Don Lancaster's

Tech Musings

A new compass sensor
Updated UFO directory
More magnetometer info
"Protecting" your designs
Vacuum forming resources

September, 1996

I certainly get lots of helpline calls from individuals who are trying to protect electronic designs with epoxies, part number grindoffs, and similar stupid pet tricks.

Well, *any* time you see a glopped and ground up project, you can pretty much rest assured that (A) All of the engineering is incompetent; and (B) The management suffers from acute recto-cranial inversion.

Besides being a monumental waste of time and energy that you should be spending improving your product and developing your design skills, these "protection" schemes simply *do not work*. In fact, they will have the *exact opposite* effect. All your "I've got a secret" stunts are a red-flag invitation for people much smarter than you to spend lots of time and creative effort cracking your mystery.

All you're doing here is providing them with free entertainment.

Master Bond resells a selection of epoxy dissolving chemicals. Besides, your super secret device either is a 16C54. Or else it should have long ago been replaced by one.

In a vastly superior circuit.

Every town, no matter how small, includes this guild of highly capable epoxy undoing specialists. Who have dedicated their entire lives to *Deftly Defiling Subterfuge*.

Why, they even put that DDS after their names so you can locate them easily. These same folks have these neat-o X-ray machines that easily let you snoop into just about anything electronic or mechanical.

Just like that story about the fur lined letter, the key protection secret is to *always hide in plain sight*. Far fewer people of far less competence will thus be attracted to tracing your product. Chances are they will blow their quest anyway.

Always provide a complete, free, and a detailed schematic with *all* of your products. And make your source code available at a fair price. A price that is well under the cost of reverse engineering. Because anything less is sheer insanity.

Magnetometer Update

Since last month's coverage, I've pinned down a bunch of new info and a few samples on magnetometers and fluxgates. Let's do an update.

As we've seen, Ripke's *Review of Fluxgate Magnetometers* you'll find in *Sensors and Actuators A*, volume 33, 1992, pages 129-141 is a real good technical starting point

Figure one shows you the winding details on a classic fluxgate sensor. A softly saturating tape wound toroidal core is normally used.

That main or *control* winding gets driven by a low distortion sinewave. This 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 it is a thoroughly tested and proven workhorse, this fluxgate 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 fluxgate support circuitry might be found in HACK14.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 two shows us an improved circuit known as a *resonant fluxgate*. The op-amp operates open loop as a comparator, generating an output square wave. This square wave is converted to a current source by the 56K resistor. The current waveform excites the control winding, driving the core in to and out of saturation.

That high-turns secondary winding gets resonated by the 0.1 microfarad capacitor, producing a sinewave. The resonant sinewave then gets strongly amplified and converted back to the output square wave.

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

Any 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 opposite polarity. The net result is that your *duty cycle* of the output ends up proportional to the single axis external magnetic field that you are sensing with the coil.

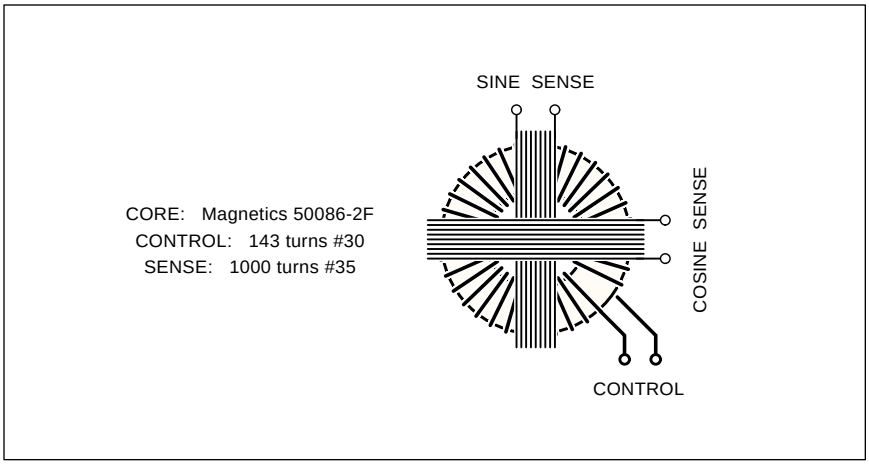

Fig. 1 – CLASSIC ANALOG FLUXGATE MAGNETOMETER. An input audio sinewave drives the control input, switching (or "gating") the core in and out of saturation and drawing in or releasing an external magnetic field. Weak signals at the sense outputs end up proportional to field strength.

