HARDWARE HACKER

Second law violations, soliton wave rectifiers, a fine new CD-ROM directory, a Santa Claus machine update, and some unusual hacker opportunities.

DON LANCASTER

I just got a call from a graduate student who is certain that second law of thermodynamics has been proven wrong and he wanted to know what should be done about it. He said something about statistical thermal gradients nailing *Maxwell's Demon* in a driveby shooting. Naturally, the effect is purely theoretical. It is "too small to measure in the lab."

The second law says heat always *tends* to flow from a hot to a cooler body, but it does not say that it is impossible for heat to flow from a cool to a hot body.

Actually, our helpline hears about three second-law violations or so per month. So let's go over the rules one more time: True, the second law of thermodynamics ("you cannot break even") has never been proven. Moreover, it probably is *not* provable.

On the other hand, and *without exception*, every attempt to find *any* counterexample that would prove it wrong has utterly and totally failed—at least on the normal everyday scale of things. Literally billions of tests are unintentionally rerun day in and day out that overwhelmingly suggest that the law really is true. Congress is not expected to repeal the second law of thermodynamics any time soon.

If the grad student is convinced he is right, he has two options: He can go the *real science* or the *pseudoscience* route. By going the real science route, he has to create a simple and easily duplicated experiment that proves the effect conclusively to disinterested third parties. It must be done so that his explanation for what is happening seems to be the most probable and the most reasonable.

The results *must* stand up. After the results are independently duplicated and verified, then his paper can be presented to a credible scientific journal for a peer review and publication.

By going the pseudoscience route, he can go to anyone in the pseudoscience industry press and get his paper instantly published. Or else he could pick slow news days in obscure rural newspapers for his coverage. Or he could go to even more obscure semi-scholarly foreign publications of questionable pedigree. But none of these alternate routes will look good on his resume.

I've just posted lots more information on exploring pseudoscience resources as NUTS26.PS on *GEnie* PSRT. Back to the real world...

Solitons

Outside of a classic ghost town in Colorado's San Juan Mountains, there is an old free-hanging mining cable. This beast is nearly a mile long and over an inch in diameter. It leads us to some utterly fascinating real-world and real-time physics. If you grab this cable near the low end and shake it once, you can watch a solitary wave running up, reflecting, and returning several seconds later.

What is really amazing is that the solitary return wave is so violent that it will try to rip your arm right off the cable. Something unusual appears to be happening.

A century ago, a mathematician decided that certain solitary waves can indeed be special. He was riding his horse along a canal bank and was daydreaming about waves. A barge suddenly stopped and then launched a solitary wave. He immediately noticed that this wave was unique in that it kept going much farther than ordinary waves. In fact, he followed the wave for miles. After some analysis, he called this special type of wave a *soliton*.

Today, solitons are an incredibly hot research topic. One application is in fiber-optic communications, where a soliton can go much further between repeating amplifiers. In fact, soliton fiber communication has been demonstrated over distances a third of the way around the earth with a 20-gigabyte data rate.

Why will any wave die out? There are three main reasons. First, the wave will *dissipate* when it does such things as flex a resisting cable or encounters air resistance. Dissipation ultimately transforms all of the wave energy into low-grade heat.

Second, portions of the wave will *reflect* whenever they encounter any changes in the media's impedance or uniformity. In the case of that San Juan cable, the end ring is something less than a perfect short circuit, so you don't get everything reflected back.

Finally, and most important for a soliton, the wave will *disperse* if the media lets higher frequency waves go by faster or slower than lower frequency ones. Usually, the wave energy "stretches out" over time.

Any waveform can be represented as a group of high-frequency and low-frequency components. If these ever get out of step, the wave shape will change drastically, as will its detectability.

A different name for one type of dispersion is *group delay distortion*. For instance, if the frequency for a one in a modem has more delay than the frequency for a zero, there might be a time when you get a one, a zero, *both*, or *neither* at the output. Obviously, "both" and "neither" are bad news when it comes to extracting useful information.

