Variable oscillator reacts to magnetic flux changes

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An oscillator employing a saturable-core reactor can detect small changes in the intensity of any magnetic field that cuts through the reactor's windings. The oscillator utilizes core hysteresis in order to generate a frequency that is directly proportional to the magnetic field component along the inductor's longitudinal axis.

As shown in (a), two 2N3020 transistors form a simple astable multivibrator that oscillates at a frequency of 11 kilohertz in the absence of an external magnetic field. The inductor, L, in the collector lead of Q_1 has a core made from μ metal, a commonly available, high-permeability magnetic alloy with the characteristics shown in (b). The μ metal consists of nickel, iron, copper, and manganese. Placed around it is an insulating layer of phenolic resin impregnated with paper or cloth, of a kind frequently used in coil forms. As shown in (c), 800 turns of AWG 36 wire, wound over the insulator, gives L a value of a few millihenries.

Circuit operation may be understood from (d). Disregarding any external field for the moment, and assuming an arbitrary start time of t_1, at which point Q_1 is on and Q_2 is off, current will build through L at the rate of $i=(V/L)t$, where V is the supply voltage and t is the time. Generated in the coil is a magnetic field of intensity H_s, in a direction determined by the corkscrew rule. As the field increases, the level of flux density also increases. As t_2 approaches, the current rises to a value sufficient to saturate the μ metal (H_{sat}). The flux density reaches B_{sat} and remains at that value.

As a result, the inductance drops to that of an air-core inductor, because the core permeability is proportional to $\Delta B/\Delta H$. Thus, at t_2, the current increases almost instantaneously towards an infinite value, and as Q_1's base current is about $V/(R_1+R_3)$, too little to keep the transistor in conduction, Q_1 is eventually cut off.

The base current into Q_2, which is approximately equal to V/R_2, is not quite enough to turn this transistor on, however. But as Q_1 turns off, an induced electromotive force, much greater than V, is produced across the inductor, giving rise to enough additional current to turn Q_2 on and keep it conducting. Q_2 remains on until t_3, when the induced current, which has been falling from time t_2 with a rate equal to $-L/R_2$, finally decreases to near zero. The collector of Q_2 rises, bringing Q_1 into conduction, current builds in L, and the process repeats.

Consider an external field with intensity H_a along the axis of the coil such that the actual field causing a flux change is equal to $H_s \pm H_a$, depending on the direction of the external field. When H_a is opposing the field, the current takes longer to bring the total field to a value equal to H_{sat} between times t_1 and t_2; hence the oscillator's frequency will be lower than with no external field present. Similarly, when H_a is in the same direction as H_s, the core will reach saturation sooner, and the cycle will be speeded up, causing a rise in frequency.

The frequency will increase from 8 to 14 kHz for an external field change of ±0.4 oersted. This change can be obtained merely by rotating the coil in a horizontal plane from the east – west to the north – south direction of the earth's magnetic field. ☐

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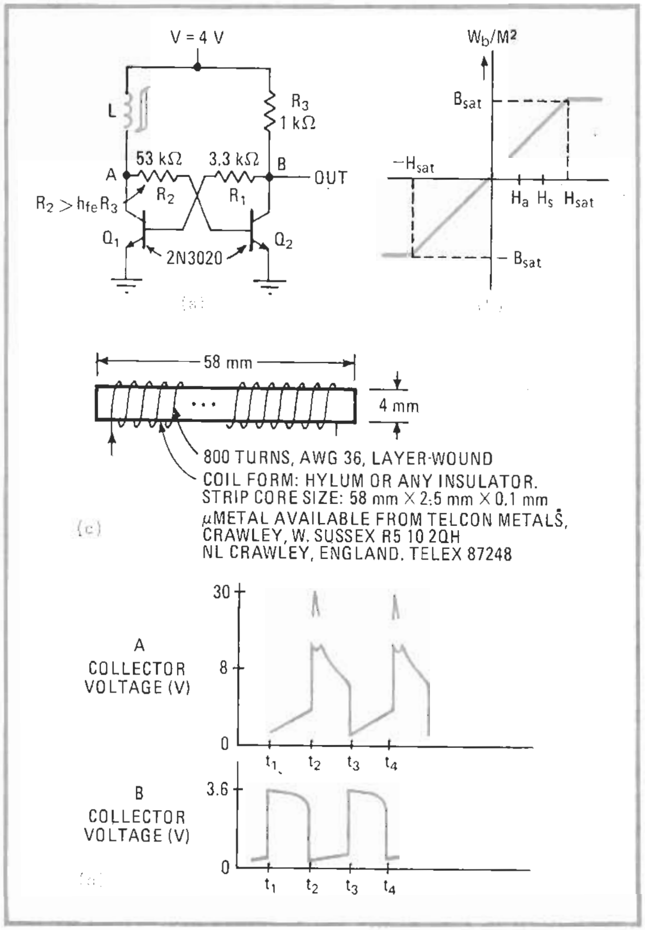

Field sensitive. Saturable core reactor enables oscillator to detect change in any magnetic field whose flux lines cut reactor windings (a). Oscillator frequency is determined by the core saturation time (b). Inductor is made of μ metal, insulated core form, and 800 turns of high-gauge wire (c). Timing diagram details operation (d).