

## Proton precession magnetometer. Principle and construction.

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*...I'm a five-year student of International Sakharov Environmental University (Minsk, Belarus). The subject of my graduation thesis is "Building of proton precession magnetometer". Therefore, I'd like to introduce my researches...*

If proton is placed in an external magnetic field,  $B$ , because of its own magnetic moment, it will experience a magnetic torque. Because it also has angular momentum, this magnetic torque will cause it to precess – this is called “Larmor precession” and the rate of precession depends on the magnitude of external magnetic field. It turns out that the rate of Larmor precession is independent of the proton's orientation with respect to the external field and depends only on the magnitude of the external field. The rate of precession,  $\omega$ , in radians per second, is given by the Larmor Equation:

$$\omega = \gamma_p B$$

$B$  – the magnitude of the external field;

$\gamma_p$  – gyromagnetic ratio ( $2.67512 \times 10^8$  in SI units).

For  $B = 50 \mu\text{T}$  (a nominal value for the earth's field),  $\omega$  is therefore  $1.34 \times 10^4$  radians/second which (divide by  $2\pi$ ) corresponds to 2130 Hz. *The basis of the proton precession magnetometer is to measure frequency and then, using the Larmor Equation, calculate the magnetic field strength.*

To make a magnetometer using proton precession, protons must be “magnetized” (lined up in the same direction) and then all “let go” as quickly as possible. They will then all precess in phase and induce a voltage at the Larmor frequency which can be measured and used to calculate the ambient magnetic field.

Typically, the protons are subjected to a polarizing magnetic field which will line them up in its direction. Then the polarizing field will be turned off and the induced voltage detected. The simplest (but not necessarily the best) configuration is a multiturn solenoid containing a core of some substance which is rich in protons – distilled water is commonly used. A large current is passed through the solenoid to generate a large magnetic field in the core in order to line up the protons. The current is then switched off and the same solenoid acts as a sensor and connected to a sensitive amplifier in order to detect the induced precession frequency. Typically, the induced voltage due to proton precession is of the order of microVolts. Because the precession of the protons will subsequently be randomized by the thermal collisions, the induced signal decays exponentially with time and has a typical time constant, which depends on the particular proton rich substance used in core, of a few seconds. The precess is prepared to make another reading.

Most amateur PPM's (proton precession magnetometers) have been solenoidal. This configuration has one great advantage and several great disadvantages. The advantage is that it is very easy to wind a solenoid. The first disadvantage is that it is sensitive to external ac magnetic fields of which the most troublesome is the very large 50 or 60 Hz field over the surface of the earth. These will induce voltages which may be much, much greater than the desired proton precession voltage. Secondly, the sensor is orientation sensitive. If the polarizing field (along the axis of the solenoid) happens to be in the same direction as the external field which it is desired to measure, the induced precession voltage will be zero! This means that the user must always be sure that the solenoid is oriented correctly in order to get a sufficient induced voltage to measure. This may be a problem in magnetometers which are towed behind boats, for example, while turns are being made. The sensitivity of the instrument depends on orientation with respect to the earth's field. The induced signal strength is proportional to the sine of the angle between the earth's magnetic field and the axis of the solenoid.



We made two equal solenoidal core (diameter=0.12 m; height=0.14 m; 10 layers; 1040 turns; aluminium wire with diameter 1.3 mm). They were been connected antiphasely. But, because of very high noise level, we didn't registered precession signal.

Most professional PPM's are made using a toroidal core. A toroidal coil is not very sensitive to external ac 'noise' magnetic fields and so this reduces external noise greatly. Secondly, the toroidal configuration is not nearly as orientation

sensitive. If the external magnetic field it is desired to measure is oriented in the least sensitive direction (in the plane of the toroid), the induced voltage is only reduced to one half of that in the most sensitive orientation (where the external field is aligned along the axis of the toroid). The signal **never goes to zero** and the worst case signal-to-noise ratio is still half that of the best. The only disadvantage of the toroid is that winding it is very labour intensive and difficult.