Figure 1 shows the essentials of solitons. An ordinary pulse that is sent through a dissipative media gets worse and harder to detect. A soliton that is sent through the

same media actually gets *better* and easier to detect. For the best results, the media has to be known, stable, and fixed in length. The soliton shape also has to be designed to match the media.

A soliton wave tries to *predistort* itself so that, by the time it is sent *through* the media to the intended receiver, the dispersion of the media and the "undispersion" of the initial waveform cancel out. The fast and later frequency components catch up with slow and early ones. The soliton wave in effect becomes self-reinforcing.

Bats and military radars depend on a more elaborate *chirp* scheme that works in more or less the same way as solitons. Send any swept FM signal through any media that has a linear delay versus frequency response, and you get a narrow and high-amplitude pulse out—Fourier transforms and all.

When you explore the literature, you will find 8,316 soliton papers on the *Dialog* information service alone! There are also dozens of textbooks available. Sadly, many are totally unreadable and involve horrendous math. I have posted a more or less random and rather short sampling of information sources in Fig. 2. These sources and their end bibliographies should be enough to get you started.

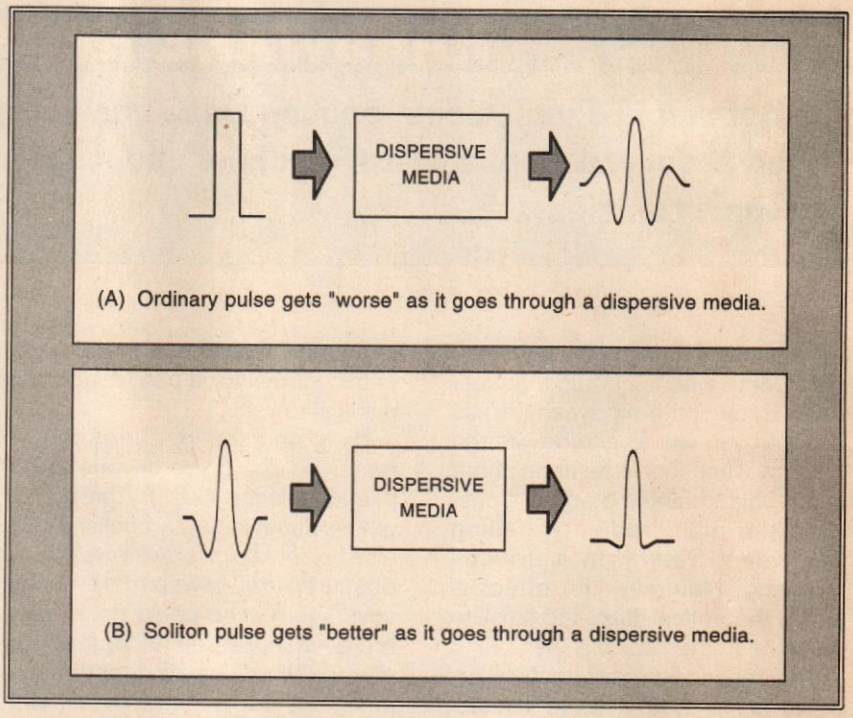


FIG. 1—SOLITONS are a special class of solitary waveforms that can travel much farther than ordinary waves. They are now a very hot research topic.

Let me know if you find any favorite soliton tutorials on your own that are easy to understand. An *Incredible Secret Money Machine II* book will be sent for your trouble.

What good are solitons for hardware hackers? Well, obviously, they are a great subject for science fair projects, student papers, or even thesis topics. But there's a possible new use for solitons that just about anybody can explore, and for which hands-on backyard testing is more important than fancy math. It is one use that is guaranteed to get your feet wet, and that might make you some big bucks.

Simply answer this question: "Can solitons improve fire streams?"

Between spelunking, *tinaja quests*, and pecan harvests, I am also a city fireman. The deck gun on a pumper has an effective fireground range of slightly over 200 feet. There are times and places when that range just isn't enough. The solitons should be able to extend this range significantly.

