Don Lancaster's

Tech Musings

August, 1996

Post-it note opportunities
Earth's field magnetometry
An introduction to vectors
New fluxgate sensors and ic's
Measuring web site popularity

We do have a new magnetic sensor this month that sure appears reasonably priced and extremely easy to use. Especially for compass and nav apps. But first, I though we might go over a fundamental or two…

Vectors

A *scalar* quantity has *one* simple value. Such as three quarts of milk. Instead, a *vector* quantity relates *two or more* values. A car may travel at a scalar *speed* of 35 miles per hour. Or travel at a vector *velocity* of 35 miles per hour to the northwest.

As figure one shows us, any two dimensional vector can get shown as an arrow. The *length* of your arrow tells us how strong the vector is and the *direction* of the arrow can tell us exactly where it is heading.

If you plot any vector graphically, you have a choice of many different *coordinate systems*. The *rectangular* coordinate system will go "so many steps over" and "so many steps up" to define a vector.

For instance, in electronics you often will plot real power left to right and the reactive power up and down. Real power is power that is actually generated or consumed in resistors or generators. Reactive power is power that gets swapped back and forth as energy storage between inductors and capacitors in your circuit.

The convention is to put resistors to the right, inductors up, generators (or "negative resistors") left, and the capacitors down. "East" is defined as the zero axis, such as you'd get when routing current into a resistor.

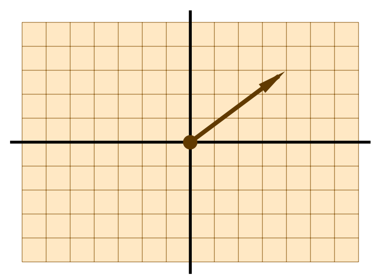
A *phase angle* is usually defined *counterclockwise* from 0 on up to 360 degrees. With zero degrees heading east. Some phase angles can also be separately defined as 0 to 90 degrees *lagging* as you go more inductive. Or as 0 to 90 degrees *leading* as you go more capacitive.

In other times and places, you pick other schemes for your rectangular coordinates. Most geographic maps place north as "up" or to your "top". And then express the *bearing* as so many degrees *clockwise*. Southwest is a bearing of 225 degrees. Needless to say, it is important to use the same origin, notation, and angle direction conventions as everyone else.

Sometimes it is best to use a vector as an arrow pointing in a direction. When you do this, you are said to be in *polar coordinates*. Possibly as an impedance of five Ohms at a phase angle of 53.13 degrees lagging. Other times, it is better to *resolve* a vector into its rectangular *component parts*. Perhaps as being four Ohms resistive and three Ohms inductive.

Simple high school trigonometry can get you between rectangular and polar coordinates. Say you have an electronic vector in polar coordinates that has a strength *r* and a direction of θ degrees. The resolved *x* and *y*

A vector can be shown in its **polar coordinate** form as an arrow. The length of the arrow *r* conveys the vector's **magnitude** and the positioning θ of the arrow will convey the vector's **direction**…



In this example, we have a vector that is five units long. Made up of whatever four blocks stand for on the horizontal *x* axis and whatever three blocks stand for on the vertical *y* axis. These blocks are in **rectangular coordinate** form.

If you are using "math" or "electronic" coordinates, real power relates along the *x* axis and reactive power along the *y* axis. The phase angles are measured **counterclockwise** from due **east**. In this case, we might be showing a 5 Ohm impedance with a 4 Ohm real component and a 3 Ohm reactive component. The phase angle of our vector is easily found to be 36.9 degrees.

On the other hand, if you are using "map" or "geographic" coordinates, north is to the top and east is to the right. Bearings will get measured **clockwise** from **north**. The bearing of the very same vector is now 53.1 degrees!

Thus, when in Rome… It is extremely important to use both the axis and the angle direction conventions that are consistent with the intended use.

If you are using electronic coordinates, these trig relationships get you from polar to rectangular coordinates and back again…

$$x = r\cos\theta$$

$$y = r\sin\theta$$

$$r = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1}(y/x)$$

Fig. 1 – A VECTOR GETS USED to represent a relationship between two or more independent quantities. Here's some of the fundamentals.

