Don Lancaster's

Hardware Hacker

Pulse monitor interface
New wireless comm mag
An update on free energy
Aerobic exercise software
Thermoelectric guidelines

September, 1993

An update to last month's free energy resource sidebar: The *International Association for New Science* newly released their 540 page proceedings from their latest *International Symposium on New Energy*. At $49.50.

Most of the major players show up here, along with bunches of historical references. All of the usual topics are covered – antigravity, Reed motors, pulsed magnetics, zero point scalar energy, homopolar generators, Tesla earth resonance, perpetual motion, and even cancer cures.

My own personal view is that this is one fascinating and wonderously bizarre work of fiction. I do feel that many of the papers presented exude a distinct aura of outright hogwash.

On the other hand, step number one in researching any controversial topic is to find out who is doing what to whom. Even a totally absurd and "not even wrong" notion can lead to genuinely innovative new concepts.

Thermoelectric review

There sure is a lot of interest in the solid state thermoelectric coolers now cropping up surplus. Sadly, most hackers don't pick up on the fact that there are several *very* rude surprises waiting when they try to use these.

So, one more time: These thermo modules are *extremely* inefficient and need *extremely* good heatsinks. They are strictly limited to very low power uses. They also *demand* heat flux calculations. For most uses most of the time, the *thermoelectric cooling modules simply do not work.*

Solid state thermoelectric modules using the *Peltier* cooling effect were developed over three decades ago and have not improved or changed one whit since. One current supplier seems to be *Melcor*.

Figure one shows a typical heat pumping curve for the larger twenty watt module. Applying a dc current across the device causes heat to be moved from one surface to another. This module might need fifteen volts at three amps for operation.

Note that the heat pumped depends inversely on your temperature drop across the device. Yes, you can pump twenty watts of heat through a *zero* temperature difference. Or you can pump zero watts of heat across a 50 degree temperature difference. With, of course, *zero* efficiency.

More typically, you'll want to both pump heat and have a high delta-T. A normal operating point might be a 25 degree drop when pumping 10 watts.

The module data sheets carefully bury their efficiency figures for most normal operating points. Often, *three* watts of energy are required to move one. For an EER *Energy Efficiency Rating* of a laughable 0.33. Compare this against an air conditioner having an EER of 15.

That low efficiency would not be all that bad if all of your excess heat was not generated in the wrong place at the wrong time. But what you have done when you use a TE module is *add* heat energy precisely where you are trying to eliminate it.

It is trivially easy to pick up more delta-T rise between your module hot side and ambient than the delta-T cooling the module is providing!

Let's use an aquarium cooler as an example. Now, there is another name for any large aquarium. It is called a *super efficient heatsink*. So, let's take our super efficient heatsink and then remove some heat from it. Because of that sad TE module inefficiency, we may have to add three new watts of heat for every one removed.

Naturally, we would not want the new heatsink to rise up as far above ambient as the aquarium goes below, or we will simply be heating up the ambient air. So, we'll shoot for an output temp rise of only a quarter the cooling drop.

Thus…

Your final heatsink will have to be 16 times better than your aquarium! A handy way to do this is to simply use a second aquarium which is 16 times larger in size.

The two key numbers you'll have to look for are your *watts of cooling required* and the *heatsink thermal impedance*. Going on back to square one, a *BTU*, or *British Thermal Unit* is the amount of energy needed to raise or lower the temperature of one pound of water by one degree F.

There are around eight pounds of water per gallon, so eight BTU's are needed to shift the temperature of a gallon of water by one degree F. A temperature change of one BTU per

