GET A FREE PC! *Details Inside*

NOVEMBER 1999

Popular Electronics®

Solid-State Tesla Coil

Wield the power of lightning with a modern design that would make Nikola proud

Nikola Tesla Scientific Savant

A look at the life and accomplishments of a true innovator

Gizmo®

Getting HDTV Now
A Powerful HPC
Gear and Games for Kids
And much more

Also Inside:

- Easy Home Networking
- Laser-Diode Holography, Part 2
- Neon-Lamp Circuits
- Finding Robot Parts

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Popular Electronics®

THE MAGAZINE FOR THE ELECTRONICS ACTIVIST!

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Editorial

Portrait of a Genius

Countless scientific and electrical experimenters have held his name in reverence for almost a century. His achievements have filled volumes and generated more than a few legends. Yet strangely, there are far too many people today unaware of who Nikola Tesla was.

While we here at **Popular Electronics** tend to reach mostly "in-the-know" individuals, we thought that it was about time to offer a Tesla refresher to anyone who comes across our pages. As hobbyists, we owe a lot to the pioneering and investigative spirit he possessed.

Hence, this special issue. Now, being a hands-on magazine, we knew we had to present our look at the man and his work in an experiential way. Rather than just present a standalone feature on Tesla's life, we decided to accompany a bit of biography with a modern version of one of the innovator's most famous devices: the Tesla coil.

And what a coil! Our solid-state version is large and powerful enough to please the most serious tinkerer. As impressive as its performance may be, though, it shouldn't prove difficult for even a casual builder to put together. We've loaded the story with diagrams and details to guide you through each phase of assembly. You'll learn a lot about high-frequency, high-voltage circuitry as you go along, and will marvel at the coil's sparks when you're done. Turn to page 31 to get started.

Then comes our in-depth bio: "Nikola Tesla: Scientific Savant." In it, you'll learn about the struggling days of a genius, his rise to fame, and his unfortunate days of financial difficulty. Some of the names associated with Tesla—historical figures he became involved with—may surprise you. And if you're not familiar with his work, the identity of some of his inventions may shock you (no pun intended). The story begins on page 40.

We hope you enjoy this special issue. Our aim has always been to encourage the type of hands-on participation in technology to which Tesla devoted his life. As we prepare to leave the century in which he had his impact, perhaps one of our readers will bring a new era of innovation to the world of electronics. And we've got some surprises planned that might help you be just that individual. We can't give away any details yet, but do look for some big expansions in the content you find here. Our first 21st century issue is about 60 days away. Wouldn't we be remiss to not mark it with a bang?

Konstantinos Karagiannis
Editor

KONSTANTINOS KARAGIANNIS

FREE PCs FROM ISPs

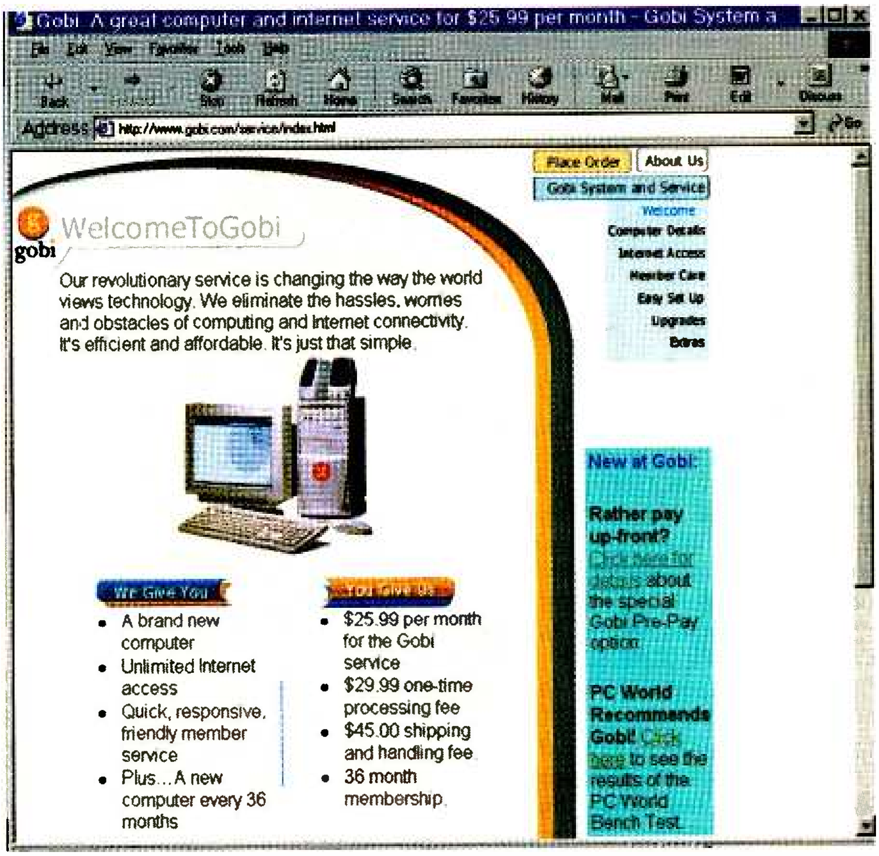
We've covered free software, free e-mail, and free Web access—offerings that have generated a lot of reader interest. Why is obvious: everyone loves a freebie, right?

But now some companies are taking it to the next level with an offer that sounds too good to be true. How does a free computer sound?

If you weren't curious about the catches involved in the previous offers, you got to think there's something to this one. And there are "catches" to the free computer deals, though ones that many people will be able to live with.

These systems are being offered by Internet Service Providers (ISPs). Both of the providers we look at this month of course charge a monthly fee for Internet access, and these fees are often higher than those of standard ISPs. Of course, standard ISPs don't set you up with a machine to access the Net, either.

So read on, and learn about all the factors you'll have to consider. How "free" is free?



For just a few bucks more a month than you'd pay with a typical ISP, Gobi provides you with a brand-new 333-MHz Celeron computer.

GOBI

Would you pay about six bucks extra a month for Internet service if it got you a free PC? Gobi, Inc. is banking that you and many others would. For $25.99 a month, you can get unlimited Web and e-mail access, as well as a brand new 333-MHz computer with an Intel Celeron processor (basically a Pentium II with 128K of L2 cache instead of 512K). The computer has 32MB of 100-MHz RAM, a 3.2GB hard drive, a 40X CD-ROM, and a 15-inch monitor. This is about as entry level as machines come, but hey, it's free. Well, almost.

To get going with Gobi, you'll need to pay a $29.99 processing fee, $45 shipping and handling fee, and your first month's service (again, $25.99). That comes to $100.98, to the penny, up front. Add in your monthly fee, which you're committed to for 36 months, and your total comes to $1010.63, or about $290 more than you'd pay for 36 months of just Internet service with another provider. Now, were you to spend about $600 up front, you could get a slightly better computer from a computer-chain store and have your choice of provider, but for those who can't spend any more than a C note up front, Gobi's offer is pretty attractive.

Best of all, you can renew your contract after 36 months and get a new PC (probably for a similar shipping fee). Gobi will ask you to donate the old PC at this time to a specific charity, or else you'll be charged $50 to keep it.

The service you get from Gobi is not the same as a typical ISP. Yes, you'll get on the Web, and do so at 56 Kbps, but your e-mail will be linked to the Web. In other words, Gobi's e-mail access is similar to any of the free Web-based ones you might have come across, like Hotmail for instance. However, you won't have to put up with any popup ads that won't go away, so your Web experience will be somewhat similar to those using a standard ISP. That's a plus.

Gobi's service covers a good portion of the country, but you might want to check with your local phone company to find out if the closest dial-up number (listed on the Web site) is actually a local call. The one near our offices was, but there are some gray areas on Long Island around us that would have to pay five cents a minute to our phone company to get online. Remember, a number with the same area code as yours is not necessarily a local call. You don't want to add $50 or so a month in phone charges to your "free" computer experience.

With these considerations made, you could be computing and accessing the Net in no time. If you're currently not online, you can call Gobi at 888-YES-GOBI (888-937-4624) to get started with the service.

DirectWeb lets you choose from three classes of PC and, consequently, three different monthly price plans for its "free" PC offer.

DIRECTWEB

Though it hasn't rolled out nationwide at the time of this writing, DirectWeb promises to be available in most areas by the time you read these words. Similar to Gobi, DirectWeb gives you a new computer for a modest cash outlay and a monthly service fee. However, this new provider offers some more choice in the process.

First, you get to pick your computer class. DirectWeb offers two 366-MHz Celeron configurations and one 450-MHz Pentium III system. The first 366 machine has 64MB of RAM, a 6.4GB hard drive, a 32X CD-ROM, and a 15-inch monitor. The other 366 adds 64MB more of memory (for a total of 128MB), a color printer, and a 17-inch monitor (instead of the 15-incher). With the high-end PIII you also get 128MB of RAM and the 17-inch monitor, plus a 10.2GB hard drive and DVD drive. Any of these machines is faster than the Gobi offering—here's how DirectWeb gets to offer this hardware premium.

First off, DirectWeb gets the machine back at the end of the service agreement (36 months), or they get to keep the deposit you have to pay at signup. This is $150 for either of the 366 machines, and $250 for the PIII. Add a $65 shipping and handling fee, and your first payment is getting high, no?

Then, there's a monthly fee difference for the systems. For $19.95 a month (certainly a great price for ISP access), you get the base 366. Add $10 to that and you get the better-loaded 366. Or, you can opt for a hefty $49.95 a month, and surf in style with the PIII.

Further, DirectWeb makes up for their hardware outlay by providing advertising that its subscribers have to put up with. It's not too bad, and they do give you a sample of it at the Web site. I suggest you use a friend's computer to check it out, if you don't currently have other online access.

If you do similar calculations to the ones we did for Gobi, you'll find that your initial outlay is more, but you will at least get some of this money back one day, which is a small consolation. Also, if you're going for the base-366 deal, you know that you won't be paying any more monthly than you would with any other provider, which makes the deal even sweeter, and the computer seem even more free.

To get started, you can either visit the DirectWeb site or call the company at 800-INVASION (800-468-2746).

HOT SITES

Circuit City
www.circuitcity.com

CompuServe
www.compuserve.com

DirectWeb
www.directweb.com

Gobi, Inc.
www.gobi.com

ANOTHER OPTION

Another way to get a free computer (or one that's almost free) is to take advantage of some of the deals that major ISPs have with chain stores. Circuit City, for example, recently began a promotion where you can get a $400 rebate on any new computer as long as you agree to three years of service from CompuServe. If you can get by with an entry-level system, then your initial outlay after rebate could end up being less than that required for either of the providers we looked at this month.

I hope this column helps some of our readers get online, whichever of the aforementioned routes are followed. The Internet was designed for everyone, and I'm happy to see companies making it easier for everyone to access it.