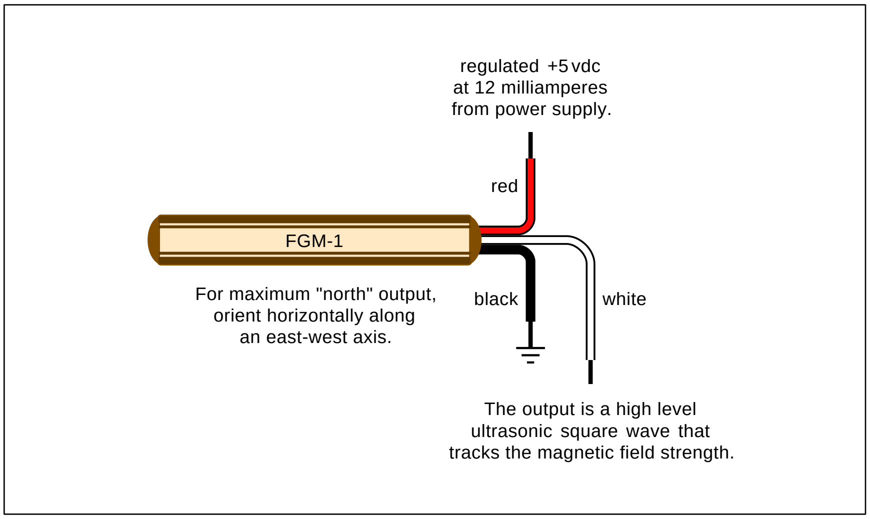


Fig. 2 – THE FGM-1 MAGNETIC FIELD SENSOR from Speake is extremely easy to interface to microcontrollers. Obvious uses include vehicle detectors, solid state compasses, navigation aides, and virtual reality apps.

rectangular components will be…

$$x = r\cos\theta$$
$$y = r\sin\theta$$

To get to polar from rectangular coordinates, just remember the indian chief who was running those fertility experiments: *The sum of the squaw on the hippopotamus hide equals the sum of the squaws on the other two hides*. Or, more conventionally…

$$r = \sqrt{x^2 + y^2}$$

And the phase angle

$$\theta = \tan^{-1}(y/x)$$

tan^{-1} is math shorthand for *arctan* or *"the tangent whose angle is"*.

Details end up somewhat different with geographic maps. You substitute *north* for your x component and *east* for the y component to get the correct bearing using the above equations.

Earth Field Magnetometry

Bunches of helpline calls lately on measuring the Earth's magnetic field. For the solid state compasses used in orienteering, surveying, or caving. For vehicle and robotics nav. For old archaeological mapping. For virtual reality headgear. Or for research into earthquake detection.

The earth is a giant magnet. Most likely created by its spinning liquid nickel iron core. At any point on the earth surface, you'll find a magnetic vector. A *three* dimensional vector having x, y and z components. The up and down part is known as *magnetic inclination* and can be measured with a *dipping needle*. Inclination varies with latitude. The inclination ends up as horizontal near the equator and as vertical near the poles.

The back and forth part is known as a *magnetic declination* and is what gets measured with a *compass*. The difference between where a compass points and where you are heading is called a *bearing*.

For accuracy, the declination and inclination *must* be kept separate. For reliable readings *a compass must be held absolutely level!* Some precision boat compass mountings are known as *binnacles*. They are either floated on some liquid or are gravity gimbal mounted to keep them level.

Note that a compass does *not* point true north. It points somewhere near true north to an eternally wandering *magnetic pole*.

Thus, it is *very* important for you to distinguish between *true north* and a *magnetic north*. Here in Arizona, your declination is some 13 degrees easterly. Which says that a compass points badly to the east of where it is supposed to. Premium compasses and survey gear will have a provision that lets you automatically subtract out this error. If you use this feature, be sure it is correct for where you are.

