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Exercise for Sun-Planet Connections (2009) - Part 2

Fluxgate Magnetometer

2.1 Measurement principle

(A) A single coil system with a ferromagnetic rod (e.g. iron, nickel) can detect temporal variation of magnetic field $\partial_t B_x$ (Fig. 1A).

Integrate the induction equation

$$\nabla \times \vec{E} = -\partial_t \vec{B} \tag{1}$$

along the pickup coil line and obtain the voltage at the pickup coil as

$$V = -NS\partial_t B_x, \tag{2}$$

where B_x is the magnetic field component along the rod axis. N is the winding number of the pickup coil, and S is the area of the coil.

(B) Consider a double coil system (Fig. 1B). One coil is used as an excitation, and the other coil is used as a pickup. The excitation coil imposes a large-amplitude sine wave pattern in voltage such that the magnetization of the rod is saturated at every half-period. The excitation field under a background magnetic field is given as

$$H(t) = H_0 + he^{i\omega t} \tag{3}$$

and the induction field $B(t)$ is given by the hysterisis curve (B-H curve) as

$$B(t) = H(t) - H^3(t). \tag{4}$$

Here all the coefficients are neglected for simplicity.

Combine Eq. (2), (3), and (4) and show that the pickup coil senses harmonics of the excitation signal, and most importantly, **the second harmonics is proportional to the external magnetic field** H_0.

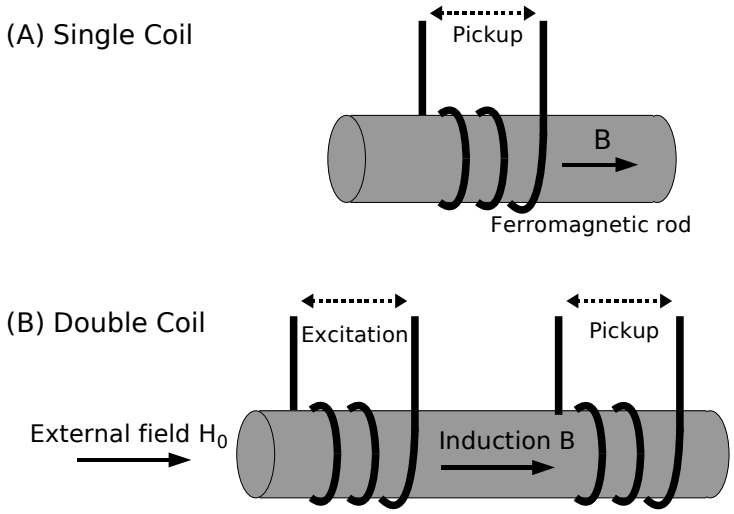

Figure 1: Single and double coil system.

2.2 Assembly

Assemble the four components (Fig. 2) into a fluxgate magnetometer: (1) Ringcore sensor with 2 coil systems ($L_1 = 0.64\,\mathrm{mH}$ and $L_2 = 13\,\mathrm{mH}$); (2) Frequency generator ($f = 8\,\mathrm{kHz}$); (3) Capacitor ($C = x\,\mathrm{nF}$); and (4) Oscilloscope.

- Why do we need a capacitor?
- How much Farad should the capacitor have?

Ringcore sensor is a double coil system with a special geometry to cancel out all the odd harmonics in the pickup signal by its geometrical configuration.

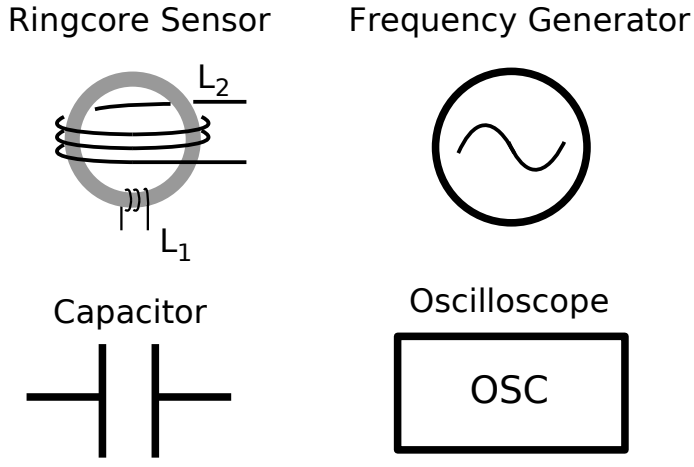

Figure 2: Components for a fluxgate magnetometer.