As always, I like to hear from you. Feel free to send me snail-mail at *Net Watch*, **Popular Electronics**, 500 Bi-County Blvd., Farmingdale, NY 11735, or e-mail at *netwatch@gernsback.com*, perhaps from your brand-new free computer? ■

ANDREW T. ANGELOPOULOS

Home Networking

Computers are taking over the American home faster than TV did when it made its appearance. Not only do most homes now have a PC, many have two or more. While convenient, especially in a family setting of multiple users, these computer collections haven't been used to their fullest potential.

Consider the benefits of networking—connecting those PCs to take advantage of their combined storage capacity and processing power or to share attached peripherals such as modems and printers. It's an upgrade any household with two or more PCs should look into.

When it comes to just sharing data or files, serial or parallel null-modem cables had been used to limited effect in the past. But these temporary connections never provided the bandwidth required with today's applications. Home users need a better way to share data between computers and to do a whole lot more while they're at it.

Forget about classical networking, though. This involves the installation of expensive Ethernet PC cards and the use of heavy-duty cable to connect them, and it has generally been more grief and cost than it was worth for the home environment. While adequate for small businesses, Ethernet is unwieldy (and downright ugly) when used in the home.

Fortunately, networking has come a long way since then. In fact, it has come so far that homeowners and small businesses can connect their PCs and share files, printers, and even Internet connections for as little as $45 per machine—with little or no PC knowledge.

For our look into home networking, we've chosen two kits that meet the criteria of being affordable, neat, and convenient. The first is Anchor Chips' EZLinkUSB cable, a straightforward wired solution that we think is just fantastic. The second is WebGear's Aviator, a wireless networking solution that is equally terrific. These two products contrast nicely, each offering slightly different features for different users while getting the same job done.

We should stress that the Ethernet alternatives we examine here do not provide the same bandwidth as Ethernet (which is typically 10 or 100 Mbps). However, our two solutions provide more than adequate bandwidth for most small-network needs and even support network group-play games (in case it's your kids asking you to connect those computers to each other).

EZLINKUSB

The EZLinkUSB has got to be one of the easiest networking solutions yet devised, fully taking advantage of the speed and daisy-chaining ability of the Universal Serial Bus (USB). At $89, this 16-foot cable is one of the cheapest ways to network two PCs. It's great for laptop users or those with desktops in close proximity to each other.

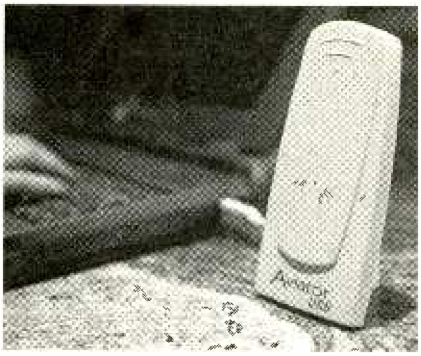
USB ports, found on Pentium MMX-and-better-class PCs, provide the kind of flexible connection that consumers have ached for over the years—one port or connector for many types of devices. A single USB port can daisy chain up to 127 devices through the use of pass-through ports on each peripheral or with the addition of multi-port USB hubs. A keyboard, mouse, scanner, and printer, for instance, can share one USB port on the back of a PC. They'll all be sharing 12 Mbps of bandwidth, but unless you plan on scanning and printing at the same time, for example, you shouldn't find this bandwidth to be a noticeable limitation. In fact, most of the time, a great majority of that bandwidth will go unused, waiting for data to run through it.

Why not put that idle bandwidth to good use?

The EZLinkUSB is a fast install and an even faster way to move data among as many as 17 USB-equipped computers.

Enter the EZLinkUSB—a two-part device. The first and most important part is the "pigtail." This is a 12-inch section of cable that ends in a fat round plastic connector, which contains a small chip that controls the bi-directional flow of data between PCs. The remaining length of the cable (approximately 15 feet) is just a standard USB cable.

With multiple EZLinkUSB cables, you can connect up to 17 PCs in a peer-to-peer network, making the product a great choice for the small



WebGear's Aviator lets your computer data take to the airwaves, allowing for wireless networking within a maximum 125-foot range. It comes in both USB and parallel-port versions.

office as well as the home. The best part? Average data-transfer rates are between 3 and 4 Mbps (between a quarter and a third of USB's total bandwidth). The cable supports standard network protocols (IPX/SPX, NetBEUI, and TCP/IP), so that you don't need to run special software to access each machine. With its file- and printer-sharing support, the cable makes it possible to access any connected PC's hard drive or attached printer. It will also support modem sharing across a network, but requires the installation of optional, third-party proxy software (such as *WinProxy*, available from Ositis Software).

What if you have two PCs located more than 16 feet apart? Don't buy a second EZLinkUSB—a standard USB hub and cable can add an additional 15 feet (more than 30 feet total) without affecting performance.

AN "EZ" INSTALLATION

Installing the EZLinkUSB is a dream. Insert the install disk into your PC and run the setup program. You'll be prompted to give each computer you do this for a unique name (one that won't be used by another computer on the same network), and that's all the configuration you'll have to do. Just reboot when these quick steps are finished on each machine and plug the cable into the USB port. That's all there is to it.

There are only two small catches. One, you need to have at least Windows 95 OSR 2 (the first Windows version with USB support). If not, you will need to get the USB support pack from the Microsoft Web site. Two, at press time, the Windows 98 Second Edition drivers were a little buggy. Anchor Chips was resolving the driver issues in response to the recent upgrade to Windows 98 and already had a Beta available for download at its Web site.

AVIATOR

WebGear's Aviator is well named, letting your data take to the air. Forget about running cable. This wireless Windows 95/98 networking solution will eliminate any chance of clutter. It's convenient and practically invisible—welcome features in any home or small office.

We looked at the two available versions of the Aviator RF modules. They are compatible, perform in much the same way, and require similar installation. The biggest differences between the modules are their interfaces—one uses the parallel port, the other USB—and prices.

The Aviator is relatively inexpensive, especially when compared to the flexibility it provides. The parallel-port model sells for $149 and the USB model for $199. Each kit will network two computers. As an added convenience, consumers can purchase single RF modules for odd-numbered networks ($99 for the USB model and $89 for the parallel-port model). And if you think you'll have to sacrifice your printer to use the parallel-port model, think again. The two-module parallel kit comes with an ISA PC printer card. Once installed, the RF module and a printer can be connected to a machine simultaneously.

VENDOR INFORMATION

Anchor Chips, Inc.
12396 World Trade Drive
M/S 212
San Diego, CA 92128
800-676-6896
www.ezlinkusb.com

Ositis Software
6150 Stoneridge Mall Drive #180
Pleasanton, CA 94588
888-946-7769
www.winproxy.com

WebGear, Inc.
111 North Market Street
Suite 500
San Jose, CA 95113
888-947-8778
www.webgear.com

Both versions of the Aviator are small and light. The USB version comes with two cables, one ten inches long and one a meter in length, and measures $5\frac{7}{8} \times 2\frac{7}{8} \times \frac{7}{8}$ inches (HWD) and weighs just 4 ounces. The parallel-port model comes with two cables, one six inches and one a meter in length, and measures $2\frac{1}{4} \times 4 \times \frac{3}{4}$ inches (HWD) and weighs 3 ounces. The sizes and weights scream "use me with a laptop." For example, have an Internet-connected PC and a printer in the living room and take your laptop to the porch to browse the Web and print documents in comfort (more on Aviator Wireless Internet access in a moment).

The Aviator broadcasts between 902 and 928 MHz, and will network computers located up to 125 feet apart (depending on various conditions, distance may be limited to as "little" as 75 feet). Like EZLinkUSB, Aviator supports popular networking protocols and file and printer sharing. WebGear has included a copy of *WinProxy* software with its kits, so a single PC and modem can provide the network with a full Internet connection. According to WebGear, up to 32 PCs can be networked by the Aviator, but you might not want to have that many computers share a 56-Kbps modem! However, you can have two or three machines running over one such Internet connection with decent results.

There is one minor sacrifice made for wireless flexibility: the data-transmission rate. The Aviator's bandwidth, under optimal conditions (weather and other environmental factors), is 1 Mbps. To ensure the quality of the data stream, the Aviator uses error-correction. Still, for most home (and even some business) applications, this should be sufficient.

SOME WIRES REQUIRED

The installation for the Aviator is a little more involved than that of EZLinkUSB, but WebGear has done an excellent job with its documentation, guiding you through the process step-by-step.

To give you an idea of what to expect, here's a brief look at what's involved:

First connect the module to the PC, insert the driver disk, and run the setup program. The program will prompt you for three bits of information: a unique computer name, a workgroup name (this can be anything, and all your PCs can share it), and a unique PC number. It will then request you to restart your system. After restart, the setup routine inspects your system to make sure that Windows networking was set up correctly. If it wasn't, Setup opens the Windows Network dialog box (found under Control Panel) and informs you of what components to install and how to configure them.

Once you configure one machine and know what to expect, you'll find the other PCs a breeze to set up. When all the computers are configured and turned on, they'll "look" for each other and check the signal quality of the connection.

With networking options like these, and at these prices, it's a wonder why home networking isn't more widespread. In a two-PC home, networking is now cheaper than buying a second printer or installing an upstairs telephone line. If you think about it that way, home networking is an upgrade that could prevent you from having to perform other upgrades! ■

MULTIMEDIA WATCH

MARC SPIWAK
TECHNICAL EDITOR
COMPUTER RESELLER NEWS

35MM COMPETITION

Digital cameras have become good substitutes for traditional film-based cameras because affordable units finally offer image quality that is good enough to compete with 35mm film. The latest digital camera from Olympus, the *C-2000 Zoom*, once again raises the bar for image quality and feature set in consumer-priced digital cameras. Olympus' new C-2000 is a 2.1-megapixel digital camera that is as easy to use as any other point-and-shoot camera, yet it incorporates more advanced features that professional photographers will surely appreciate.

The aluminum-body C-2000 camera has a completely automatic "program" mode for point-and-shoot users, plus aperture- and shutter-priority modes for more advanced users. Shutter speeds range from ½ to 1/800 second. The C-2000's 2.1-megapixel CCD produces a maximum image size of 1600 × 1200 pixels.

The standard image format is JPEG, with different image sizes and levels of compression to choose from. The C-2000 can save standard quality (SQ), high-compression JPEG images in 640 × 480 and 1024 × 768 sizes. It can also save high quality (HQ), medium-compression images, or super-high-quality (SHQ), low-compression images, at 1600 × 1200 pixels. The C-2000 also has a zero-compression, zero-loss TIFF mode for 1600 × 1200 images.

Images are stored on SmartMedia memory cards, and one 8MB card is included with the camera. That is enough memory to store between seven 1600 × 1200 low-compression images and 122 high-compression 640 × 480 images. Only one 1600 × 1200 uncompressed TIFF image will fit in the 8MB of memory. Re-usable SmartMedia cards with higher or lower capacities can be swapped like rolls of film.

Olympus C-2000's 2.1-megapixel camera produces a maximum image size of 1600 × 1200 pixels, providing some good competition for 35mm cameras.