In Kansas, there is very little error between true north and a magnetic north. This is along *the line of zero declination*. But, when you are not in Kansas anymore, the rule is *the error points to Kansas*. In California, the compass points to the *right* of where you'd expect it to. In Vermont, it will point to the *left*.

Despite its humongous size, your earth's field at any locale is rather weak. One Gauss is the nominal field strength. At mid-latitudes, 0.6 Gauss is much more typical. An older field measure is the *gamma*. You will find 100,000 gammas in a Gauss.

It is extremely difficult to build an electronic solid state compass having an accuracy that is better than a few degrees. A minimum of twelve bits of resolution is an absolute must, but fourteen to sixteen bits are preferred. Temperature and calibration effects cut into this margin. A level scheme of one sort or another is manditory.

Also required is some method to compensate for nearby metal. Parts of an automobile exude *ten times* or higher fields than the one you want to measure. A well designed digital car compass offers some calibration procedure you have to go through.

Such as driving around the block exactly one time.

One classic paper on all this is called *Earth's Field Magnetometry* by W. F. Stuart. In the *Reports on Progress in Physics*, 1972, vol 35, on pages 803-881.

Some Approaches

The classic approach to a compass is to magnetize something and float it. Or mount it on leveled low friction bearings. It will continuously try to point to the north. Obvious problems here include damping, stiction, and vibration. Besides being real tricky to get a digital data conversion.

There are quite a few *Hall Effect* devices cheaply available. These are usually a transistor sized device that produces a digital or analog output when any magnet gets placed nearby. *Allegro* and *MicroSwitch* are typical sources. Unfortunately, today's Hall Effect devices aren't nearly sensitive enough for earth magnetometry uses. They will usually miss by a factor of *one hundred* or more.

You'll also find *magnetoresistor* components. Resistors whose value changes with magnetic field strength. Unfortunately, every magnetoresistor

I have seen has such incredibly bad habits as to make them *totally useless* for earth field magnetometry.

Today's magnetoresistors aren't all that accurate or linear, have a strong temperature dependence, need bias magnets, and offer poor cross-axis sensitivity. They also have the nasty habit of suddenly insiding themselves out without warning.

Literally flipping out.

A *proton precession magnetometer* is a bottle of pure water having a coil around it. The heavy current through the coil can suddenly cease, causing wobbling of certain spinning water molecules. This precession in turn can induce a noisy and sub-microvolt audio signal around 1500 Hertz back into the coil for a tiny fraction of a second. Accurately measuring this frequency indicates the strength of the magnetic field. Sensitivity can be exceptionally high.

The proton precession devices are scalar sensors which measure *only* a total field and *not* its direction. While powerful for archaeological mapping and oil exploration, there is no way to make a compass out of one.

Instead, the mainstream solid state compass sensor for years has been the *fluxgate*. A fluxgate is simply a lower cost *hard saturating* magnetic core with a drive winding and a pair of sense windings on it. Typically, a toroid will be used. A drive winding goes round and round the core as a normal toroid winding. These sense windings are often wound flat on the *outside* of the core. And are arranged precisely at 90 degrees to each other.

When *not* energized, a fluxgate's permeability "draws in" the earth's magnetic field. When energized, the core saturates and then ceases to be magnetic. As a switching occurs, the earth field is drawn into or released from the core. Resulting in a small induced voltage that is proportional to the strength and direction of the external field. This voltage pulse is often at the *second harmonic* of the drive waveform. Allowing for fairly simple signal extraction.

For more background on fluxgates, see *hack12.pdf* and *hack70.pdf* on *www.tinaja.com* A rather expensive ready-to-go source for these fluxgate compases is *KVH Industries*.

A well done *Review of Fluxgate Sensors* did appear in *Sensors and Actuators A*, volume 33 for 1992 on pages 129-141.