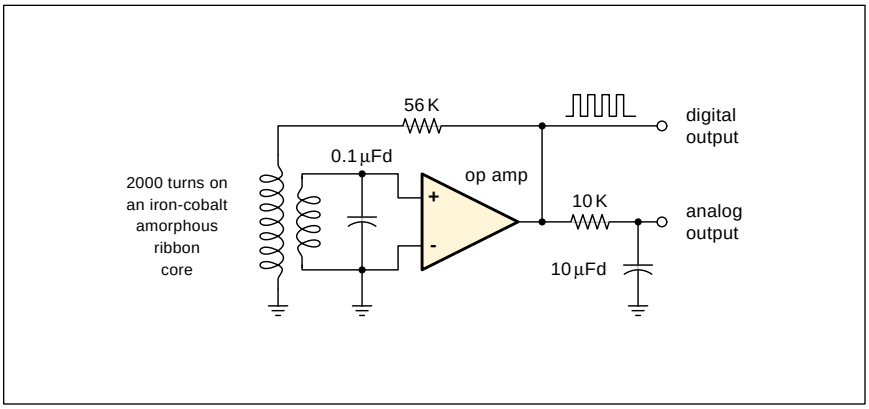

Fig. 2 – A RESONANT FLUXGATE MAGNETOMETER. As before, the core will get switched in and out of saturation. The output duty cycle varies in proportion to the single axis field strength and direction. The high level output square wave is easy to interface to a PIC or other microcontroller.

You might digitally measure this output duty cycle with a PIC or other microcontroller. Alternately, a simple resistor-capacitor lowpass duty cycle integrator can create a bipolar analog output voltage which tracks the input field strength for you.

Additional details on duty cycle integration circuits and techniques in my *CMOS Cookbook*.

Resolution and noise can be as low as *one millionth* of the earth's field. 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. Find this in that *IEEE Transactions on Magnetics*, MAG-20, Sept 84, pp 1723-1725.

As we've seen a time or two before, *UMI* is a great reprint source.

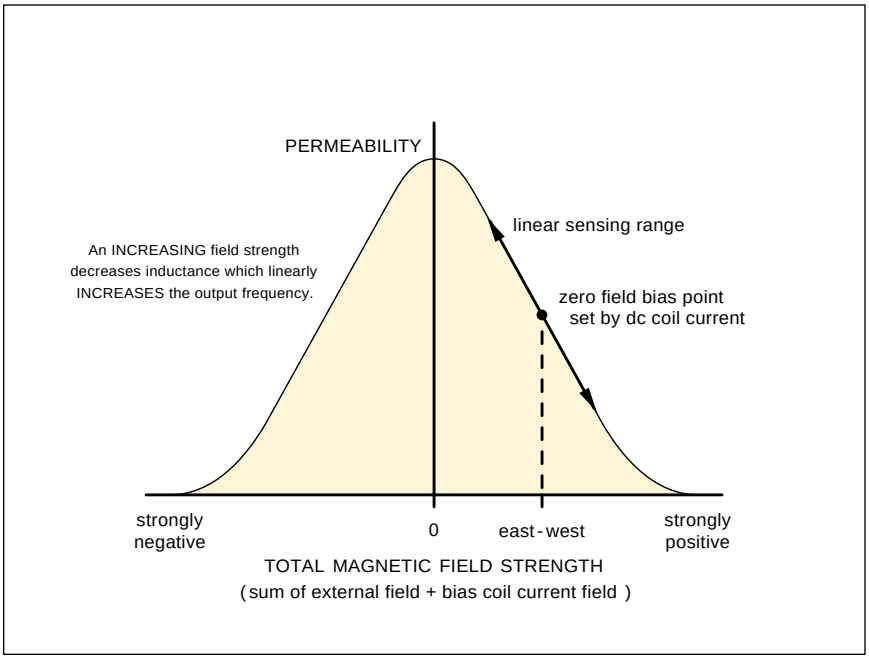

Fig. 3 – SPECIAL ISOTROPIC MAGNETIC ALLOYS are newly available. Whose permeability varies with field strength. By biasing as shown, a coil can be built so its inductance strongly varies with compass orientation.

The Variable Permeability Method

A brand new *isotropic* approach to earth's field sensing has been newly 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*. One which is independent of the applied field or bias currents. Fail to do this 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. A partial air gap gets used so that you'll end up with additional inductance (and more filtering) at low currents. And faster response at higher currents.