The C-2000 has an all-glass, 8-element 3X zoom lens with a 35-mm equivalency of 35 to 105 mm, and an f2.0 to f11 aperture. The camera also has a 2.5X digital telephoto feature that, when used in conjunction with the optical zoom, provides the camera with a "lens" that's equivalent to a 260-mm unit. A macro capability allows focusing from as close as eight inches. The C-2000 also offers the user a choice of 100, 200, or 400 ISO film-speed equivalency.

A built-in, 1.8-inch LCD allows the reviewing and composing of images. Stored images can be inspected at up to 3X magnification, and the area of inspection can be shifted. The C-2000's video output allows stored images to be viewed on a TV set or be transferred to videotape. An included remote control allows you to select and view images on a TV set while seated at a distance from the camera.

The C-2000 has a built-in flash with four modes including red-eye reduction, force-fill, low-light/back-light, and force-off. External lighting can be synchronized to the camera, and the automatic metering system can be manually overridden. High-speed DRAM contained within the C-2000 allows sequence shooting of 5 to 45 images in half-second intervals.

The C-2000 can link to a PC through the serial port. But a much slicker solution is Olympus' optional FlashPath floppy-disk adapter. FlashPath looks like a floppy disk with a slot for SmartMedia. After a quick software install, a PC will recognize FlashPath as a floppy disk with the capacity of the inserted SmartMedia card. Though not terribly fast, the FlashPath adapter is an elegant solution that eliminates the need for any cables.

The C-2000 retails for less than $1000.

MPMAN F20

A while back I talked about Diamond Multimedia's handheld MP3 player called Rio. MP3 audio is basically MPEG-encoded, compressed audio that is highly suited for being distributed over the Internet—legally or illegally. You can find MP3 files on the Internet or create your own from CDs using software that's also available on the Web. You can then download the MP3 files from a PC into a portable MP3 player and use it like a walkman.

It seems everyone is getting in on the MP3 action now, and Eiger Labs is no exception. The folks there have put out a new portable player—the *MPMan F20*—that features 32MB of permanent memory to accommodate up to 30 minutes of CD-quality audio. And you can pop in SmartMedia memory cards for even greater capacity. The MPMan F20 looks sleek and stylish, and it features faster downloads from a PC than an earlier version of the product. Like all MP3 players, the MPMan is 100% solid-state, so there are no moving parts to wear out and nothing that can ever skip or wobble.

The MPMan weighs 2.4 ounces, including its single alkaline AA cell that lasts up to 12 hours. Also included is a bundle of MP3-related software so you can make and manage audio files. The MPMan F20 costs under $200 and comes with a soft carrying case and headphones.

ACS INNOVATION PS39U

If you're looking for a PC video camera for videoconferencing, video capture, image capture, and so on, and don't feel like breaking the bank, consider ACS Innovation's *Compro PS39U* digital video camera with a USB interface. It's so simple to connect the device to a USB port and then let Windows 98 do the rest. All you have to do is a quick software installation, and you're ready

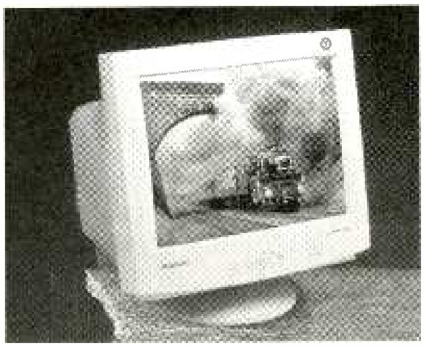
ACS Innovation's Compro PS39U digital video camera has a convenient and fast USB interface. Intended for videoconferencing and still capture, the Compro costs $179.

for videoconferencing.

The PS39U captures over 40 frames per second of full-motion video, as well as still images up to 1280 × 960 pixels in true color. It gives you full software control over shutter speed, brightness, color balance, color saturation, scan frequency, and more. It automatically adjusts to all lighting conditions using an automatic gain-control function. A non-USB, parallel-port version of the product is compatible with Windows 3.x, Windows 95, and Windows NT. The PS39 video camera costs $179, for either parallel or USB versions.

SYNCMASTER 900SL

You can't ignore the part of a PC's video system that you look at all day. A good display or monitor is important, which is why I recommend Samsung's new, very affordable 19-inch monitor, the *SyncMaster 900SL*.



The SyncMaster 900SL is Samsung's affordable 19-inch monitor, with a short-depth footprint. The display has an impressive 18-inch viewable area and a street price of only $569.

This 19-inch monitor has an 18-inch viewable area with a 0.25-mm dot pitch and maximum input resolution of 1600 × 1200 at 76 Hz. As large as the screen is, don't worry too much about desk space for it. The SyncMaster 900SL is one of those new short-depth monitors and is only about 16 inches front to back. The 900SL fits into a lot of places where most other 19-inch displays will not.

Of course, the monitor is Plug and Play and TCO '99 certified. Just connect it and enjoy. And enjoy you will. It's a great feeling moving up to a 19-inch screen from either a 15- or 17-inch display. And best of all, you don't have to be rich to afford the 900SL. It has a street price of only $569.

MONITORTV

If you'd like a monitor that pulls double duty as a TV, consider instead the *MonitorTV* from Miracle Business. The MonitorTV works as a Plug and Play 0.27-mm dot-pitch monitor, available in 14-, 15-, 17-, and 19-inch sizes. The unit can handle resolutions up to 1600 × 1280. That's fine for a computer monitor.

However, Miracle Business has also added an autoscanning, cable-compatible TV tuner with an RF input—there are even stereo speakers and a built-in amplifier. The unit is equipped with a composite video input

WHERE TO GET IT

3dfx Interactive, Inc.
4435 Fortran Drive
San Jose, CA 95134
972-234-8750
www.3dfx.com
CIRCLE 60 ON FREE INFORMATION CARD

ACS Innovation, Inc.
3171 Jay Street
Santa Clara, CA 95054
408-566-0900
www.acscompro.com
CIRCLE 61 ON FREE INFORMATION CARD

Eiger Labs, Inc.
37800 Central Court
Newark, CA 94560
510-739-0900
www.eigerlabs.com
CIRCLE 62 ON FREE INFORMATION CARD

Expert Software, Inc.
802 Douglas Road
North Tower, Suite 600
Coral Gables, FL 33134
305-567-9990
www.expertsoftware.com
CIRCLE 63 ON FREE INFORMATION CARD

Grolier Interactive, Inc.
90 Sherman Turnpike
Danbury, CT 06816
203-797-3530
www.grolier.com
CIRCLE 64 ON FREE INFORMATION CARD

Head Games Publishing
7646 Golden Triangle Drive
Eden Prarie, MN 55344
612-942-5202
www.headgames.net
CIRCLE 65 ON FREE INFORMATION CARD

Humongous Entertainment
13110 NE 177th Pl.
Suite B101
Woodinville, WA 98072
800-499-8386
www.humongous.com
CIRCLE 66 ON FREE INFORMATION CARD

MetaCreations
6303 Carpinteria Avenue
Carpinteria, CA 93013
805-566-6200
www.metacreations.com
CIRCLE 67 ON FREE INFORMATION CARD

Miracle Business, Inc.
2038 West 11th Street
Upland, CA 91786
909-946-9688
www.miraclebusiness.com
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Olympus America, Inc.
Two Corporate Center Dr.
Melville, NY 11747
800-347-4027
www.olympus.com
CIRCLE 69 ON FREE INFORMATION CARD

Psygnosis
919 East Hillsdale Blvd.
Foster City, CA 94404
800-438-7794
www.psygnosis.com
CIRCLE 70 ON FREE INFORMATION CARD

Samsung Electronics America, Inc.
105 Challenger Road
Ridgefield Park, NJ 07660
800-933-4110
www.samsung.com
CIRCLE 71 ON FREE INFORMATION CARD

and output, an S-Video input, and audio inputs and outputs. Of course a remote control is thrown in as well, to complete the TV experience.

The MonitorTV is intended for both business and home users, and it's perfect for home offices that double as a TV room. This wonderful display product costs only $369 in a 17-inch size, or only $249 in a 15-inch size. That's only slightly more than what you'd pay for a similar-size computer monitor alone. Think of it as a cost-effective, universal display unit.

VOODOO 3

Want a state-of-the-art video card to go with your new monitor? One that will accelerate demanding graphics in the latest computer games? Then look no further than 3dfx's new *Voodoo3 2000* and *3000* graphics accelerator cards.

The Voodoo3 is one of the most popular 3D gaming cards available. The 143-MHz Voodoo3 2000 costs just $129, and it comes in AGP and PCI versions. The card can generate up to 6 million triangles and 286 Megatexels per second at resolutions of up to 2046 × 1536 pixels.

For even faster acceleration, there's the 166-MHz Voodoo3 3000, available in an AGP version only for $179. This model generates up to 7 million triangles and 333 Megatexels per second at resolutions of up to 2046 × 1536 pixels. Either one of these cards is all you need for scorching computer games. They'll do nicely with advanced 3D business applications as well.

NEW SOFTWARE

A new game from Psygnosis, called *Rollcage*, is sure to get your adrenaline flowing. *Rollcage* is an ultra-destructive, hi-octane racing game where you recklessly drive an indestructible car. You can take the vehicle anywhere and everywhere, smashing through buildings and leaving only rubble behind to block your opponent's path. The vehicles are also equipped with weapons to help slow down your opponents. Choose from 20 different tracks set in four different environments and then let the term "road rage" take on new meaning. *Rollcage* costs $49.

New for kids from Humongous Entertainment comes an all-new underwater western adventure called *Freddi Fish 4: The Case of the Hogfish Rustlers of Briny Gulch*. In this game, children guide detective Freddi Fish and her best pal Luther through exciting encounters with all sorts of interesting characters. Kids must search for clues and solve puzzles in order to solve the case of Cousin Calico's rustled hogfish. Kids have to find the rustlers' secret hideout and rescue the hogfish. *Freddi Fish 4* costs $29.

Lots of people are familiar with the *Grolier Multimedia Encyclopedia*, even the latest 1999 version. But not many people are aware yet that there's a version of the product available exclusively for iMac computers. The *GME99 iMac Edition* features the same huge database as other versions, including over 36,000 articles, 15,000 images, 1200 maps, 163 videos and animations, and 15 hours of sound. Basically the video, audio, and interface of *GME99* have been tweaked to take advantage of iMac and high-end Power Mac processing power. You'll see full-screen video playback and hear digitally re-mastered stereo sound. Mac users will definitely want to check this one out. The *GME99* disc costs $59.

Dragon's Challenge, from Expert Software, is the ancient Oriental tile game that is hard to walk away from. The game requires that you quickly uncover stacked groups of tiles and matching pairs. Your quick thinking is required to win. *Dragon's Challenge* features twelve different tile games with different strategies and levels of difficulty. You can even customize your game with multiple backgrounds and tile sets. This title costs about $15, and all you need is a 486-MHz PC to play it.