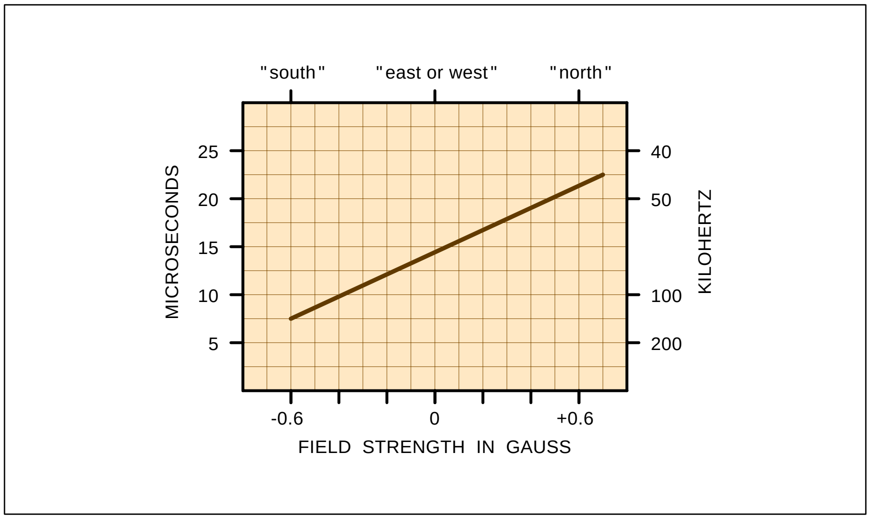


Fig. 3 – THE TIME PERIOD OF THE FGM-1 increases or decreases with changing magnetic field strength and polarity. The initial 6% linearity can be significantly improved by table lookup or by using field nulling techniques.

But your best starting point on all this is that *Magnetic Mesurements Handbook* by J. M. Janicke. Newly available from *Magnetic Research*. Included are full construction details on how to build up your own fluxgate magnetometer compass.

A New Fluxgate Sensor

Several new fluxgate variations have recently emerged. They still are driven and cored small coils, but are potentially a lot cheaper and allow

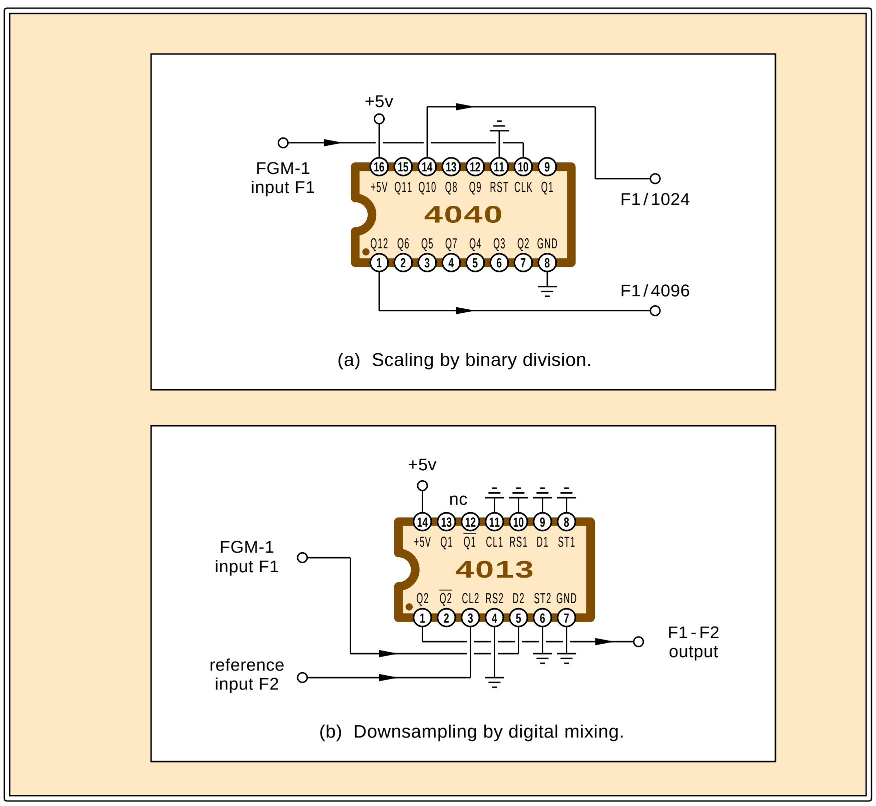


Fig. 4 – THE FGM-1's OUTPUT SIGNAL can be reduced in frequency for accurate conversions in certain low end microcomputers.