A unique new class of *MetGlas* magnetic materials manufactured by *Allied Signal* purposely goes out of its way to provide you a *variable permeability which changes with the applied field strength or bias current.*

As figure three shows us, this 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 this point by running some dc current through an overwound sensing coil. The earth's magnetic field (or some other mag source) will add to or remove from this magnetic bias level. *Raising or lowering the coil's inductance!*

You thus end up with a plain old coil whose inductance varies with the applied field strength. Put this 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 2:1 frequency change can be caused when you rotate the sensor through the compass points.

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

The falling slope is chosen for the following reason: An *increasing* mag 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.

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 compass, robotics and for vehicle navigation apps. 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 mils, and sells for $80 or so.

Do remember that any accurate compass measurement *must* be dead level. To cure this problem, Precision Navigation has introduced a *Vector 2XT* gimbaled electronic compass module. Introductory pricing is $100 for this self-levelling unit.

By making use of this exciting new isotropic technology, there's no real reason why any consumer compass, nav, 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. Plus a lot of tech venture opportunities.

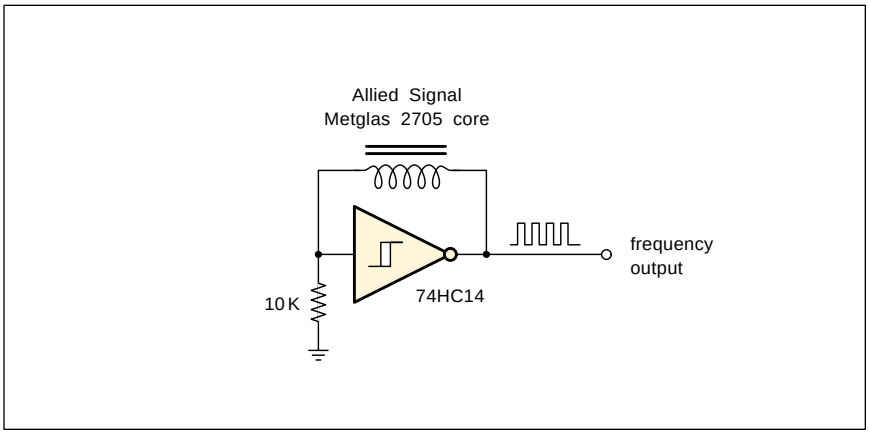

Fig. 4 – THIS ELEGANTLY SIMPLE earth's field detector using a special variable permeability cored coil. The output frequency varies with orientation.

Vacuum Forming

I just received some intriguing new *vacuum forming* info, so I thought this might make a useful sidebar.

As figure five shows us, vacuum forming is the process of bending a plastic sheet. The sheet is first heated to a carefully controlled temperature above its softening point. It is then draped over a male mold.

The mold could be made of wood or plaster or most anything rigid and capable of withstanding medium hot temperatures. The mold has zillions of tiny holes in it that are routed to a vacuum source.

A vacuum then gets applied which sucks your sheet down to conform with the mold shape. Two stages of vacuum will sometimes be applied. High volume to get rid of most of the trapped air. Then a high pressure to force an exact match to your mold. Finally, the part is cooled and taken out of the mold.

Important vacuum forming uses are signs, packaging materials, and theater props. But there should be all sorts of custom electronic enclosure