Ideally, all of the solitons should be generated through water pressure only, using some sort of bolt-on and pass-through flutterwumping adapter that is in series with the water supply.

But go ahead and use electronics or even high-pressure air to prove the idea works. Because of an exciting and an incredibly effective new foam firefighting technique, certain new pumpers now include a reliable compressed air supply.

Let me know what you can come up with here. Obviously, you can use an ordinary garden hose for all your initial tests. This subject appears to be an outstanding new hacker opportunity.

Santa Claus machines

The science fiction authors called them *Santa Claus machines*. These magic boxes could run off a copy of anything—a BMW, a pastrami on rye, a new girlfriend, or a duplicate $20 bill. It would start with either a sample or a set of software plans.

These days, crude approximations of the Santa Claus machine really do exist, and they are getting better every day. Today, these are often known as *desktop manufacturing* or else *rapid prototyping systems*. The pastrami on rye sandwich still leaves a distinctly acrylic after-

All-optical Waveguide Switching, Stegeman, G.I.& Wright, E.M. *Optical and Quantum Electronics* V22, no.2, p95-122 March 1990 (62 refs).

Darboux Transformations & Solitons, Matveev, V.B.; Salle, M.A., *Springer Series in Nonlinear Dynamics*, Springer-Verlag Press, 1991.

Dispersion and Nonlinear Effects in Optical Fibres, Ghatak, A. & Kumar, A., *Int. Jnl. of Optoelectronics*, V8, no.4, p299-318 July-Aug 1993 (44 refs).

Dynamical Chaos of Solitons, Spatschek, K.H., World Scientific, 1993.

Optical Solitons in Fibers, Hasegawa, A., Springer-Verlag, 1990.

Solitons and Chaos, Antoniou, I. & Lambert F., *Research Reports in Physics*, V16, Springer Verlag Press, 1991

Soliton-based Communication, Hasegawa, A., *Journal of the Institute of Television Engineers of Japan*, V47, no.8, 1088-96 Aug 1993 (23 refs).

Soliton Equations and Hamiltonian Systems, Dickey, L.A., World Scientific Publications, 1991.

Solitons in Molecular Systems, Daavydov, A.S., *Mathematics & Its Applications, Soviet Series* Kluwer Ac, 1990.

Solitons in Multidimensions, Konopelchenko, Boris G., World Scientific Publications, 1993.

Solitons, Nonlinear Evolution Equations & Inverse Scattering, Ablowitz, M.A & Clarkson, P.A. *London Mathematical Society Lecture Note Series*, #149 Cambridge University Press, 1992.

Soliton Phenomenology, Makhankov, Valdmir, G, *Mathematics & its Applications, Soviet Series*, Kluwer Ac, 1990.

Soliton Theory: A Survey of Results, Fordy, A. P. *Non-linear Science Series*, Wiley, 1992.

FIG. 2—SOME RECENT SOLITON REFERENCES. There are over 8000 more!

taste, but it definitely is low in fat and has zero cholesterol.

There are now a dozen approaches to Santa Claus machines, so I thought I would once again gather the names of several of the bigger players together into this month's resource sidebar. Most of the systems we'll look at are outrageously expensive—a house and two cars. But there is no reason why the whole kit and kaboodle of them can't be replaced with $175 worth of hacker parts, bunches of time, and a lot of imagination. Some of the major approaches to Santa Claus machines are shown in Figs. 3 and 4. Here's a brief rundown:

Direct toner method. This one is the cheapest, the most accessible, and the most hacker friendly. But it is pretty much restricted to two-dimensional work such as making instant printed circuits, front panels, or dialplates.

With this method, you laser print the toner image onto a transfer sheet. The transfer sheet is placed in contact with your printed circuit board or whatever. Heat and pressure is then applied. The toner transfers to the board and becomes the etch resist or the image.

The two leading suppliers of direct-toner materials are *DynaArt Designs* and *Techniks*, with the printed circuit supplies sold by *Kepro*.