If you're into graphic arts, then you'll want to check out *Bryce 4* from Metacreations. *Bryce 4* is intended for designing, rendering, and animating natural 3D worlds and abstract 3D sculptures. The software includes libraries of presets that you can use in your own work, as well as an extensive collection of importers and exporters. You can even export to QuickTime. This is quite a powerful tool for web developers. *Bryce 4* costs $199.

Also new from Metacreations comes *Canoma*, the software that lets you create photorealistic 3D models from scanned or digital photographs. You can easily model furniture, interiors, buildings, and more. You can even interactively walk through models and create animations. The 3D models can be used in online catalogs or other similar applications where customers can preview products at their leisure. Game developers will also find this product useful. *Canoma* is available for $499.

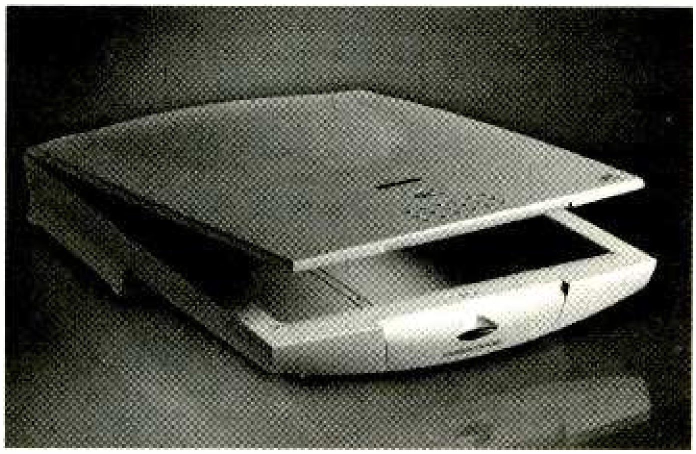
Head Games Publishing has a series of *"Extreme"* games that push your virtual abilities to the limit. *Extreme Mountain Biking* tests your skills in downhill, gate racing, trials, or single track events. Featured are over 15 tracks. *Extreme Boards & Blades* is a skating fan's dream game, with plenty of inline and big-board actions. From the halfpipe to the streets, the excitement is all here. *Extreme Wintersports* is loaded with snow, ice, sleds, and skis. There are over 25 different tricks you and three other players can perform. *Extreme Rodeo* puts you in the arena with rodeo events including Saddle Bronc, Barrel Racing, Calf Roping, Bareback, Bull Riding, and more. These extreme games cost $25 each. ■

TED NEEDLEMAN

Scanners 101

The previous two columns have focused on video—that is, capturing both single frames and full-motion clips. But, as I mentioned right up front, I like to use scanned and photographed images as well. One thing I do frequently is scan a small wallet-sized or smaller photo, such as the ones I get from my kids' school photos, and make enlargements. And all four of my kids use scanners to help with homework and reports. I've even played around a bit with optical character recognition (OCR) occasionally, to help me produce editable text from printed documents. So for this and the next column, I thought I'd concentrate on some of the things you can do with a scanner, as well as explain some of the basics of buying and using one.

If it's been a while since you've looked at or priced a scanner, you're in for a very pleasant surprise. Prices have tumbled, and capabilities have improved. Right now, it's easy to find a good quality flatbed scanner for about a hundred bucks. And by the time this column appears, I'll bet that prices will have fallen even lower.



The Canon CanoScan FB 620U has a USB interface, making it a fast-operating, easy-to-install scanner.

THE BASICS

Scanners come in two basic types: sheet-fed and flatbed. The basic premise is the same regardless of the style—light is reflected off the document being scanned onto a sensor, where it is imaged into areas of white, black, or color. This data is passed though to your PC. With a sheet-fed scanner, the document is moved past the sensing array. A flatbed scanner uses a glass platen, like that of a photocopier, onto which the document is placed and remains fixed.

Sheet-fed scanners are a lot less popular these days. The reason is that it's difficult to move a sheet of paper though the unit very precisely, which limits the ultimate optical resolution at which the document can be scanned. And it's this resolution, along with the ability of the scan element to accurately resolve the actual color being scanned (called color depth), which determines the final quality of the scanned image.

Resolution, given in a form of horizontal × vertical pixels (picture elements) per inch (ppi), depends on two factors. One is how many physical scanning elements per inch are used in the scan sensor. If there are 300 elements per inch in the sensor array, then the maximum actual or optical resolution can be no more than 300 ppi. Most scanners today use a sensor containing at least 600 elements per inch, providing a horizontal resolution of 600 ppi. Many scanner vendors use "dots per inch" or dpi, rather than ppi. For most discussions, there is no difference between the two.

With a flatbed scanner, a scanning head is moved vertically down a path below the glass platen. By using a stepper motor for this movement, the scanner has precise control over this movement, stopping many times for brief moments to query the sensor array. This builds up a line-by-line scan of the documents by scanning a horizontal line, moving the scanning element a bit further down the page, then scanning another line.

The actual optical vertical resolution depends upon how fine a movement the stepper motor and its gearing can produce. In many cases, you can obtain a minimum vertical optical resolution of 600 ppi. Many of the newest scanners up this to 1200 ppi, producing a true resolution of 600 × 1200 ppi. And some of Epson's moderately priced 636 scanners carry this even further, with 2400-dpi claimed resolution in the vertical plane.

FINER POINTS

If you look at ads for scanners, or even browse through the computer store looking at the packaging, one thing that you'll notice is that many scanners claim resolutions of up to 9600 × 9600. Resolutions higher than the actual optical resolving power of the scanner element are produced by a software process called interpolation. At its simplest, interpolation is the process of "guessing" what color areas exist between the pixels that are actually imaged. Here's an example: working in one dimension. If you have two adjacent imaged pixels that are both red, it's a good bet that the area between these is also red. Extending this analogy into two dimensions, interpolation takes the actual 600 × 600-ppi imaged matrix and uses a set of software algorithms to calculate what color and brightness the "unimagable" pixels are. Depending on how many times you do this, you can extend the "resolution" considerably beyond the limits of the optical resolving capability of the sensor array. Of course, the process of software extrapolation also introduces a measure of inaccuracies, as it is only a statistical approximation of what could lie between those areas actually scanned.

Is there a need for interpolation? For many applications, you will probably scan at resolutions lower than the optical capability of your scanner anyway. Using higher resolutions is usually done only when you want to produce an image larger than the originally scanned document without losing too much detail. The other side of resolution is that the higher the resolution at which you scan a document, the larger the resultant file will be. It's not unusual for a 4 × 6 photo scanned at 2400 ppi/dpi to generate a file over 100MB. We'll go back to scanning resolution in more detail later. For most uses, a scanner that delivers true 600 × 600 optical resolution will be just fine.

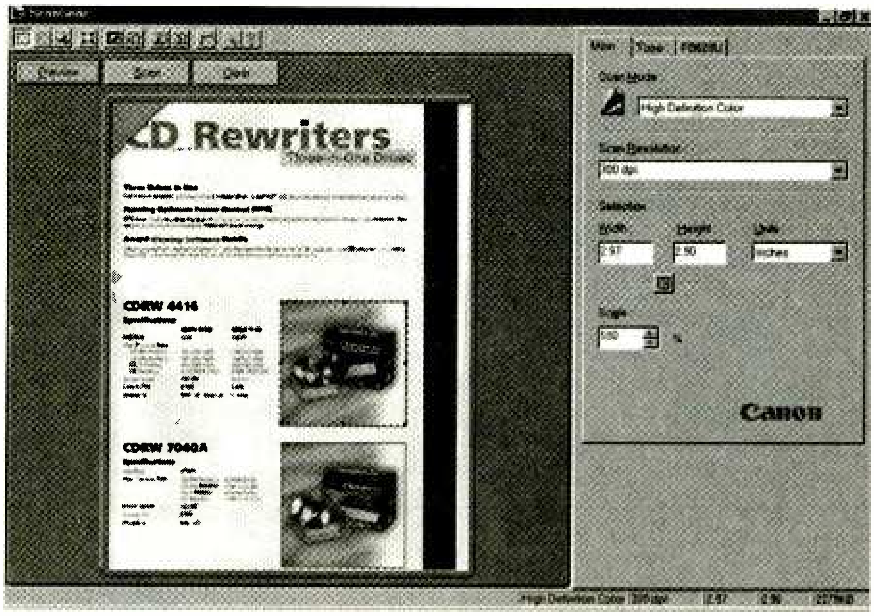
Color depth is another specification that you'll see frequently when shopping for scanners. In essence, the more colors a scanner is able to optically resolve, the closer the scan will resemble the original document being scanned. Scanning at a color depth of 36 bits per pixel results in each primary color (red, blue, green) having 12 bits of color information. Most scanners today offer at least this color-depth capability, though some very inexpensive scanners use only 10 bits per primary color. Unless you really need to produce super-accurate scans, you really don't need to worry too much about this specification. Most Windows graphics applications, except for Adobe's Photoshop, only use 24 bits of color data anyway. In fact, most scanners actually only pass 24 bits of this data through the interface to the PC, dropping the least significant bits.

So why do scanners take in more data than they can pass on? As it turns out, there's an advantage to having a deeper color-resolving capability than what is actually used. With 36-bit capability, for instance, the scanner chooses the *best* 24 bits for each scanned pixel—a 24-bit scanner might transfer some incorrect colors because it doesn't have the extra sensitivity to "play with."

I/O OPTIONS

Speaking of passing data on to the PC, there are two major interfaces being used in scanners right now. Which one you choose depends on what type of system you have, and which version of Windows you are running. To illustrate the interfaces, we'll use two of my favorite scanners here in the house as examples: a Visioneer One-Touch and a Canon CanoScan FB 620U.

The Visioneer One-Touch has a parallel-port interface. You plug it into your PC's printer port and plug the printer cable into a pass-though connector on the rear panel of the scanner. This works pretty well, though sometimes it can be disruptive if you



This TWAIN driver for a Canon scanner allows you to preview the document, set resolution, and tweak the settings before performing the final scan.

use other parallel-port devices such as a Zip drive. The advantage is that you can have a somewhat older system, with Windows 95.

The Canon CanoScan FB 620U scanner has a Universal Serial Bus (USB) interface. If you have a newer PC with the USB interface, a scanner like this one is the way to go. USB is a faster interface. However, the original release of Windows 95 does not include support for USB, so if you are running an early version of Win 95, you're pretty much out of luck even if your PC has a USB port. Some later updates of Windows 95 (called OEM service releases or OSRs) provided to hardware vendors do contain a USB supplement, but Windows 98 is really the OS to have for problem-free USB support.

Because USB peripherals install quickly (just plug them in), and don't interfere with the printer port, they're a great choice to consider when you're shopping for a PC add-on.

WHO HAS THE BUTTON?

Another popular feature that's been showing up on even inexpensive scanners is the "one-touch" button. Visioneer was actually the first vendor to name some of its scanners "One-Touch," but even the Canon FB-620U has a button on its front panel. What's so great about these buttons?

