Magnetometer Update

Since last month's coverage, I've pinned down a bunch of new info and a few samples on magnetometers and fluxgates, so let's do an update. First off, Ripke's *Review of Fluxgate Magnetometers in Sensors and Actuators A* ,volume 33, 1992, pages 129-141, is a real good technical starting point.

Figure I shows you the winding details on a classic fluxgate sensor. A softly saturating tape-wound toroidal core is normally used. The main or control winding gets driven by a low-distortion sinewave. That sinewave switches (or gates) the core in to or out of saturation.

Paired orthogonal sine and cosine sense windings tell the strength and direction of the external field as it is drawn in to and released from the core. For signal isolation, the sensing is normally carried out at the second harmonic of the drive frequency.

Although that fluxgate is a thoroughly tested and proven workhorse, it involves quite low-level, noisy, analog signals that are tricky to accurately interface to any micro. The multiple precision windings also add greatly to your final cost and complexity.

Additional details on the flwgate support circuitry might be found in HACKl4.PDF on www.tinaja.com and in the useful *Magnetic Measurements Handbook* from *Magnetic Research.* Magnetic Research also sells wound cores and working magnetometers.

Figure 2 shows us an improved circuit known as a resonant fluxgate. The op-amp operates open loop as a com-

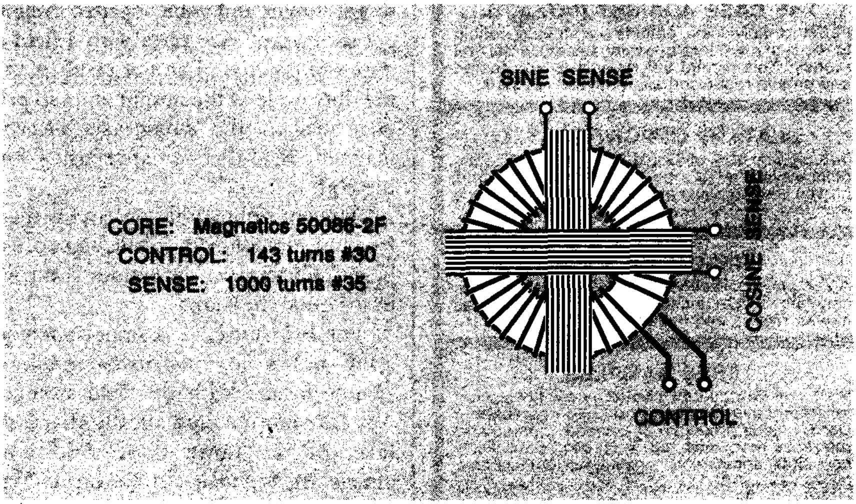

FIG. I-CLASSIC ANALOG FLUXGATE MAGNETOMETER. An input audio drives the control input, switching (or "gating") the core in and out of saturation and drawing in or releasing an external magnetic field. Weak signals at the sense outputs end up proportional to field strength.

parator, generating a squarewave output. That squarewave is converted to a current source by the 56,000-ohm resistor. The current waveform excites the control winding, driving the core in to and out of saturation.

The high-turns secondary winding is made resonant by the 0.1µF capacitor, producing a sinewave. The resonant sinewave then gets strongly amplified and converted back to the output squarewave.

The operating frequency is determined by your drive current, the inductance, and the time that is required for the core material to unsaturate. Any

seen a time or two before, *UMI* is a great reprint source for these.

Finally, note that the circuit has both digital and analog outputs. The digital output might be interfaced with an appropriately programmed PIC or other microcontroller that will then handle the measurement function. Alternately, as shown, a simple resistor/capacitor low-pass duty-cycle integrator can create a bipolar, analog, output voltage (available at the circuit's analog output> that tracks the input field strength for you. Additional details on duty-cycle integration circuits and techniques arc available in my ***CMOS Cookbook.***