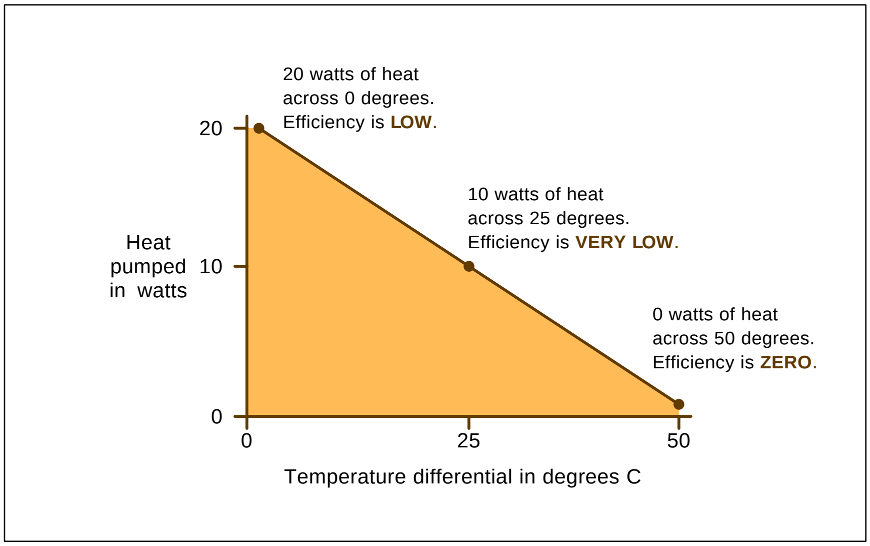

Fig. 1 – HEAT PUMPING CURVE for a larger thermoelectric module. Note that the efficiency goes down as the temperature differential increases.

1. The area to be cooled *must* be superinsulated. All avoidable sources of heat gain *must* be carefully excluded.
2. Realistic heat flux calculations and heatsink thermal impedance calculations *must* be carefully made ahead of time.
3. Current thermoelectric modules are an inappropriate solution if more than twelve watts of actual cooling are called for.
4. The rise of the module hot side temperature above ambient *must* be kept as low as possible. This rise must *never* exceed a small fraction of the total temperature drop desired.
5. Very large and extremely high quality heatsinking is a must. Use forced air cooling at the very least. Pumped water cooling may be required to achieve an acceptable efficiency.
6. Power sources *must* have very low ripple and hum, since the ripple peaks heat much worse than the troughs cool.
7. Surfaces contacting the module *must* be ultra-flat. 100% contact is essential. Thermal grease *must* always be used.

Fig. 2 – USE THESE GUIDELINES for all of your thermoelectric module designs. Otherwise, you are likely to end up heating instead of cooling!

minute mwill occur when 17.58 watts of power are input.

Heat flux ends up proportional to temperature difference. For a given heatsink, you'll get twice the delta-T for twice the watts passed through. Math similar to plain old Ohm's law defines the *thermal impedance*.

A typical ordinary heatsink might have a thermal impedance of between two and ten degrees C per watt. If the thermal impedance is five degrees per watt and if you are transferring eight watts, the thermal rise will be a total of forty degrees.

To get below one degree per watt, you usually have to go to forced air cooling. To get under half a degree per watt, a pumped water cooling is often the best choice.

The key problem with solid state thermoelectric coolers is that *the heat rise of your hot side of the TE module above ambient can easily exceed the net cooling of the module itself!*

Ferinstance, you might have your module doing a 30 degree cooling, but your heatsink hot side might have a 40 degree rise above ambient. For a net result of ten degrees of *heating*.

In the case of the aquarium, you can easily measure the heat flux. The results will depend on the surface area of the aquarium, the ambient air flow, the temperature drop required, and the amount of water present.

Temporarily remove the fish and fill the aquarium with ice water. But otherwise leave it run with the usual lights and pumps and whatever. Next, carefully measure your temperature *vs* time as the ice melts and slowly reaches room temperature. The *Radio Shack* #277-0123 digital thermometer is ideal for this.

Then plot your temperature rise versus time on a graph. Next, find the *slope* of the warming curve *at your target temperature*, in degrees per minute. To hold the target temp, the degrees per minute cooling you need should equal the degrees per minute warming taking place.

Multiply the pounds of water times the degrees per minute of cooling you will need to find the BTU's per minute required. Multiply again by 17.58 to get the cooling watts needed.

Finally, multiply by some fudge factor like 1.5 for a safety margin.

The chances are your final cooling power required will be *hundreds* of times higher than what can be done using TE modules.