On the Visioneer One-Touch models there are actually several buttons, each labeled with a different task such as "Copy," "Fax," and "Scan." You can easily program these buttons so that they automatically launch the appropriate utility when they are pressed. So when you put a document on the platen, and press the Copy button, a utility that scans the document and outputs it to a color printer is automatically activated.

On scanners such as the Canon FB-620U, which sport only a single button, you need to determine and configure which application will be launched when the button is pressed. By default, pressing the button on the FB-620 starts the TWAIN driver to perform a scan.

SCAN ELEMENTS

Another consideration is what type of scan element is being used in the scanner. For years, the most common imaging device has been the CCD (charge coupled device). This is familiar and proven technology, and with the huge numbers of CCDs manufactured for use in other applications, such as video cameras, prices continue to fall. Within the last year, however, a new technology, called CIS (contact image sensor) has shown up in low-end page scanners. CIS sensors aren't really new—they've been used in fax machines for years. But until recently, they haven't been available with enough resolution and color sensitivity to be used in flatbed scanners. That's changed, though CCD sensors still give a marginally better image at the $100 price point.

The big advantages that CIS sensors offer are their weight and size. Considerably smaller and lighter than CCD arrays, CIS-based scanners, such as the Canon FB 620U, actually mount the sensor array and an LED or fluorescent light source on the scan head that's moved beneath the glass platen. CCD-based designs, however, are too large and bulky to do this with. On a CCD-based flatbed scanner, the light source and scanning element are fixed inside the case, and a mirror is moved underneath the scanned document. This requires that a much higher level of tolerances be maintained, and increases the cost to manufacture the scanner.

VENDOR INFORMATION

Canon USA, Inc.
1 Canon Plaza
New Hyde Park, NY 11042
800-OK-CANON
www.canon.com

Visioneer
34800 Campus Drive
Fremont, CA 94555
510-608-6300
www.visioneer.com

A LITTLE BUNDLE OF JOY

Finally, the last element to consider in a scanner purchase is the software that comes with it. Most vendors include a bundle that consists of an image-editing application, optical character recognition (OCR), and a TWAIN driver. TWAIN is an acronym for Technology Without An Interesting Name and is the software driver that interfaces the scanner to both Windows and other Windows-based applications. Every scanner comes with a TWAIN driver, and most times you'll let the driver determine the best settings to use. A good TWAIN driver, however, offers you the opportunity to make lots of adjustments to tweak the scan.

Just what these adjustments are, and how they influence what you get from a scan, will have to wait until next column. We're out of room for this month.

As always, feel free to e-mail me with your comments and suggestions at *tneedleman@aol.com.* ■

LETTERS

AMPLIFIER CORRECTIONS

It seems some errors crept into the schematic and layout illustrations in my article: "200-Watt Audiophile Amplifier" (**Popular Electronics**, September 1999). To get the unit to work properly, the following modifications should be made to the schematic diagram (Fig. 4):

1. The emitters of Q12 and Q13 should be tied to the output rail (*i.e.* the common junction of R23 and R24).
2. The orientation of C27 and D1 should be reversed.
3. The emitters of Q20 and Q21 should be connected to circuit common.
4. The positive power-supply volt age should be labeled +63VDC instead of +83VDC.

Regarding the top-view layout diagram (Fig. 6):

1. Q8, located directly above R11, should be turned around (*i.e.* the back-side of the transistor should be facing up instead of down).
2. Q11 should be turned around also.
3. The polarity of C10 should be reversed.

If anyone has any questions regarding these corrections, they may contact me at *sealelec@eastky.net* or by telephone at our business number below.

G. Randy Slone
SEAL Electronics
P.O. Box 268
Weeksbury, KY 41667
606-452-4135

HAVES & NEEDS

I need a solution to my problem. I reside on the east coast of Saudi Arabia, near Bahrain. I am able to receive UHF transmissions from far away stations like Qatar, Sharjah, and Dubai. However, due to weather problems, the signal becomes weak and transmission suffers interference at times. All of these stations transmit English-language programming not available by dish.

Could any readers provide a circuit diagram to enable me to boost these transmissions, or perhaps an antenna design that would receive them better? I would be very grateful for any help they could give.

Dr. S. M. Husain
P.O. Box 505
Dharain Airport
31932, Saudi Arabia
e-mail: husain@zajil.net

KEEP IN TOUCH

We appreciate letters from our readers. Comments, suggestions, questions, bouquets, or brickbats ... we want to hear from you and find out what you like and what you dislike. If there are projects you want to see or articles you want to submit—we want to know about them. And now there are more ways than ever to contact us at **Popular Electronics**.

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I am in need of a user's manual/schematics for a Lafayette, Model TE-25, C. R. Analyzer. I will gladly pay shipping costs.

Thank you in advance.

Walter Gundy
1106 Halsey Terrace
Harrisonville, MO 64701

I have been reading your publication for some time now and look forward to every copy. I own the assembly of a G M-H50 Bridgeable Power Amplifier produced by Pioneer. It is inoperable, but it appears to be in very good physical shape. Now if I could just get some sound to come from the unit!

I wonder if any reader knows where I can get a schematic of this amplifier. I am willing to refund reasonable expenses.

Ernie Schulman
Box 184
Reston, Manitoba
R0M 1X0 Canada

Thanks for a great electronics magazine. My favorite column is *Circuit Circus*.

I'm looking for a simple circuit to let my Apple Macintosh Classic Computer control up to six lamps (230VA/60 watts). Can this be done with the modem and printer port? Also, is it possible to control these ports in *Think Pascal*?

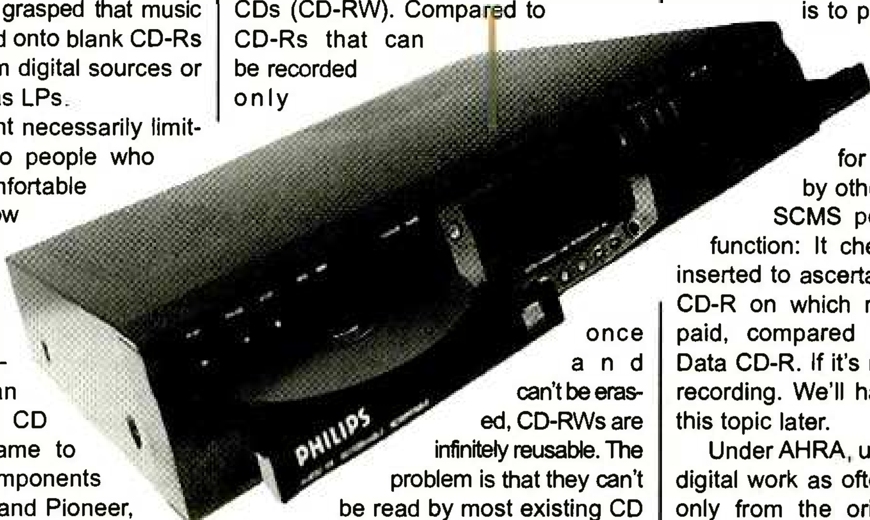
Any reader ideas would be greatly appreciated.

Gerry Laureys
Laaglandei 112
B 2900 Schoten
Belgium
e-mail: gerry.laureys@wuerth.be ■

PRODUCT TEST REPORT

Philips Dual-CD Dubbing Deck

STEPHEN A. BOOTH



At first, consumer recording on CDs was possible only though a personal computer (PC) equipped with a CD-R drive. Ostensibly, the purpose was for data backup or for archiving material such as photographs. But savvy users quickly grasped that music too could be dubbed onto blank CD-Rs through the PC from digital sources or analog ones such as LPs.

This arrangement necessarily limited CD recording to people who had PCs and a comfortable understanding of how to operate them, for the process of "burning" a disc is more complicated than hitting the Record button on an audio tape deck. CD recording finally came to the world of hi-fi components courtesy of Philips and Pioneer, in a form similar to the analog cassette deck and nearly as easy to operate. These first CD-R decks were single transport recorders that required external sources, such as another CD player, to make dubs or custom music compilations.

The natural progression of the format would be dual-transport models, which, like cassette dubbing decks, incorporate a playback drive to feed the integral recorder. That's now here in the Philips *CDR765* dual-CD dubbing deck, which is the subject of this report.

While the deck was covered in last month's *Gizmo*, we here at **Popular Electronics** thought taking a closer look at its internal performance was in order. Hence, this report.

As the lab measurements in the accompanying charts will show, recordings from the CDR765 unerringly replicate their original digital source. Moreover, there's little loss when second-generation digital dubs are made from a digital source that has undergone conversion to analog before re-recording—as a matter of copyright law. That's a little trick of the CDR765 that caused some annoyance to the music industry, which already feels there's much to fear from consumer digital recording.

Yet another innovation of the CDR765 is its ability to use rewritable CDs (CD-RW). Compared to CD-Rs that can be recorded only once and can't be erased, CD-RWs are infinitely reusable. The problem is that they can't be read by most existing CD players, whereas CD-Rs can. This is one of several peculiarities of audio CD re-cording, which bear some explanation.

DIGITAL LAW

The first difference between recording CDs on a PC and an audio system is that aforementioned matter-of-law.

The so-called "Audio CD-R" configuration is covered under the 1992 Audio Home Recording Act (AHRA), which places restrictions and royalties on its use. Since PCs at the time weren't deemed to be "audio recording devices," so-called "Professional" or "Data" CD-R blanks and CD-R drives for PCs need not be AHRA-compliant.

One aspect of AHRA imposes a levy on Audio CD-R hardware and blanks (2% and 3% respectively on the "landed cost"), which goes to a royalty fund to compensate artists and labels for digital copies made by consumers. The other aspect of the law controls how those copies may be made. It specifies that only a single digital copy can be made from a digital original—and is backed up by some technical muscle in the hardware.

By law, Audio CD-R decks must incorporate the Serial Copy Management System (SCMS), whose circuitry would prohibit the deck from making a digital copy of a digital copy. The point is to prevent "serial" copying: A digital dub made by one person and passed on chain-letter style for infinite digital duping by others.

SCMS performs yet another function: It checks the blank disc inserted to ascertain that it's an Audio CD-R on which royalties have been paid, compared with a royalty-free Data CD-R. If it's not, SCMS prevents recording. We'll have more to say on this topic later.

Under AHRA, users can re-record a digital work as often as they like—but only from the original, not a digital copy. Also, there's no restriction on digital copying of analog material. This would include a CD-R copy that is fed to the recorder as an analog signal, for example, passing through a CD player's analog outputs after undergoing digital-to-analog conversion. It is here where the CDR765 performs the little trick that annoys record companies. Instead of refusing to dupe a digital CD-R copy, it automatically shunts the source disc through its internal digital-to-analog converter and then re-digitizes it for the dub.