CAD/CAM. This method has been around for a while. It works like an ordinary lathe or milling machine, machining materials to leave the desired object. The difference is software control. The machine is fed a set of plans in software form and it does the rest by itself. Low-end machines have only started to appear here. Although much lower in cost than old "industrial strength" machinery, they still remain obscenely overpriced for most hacker uses.

Typical low-end CAD/CAM suppliers include *Roland*, *Techno Isel*, and *Light Machines*. Other vendors advertise in such places as the *School Shop* and *Industrial Education* trade journals.

Custom CAD/CAM bits and pieces are available at *Stock Drive Products*. Two other material

sources are *MSC Specialties* and *McMaster-Carr*. *John Rees* offers a hacker version here that lets you use ordinary car alternators as power stepper motors.

A CAD/CAM prototyping system can be used with a machineable wax instead of metal or plastic. The wax can then become a pattern or a mold for your final product. This is easier on tools, and mistakes can be recycled. Wax is also a good material for practice. One source of machinable wax is *Freeman Supply*, while *Kindt-Collins* provides a wide range of industrial and artist waxes.

Laser Blasting. The medium power laser is one variation on CAD/CAM that is revolutionizing crafts, model making, and smaller part manufacturing. Parts are cut quickly, accurately, and splinter free. A 20-watt carbon-dioxide laser could be used for such tasks as the precision cutting of doll-house furniture or slicing up parts for model railroad structures. More information on power laser systems appears in *Industrial Laser Review*, while two hacker-friendly sources for lasers are *Meredith* and MWK.

Water Knives. Here an ultra high pressure water stream does all the cutting. My favorite demonstration is one of these chopping up a gooey piece of chocolate cake *and* a four-inch thick steel slab at the same time. *Flow International* is one source of equipment. *Haskell* makes the special pumps.

Stereolithography. The pioneer here is a company called *3D Systems*. With stereolithography, a vat of a liquid photopolymer is hardened one layer at a time by a scanning laser. The laser is lowered slightly as each new layer is finished so that the next layer can be hardened. The process is repeated until the part is completed. Virtually any shape can be made, including ones that are difficult to machine.

The photopolymers aren't all that different from the ones used in flexographic printing and rubber stamps. Two suppliers are *Merigraph* and *Grantham Polly-Stamp*.

Selective Laser Sintering. This is a rapid prototyping method that starts with a fine powder of wax, plastic, or even certain metals.

NAMES AND NUMBERS

Aero/Skyways
15 Crescent Road
Poughkeepsie, NY 12601
(914) 473-3679

Buddy Products
117-A Commercial Drive
Thomasville, GA 31792
(912) 225-9758

Burman Industries
1441 Covello Street, Ste 6A
Van Nuys, CA 91405
(818) 782-9833

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

First Light Video Publishing
8536 Venice Blvd
Los Angeles, CA 90034
(800) 777-1576

Fluorescent Mineral Society
PO Box 2694
Sepulveda, CA 91343
(818) 786-4885

GEnie
401 N Washington St
Rockville, MD 20850
(800) 638-9636

The Calculator Collector
Intl Assn Calculator Collectors
10445 Victoria Avenue
Riverside, CA 92503

Morph's Digital Outpost
PO Box 578
Orinda, CA 94563
(510) 238-4545

Polytek Development
PO Box 384
Lebanon, NJ 08833
(908) 534-5990

Save the Planet Software
Box 45
Pitkin, CO 81241
(303) 641-5035

Sony Semiconductor
10833 Valley View Street
Cypress, CA 90630
(800) 288-SONY

Telecom Library
12 West 21st Street
New York, NY 10010
(800) LIBRARY

The laser selectively melts and bonds portions together in a thin layer by *sintering*. (Sintering is melting things just enough so that they stick together.) Then the part is lowered, more powder is leveled, and a second layer is imaged, building up the desired prototype.

The final objects are often sturdy enough for use as actual production parts. Unlike stereolithography, the materials used are low-cost and non-hazardous. The laser is also cheaper because it emits infrared rather than ultraviolet light. *DTM Corp* in Austin seems to be the champion of selective laser sintering.