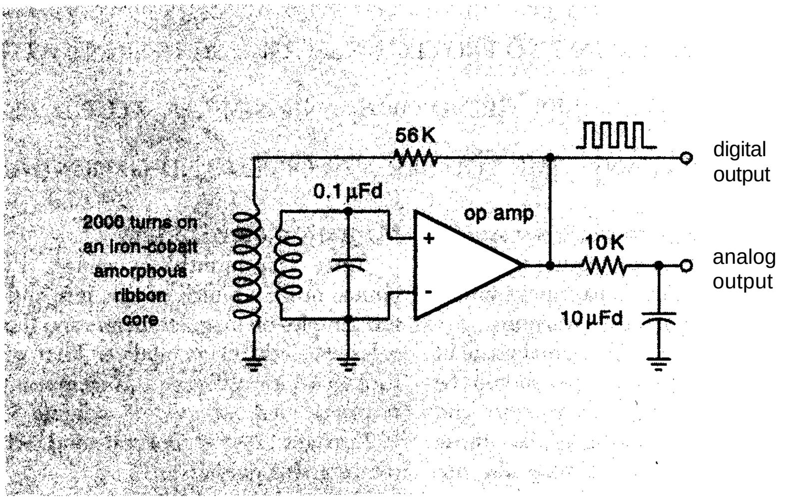

FIG. 2-A RESONANT FLUXGATE MAGNETOMETER. As before, the core Will get switched in and out of saturation. The output duty cycle varies in proportion to the Single axis field strength and direction. The high level output square wave is easy to interface to a PIC or other microcontroller.

external magnetic field should bias your core material, causing the positive cycle to get longer and your negative cycle to get shorter, or vice versa with a field of opposite polarity. The net result is that the duty cycle of the output ends up proportional to the single-axis external magnetic field that you are sensing with the coil.

The amorphous ribbon core is made from an alloy of iron, cobalt, silicon, and boron. Chromium sometimes is thrown in for good measure.

For low noise, it is important your alloy has a low ***magnetostriction,*** or change in size with the field strength. Any core motion dramatically affects the level of the noise floor. Additional details are found in "A Resonant-Type Amorphous Ribbon Magnetometer That Is Driven By An Operational Amplifier" by Takeuchi and Harada, ***IEEE Transactions on Magnetics, MAG-20,*** Sept. ***84,*** pp 1723-1725. As we've

The Variable Permeability Method

A brand new isotropic approach to earth's field sensing has been championed by Precision Navigation. Surprisingly-full tech details appear in their patent (#4,851,775).

The inductance of any winding is proportional to the permeability of its core. Normally, you will want your permeability to be a constant, and one that is independent of the applied field or bias currents. Fail to do that in an audio transformer and you will get mild to severe distortion.

One location where a variable or nonlinear permeability has been used for years is as a swinging inductor in DC power-supply filters. In those, a partial air gap is used to produce additional inductance (and more filtering) at low currents, and faster response at higher currents.

A unique new class of ***MetGlas*** mag-

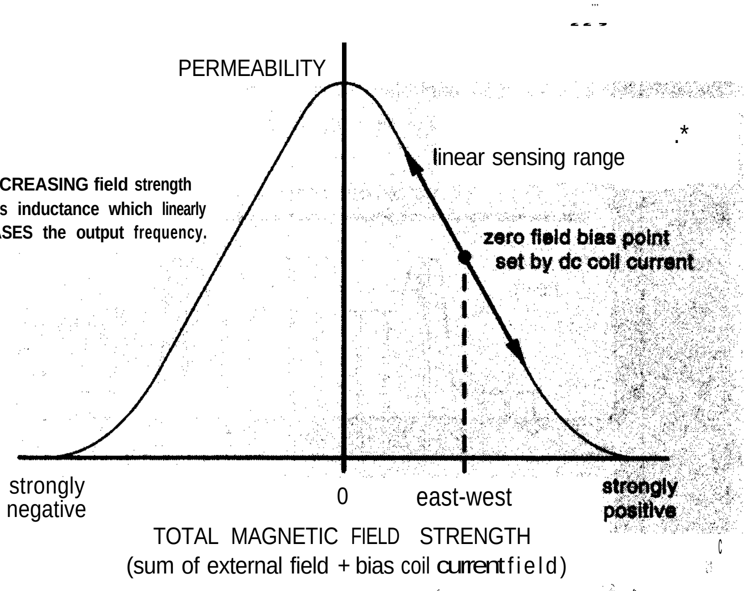

FIG. 3-SPECIAL ISOTROPIC MAGNETIC ALLOYS, whose permeability varies with field strength, are newly available. By biasing it as shown, a coil can be built so its inductance strongly varies with compass orientation.

netic materials manufactured by Allied Signal purposely goes out of its way to provide a variable permeability that changes with the applied field strength or bias current.