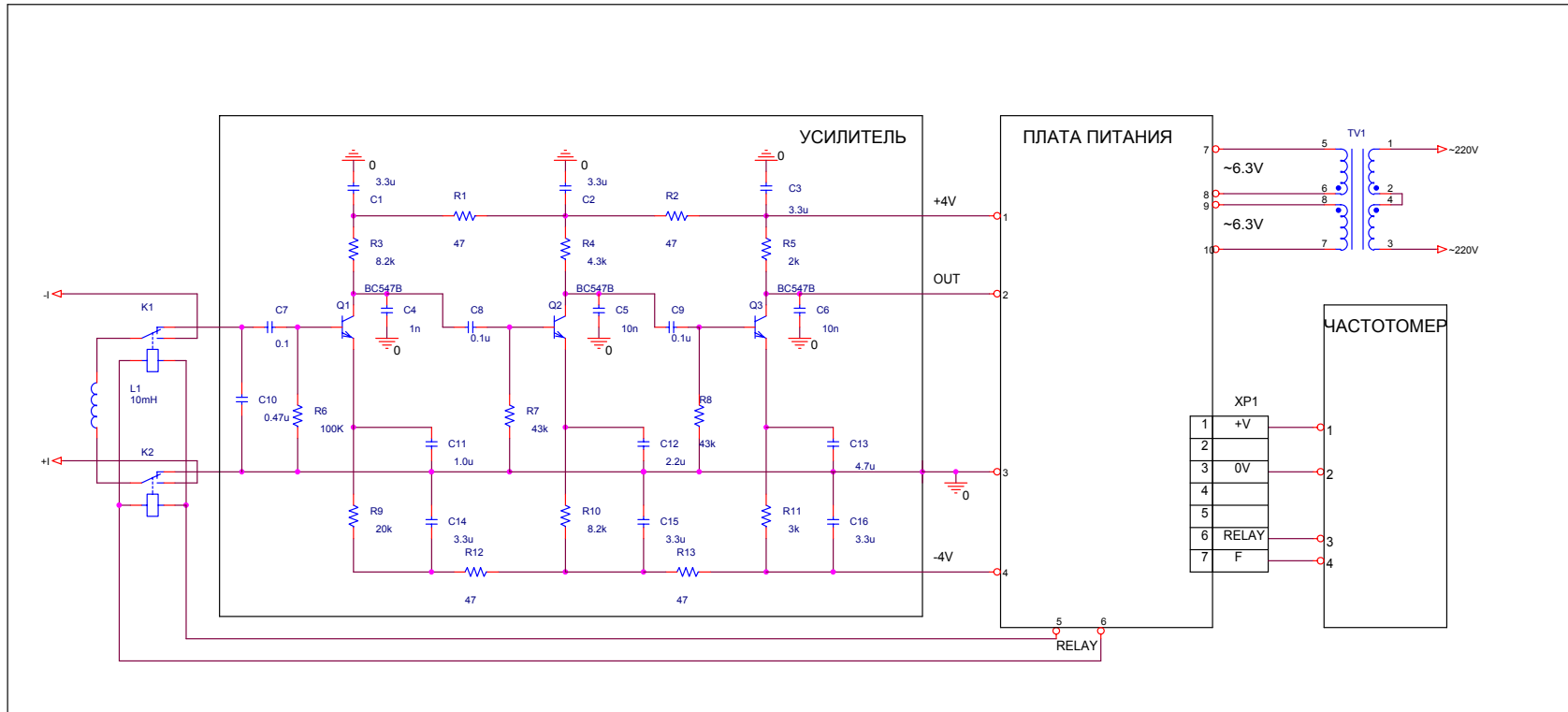


At this picture you can see our toroidal core. Internal radius=25 mm; external radius=60 mm; height=70 mm; number of turns=1600; copper wire 0.2 mm. But here we don't detect any signal too. The reason of this, to my mind, is in heterogeneity of magnetic field in our laboratory( a lot of different metal equipment; incoming in building electrical cable behind the wall).

The scheme of our amplifier is enclosed.

I would be very grateful for any help in construction of proton precession magnetometer( as advices).

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