnetic field** and in geophysical surveys to detect the **magnetic anomalies** of various types. They are also used in**military** to detect submarines. Magnetometers can be used as **metal detectors**, they are able detect only magnetic (ferrous) metals, but can detect such metals at a much larger depth than conventional metal detectors; they are capable of detecting large objects like cars, at tens of meters, while a metal detector's range is rarely more than 2 meters.

An **Overhauser proton precession magnetometer** provides the slight technological improvement over conventional proton precession method. This type of magnetometer is basically same as the conventional proton precession magnetometer with the exception of differences in the processing electronics, sensor fluid and type of current applied around the fluid. Rather than just having proton rich fluid, the fluid has been "spiked" with the free radicals to enhance the reactiveness of the protons in the fluid to an electrical stimulus. The other difference is non-application of high power Direct Current (DC) around the sensor (as in the conventional systems), instead, a low power radio frequency magnetic field is applied for a very short time interval around the fluid. This type of system maximizes the resolution and is more efficient since polarization and measurement of the protons occurs almost simultaneously.

PROTON: It is a stable subatomic particle occurring in all atomic nuclei, with a positive electric charge equal in magnitude to that of an electron.

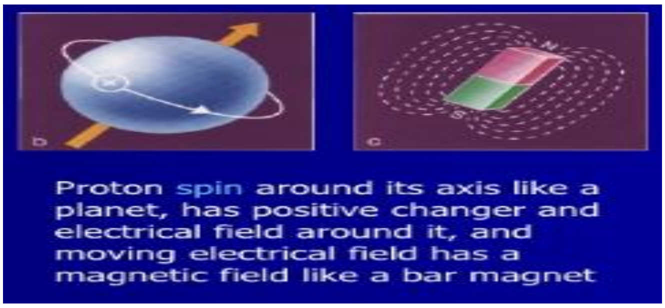


Fig1 : Proton spin

PRECESSION: If the axis of rotation of the body is itself rotating about a second axis, that body is said to be precessing about the second axis. It refers to the slow movement of a axis of the spinning body around another axis due to a torque (like gravitational influence) acting to change the direction of the first axis. It is seen in the circle slowly traced out by the pole of the spinning gyroscope

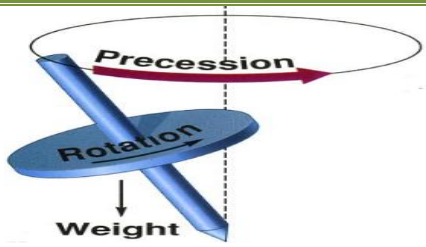


Fig 2 .Pression

PROTON PRECESSION SIGNAL:

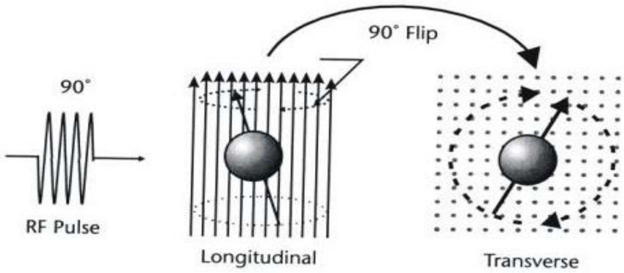
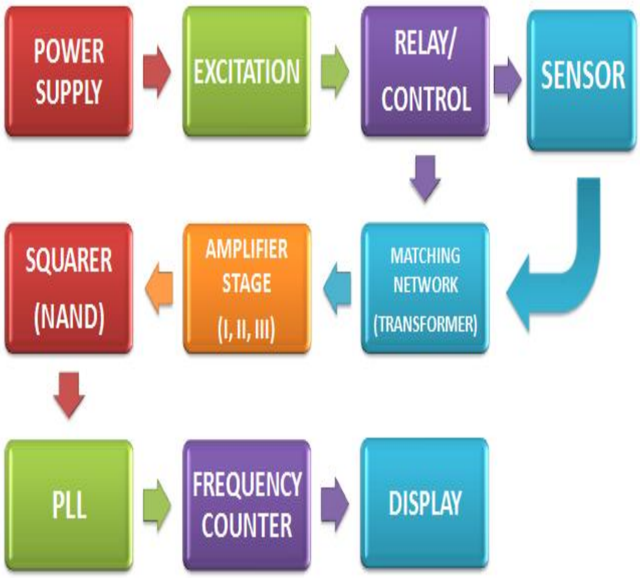


Fig 3 .Proton Precession

II. BLOCK DIAGRAM FOR DC PLARIZATION



III. OPERATION

Power supply supplies 12 Volts DC supply to the EXCITATION STAGE where the transistor TIP2955 is used which is a pnp series pass transistor. This transistor is used as a switch. The current through base is given to the microcontroller. There is a transistor connected to microcontroller as microcontroller current is less and the current required in next stage to switch off the relay and excitation drive is more. So this transistor prevents the flow of excess current through microcontroller and also prevents microcontroller from damage.