I haven't actually run this warming test, but I'd guess that 300 watts of cooling would not be unreasonable for a larger aquarium.

And if you do burn up three watts of inefficiency for every single watt pumped, something like 1200 watts

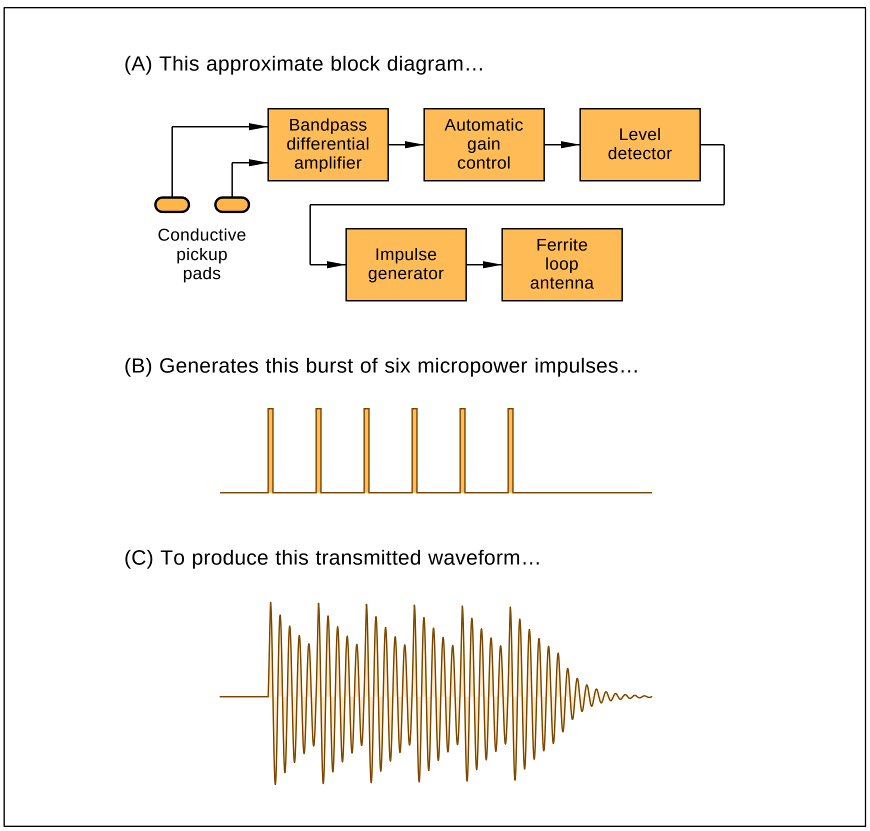

Fig. 3 – THE MYSTERY WAVEFORMS inside a typical "chest type" pulse monitor revealed. The transmitted signal approximates a 36 cycle burst of 5 kilohertz sinewaves. One burst per pulse event. What you really have here is plain old inductive coupling using an air core transformer.