EARTH'S FIELD MAGNETOMETRY RESOURCES

Allegro Micro Systems Box 15036 Worcester MA 01605 (508) 853-5000	**GPS World** 859 Willamette St Eugene OR 97440 (503) 343-1200	**Magnetics Inc** Box 391 Butler PA 16003 (412) 282-8282	**Phillips Magnetics** 1033 Kings Highway Saugerties NY 12477 (914) 246-2811
F. W. Bell 6120 Hanging Moss Road Orlando FL 32807 (407) 678-6900	**Honeywell** 12001 State Hwy 55 Plymouth MN 55441 (800) 323-8295	**Measurement & Control** 2994 W Liberty Ave Pittsburgh PA 15216 (412) 343-9666	**Precision Navigation** 1235 Pear Avenue Ste 111 Mountain View CA 94043 (415) 962-8777
Dinsmore Instrument 1814 Remell St Flint MI 48503 (313) 744-1330	**ITS World** 859 Willamett Street Eugene OR 97401 (541) 343-1200	**Micro Switch** 11 W Spring St Freeport IL 61032 (815) 235-6600	**Sensors** 174 Concord St Peterborough NH 03458 (603) 924-9631
Fat Quarters Software 24774 shoshonee Drive Murrieta CA 92562 (909) 698-7950	**KVH Instruments** 110 Enterprise Center Middletown RI 02840 (401) 847-3327	**Natl Speleological Society** Cave Ave Huntsville AL 35810 (205) 852-1300	**TDK** 1600 Feehanville Dr Mount Prospect IL 60056 (708) 803-6100
Ferroxcube 2001 W Blue Heron Blvd Riviera Beach FL 33404 (407) 881-3200	**Magnetic Research** 122 Bellevue Ave Butler NJ 07405 (201) 838-6348	**Navtech Books & Software** 2775 S Quincy St #610 Arlington VA 22206 (800) NAV-0885	**Walker Scientific** Rockdale St Worcester MA 01606 (800) 962-4638

lower operating currents. The highest profile source for these new products has been *Precision Navigation*

There is an exciting new British magnetometer development from *SCL* called the *self-oscillating fluxgate*. And offered in the US by Erich Kern at *Fat Quarters Software*. The initial prices start around $35.

Figure two shows details on their FGM-3 sensor. You basically have a small cylinder into which you send a regulated +5 volts of dc and ground. Twelve mils total. And out of which you *directly* will get a high level and microcontroller friendly square wave. There's no low level analog circuitry and no signal conditioning involved!

The temperature variation and the cross-axis sensitivities are also low.

The square wave's *time period* is pretty much proportional to the field strength. As figure three shows us, the time period ranges from around 7 microseconds at -0.6 Gauss (south) to 14 microseconds at 0.0 Gauss (east or west) up to 25 microseconds at +0.6 Gauss (north).

The initial linearity is around five percent or so. But it can be corrected down into the 0.3 percent range. For fractional degree accuracy.

These time periods are a tad fast for certain older micros to accurately resolve. Figure four shows us two methods of making the outputs more micro friendly. A simple CMOS 4040 binary divider can be used to directly lower the output frequencies and thus lengthen the measurement period.

Or half of a CMOS 4013 D-flop can be used to serve as a digital mixer or downconverter. Downconverting can give you a greater difference between minimum and maximum values.

Do note that creative PIC machine language programming can eliminate the need for either of these circuits. By doing the same job in high speed internal firmware. Older micros may not be nearly so lucky.

To build a compass, you can place one FGM-3 on some spinnable level surface. Or you might use a pair of these at right angles to each other. There is also a new dual unit called the FGM-2. This one is disk shaped, being tad over an inch in diameter and a quarter inch thick.