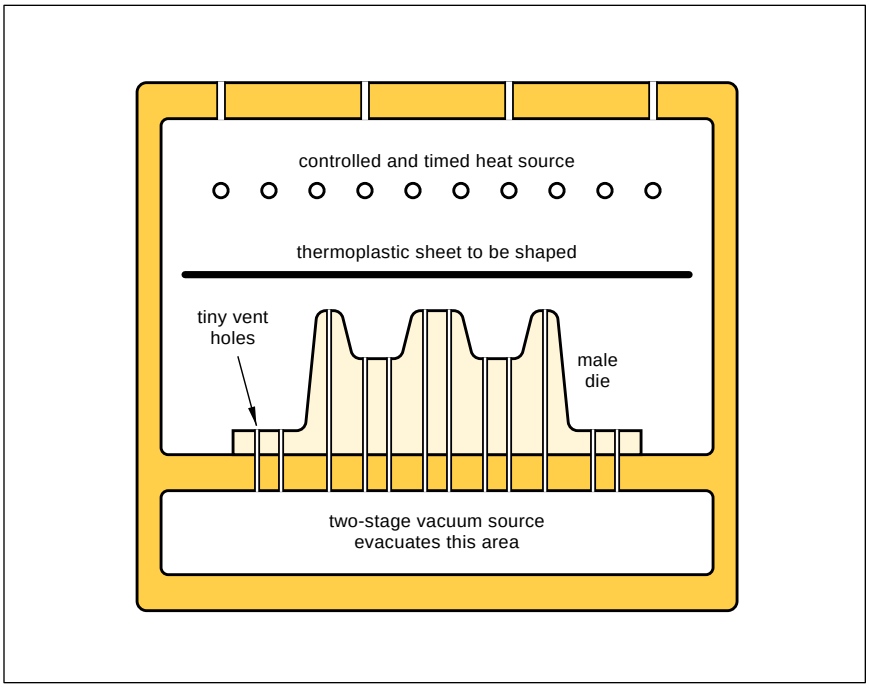

Fig. 5 – VACUUM FORMING is a process that first heats a plastic sheet and then draws it against a form. This low- to mid-quantity process is fairly cheap and low tech. Custom electronic enclosures are one app.

VACUUM FORMING RESOURCES

AIN Plastics
249 E Sandford Blvd
Mt Vernon NY 10550
(914) 668-6800

Bell Jar
35 Windsor Dr
Amherst NH 03031
(603) 429-0948

Betterway Books
1507 Dana Avenue
Cincinnati OH 45207
(800) 289-0963

Cinefex
Box 20027
Riverside CA 92516
(909) 781-1917

Delvies Plastics
133 W Haven Ave
Salt Lake City UT 84165
(800) 533-5843

IASCO
5724 W 36th St
Minneapolis MN 55416
(612) 920-7393

Industrial Education
1895 Crooks Rd #135
Troy MI 48084
(313) 649-4900

Lindsay Publications
PO Box 538
Bradley IL 60915
(815) 935-5353

Pitsco
1004 E Adams
Pittsburg KS 66762
(800) 835-0686

P-O-P & Sign Design
7400 Skokie Blvd
Skokie IL 60077
(708) 675-7400

School Shop
Box 8623
Ann Arbor MI 48107
(313) 769-1211

Sign Business
1008 Depot Hill Office Pk
Broomfield CO 80020
(303) 469-0424

SignCraft
PO Box 06031
Ft Myers FL 33906
(813) 939-4644

Southern Sign Supply
127 Roesler Rd
Glen Burnie MD 21060
(310) 768-8600

US Plastics
1390 Neubrecht Rd
Lima OH 45801
(800) 537-9724

Vacuum Form
272 Morganhill Drive
Lake Orion MI 48360
(810) 391-2974

possibilities as well. The process can be cheap and low tech. Especially when compared against an injection molding. You can easily build your own machines.

Vacuum forming obviously works best when there are no undercuts and when a whole lot of stretching is not needed. As the sheet stretches, it gets thinner. You can only go so far.

Let us start off with *The Molding and Casting Handbook* by Thurston James. This one is mostly on theatric props. This includes an outstanding chapter on how to build your own vacuum forming machine and then use it. From *Betterway Books*.

There is no real upper limit to vacuum forming sizes. Full four by eight plastic sheets can be formed if you need big results.

Other books on vacuum forming are sold by *Lindsay Publications*

A company called, of all things, *Vacuum Form* view themselves as the leaders in low cost vacuum forming. Prices on their *Hobby-Vac* series start at $99. They do cheat a little on this one, requiring your kitchen oven to presoften the plastic. And your shop vac for first stage vacuum. A small hand pump is provided for the final forming drawdown.

This one does sheets up to 6 x 9 inches and, amazingly, can handle up to a 3/16 inch thickness. Prices on their fancier commercial machines that include heaters and pumps start at $458. They also retail books and precut plastic sheets. But you can save a lot by cutting your own from full sized sheets.

Other sources of low end hobby and school vacuum formers include *Pitsco*, *Delvies*, and *IASCO*. Outfits who specialize in the school markets and who also offer reasonably priced injection molding and blow molding machines, molds, and materials.

Yes, anyone can buy from these low cost sources. They just happen to advertise mostly to the school shop market. Making them hard to find.

Two common plastics suitable for vacuum work are *Styrene* and *Vivak*. The latter is sometimes used for clear helicopter canopies. Rigid vinyl and acrylic also work fairly well.

Actually, most any thermoplastic will do just fine. So long as it has a reasonable softening temperature.

Friendly plastic suppliers include both *United States Plastics*, and *AIN Plastics*. Also check out the folks at *Southern Sign Supply*.