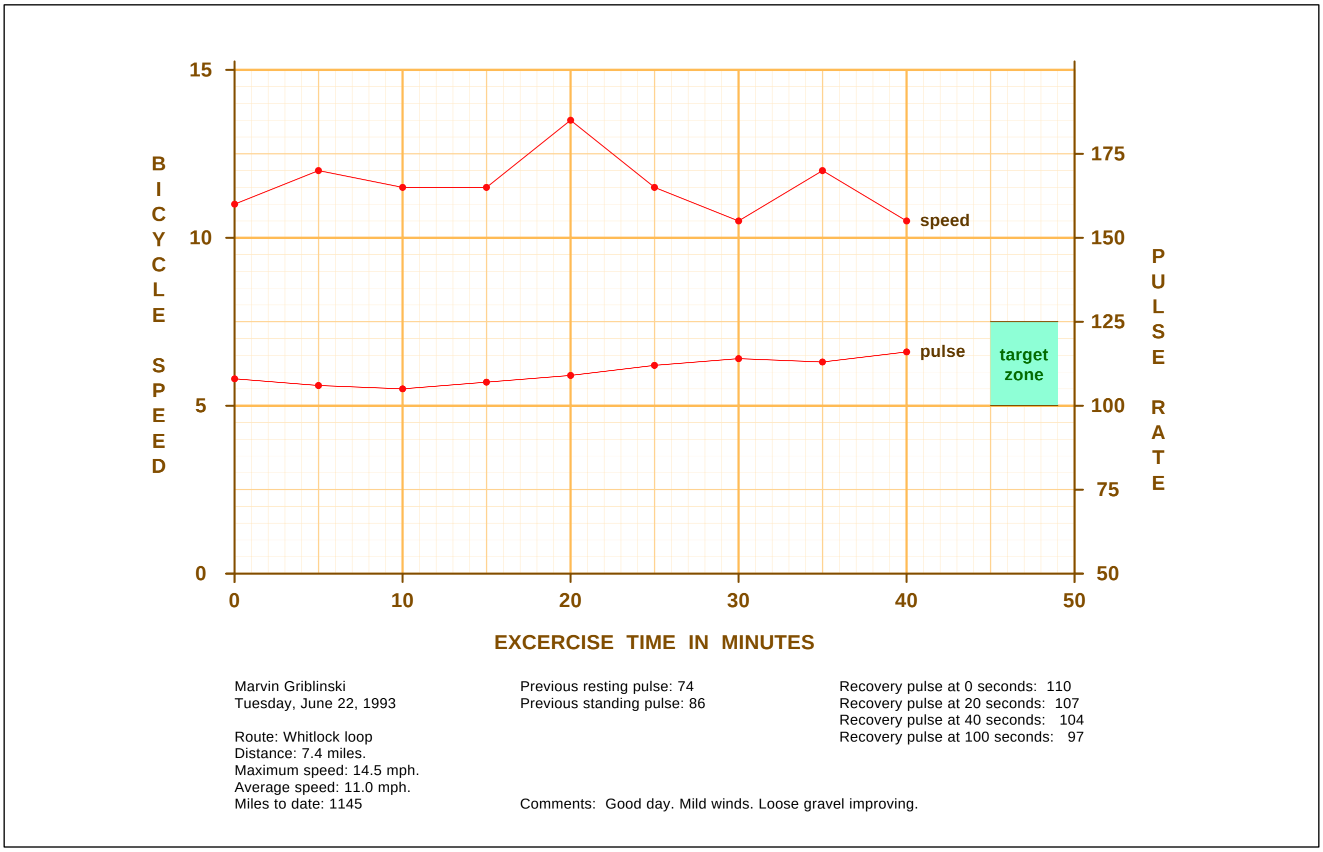

Fig. 4 – AEROBIC EXERCISE RECORD written in PostScript. Editible source code is in HACK68.PSL

of heat will have to go out through your heatsink. With a one watt per degree C rise heatsink, the module hot side temperature will try to go to 1200 degrees Farenheit.

Otherwise known as a fish fry.

Thirty of the twenty watt modules would be needed!

Do those new CPU thermoelectric coolers work? I'd be willing to bet that if you removed the cooler and coupled the heatsink directly to the CPU chip itself, the results would end up as good or better. Simply because you are not adding extra heat at a 3:1 premium where you don't want it.

A related story: Years ago there was this total federal solar fiasco involving a school in the rural south. This was to be a pilot demonstration project of a solar adsorption cycle cooler. Their results weren't quite as good as expected, so they added a new five ton evaporative cooler to the output to improve the heatsinking to ambient air.

Then someone asked this rather embarassing question: How much evaporative cooling would have been needed if the solar adsorbtion cooling was never in use at all? The answer?

Three tons!

Using TE modules for many hacker applications can end up the same as building a bonfire inside an icebox.

Are there any places at all where TE modules can be used? Certainly. *If* you have carefully made your heat flux measurements. And *if* you are only moving tiny amounts of heat out of a superinsulated region. And *if* you are dumping into a big heatsink with an unusually low delta-T.

You also have to use super smooth surfaces, proper thermal grease, and avoid *all* power supply ripple. The tiniest amount of ripple will foul things up because the ripple troughs heat six times better than the peaks will cool.

Naturally, trying to freeze ice will be beyond the pale.