The free *SCL* ap notes show you simple *octant* algorithms that get rid of any fancy math.

Specialized support chips are also available. Their SCL001 is for field nulling Gauss meters. The -002 is for vehicle detectors, and the -006A for single axis earth magnetometry.

The *Basic Stamp* or another PIC is your obvious choice for interface and display. Stay tuned for more.

NEED HELP?

Phone or write all your US Tech Musings questions to:

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(520) 428-4073

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

Magnetometry Resources

For this month's resource sidebar, I've gathered together a few places to go for more compass info. Let's see. *Dinsmore* is big on low cost and low resolution devices based on moving magnets and Hall sensors. *Honeywell* is into overpriced magnetoresistors.

Your useful tech journals include *Sensors*, *Measurement & Control*, the *ITS World* (*Integrated Transportion Systems*), or GPS World. Books on all this from the *Navtech Bookstore*.

I have also got some key nav and GPS web site links up for you on my *www.tinaja.com*.

Web Hits and Misses

You don't have to be on the web all that long to discover that *www* means *world wide wait* and *url* stands for *utterly rancid location*. You will also see lots of people ranting and raving over the number of *hits* their site gets. Just what is a hit?

Well, a *hit* is an obscenely bloated

NAMES AND NUMBERS

Andrews Decal
6559 N Avondale Avenue
Chicago IL 60631
(312) 775-1000

Bertonee
184 High Street 7th Fl
Boston MA 02110
(800) 510-5400

Clegg
19220 S Normandie Avenue
Torrance CA 90502
(310) 542-1600

Instant & SC Printer
425 Huehl Rd Bldg 11
Northbrook IL 60065
(708) 564-5940

National Semiconductor
2900 Semiconductor Rd
Santa Clara CA 95052
(800) 272-9959

Paper Plus
300 Oceangate #800
Long Beach CA 90802
(213) 436-8291

Pericom
2380 Bering Drive
San Jose CA 95131
(408) 435-0800

Philips Semiconductor
811 E Arques Avenue
Sunnyvale CA 94088
(800) 234-7381

Power Integrations
477 N Mathilda Avenue
Sunnyvale CA 94086
(408) 523-9265

Quick Printing
1680 SW Bayshore Blvd
Port St Lucie FL 34984
(407) 879-6666

Raychem
300 Constitution Drive
Menlo Park CA 94025
(800) 227-7040

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

3M
3M Center Bldg
St Paul MN 55144
(800) 826-4886

Velcro Systems
406 Brown Avenue
Manchester NH 03108
(603) 669-4892

WEB Trac/LDS
571 Central Avenue
Murray Hill NJ 07974
(800) ASK-LDSI

Web Master
492 Old Connecticut Path
Framingham MA 01701
(508) 872-0080

and utterly misleading measure of the supposed popularity of a web site. So much so that *hits are a totally useless index of your site's popularity!*

Unlike any book reader or a store customer, web site access gets done in bits and pieces. One web page or one file at a time. As these bits and pieces are sent, they get recorded in a pair of very important files.

Called the *log* file and the *error* file. Your access provider should tell you how to get at these crucial files. They are ordinary text files that can easily be copied to host.

Each access is noted as a one line record of characters in the log file. So is an access a hit?

Uh, not so fast.

Typical access to your home page probably also grabs some wallpaper, some buttons, and some fancy rules. Which *also* will go into your log file. Is this one hit or four? If the same visitor comes back in a few minutes, is this the same hit or a new one? Or a few hours? Or a few days?

What if the visitor is really some *spider* from a search service? Is this a hit? How many? What if you have no foreign sales or support. Do foreign hits count? What if someone takes one look at your home page and then quickly leaves?

These log files tell you about each visitor. Which pages he requested in what order. Plus how he left and any site bugs they discovered along the way. These mistakes are summarized in the separate error file.