The microcontroller is programmed such that the transistor starts conducting which starts the dc excitation for around 6-8 seconds and by connecting dc excitation circuit to the sensor through switch and thus the current starts flowing through the sensor. After 6-8 sec the microcontroller switches off the relay and then the switch connects the transformer to the sensor by disconnecting the dc excitation circuit to the sensor.

Sensor consist a hollow metal tube filled with protons rich material (such as kerosene, deionized water, hexane) with a copper coil dipped in it. The coil is a solenoid made up of a copper wire such that the inductance of coil is 30mH with a resistance of 10ohms,this solenoid is then oriented in east-west direction. Due to strong magnetic field the protons get aligned in east-west direction. On breaking current (excitation) the magnetic field will start to collapse the protons will start precessing towards north-south direction due to the torque as the orientation of initial magnetic field of protons and magnetic field of earth is 90degree apart from each other. Thus the protons will be oriented in the north-south direction and will remain in that position for around 1-2 seconds.

The sowter transformer with gain of 4 is used for matching network. Transformer is also used as amplifier, to obtain the differential output and for the purpose of isolating the sensor and the amplifier stages. The signal is then fed to the 2nd amplifier stage which consist of JFET with gain of 8-10. Then in output of JFET is fed to the 3rd amplifier stage consist of BC109 npn transistor and designed to get obtain gain of 40. Then the output from transistor is fed to the 4th amplifier stage which is an Op-amp LM725CN designed to get gain around 800-1000. The total gain of four amplifier stage should be minimum 2lakhs.

The output of amplifiers is a sinusoidal signal which is then converted into square wave(signal) by using IC LM108J-8/883. Which is then fed to the NAND gate in order to obtain the sharp square signal with 50% duty cycle.

The output is then fed to PLL which generates an output signal whose phase is related to the phase of an input signal. It contains oscillator which generates a periodic signal, and phase detector compares phase of that signal with the phase of the input periodic signal, adjusting the oscillator to keep phases matched. The input and output phase in lock step also implies keeping the input and output frequencies the same. Consequently, in addition to the synchronizing signals, a phase-locked loop can track an input frequency, or it can generate a frequency that is a multiple of the input frequency.

The output is now fed to frequency counter where the voltage is converted from 12V to 5V as microcontroller requires 5V maximum voltage. The microcontroller is programmed such that it controls the relay and initial excitation connection with sensors and used in frequency counter to count the total frequency which is then multiplied by gyromagnetic ratio (23.496241) to obtain the total magnetic field. The result is then displayed on LCD.

IV. SENSOR

The heart of overhauser magnetometer is the sensor which consists of a coil of copper wire wound around a container filled with a proton rich material such as deionized water,kerosene.

In this configuratio, two identical single coil sensors are placed side by side for sensingmagnetic field. The coils are connected in series so that the signals generated inside and then they are added together. In this arrangement, any noise induced in the two coils due to external sources will be canceled.

Fig4 . Sensor

The sensor consist of :

1. Cylindrical tube
2. Metallic rod
3. Solenoid
4. Chemical
5. Connector

V. PHASE LOCKED LOOP

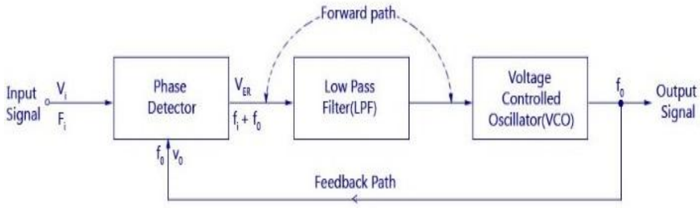


Fig5 . PLL Block diagram

PLL is basically the flip flop consisting of a phase detector, a low pass filter (LPF),and Voltage Controlled Oscillator (VCO).Block Diagram - Phase Locked Loops. The input signal Vi with an input frequency fi is passed through a phase detector. A phase detector basically a comparator which comparesthe input frequency fiwith the feedback frequencyfo .The phase detector provides an output error voltage Ver (=fi+fo),which is a DC voltage. This DC voltage is then passed on to an LPF. The LPF removes the high frequency noise and produces a steady DC level, Vf (=Fi-Fo). Vf also represents the dynamic characteristics of the PLL.The DC level is then passed on to a VCO.

The output frequency of the VCO (fo) is directly proportional to the input signal. Both the input frequency and output frequency are compared and adjusted through feedback loops until the output frequency equals the input frequency. Thus the PLL works in these stages – free-running, capture and phase lock.