As Fig. 3 shows us, that new material has a high permeability with low applied fields and a much lower permeability with high fields. Note particularly the fairly linear permeability shift with applied field above and below the bias point I've shown. You can bias to that point by running some DC current through an overwound sensing coil. The earth's magnetic field (or some other magnetic source) will add to or remove from that magnetic bias level, raising or lowering the coil's inductance!

You therefore end up with a plain old coil whose inductance varies with the applied field strength. Put that in any suitable oscillator circuitry, and your output frequency should follow the strength and direction of the earth's applied field. With proper design, as much as a 2:l frequency change can be caused when you rotate the sensor through the compass points.

What is really interesting here is that a single, ultra-cheap solenoid winding over an ordinary core bar or rod acts both as a field sensor and the control bias setter. The sensing gets done by measuring the inductance, and the biasing by inputting a DC current.

Note that this is not a fluxgate, and that your core material never really gets into hard saturation. Instead, you have a variable permeability sensor that progressively saturates.

The rest is easy. Place the coil in a relaxation oscillator, add some DC bias, and shove the variable-frequency output into your microcontroller.

Figure 4 shows us one possible circuit. Unlike fluxgates, one simple winding over the core material is all you'll need. To calibrate your sensor, rotate it through 360 degrees or else drive around the block.

Though we have not said so explicitly thus far, we are working with the falling slope of the magnetic field. The falling slope is chosen for the following reason: An increasing magnetic field will decrease the permeability. Which in turn decreases inductance, and the decreasing inductance will increase frequency in most oscillator circuits. Thus, your output frequency should linearly track your input field strength on the falling slope.

Note also that an op-amp or comparator can give you better accuracy than the simple CMOS Schmitt trigger I have shown here. Your oscillator circuit must be voltage and temperature stable if you are to get useful results. Two or three axis operation could get picked up by use of two or three sensors, and then positioning them in quadrature to each other.

Precision Magnetics offers a wide variety of sensor solutions suitable for digital compasses, robotics, and for vehicle navigation applications. The coils themselves measure about 3/16-inch in diameter by 3/4-inch long. Their typical dual-axis compass magnetometer measures a tad over an inch square, draws a few milliamps, and sells for $80 or so.

Remember that any accurate compass measurement must be dead level. To cure that problem, Precision Navigation has introduced a Vector 2XT gimbaled electronic compass module. Introductory pricing is $100 for that self-leveling unit. By making use of that exciting new isotropic technology, there's no real reason why any consumer compass, navigation device, or robotics sensor that costs less than a dollar per axis cannot be built in large quantities.

Let's have your thoughts on this. It would seem that there are all sorts of exciting new possibilities here-and a lot of tech venture opportunities.

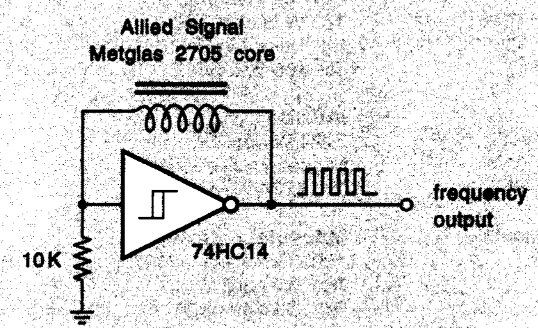

FIG. 4-THIS ELEGANTLY SIMPLE earth's field detector uses a special variable permeability cored coil. The output frequency varies with orientation.