Again, CD recording apparatus for PCs isn't (as yet!) governed by AHRA. Consequently, there's no royalty levy on hardware or software, and, with one known exception (Sony), no SCMS to restrict operation. This means Data CD-R products are cheaper than Audio CD-R, and, a digital copy made on an Audio CD-R recorder and blank could be digitally copied on a PC-based system—with the aforementioned Sony exception. And why do Sony-brand PCs incorporate SCMS? Sony executives point out that the electronics giant is also the

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DATA DIFFERENCES

Compared with Data CD-R operation, there are other differences in Audio CD-R operation, as exemplified by the Philips CDR765.

For one thing, the deck won't copy CD-ROMs or MPEG-1 Video CDs from its playback drive—something any PC drive will do with the appropriate applications program.

Also, the CDR765 exhibits some quirks when asked to copy non-standard music CDs, or even some spoken-word CDs. For example, the deck won't copy a CD whose length is greater than 74 minutes when it's examined by the playback drive. Presumably, this is to prevent disappointment to the user, since CD-R blanks of all kinds have been limited to 74 minutes capacity until recently (TDK has begun offering 80-minute blanks, but warns that these might not record or play back in all drives).

Meanwhile, the record drive in the deck will copy the over-length CD when it's fed from an external CD player, but there's a risk of having the recording cut off short unless the user has programmed some editing of the tracks. Why the playback drive of the CDR765 won't recognize some spoken-word CDs (for example, a folktales collection) isn't clear, but SCMS is one possible cause.

Although SCMS is mandatory in any home digital audio-recording device (including MiniDisc and Digital Audio Tape or DAT), the record labels aren't obliged to use it. If they don't, it essentially means unlimited digital copies may be duped. On the other hand, besides using the SCMS code to permit the deck to make a single digital copy, the content owner also may flag the player to permit no digital copying at all.

SCMS aside, another possible cause for the CDR765 to reject some CDs might arise if non-standard authoring were used on the source CD. If so, the CDR765's play drive—which very strictly adheres to the Red Book standards for audio CDs—simply wouldn't recognize it as a compliant music disc, any more than it would a CD-ROM or Video CD.

So long as we're on quirks, let's look at the CD-RW function of the CDR765—a blessing or a curse, depending on your perspective.

On the positive side, the CD-RW (relatively expensive, at about $15 each) can be used over and over. Also, if home recordists makes a mistake or miscue in recording, they can start over at no financial loss—not the case with write-once CD-R, where it's take it or toss it.

The problem with CD-RW is that it's not universally backward-compatible with most of the installed base of CD

TABLE 1—PERFORMANCE MEASUREMENTS

The following test results were furnished by the Advanced Product Evaluation Laboratory (APEL), an independent testing facility located in Bethel, CT. All electrical measurements were performed using the CBS CD-1 and Sony CD-Type 3 Test Discs, recording onto Philips CD-R and CD-R Megalife audio discs and TDK CD-RW (rewritable) audio discs. Performance data represent measurements made at the deck's analog outputs.

BRAND: Philips
MODEL: CDR765 Dual-Drive CD-R/RW Recorder
PRICE: $649 (MSRP)

DIGITAL AUDIO MEASUREMENTS	
0 dB Reference Level (volts @ 1 kHz):	
CBS CD-1 Test Disc	1.93
CD-R digital copy	1.92
CD-R analog copy	1.64
CD-RW digital copy	1.92
Sony CD-3 Test Disc	1.93
CD-RW digital copy	1.93
Frequency Response (dB, from 17 Hz to 20 kHz):	
CBS CD-1 Test Disc	0.0/−0.8
CD-R digital copy	0.0/−0.8
CD-R analog copy	0.0/−1.07
CD-RW digital copy	0.0/−0.7
Frequency Response (dB, from 20 Hz to 20 kHz)	
Sony CD-3 Test Disc	0.0/−0.9
CD-RW digital copy	0.0/−0.9
Signal-to-Noise Ratio ("A" weighted, in dB):	
CBS CD-1 Test Disc	94.2
CD-R digital copy	94.1
CD-R analog copy	87.2
CD-RW digital copy	94.0
Sony CD-3 Test Disc	91.0
CD-RW digital copy	89.9
Dynamic Range (in dB):	
CBS CD-1 Test Disc	90.0
CD-R digital copy	90.0
CD-R analog copy	79.3
CD-RW digital copy	90.0
Sony CD-3 Test Disc	88.1
CD-RW digital copy	88.0
Total Harmonic Distortion (percentage, 0 dB @ 1 kHz, including noise):	
CBS CD-1 Test Disc	0.0051
CD-R digital copy	0.0055
CD-R analog copy	0.0114
CD-RW digital copy	0.0056
Sony CD-3 Test Disc	0.0054
CD-RW digital copy	0.0056
Channel Separation (re 0 dB @ 1 kHz, left channel):	
CBS CD-1 Test Disc	87.3
CD-R digital copy	87.2
CD-R analog copy	83.7
CD-RW digital copy	87.2
Sony CD-3 Test Disc	86.3
CD-RW digital copy	86.2
ADDITIONAL DATA	
Random Access Time:	2.5 seconds
Scan Time:	4.9 seconds
Power Requirements:	13.5 watts
Dimensions (HWD, inches):	3 7/16 × 17 1/8 × 12 7/16
Weight:	8 3/4 pounds

or CD-ROM drives. That's because the laser optics in most existing drives can't read the lower reflectivity of CD-RWs. The playback drive needs a so-called "multi-read" laser to do so. Although most PC-based CD drives made in the past 18 months are multi-read, virtually no audio CD players are.

Philips, which champions the CD-RW standard, says it will make all its CD drives multiread on a going-forward basis. To date, though, the manufacturer has implemented this in just a handful of autosound, portable, and home CD players. Meanwhile, no other CD-player manufacturers are rushing to add expense to their products in order to make them compatible with Philips' CD recordings—least of all backers of the rival MiniDisc digital recording format, such as Sony. Bottom line: Use the cheaper ($3-5) Audio CD-Rs if you're not certain that your playback equipment (and those of your friends) can handle CD-RW.

LAB RESULTS

This will be the shortest section of this report, as the measurements are so clear-cut. They were performed by the Advanced Product Evaluation Laboratory (APEL), the Bethel, CT-based independent facility that performs bench tests for this column.

In any given category of performance (*e.g.*, Frequency Response, Signal-to-Noise Ratio, *etc.*), you'll see that the CD-R and CD-RW digital copies are virtually identical to the CBS-1 Test Disc that was the source used to make them. Ditto for the CD-RW digital dupes from the Sony CD-Type 3 Test Disc. The Sony disc, by the way, was used to test the erasability of the blank CD-RW. It's different enough from the CBS torture-disc previously duped onto the CD-RW so that APEL could tell if that original recording was completely erased.

APEL's most interesting measurement of the CDR765 is the one where the CD-R digital copy is converted to analog before being recopied digitally. It's the third measurement in each category, called "CD-R analog copy."

There's some loss in most categories from the analog conversion, compared with digital-to-digital dubbing. But the losses are slight and, in APEL's opinion, won't be audible to most listeners. Moreover, keep in mind that the material being copied comes from a push-the-limits test disc. Not all prerecorded CDs will have source material this challenging. Certainly, Total Harmonic Distortion and Channel Separation from the analog conversion are no problem. The 1-dB dropoff in Frequency Response at 20 kHz is well within the 3-dB definition for "flat" response.

The weakest points of the analog conversion might be Signal-to-Noise Ratio and Dynamic Range. But these are in the ears of the beholders—and subject to the capabilities of their CD playback and stereo reproduction systems (some of which, particularly portable and mobile equipment, don't measure this well anyway). From APEL's measurements of the analog-to-digital dub, it should be obvious why the record industry resents such copying—especially given a new generation that considers MP3-compressed music to be of "CD-quality." In truth, only with careful selection of encoding bit rate and other factors can MP3s get close to their CD originals.

(Continued on page 89)

GIZMO®

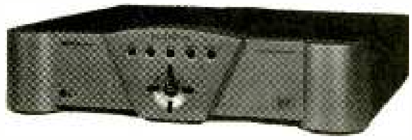
Here Comes HDTV

HDTV is on its way, but right now high-definition broadcasts are still few and far between. So what do you do if you need a new TV—*now*—but don't want to end up a few years down the road with a dinosaur that can't display HDTV? Nor do you want to plunk down ten grand or so to buy a fully integrated HDTV-ready set when programming is still so scarce.

Thomson is one company that's offering a reasonably affordable component solution to digital television, including HDTV. Its RCA *MM61100*

high-resolution multimedia monitor ($3399) is a rear-projection set with a 61-inch (diagonal) screen. Used as is, it will optimize the performance of digital sources such as DVD players and digital satellite TV. With SVGA display capability, it can also serve as a computer monitor. When you decide it's time to upgrade to HDTV, add a Thomson-brand set-top digital converter like the *Proscan PSHD105* ($649). Connect it to the MM61100, and the monitor will be able to display HDTV-quality video resolution as well as SVGA and VGA resolution for video games and computer graphics.

Take the component approach to digital TV, and you'll have a high-quality TV for today. Then, when you decide to add the converter, you'll be able to enjoy the crystal-clear images



and 5.1-channel surround-sound capability of HDTV—along with all of its potential interactive and data applications.

HDTV Rooftop Antenna

As we approach the new millennium, the rooftop antenna sounds like a fossil from the olden days of pre-cable TV. Not so, says Terk Technologies, noting that cable companies are dragging their feet when it comes to implementing HDTV broadcasts. For those viewers who count on cable instead of satellite for their programming, antennas will be needed to experience the digital picture quality of HDTV.

Terk's *TV60HD* rooftop antenna was engineered to optimize the performance of high-definition, as well as analog, signals. Following the guidelines for HDTV as they were being developed, the company designed the TV60HD to capture digital as well as analog UHF and VHF signals.

Smaller than typical outdoor antennas, the TV60HD uses a helical coil that does not compromise the large antenna element necessary to capture channels 2 through 13. The helical coil antenna receives both UHF and VHF frequencies along its surface, and a reflector reduces the effects of multipath—"ghosting" on analog programming and possible total picture loss called the "cliff effect" on digital signals. A preamplifier boosts the signal at the cleanest point to prevent signal loss between the antenna and the television.

CD Recorder Mini-System

Recording CDs keeps getting easier, and now the equipment to do so has begun getting smaller. Philips has introduced the first CD mini-system that plays and records compact discs. The *FW930R* ($599.99) adds a compact audio-CD recorder to a mini-system consisting of a CD carousel, cassette deck, and tuner that allows you to record from disc, tape, or radio without connecting any external sources.

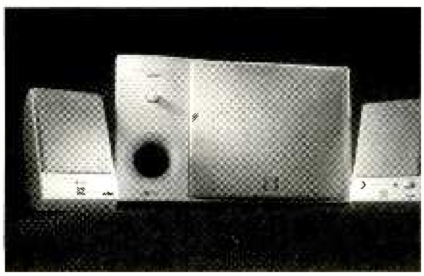
The recorder portion of the system features both CD-R and CD-RW compatibility, coaxial digital inputs and outputs, and analog inputs and outputs, CD-Synch recording, and manual track insertion. The FW930R provides CD playback through both the CD recorder and the three-disc changer. Because the changer is integrated with the recorder, you can easily program a mix of up to 40 songs from three different discs and

record it at the touch of a button. When recording is done from the dual-logic tape deck, recording levels are set automatically to ensure accurate reproduction. The CD Synch feature works with analog as well as digital sources, making it easy to dub entire albums from tape to CD.