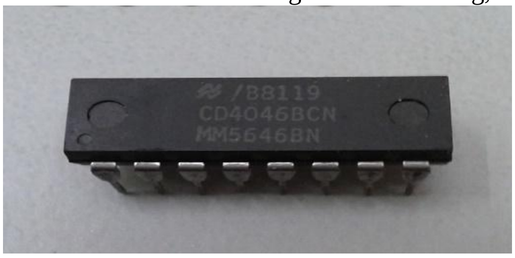


Fig6 .PLL CD4046BC

The CD4046BC micro power phase-locked loop (PLL) consists of a low power, linear, voltage-controlled oscillator (VCO), a source follower, a Zener diode, and two phase comparators. The two phase comparators have a common signal input and a common comparator input. The signal input can be directly coupled for a large voltage signal, or capacitive coupled to the self-biasing amplifier at the signal input for a small voltage signal.

Phase comparator I, an exclusive OR gate, provides a digital error signal (phase comp. I Out) and maintains 90° phase shifts at the VCO center frequency. Between signal input and comparator input (both at 50% duty cycle), it may lock onto the signal input frequencies that are close to harmonics of the VCO center frequency.

Phase comparator II is an edge-controlled digital memory network. It provides a digital error signal (phase comp. II Out) and lock-in signal (phase pulses) to indicate a locked condition and maintains a 0° phase shift between signal input and comparator input. The linear voltage-controlled oscillator (VCO) produces an output signal (VCO Out) whose frequency is determined by the voltage at the VCOIN input, and the capacitor and resistors connected to pin C1A, C1B, R1 and R2. The source follower output of the VCOIN (demodulator out) is used with an external resistor of 10 kΩ or more. The INHIBIT input, when high, disables the VCO and source follower to minimize standby power consumption. The Zener diode is provided for power supply regulation, if necessary.

VI. MICROCONTROLLER

The P89C668 device contains a non-volatile 64 Kbyte’s Flash program memory that is both parallel programmable and serial In-System Programmable. In-System Programming allows devices to alter their own program memory, in the actual end product, under software control. This opens up a range of applications that can include the ability to field update the application firmware.

A default serial loader (boot loader) program in ROM allows serial In-System programming of the Flash memory without the need for a loader in the Flash code. User programs may erase and reprogram the Flash memory at will through the use of standard routines contained in ROM.

Fig7 .uC P89C668HFA

This device is a Single-Chip 8-Bit Microcontroller manufactured in advanced CMOS process and is a derivative of the 80C51 microcontroller family. The device has the same instruction set as the 80C51.

The device also has four 8-bit I/O ports, three 16-bit timer/event counters, a multi-source, four-priority-level, nested interrupt structure, an enhanced UART and on-chip oscillator and timing circuits.

The added features of the P89C668 makes it a powerful microcontroller for applications that require pulse width modulation, high-speed I/O and up/down counting capabilities such as motor control.

VII. OUTPUT

Fig8 . Magnetic field

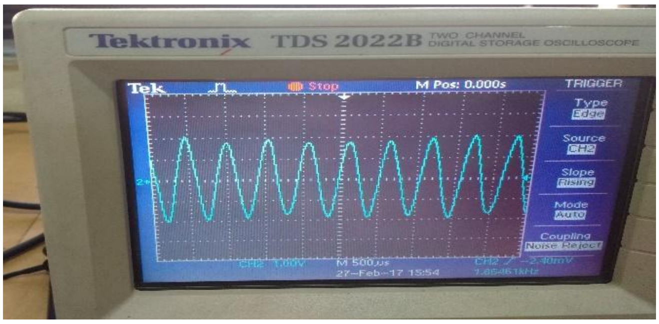


Fig9 . Proton Precession Signal

VIII. ADVANTAGES

1. Energy Efficient
2. Less Power Consumption
3. Less Noise
4. Better Signal Strength
5. Better Sensitivity
6. Rapid Speed Of Operation
7. Low Maintenance
8. High Absolute Accuracy

IX. APPLICATIONS

1. Magnetometer detect minute deviations in the earth's magnetic field caused by iron artifacts, kilns,some types of stones structure, and even ditches and middens in archaeological geophysics.
2. It is used to find out magnetic anomalies.

3. They are used for navigational purposes.
4. It is used to search world-class deposits of gold, silver, iron copper, etc.
5. They are used in many defense applications; UAVs, submarines, etc.
6. To detect the archaeological sites, buried and submerged objects.
7. Used while drilling the discovered wells.
8. Used while studying about solar wind and planetary body.

X. FUTURE SCOPE

Overhauser magnetometer produces a continuous effect.Less time is needed to make a measurement and it can thus sample more rapidly up to one reading per second may be made.

The signal strength is 1-10uV , so the signal-to-noise ratio is better for proton precession magnetometer.

XI. CONCLUSION

The results shown above indicate that the designed proton magnetometer is capable of measuring the Earth's magnetic field with sufficient precision.

The main difficulty that had be faced in the development of this instrument was the low signal to noise ratio of precession signal.

It has various advantages over other magnetometers and has the high absolute accuracy. Preparation and safety measures can be taken from various problems if the problems are known in advance by measuring the earth's magnetic field. In order to maintain the accuracy and lowest noise each stage has to be implemented properly with minimum error and tuning has to be done properly.

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