Figure two shows some guidelines for proper use of TE modules.

These modules can be a sure fire winner for most science fairs, where you can easily feel all the heat going from your thumb to your finger. Even with a single alkaline or lithium "D" cell. They are also quite useful for chilled mirror dewpoint instruments. And handy in high vacuum aps where moving parts are a no-no.

TE modules are great for cooling microscope stages, special astronomy instruments, and infrared detectors. But the modules don't seem usable in satellite dishes because gain drops faster than noise figure improves.

What are the practical alternates to TE modules? Small compressors are not that big a deal. Obvious sources are drinking fountains, refrigerators, icemakers, and reworked auto air conditioners. One source of info on this is *HVAC Contractor*. A drinking fountain compressor will only need 60 watts of new energy to pump 300.

But the neatest substitutes for TE modules are called *vortex coolers*.

This second cousin to a perpetual motion machine seems to blatantly violate thermodynamic laws. They do not, of course.

A vortex cooler is simply a magic Tee-shaped pipe. No moving parts at all. You blow ordinary air into the

SOME PULSE MONITOR RESOURCES

ACT USA
Box 5490
Evanston, IL 60204
(708) 491-9628

Bicycling Magazine
33 East Minor Street
Emmaus, PA 18098
(215) 967-5171

Creative Health Prods
5148 Saddle Ridge Road
Plymouth, MI 48170
(800) 742-4478

Dialog
3460 Hillview Avenue
Palo Alto, CA 94304
(415) 858-2700

Medical Electronic Prods
2994 W Liberty Avenue
Pittsburgh, PA 15216
(412) 343-9666

Medical Equipment Designer
29100 Aurora Road #200
Solon, OH 44139
(216) 248-1125

Polar
99 Seaview Blvd
Port Washington, NY 11050
(516) 484-2400

Precise International
15 Corporate Drive
Orangeburg, NY 10969
(914) 365-3500

Pulse Stick II/Claggk Inc
PO Box 4099
Farmingdale, NY 11735
(516) 293-3751

RacerMate, Inc
3016 NE Blakeley Street
Seattle, WA 98105
(800) 522-3610

REI
1700 45th Street East
Sumner, WA 98352
(800) 426-4840

Synapse Enterprises
Box 35311
Canton, OH 44735
(216) 455-1162

Trek
801 W Madison Street
Waterloo, WI 53594
(800) 879-8735

Vetta/Orleander USA
14553 Delano St, Ste 210
Van Nuys, CA 91411
(818) 780-8808

middle, and hot air comes out one end and cold air out the other. Down to -40 Farenheit temperatures and tons of equivalent cooling.

Leading suppliers include *Vortec* and *Exair*. Some important uses are for electronic cooling and stopping needle breakage on industrial sewing machines.

Some pulse monitor discoveries

Warnings: Do not ever modify an EKG-type pulse monitor any way for any reason! Do not ever attempt to build up your own units of this type! What follows is not in any manner to be construed as medical advice.

I've been developing some aerobic exercise software for a client. Using PostScript, of course. Which I have found to be the greatest universal hacker's language anywhere ever. I have also been looking closely at the pulse monitors and have found some fascinating new electronic concepts that you might wish to expand upon one way or another. These concepts should apply beautifully to short haul telemetry apps. But *please* be careful to heed all of the above warnings.

One way to deal with exercise, of course, is to get yourself a corned beef and pork fat sandwich, add a helping of Eggs Benedict, and chow down until the urge goes away. There are others who do feel that sustained exercise programs provide positive benefits towards longevity, physical conditioning, well being, and for use as medical therapy.

The harder that you exercise, the higher your heart rate. An *aerobic* (or "with oxygen") exercise attempts to set up a *target zone* elevated pulse rate over a fairly long time period.

Say half an hour to an hour for cycling, group aerobics, swimming, jogging, or fast walking.

A conditioning target zone might be 60 to 75 percent of the maximum heart rate. This max rate in turn can depend upon sex, age, and upon the advice of your physician or aerobics instructor. Ferinstance a 30 year old male might have a target zone of 114 to 142 beats per minute.