The FW930R provides 100 watts of total power, three-step dynamic bass boost, a three-way bass reflex speaker system, and a clock/timer. Philips' "Sound Navigation with Incredible Surround" and 26 "Digital Sound Control"s are designed to provide a range of sound options that can be fine tuned to suit personal tastes by using the jog-shuttle control.

Rockin' USB PC Speakers

Yamaha's *YST-MS55D* three-piece powered multimedia speaker system ($179.99) supports the Universal Serial Bus (USB) connection standard that simplifies the process of installing computer peripherals. Traditional analog inputs are also provided. The system boasts 80 watts of total power



and features Yamaha's Advanced Active Servo Technology. Advanced YST uses an extremely rigid speaker cone to maximize bass performance by channeling internal resonance waves through the speaker's air port. The result is said to be a deep, smooth low-frequency response with a significantly wider frequency range than that of similarly priced competitors.

The YST-MS55D's dedicated subwoofer, featuring a 6.5-inch driver powered by a 40-watt amplifier, is paired with a couple of two-way satellite speakers. Each magnetically shielded satellite has a 3/4-inch dome-style tweeter mounted above a 3-inch cone mid-range driver. The power switch and a headphone jack are located on one of the satellite speakers.

Palmcorder Plus

The Palmcorder Compact-VHS camcorder line from

Panasonic—you know, the ones that come with a PlayPak adapter that allows your recordings to play back on any VCR—now includes the *PV-L859* ($899.95) with built-in PhotoShot digital still camera. The camera's 640 × 480-pixel images can be viewed directly on a television, saved, or printed with a PC and the included Adobe *PhotoDeluxe* software. Downloaded images can be edited and manipulated and added to e-mail messages or Web sites. You can preview the images on the camcorder's four-inch color LCD and keep only those you like best. Up to 60 standard resolution and 15 high-resolution photos can be stored on the camcorder's 2MB memory card.

The PV-L859 features a 300X digital zoom lens and an array of digital effects such as still and strobe, wipe, and color digital fade. The flip-out LCD monitor swivels 270 degrees to allow taping from angles that are difficult with a standard viewfinder. Combined with the camcorder's built-in speaker, the monitor allows instant playback of taped footage. Panasonic's "IQ Operation" ensures that the camcorder will optimally set all recording parameters, such as shutter speed, iris, back-lighting, and focus. A five-head recording system provides improved picture quality in SP mode.

Powerful Portable

We never bought into those relax-at-the-beach-with-your-portable-office commercials. If we go to the beach, we want to hear the roar of the surf and the squawks of the sea gulls, not the ring of a cell phone or the beeps of an incoming fax. That goes double if that beach is on some tropical island, where we're spending our hard-earned money on a well-earned vacation. We want to stare out at the endless waves, not into a small laptop screen.

On the other hand, we don't think twice about bringing entertainment devices along on a business trip. We wouldn't consider traveling without a portable CD player, at the very least, and often some handheld games to pass the time on the plane.

But it just keeps getting harder to draw a line between work and play. Lately, our vacations seem to have devolved into a day or two tacked on to the end of a business trip with the philosophy that we're already there, so why not enjoy it—wherever *it* might be. And that means, like it or not, a good deal of office paraphernalia is finding the way to our vacation spots.

Fortunately, it keeps getting easier to lug along all the computing and communications power you could possibly need on a business trip, without overly burdening yourself on those "off" days. Slip a little handheld PC into your carry-on, and you'll add only a couple of pounds.

One such unit is Hewlett-Packard's *Jornada 820* ($999), a 2 1/2-pound handheld that's about the size of a hardcover book (9.7 × 7 × 1.3 inches). It provides access to e-mail and the Internet, note-taking, faxing, color printing, and schedule planning. And it runs for up to ten hours

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without recharging the battery; an optional extended battery pack brings that to 15 hours. The Jornada 820 contains an Intel StrongARM 190-MHz processor, a built-in 56-Kbps v.90 modem, 16MB of RAM, and 16MB of ROM. For additional storage, there's a CompactFlash slot and a PC Card Type II slot. The Jornada also sports an infrared IrDA port. A VGA port allows you to connect a full-size monitor, which could come in handy for presentations.

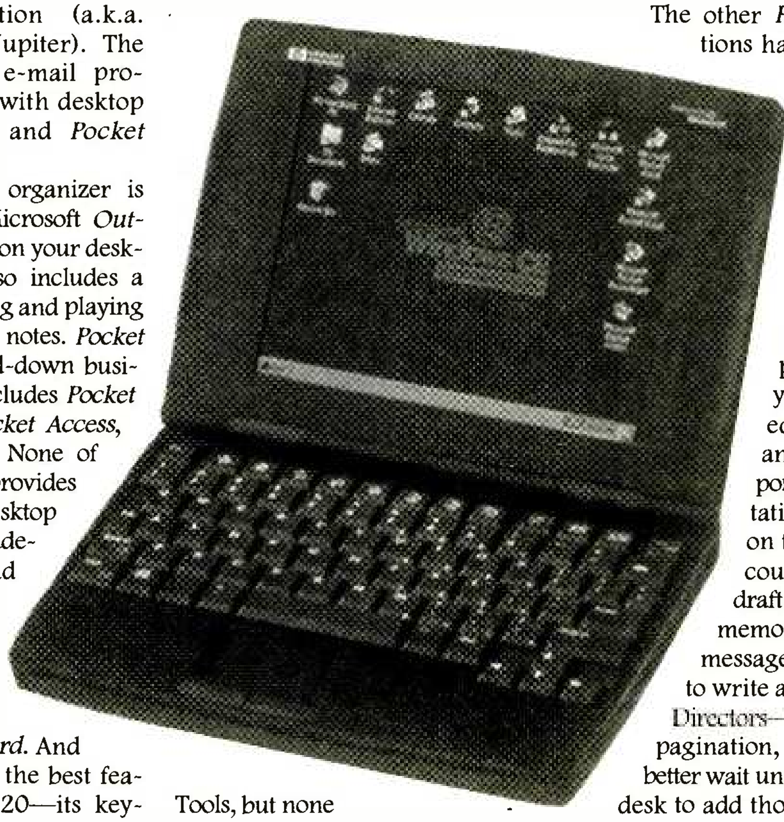
As the "Professional Edition" in HP's Jornada line, the 820 runs Microsoft Windows CE Handheld PC Professional Edition (a.k.a. Windows CE Pro or Jupiter). The software includes an e-mail program, synchronization with desktop PCs, *Pocket Outlook*, and *Pocket Office*.

The *Pocket Outlook* organizer is fully compatible with Microsoft *Outlook* and *Schedule+* data on your desktop PC. The Jornada also includes a voice recorder for creating and playing back spoken memos and notes. *Pocket Office* is a suite of pared-down business applications that includes *Pocket Word*, *Pocket Excel*, *Pocket Access*, and *Pocket PowerPoint*. None of these mobile versions provides the full power of its desktop predecessor, but each is adequate for on-the-road office tasks —and carrying the 820 sure beats toting an 8–10-pound notebook PC.

In fact, we typed this review using *Pocket Word*. And that brings us to one of the best features of the Jornada 820—its keyboard. Although it's compact, it isn't microscopic, and touch-typing on it quickly becomes second nature.

Below the keyboard is a touchpad that replaces a mouse or rollerball. Move your fingertip across the $1^3/_4$- × $1^1/_2$-inch pad, and the on-screen cursor will follow that motion. Two buttons below the pad serve as right and left mouse buttons. If you're not used to touchpads, you'll find that it requires slightly more acclimation than the keyboard did. The cursor can "get lost" on screen, and it might take some time before you learn how to move it accurately. (What finally got us completely at ease with the touchpad was the hours we logged playing Moose Software's *LineUp*, a highly addictive game for handhelds running Windows CE that we downloaded via the Internet.) It is possible, if you prefer, to disable the touchpad and connect a mouse to the Jornada's serial port.

At first glance, *Pocket Word* appeared to be missing some of the features that we commonly use. Its toolbar pull-down menus include File, Edit, View, Format, and Tools, but none of those menus offers all the options found in standard *Word*. Under File, for instance, there's no Print Preview listed. We normally use that feature to adjust the margins on our manuscripts and correspondence. With *Pocket Word*, however, selecting Print from the File menu brings up a box that includes standard print-setup options such as margin settings and orientation. We also thought the program lacked desktop *Word's* Insert menu, which we use to insert symbols not found on the QWERTY keyboard. When we pulled down the Tools menu to do Spell Check, however, we found the Insert Symbol option located there.



But Spell Check and Insert Symbol were the only two options found in the Tools menu. There's no Mail Merge or Thesaurus, or Word Count or Label Printer. The Window and Table menus are nowhere to be found in *Pocket Word*. There are five fonts available, but while text can be changed to boldface or italics, there is no underlining. All in all, however, this "pocket" version of *Word* lets you get 90% of your work accomplished.

The other *Pocket Office* applications have similar limitations, though all of them are fine for the basics. They're all spin-offs of familiar programs, and the Jornada's ergonomic keyboard and brilliantly clear screen make them easy to use any time and any place. *PowerPoint* lets you view, annotate, and edit images, for instance; but it doesn't support multimedia presentations. And while you're on the road, you certainly could use *Pocket Word* to draft a document, write a memo, or compose an e-mail message. However, if you need to write a report for the Board of Directors—complete with tables, pagination, and footnotes—you'd better wait until you get back to your desk to add those flourishes.

Just as *Pocket Outlook* is specifically designed for seamless integration with Microsoft *Outlook* or *Schedule+*, *Pocket Office* works almost flawlessly with Microsoft *Office* desktop applications. In most cases, there's no problem transferring *Pocket Word* files and tweaking them in *Word* on your office PC. If you download a *Word* file to the Jornada, however, you might lose some of the formatting that *Pocket Word* doesn't support.