Cubital Toner Imaging. This method is related to the direct-toner method. An *unfused* toner laser image is contact-printed onto a photopolymer. After the uncovered photopolymer is hardened by exposure to ultraviolet light, the unhardened photopolymer is sucked up and recycled, as is the toner image. Voids are then replaced with a wax filling.

The surface is carefully milled flat and another layer is created. Unlike stereolithography, an entire layer rather than a single spot is formed at one time. Cubital toner imaging also requires far less photopolymer, since only a thin layer is used. First developed in Israel, one source is *Cubital America* and one service bureau is *Stature Machining Technologies*.

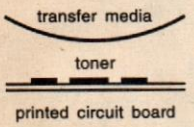
Sticky Strings This approach seems well suited for forming such hollow objects as shampoo bottles or similar packaging containers. The correct name for the process is *fused deposition modeling*, and *Stratasys* is its main source.

In use, a large reel of thermoplastic rod is unwound along a path. The rod is deposited at a temperature just hot enough so that the outside is liquid, causing it to stick to the previous layer of the pattern.

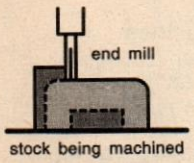
The results look sort of like corduroy, but you could trade off wire diameter against smoothness. A final polish or filler or solvent spray can improve the surface finish.

It appears to me that a hacker might easily fake this with a hot glue gun by substituting polyethylene for the glue sticks. One obvious use is custom cast house number or name plates.

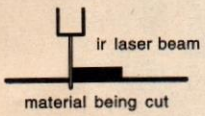
Laminated Paper Shims. This method works just like the contour lines on a topographical map. It is also known as *laminated object*



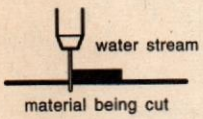
DIRECT TONER METHOD uses heat and pressure to transfer toner to a flat substrate for pc board etching or dialplate artwork.



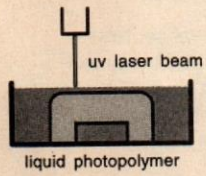
CAD/CAM METHOD uses a programmable lathe or milling machine to remove scrap from around the prototype object.



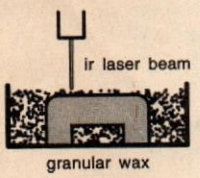
LASER BLASTING METHOD uses a medium to high power laser to physically cut out the parts to their desired shapes.



WATER KNIFE METHOD uses an ultra high pressure water stream to cleanly and quickly slice materials such as food or fabrics.



STEREOLITHOGRAPHY METHOD uses an ultra violet laser to selectively harden certain areas out of a liquid photopolymer.



LASER SINTERING METHOD will use an infrared laser to selectively bond certain wax, plastic, or metal granules.

FIG. 3—SOME CURRENT APPROACHES to Santa Claus machines.

manufacturing. At the present chosen elevation, a piece of adhesive-coated paper of the desired thickness is cut out with a laser.

The latest piece is then carefully aligned to the previous sheet and is then heat-set. This process repeats often enough to build up the desired part. A final surface coating can eliminate the individual steps.

Materials costs are exceptionally low, and only a low-power laser is needed. This method is particularly good for sand casting. One supplier of these systems is *Helisys*.

Ceramic Shell Casting. Originally developed at MIT, *Soligen* is now the leading proponent of this method. A thin layer of ceramic powder is put down, and a scanning head with one or more inkjets passes over the powder, selectively applying a binder.

The part is lowered and the process is repeated, causing layer upon layer of binder to build up in the desired shape. The final shell can be directly used for the high-temperature casting of chrome alloys, aluminum, and even nickel. Hollow items can be made by building up integral cores.

Wax Vacuuming This is a new hacker concept that just might revolutionize jewelry and small art object creation. Picture a hypodermic-like

needle that has a hot tip that can be moved along five or six mechanical axes.