Useful magazines here are *School Shop*, *Signcraft*, *Sign Business*, *POP & Sign Design*, and *Cinefex*.

Bunches more content on amateur vacuum in general appears in Steve Hansen's *Bell Jar*. All your usual net search engines will give you dozens of effective hits on vacuum forming. And including a not-quite-so-useful hit on something that I've always suspected: *vacuum formed fruitcake*.

I've got hot links to these sites on my *www.tinaja.com* More on plastics in general can be located in my file RESBN50.PDF on the new *Resouce Bin* library shelf.

NEED HELP?

Phone or write all your US Tech Musings questions to:

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US email: *don@tinaja.com*
Web page: *www.tinaja.com*

New Tech Lit

From *Integrated Circuit Systems*, a superb data book on a mind-blowing collection of music synthesizer chips, video and audio circuits, multimedia, battery chargers, timers, and bunches more. From *Elantec* a *New Products Supplement* on fast video and comm chips. From *Fujitsu*, their *Wireless Communications Products* and *Power Management* data book.

A new book and video catalog on Santa Claus machines, on CAD/CAM and even on ingenious mechanisms from the *Society of Manufacturing Engineers*.

Outer Space Frequency Directory is mostly a detailed listing of NASA and the other satellite related comm channels. From *Tiare Pubs*.

Speaking of outer space, the fourth edition of that *International UFO Directory* by David Blevins is now available for $12.50.

NAMES AND NUMBERS

AlliedSignal
1090 S Milpitas Blvd
Milpitas CA 95035
(408) 946-2411

Elantec
1996 Tarob Ct
Milpitas CA 95035
(408) 945-1323

Epoxyworks
PO Box 908
Bay City MI 48707
(517) 684-7286

Fujitsu
3545 N First St
San Jose CA 95134
(800) 642-7616

IEEE Transactions
445 Hoes Ln
Piscataway NJ 08855
(908) 981-0060

Integrated Circuit Sys
PO Box 968
Valley Forge PA 19482
(610) 630-5300

Magnetic Research
122 Bellevue Ave
Butler NJ 07405
(201) 838-6348

Master Bond
154 Hobart St
Hackensack NJ 07601
(201) 343-8983

Phaedra Enterprises
PO Box 1241
San Bruno CA 94066
(415) 359-0432

Precision Navigation
1235 Pear Avenue Ste 111
Mountain View CA 94043
(415) 962-8777

Science First
95 Botsford Place
Buffalo NY 14216
(716) 874-0133

Society Mfg Engineers
One SME Drive Box 930
Dearborn MI 48121
(800) 733-4763

Synergetics
Box 809
Thatcher AZ 85552
(520) 428-4073

System Three Resins
PO Box 70436
Seattle WA 98107
(206) 782-7976

Tiare Publications
PO Box 493
Lake Geneva WI 53147
(800) 420-0579

West System
PO Box 908
Bay City MI 48707
(517) 684-7286

From *Phadera Enterprises*.

This text is sort of a combined *Michelen Guide* and *Thomas Registry* to a wild assortment of hundreds of organizations world wide. Uh, the quality and the annotation detail is a tad down from earlier editions, but the price is certainly right.

I really enjoy watching the UFO industry move from one happening to the next. The big trouble is that they never seem to build on anything. And hard evidence sure seems elusive.

Science First has a new catalog on Van De Graaf generators and similar low priced science demos. But their product that impresses me the most is their #40-500 *Roman Arch Kit*. A puzzle made of lightweight wooden kiddy blocks. Put them together just right without any glue or support and *you can stand on it*. Clearly carrying hundreds of times its own weight.

It's absolutely amazing what you can do when you apply modern solid state technology.

Additional fiberglass info: From *EpoxyWorks*, a *West Systems* booklet on building, restoration, and repairing with epoxy. *System Three Resins* offers a similar full resin products line. Plus support info.

For the fundamentals of starting up your own technical venture, be sure to check my *Incredible Secret Money Machine II* book. Available per my nearby *Synergetics* ad. I've also still got lots of surplus test equipment bargains. Especially mint Tek 1230 logic analyzers, a like-new TG-501 time mark generator, and bunches of bargain priced Heathkit test items. You can view this catalog online as SURPCAT01.PDF

As usual, most of the mentioned resources appear in those *Vacuum Forming* or in the *Names & Numbers* sidebars. Be sure to check here first before using my US tech helpline or visiting *www.tinaja.com* ✦