That old "thumb and stopwatch" method of measuring pulse rate has some obvious problems. Not the least of which is that it woefully disrupts your program in progress. There are instead two popular new methods to measure pulse, the *plethsymograph*, and the *EKG sensor*.

The plethsymograph is based on finger or toe capillaries expanding and contracting with each pulse beat. Shine infrared light on through your finger, and its transmission will vary with your pulse. Opacity depends on how much blood is present. You can then amplify, condition, and digitally average these variations to extract the current pulse rate. Cheaply, simply, and totally noninvasive.

Infrared plethsymographs are easy to find, even as the $19.95 specials at K-mart. Unfortunately, many of these simply will not operate properly in aerobic exercise situations. The main problem involves *motion artifacts*. Any relative motion between sensor and finger will give false outputs and very erratic results.

Better yet, there are *EKG-style* or "chest type" monitors that directly measure the electrical activity of the heart. These usually are offered in two pieces, a small chest strap, and a stopwatch-type display that is either worn on your wrist or mounted on the bicycle or other exercise gear.

The cost of these systems is often in the $70 to $200 range. But they are totally free of motion artifacts. And you can *instantly* check your pulse at any time during the activity. Simply glance at your display. These also offer settable alarms that trip if you wander outside the target zone.

One typical unit is the *Edge Heart Rate Monitor* distributed by *Polar* and stocked by such yuppy outdoor stores as *REI*. I did try this one in combination with a *Trek* bicycling computer. A second brand is *Favor*. You could also get a combo monitor

NEED HELP?

Phone or write all your US Tech Musings questions to:

Don Lancaster
Synergetics
Box 809-EN
Thatcher, AZ, 85552
(520) 428-4073

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

NAMES AND NUMBERS

Antique Radio Labs
Rt 1, Box 41
Cutler, IN 46920
(317) 268-2214

Exair
1250 Century Circle North
Cincinnati, OH 45246
(513) 671-3322

HVAC Product News
1350 East Touhy Avenue
Des Plaines, IL 60018
(708) 635-8800

Intl Assn New Science
1304 S College Avenue
Fort Collins, CO 80524
(303) 482-3731

Melcor
1040 Spruce Street
Trenton, NJ 08648
(609) 393-4178

Mondo-tronics
524 San Anselmo #107
San Anselmo, CA 94960
(415) 455-9330

Oughtred Society
8338 Colombard Court
San Jose, CA 95135
(408) 238-8082

Resources UN-LTD
8030 South Willow Street
Manchester, NH 03103
(603) 668-2499

Synergetics
PO Box 809
Thatcher, AZ 85552
(602) 428-4073

TriQuint Semi
3625A SW Murray Blvd
Beaverton, OR 97005
(503) 644-3535

Vortex
10125 Carver Road
Cincinnati, OH 45242
(800) 441-7475

Wireless Design & Dev
Box 650
Morris Plains, NJ 07950
(201) 292-5100

and bike computer in one unit, such as the *Vetta* HR-1000 also offered by *REI*. At $95 list.

How do they work?

The chest unit is totally sealed and has an internal battery. In normal use, it gets replaced every year or two. The internal battery is purposely *not* replaceable to guarantee that the unit remains unmodifiable. There are extremely stringent regulations over anything electronic which directly attaches to your chest.

Obviously, the chest unit acts as a transmitter and the wrist unit serves as a receiver. The effective range is typically four feet or so.

But what gets transmitted how? The answer to this one is yet another stunningly beautiful example of our quest for elegant simplicity.

What we really have here is more short haul telemetry. But one that has to remain totally sealed, be compact and lightweight, reliably run forever under micropower, and literally be a throwaway item. At five bucks max manufacturing cost.

The secret is a plain old inductive coupling. Figure three shows the secret waveforms that are used. What you really have here is a 5 kilohertz air core transformer, with the primary in the chest unit and the secondary in the wrist or handlebar receiver. Each pulse gets converted into a 36 cycle burst of 5 kilohertz sinewaves.