The needle works its way around a block of wax, first melting and then vacuuming the molten wax away from the pattern. Curved needles can form the internal details or hard to access points. The intended use is for casting such things as class rings, and silver ornaments. *John Rees* is one source.

By the way, anytime you are using both X and Y motions, it pays to split up the problem. Move your tool in the X direction and your workpiece in the Y direction. This can convert a thorny two-dimensional problem into simpler one-dimensional ones.

For more information, a pricey industry newsletter called the *Rapid Prototyping Report* is available. *Batelle* does fancy research on rapid prototyping. Many ongoing Santa Claus machine developments are likely to appear in the *Machine Design* and *Design News* magazines.

New tech lit

Morph's Outpost on the Digital Frontier is a unique new multimedia magazine in newspaper format. It offers the latest inside scoop on multimedia developer happenings.

Two other unusual magazines are *Skyways* and *WWI Aero* for those of you interested in early aviation.

From *Sony*, there's a new *Computer Audio & Video Multimedia* data book.

A *CD-ROM Selector* from *Save the Planet Software* is a well researched directory of 1600+ CD-ROM titles.

Laser Buddy Document Spray by *Buddy Products* offers Bakerizing in a can. You can spray this stuff on any laser-printed output and it will get blacker, smoother, and more durable. The resolution appears to improve and text becomes slightly bolder.

The spray is mostly methylene chloride, acetone, and some isobutyl acetate. It works like a champ. But use this spray outdoors only and watch out for fingerprints. No, it won't help direct-toner printed-circuit transfers much because of the residues it leaves.

The *Calculator Collector* is a new labor-of-love newsletter published by the *International Association of Calculator Collectors*.

Lots of telecommunications books are offered by the *Telecom Library*. Some useful multimedia videotapes are sold by *First Light Video*.

The *Fluorescent Mineral Society* looks at rocks in the dark.

A fine catalog on moldmaking and casting materials is available from *Polytek Development*. A similar new catalog is available from *Burman Industries*, another special effects supplier.

NEED HELP?

Phone or write your **Hardware Hacker** questions to:

Don Lancaster
Synergetics
Box 809-EN
Thatcher, AZ, 85552

(602) 428-4073

For fast **PSRT** access, modem (800) 638-8369, then an HHH. Then a JOINGENIE,DMD524.

Internet email access link:
SYNERGETICS@GENIE.GEIS.COM

SANTA CLAUS MACHINE RESOURCES

Cubital America
1307F Allen Drive
Troy, MI 48083
(313) 585-7880

DTM Corp
1611 Headway Circle, Bldg 2
Austin, TX 78754
(512) 339-2922

DynaArt Designs
3535 Stillmeadow Lane
Lancaster, CA 93536
(805) 943-4746

Grantham Polly-Stamp
418 Central Avenue NE
E Grand Forks, MI 56721
(218) 773-0331

Helisys
2750 Oregon Ct Bldg M-10
Torrance, CA 90503
(310) 782-1949

Kepro
630 Axminister Drive
Fenton, MO 63026
(800) 325-3878

Light Machines
669 E Industrial Drive
Manchester, NH 03103
(603) 625-8600

McMaster-Carr
Box 54960
Los Angeles, CA 90054
(213) 692-5911

Meredith Industries
5035 N 55th Ave Ste 5
Glendale, AZ 85301
(602) 934-9387

Merigraph
Box 3064
Naperville, IL 60566
(800) 323-1832

MSC Specialties
6700 Discovery Blvd
Mableton, Ga 30059
(800) 645-7270

MWK Industries
1440 S State College Blvd 3B
Anaheim, CA 92806
(800) 356-7714

Rapid Prototyping Report
841 Turquoise Street, Ste D
San Diego, CA 92109
(619) 488-0533