Your simpliest and cheapest way to measure site "hits" is to note the *change of size* of your log file each day. Divide by 75 to get your total number of hits. The 75 comes about because there are around seventy-five characters in an average log line.

What if you want to know exactly how many left-handed Brazilian cat fanciers visit your site during 2 am on tuesdays? You can snoop around inside your log file to extract all this info. This is especially easy to hack using the general purpose PostScript computing language. Just write the file to your printer's hard disk. But any old data word processor or data base tool will work.

There are quite a few sources for *hit analysis* software. One shareware location is *www.lds.com* with their *Webtrac* product. This one generates all sorts of fancy printed reports and colorful graphs and charts.

Your best overall measure of the performance of your web site is how many people actually get far enough to fully download a lengthy file that you really want them to. Such as a catalog. Or hot new content.

All of which leads to an "exchange rate" between hits and useful visitors. One month a while back when it was just starting, my new *www.tinaja.com* received some 18,000 "any page" US hits. While actually sending out 285 catalogs. My web exchange rate here would appear to be around 63:1.

Which leads to this rule: To find your *useful* web site visitors, divide your total hits by *sixty*. Or your log file characters by *4500*.

Post-it Note Opportunities

Making up custom ink jet or laser printed Post-it notes are an obvious local service opportunity. For higher quantities, several sources advertise in *Quick Printing* and *Instant Printer* magazines. Doing your own notes have certainly been possible, but this has been rather labor intensive.

The usual do-it-yourself ploy is to make up a carrier sheet with marked rectangles on it, stick a blank note on each one, print your sheet, and then manually stack the results into pads. Or else play around post-applying a gentle spray-on adhesive.

3M has come up with an interesting alternative that greatly reduces your custom post-it note labor and hassle.

But at higher materials cost.

What they have done is taken *two* sheets of paper and applied magic glue in exactly the right places. They then stuck these two sheets together with *the glue on the inside*.

You'll then print *both* sides of the sheet in some eight-up note pattern. Next, you peel each sheet pair apart, flip the bottom sheet and restick them together. Which gives you a pad of 8-up note stock. Finally, you cut up the individual notepads using a paper cutter or shear.

Since it is much easier to fuss with one big sheet than eight little ones, the hassles are greatly reduced.

The 3M product is called *Post-it On-Demand Notepaper*. They should be available at *Paper Plus* and those other retail or direct mail chains.

Bunches of additional tech venture opportunities appear in my *Incredible Secret Money Machine II*.

New Tech Lit

From *National Semiconductor*, a whole slew of fat resources. Included are databooks on *Power IC's*, *Data Acquisition*, *Operational Amplifiers*, *Analog Products*, and on *Application Specific Analog*.

From *Philips Semiconductors*, a freebie *Car Radio Designer's Guide*. From *Raychem*, a *Circuit Protection Databook*. From *Pericom*, a new data book on high performance CMOS and BiCMOS integrated circuits.

Some free samples of line operated switchmode *TOPSwitch* circuits are obtainable from *Power Integrations*.

Along with ap notes.

Decal papers for your own custom decals are offered by *Andrews Decal*. Free samples of *One-Wrap Straps* are available from *Velcro Systems*.

An extensive line of very low cost sound systems for greeting cards and ad specialty items are made by *Clegg Industries*. Smaller replacements for neon animation transformers are now offered by *Bertonee*.

Webmaster is yet another of those brand new internet magazines.

For most individuals and smaller scale startups most of the time, any involvement with patents is virtually certain to end up as a *totally useless* waste of your time, energy, money, and sanity. Find out why in my *Case Against Patents* package. Along with tested and proven alternatives that work in the real world. Available per my nearby *Synergetics* ad.

A reminder that I've got a hot new web site up at *www.tinaja.com* Your quickest way to pick up my catalogs is as *syncat01.pdf* and *surpcat01.pdf* at this location.

Most of the mentioned items do appear in our *Names & Numbers* or *Earth Magnetometry* sidebars. Do be sure to check these first. As usual, a no-charge US technical helpline is available per the *Need Help* box.

Let's hear from you. ✦