You can very easily monitor these waveforms. Just take any old coil, such as the fifty foot roll of *Radio Shack* wire. Add an iron core, such as a screwdriver. Center the coil near the chest unit. Watch the results on your scope.

A pair of conductive pads pick up the EKG signals on either side. These microvolt-sized signals are strongly amplified in a bandpass amplifier. There is probably some type of AGC automatic gain loop to standardize the output levels. Then, a comparator of some sort derives a digital output for each pulse event.

Each pulse event then generates a series of six digital impulses. Each impulse is around 80 microseconds wide and has an interpulse spacing of one millisecond.

When very low power is your goal, you cannot use any kind of linear amp for your transmitter. Instead, the antenna is simply a five kiloHertz resonant coil. The plots found in my *Active Filter Cookbook* tell us the Q of this coil is around 20 or so.

To transmit a signal, the resonant antenna coil gets whapped *once every* *five cycles*. The high Q of the coil fills in during intermediate cycles. If you do look at your scope display very carefully, you will observe the modest exponential decay of all the intermediate cycles between impulse whappings. The long rundown time is also quite obvious.

The spacing of the impulses can be tightly controlled. Which elegantly minimizes any need for super precise or ultra stable antenna tuning.

Only the bandpass amplifier draws continuous current. Both *Maxim* and *Linear Technology* do make suitable amps that consume only microamps. In absence of any pulse input, there is no output and no transmitted signal sent. Even when a burst gets sent, the duty cycle to generate the burst is 10:1 and the duty cycle of the burst itself is typically 80:1 or so.

X-raying the unit revealed a few surprises. A large lithium coin cell is used. The antenna is a ferrite rod, long axis horizontal that is apparently tuned by unwrapping a few turns. It gets resonated by a polystyrene cap. A 14 pin chip drives the antenna. Probably a CMOS gate.

The majority of the input circuitry is built up from nine SOT transistors and 24 assorted resistors and caps. Special techniques are needed for noise rejection and ultra low power.

The receiver is just a resonant coil and a bandpass amplifier that inputs into typical micro current stopwatch circuitry. This amplifier apparently shuts itself down in the absence of any transmitted signals. The receiver battery can get replaced and lasts a year or so. An averaging algorithm is used to smooth out the results.

A sample printout for a routine exercise session is shown in figure four. The complete PostScript code to custom run these can be extracted from HACK68.PSL

You could build up an automatic data acquisition system to automate the whole process. But it is simpler and cheaper just to use a one-hand cassette recorder every five minutes and talk the speed and pulse rate to it. With practice, it takes less than two minutes to transfer the data.

I've gathered several places to go for more info on pulse monitors into our resource sidebar for this month. *Creative Health Products* offer a free comparison guide.

New tech lit

Up the Infinite Corridor is a new book on the history of engineering at *MIT* by Fred Hapgood. A really good read. Best is Fred's revival of a very old definition of engineering:

A sense for the fitness of things.

Lots of night vision electronics and surplus infrared viewers are sold by *Resources Unlimited*.

A new $9.95 book on the history of *Heathkit* from *Heath Nostalgia*.

Antique Radio Laboratories has a free catalog on all their products for radio restoration buffs. Included are pins, bases, and coil forms.

An *Oughtred Society* exists for the collectors of traditional slide rules and related calculating instruments. Named for the seventeenth century slide rule inventor. $20 for meetings and classified ads.

Motorless Motion is a project book from *Mondo-tronics* on working with the shape memory "muscle wires" for robotics and similar uses. Included are fifteen easy-to-build projects and layout templates.

From *TriQuint Semiconductor*, a new *Data Communication Products* data book. About microwave mixers, amplifiers, and converters.

Wireless Design & Development is a new trade journal on new products for the emerging personal microwave communication services.

As we've seen a number of times in past columns, any hardware hacker involvement with the patent system is virtually certain to end up a net loss of your time, energy, money, and sanity. Caused by the outrageous popular mythology which surrounds patents and patenting. A mythology that is almost always dead wrong.

I have put together my new *Case Against Patents* reprint package that includes several hundred pages of proven alternates to patenting. A big directory of hundreds of the inventor organizations is included. ✥