John Rees
Route 1 Box 1551
Sautee, GA 30571
(706) 865-5495

Roland Digital
7200 Dominion Circle
Los Angeles, CA 90040
(213) 685-5141

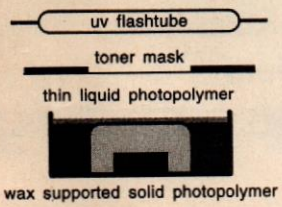
Soligen
19408 Londelius Street
Northridge, CA 91324
(818) 718-1221

Stock Drive/Techno
2101 Jericho Turnpike
New Hyde Park, NY 11042
(516) 328-0200

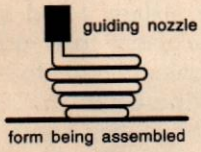
Stratasys
14950 Martin Drive
Eden Prairie, MN 55344
(612) 937-3000

Techniks
45 J Ringo Road
Ringoes, NJ 08551
(908) 788-8249

3D Systems
26081 Avenue Hall
Valencia, CA 91355
(805) 295-5600

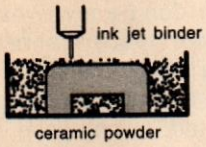


CUBITAL TONER METHOD transfers toner images a layer at a time to a wax supported and flat milled liquid photopolymer.

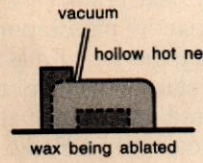


STICKY STRING METHOD uses a heated roll of plastic rod to bond to previous layers for bottles and hollow objects.

SHIM LAMINATING METHOD uses laser cut thin sheets of heat bonded paper to build up a composite object with low materials cost.



CERAMIC SHELL METHOD can selectively form ceramic powders by using an inkjet to apply suitable binding agents.



HOT WAX VACUUM METHOD uses a fine heated needle to remove unwanted portions of a wax block, leaving a pattern.

FIG. 4—ADDITIONAL APPROACHES to Santa Claus machines.

I've managed to get a great *GEnie* deal specially for all you Hardware Hackers. Ten free hours with no first-month minimum. Just use the new JOINGENIE,DMD524 password that is shown in the *Need Help* box.

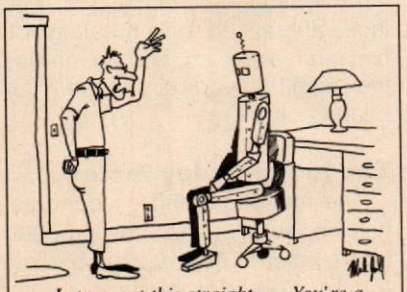
Be sure to type that HHH *quickly* after your communication program shows a connect. That is how GEnie figures out your computer's baud rate and format.

You'll find reprints of most of my previous columns and bunches of other unique stuff on Genie's PSRT Roundtable. But be sure to check out its RADIO, IBM, MAC, A2PRO, and DTP Roundtables as well. Look at the stock quotes on page 270 and the free DIALOG training area.

New graphic Mac and PC interfaces are finally on Genie.

I've also got a brand new catalog with a greatly expanded insider secret section in it. Write, call, or send E-mail to me for a free copy. You might also send me technical questions, new catalog requests, and orders to SYNERGETICS on GEnie or SYNERGETICS@GENIE.GEIS.COM via the Internet.

Most items mentioned are found in the *Names & Numbers* or *Santa Claus Machine* sidebars. Be sure to check those first before calling our no-charge technical helpline. Ω



Let me get this straight . . .You're a woman trapped in a robot's body.

EQUIPMENT REPORTS

continued from page 20

decimal point is determined by the selected range. The LED display will flash when an overrange condition is encountered. If an illegal combination of front-panel switches is selected (for example, if DC volts and the 20-megohm range are selected at the same time), all of the decimal points will light.

The unit is said to be maintain its accuracy for at least a year. After that time, it should be calibrated. That one-year period also matches the limit of the manufacturer's warranty on the BDM40.

The Wavetek BDM40 doesn't contain many "bells and whistles." Rather, it has a straightforward design that makes it right at home on a professional test bench. For reliable voltage, current, and resistance measurements, the BDM40 shines through with its ease of use, highly visible 4½-digit LED display, and wide operating ranges. Ω