There are several ways to transfer

MANUFACTURERS

Hewlett-Packard Company
3000 Hanover Street
Palo Alto, CA 94304
408-343-5761
www.hp.com/jornada
CIRCLE 100 ON FREE INFORMATION CARD

Panasonic Consumer Electronics Company
One Panasonic Way
Secaucus, NJ 07094
800-211-PANA
www.panasonic.com
CIRCLE 101 ON FREE INFORMATION CARD

Philips Consumer Electronics Company
64 Perimeter Center East
Atlanta, GA 30346
800-531-0023
www.philips.com
CIRCLE 102 ON FREE INFORMATION CARD

Sony Computer Entertainment America
919 East Hillsdale Boulevard
Foster City, CA 94404
888-778-6337
www.playstation.com
CIRCLE 103 ON FREE INFORMATION CARD

Terk Technologies Corporation
63 Mall Drive
Commack, NY 11725
516-543-1900
www.terk.com
CIRCLE 104 ON FREE INFORMATION CARD

Thomson Consumer Electronics
10330 North Meridian Street
INH-310
Indianapolis, IN 46290
317-587-3000
www.rca-electronics.com
CIRCLE 105 ON FREE INFORMATION CARD

VTech Industries
101 East Palatine Road
Wheeling, IL 60090
800-521-2010
www.vtechkids.com
CIRCLE 106 ON FREE INFORMATION CARD

Yamaha Corporation of America
P.O. Box 6600
Buena Park, CA 90622
712-522-9000
www.yamaha.com
CIRCLE 107 ON FREE INFORMATION CARD

files between your PC and the Jornada 820—a Universal Serial Bus (USB) port, an infrared port, and a v.90 56-Kbps modem. To use the serial cable, you must first install Windows CE synchronization software on the desktop PC. The Jornada automatically senses the connection to the PC and attempts to log in. The IR option, of course, requires an infrared port on the home PC, and that's not a common feature except on laptops. With the modem, you can e-mail files to yourself and then download them.

The Jornada 820 uses Microsoft's *Pocket Internet Explorer* and its Windows CE e-mail program, which, again, provide bare-bones features. We had no trouble going online, accessing our e-mail, or downloading some utilities. But while corporate users might have no problems—especially if they have competent IS departments—consumers would likely be stymied. There's no "Pocket AOL," for example.

On the plus side, the Jornada's $6^3/_4$- × 5-inch, backlit, passive-matrix color LCD screen provided excellent viewing of Web sites as well as work files and games. The colors are bright and true, and the text easy to read. Between the screen and the eminently usable keyboard, you can almost forget that the Jornada is a handheld, not a notebook.

We say "almost" because there are a number of important differences between the Jornada and a notebook. First, of course, is the fact that the handheld can't run regular Windows programs, but is limited to the Pocket apps we've described. Second, the Jornada stores data and programs in RAM instead of on a hard drive, with additional data stored on CompactFlash or PC Cards—Windows CE devices aren't compatible with CD-ROMs or floppies. On the other hand, the Jornada has notebooks beat on two counts: size and battery life.

In one important area, there's little difference between the Jornada and a notebook: They're similar in price (well, similar in price if you're considering an entry-level notebook—not a $2500 powerhouse, for instance). Which one is the better choice for you? That depends on the type of work you do while traveling, and on whether you value the convenience of true portability and long battery life over the full computing power of a notebook.

Personally, we like to travel light; and we've had our fill of "two-pound" notebooks with their eight-pound accessories and battery chargers. The Jornada 820 provided e-mail and Internet access, handy scheduling and contact updates, and the word-processing we needed to write this article. And while it didn't run any of the CD-ROM-based games we usually play to pass the time on planes, we discovered some Windows CE-based games that kept boredom at bay. We never managed to run down the Jornada's batteries, even on cross-country flights—which is something we certainly can't say of any laptop we've used. What's more, carrying the Jornada instead of a notebook PC prevented any hint of the back pain that generally plagues us while traveling. The Jornada 820 was a perfect companion on those business/pleasure trips—and we sure made a lot of our laptop-toting seatmates jealous!

PC Jr.

In our neck of the woods, virtually every family has at least one PC in the home. In fact, in this day of inexpensive upgrades, it's common for the kids to have their own, albeit a trailing-edge, hand-me-down, computer. Children are exposed to computers at an early age—often before they learn to read or do basic arithmetic. And video games—from the omnipresent *Pokemon*-playing Gameboys to Nintendo and PlayStation consoles—compete with PCs for the kids' time and attention.

So when we first saw VTech's *Computer Pal* ($79.99), an electronic learning toy for kids aged five and up that's designed to look like a computer, we wondered if it could possibly find a niche in our home (where, admittedly, the proliferation of electronic gadgets is awe-inspiring). The Computer Pal is intended not only for homes without PCs, but also for single-computer households. It can keep the kids from mess- ing with their parents' computer, while giving them the pride of having their own PC.

The latter turned out to be right on the money. When we pulled the Computer Pal from its box, the first words out of our 4-year-old's mouth were, "Wow, my own computer! And it's my favorite color."

The purple Computer Pal stands 10 inches tall; the base-and-monitor section is about 9 inches wide. The monochrome screen is small (2 × 4 inches), and the contrast switch below it affects minimal changes in the image. The kid-sized QWERTY keyboard features turquoise letter and number keys, yellow function "special" keys, and a primary-colored cursor pad. The mouse is also purple with yellow buttons; a small mouse pad is included.

The Computer Pal teaches through play, with "lessons" in four categories: language, math, logic, and music. Power up, and the Desktop Dragon greets you, prompts you to select one of these categories, and then recites a list of games available in your selection. Activities are heavily weighted toward the three "R's," with ten language games and eight math challenges, compared to six logic games and a scant two music activities.

Some games teach basic skills such as spelling, adding, and subtracting; others focus on more advanced concepts, such as synonyms and antonyms, fractions, and number patterns. In every game, the Desktop Dragon provides verbal encouragement: "You're smart!," "Well done," and "Try again." Most of the games are available in three different skill levels, allowing kids to build on what they learn and progress to more difficult activities.

In most instances, Level 1 was much easier than Levels 2 and 3—requiring kids to add single digits instead of double-digit numbers, for example. In the Missing Letter game, however, we came across tricky words (yolk) and long words (umpire) interspersed with the simple three-letter words (map, ant, hen) in Level 1 and relatively easy words (card, kite) in Level 3.

All in all, the subject matter is age-appropriate, fun, challenging without being frustrating; and it offers a good mix of solo and parent-assisted activities. Our son, who doesn't yet read, was happy to play the language games with the help of an adult or an older kid to help sound out the words. He could play only a few of the math games on his own. That's all right, though — the Computer Pal provides a way for parents to help their kids learn with- out making it seem like work. He played the music games by himself, lea- rning to "compose" and play back his own songs or listen to the tunes in the music library. For a non-reader, however, the logic games offered the most do-it-yourself activities.

The Computer Pal comes with four plug-in cartridges: *Time Tutor*, *Maze Challenge*, *Who Am I?*, and *Typing Ace*. Each provides additional learning activities to help kids tell time, maneuver through mazes, identify people and activities, and use a keyboard. *Time Tutor* uses good ol' analog clocks to teach time, and it definitely requires a patient parent to help impart the concepts. *Who Am I?* displays pictures of people wearing certain clothes or performing activities, and then offers a multiple choice list of identities. It would be easy for non-readers if the Desktop Dragon spoke the choice of answers, but he doesn't. Children must be able to read words like climber, dancer, and soldier to play on their own.

Typing Ace and *Maze Challenge* have dual purposes. The former teaches letter recognition and typing, and the latter involves spatial and mouse skills. *Typing Ace* is quite challenging on all levels. A string of letters parades across the screen, and the player must type each in turn. Touch-typing is required; if you take the time to hunt and peck, the letter parade passes you by. (Think *I Love Lucy* and the candy factory.) Level 1 uses only letters from the middle row of the keyboard, Level 2 adds the top row, and Level 3 uses all three rows. This, by itself, teaches children an extremely important skill.

The three levels in *Maze Challenge* range in complexity from simplistic to easy, even for pre-schoolers. The only challenge comes from using the Computer Pal mouse to move the little dot from start to finish (even if it's just one straight line). That mouse was frustratingly unresponsive in every application, for adults and kids alike. We found ourselves abandoning it in favor of the keyboard's cursor pad whenever possible. It was particularly disappointing since we'd hoped to wean our son away from Microsoft's EasyBall pointing device and help him feel comfortable with a standard mouse that just happened to be purple.

The other disappointing feature is the Computer Pal's screen. The graphics are amateurish, resembling Etch-a-Sketch drawings. In a few instances, the pictures are almost unrecognizable, making it difficult for kids to get the right answer. The poor graphics make it hard for the Computer Pal to compete with Nintendo, PlayStation, regular PC games, and even GameBoy for the attention of electronics-savvy kids.

Of course, if the Computer Pal is to be the first introduction to electronic computer-ish game playing, that's another story. Your children won't be as jaded as our testers, who included our six- and nine-year-old GameBoy-addicted neighbors, in addition to the only four-year-old we know who has his own PC with a 27-inch monitor/TV. (Hey, there's some advantages to having parents in this line of work!) Kids with less electronics' experience will most likely be thrilled to have their own computer (just like Mom and Dad's!). They will be entertained for hours with activities that teach them important skills—academic as well as computer-oriented.

We were a bit surprised to find that all three of our "sophisticated" testers loved using the VTech "computer." In fact, keeping the Computer Pal near the PlayStation greatly reduced the level of bickering between those awaiting their turn at, and the kid currently playing, *Ape Escape* or *Tarzan*!

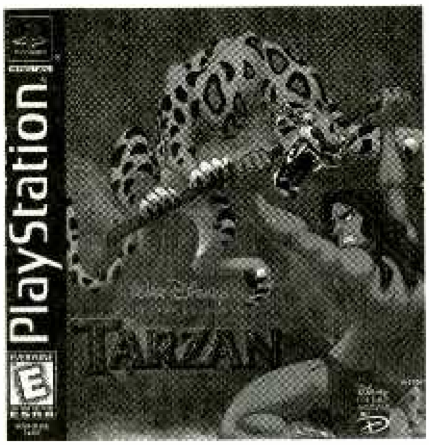
HEY, HEY, WE'RE THE MONKEYS

There's a distinctly simian theme running through recent family entertainment. First we *had Mighty Joe Young*. Then there was *Tarzan*. Now, from Sony Computer Entertainment America, there's Disney's *Tarzan* for the Sony PlayStation (MSRP: $35–$55) and yet another dose of monkey mayhem in *Ape Escape* (MSRP: $35–$55). Both games are rated "E," making them suitable for the entire family.

Disney's *Tarzan*

The *Tarzan* video game opens with an animated sequence from the feature film, and other movie clips are used throughout the game to clarify the story line. Some of the voices of the original actors are used on the game disc, and five original songs from the soundtrack are included. *Tarzan* can be played using the standard PlayStation controller or the Dual Shock Analog Controller, which lets you feel vibrations and impacts that coincide with on-screen action.

If you've seen the movie, you know that Tarzan has developed quite a few smooth moves, from vine-swinging and cliff-climbing to "tree-surfing." When you assume the role of Tarzan, you have all those moves at your disposal as you struggle to



save your jungle family from various villains and hazards. The nasty leopard that killed Tarzan's human parents now stalks his ape family. You must also contend with the gun-toting Clayton and his band of thugs as they try to capture the gorillas. Less threatening, but still potentially deadly, are coconut-dropping birds and various jungle animals that drain Tarzan's power. Tarzan can regain his strength by collecting bananas.

He's assisted along the way by Terk, Jane and her father, Tarzan's adoptive parents, and a young elephant. As you advance through the 13 regular game levels, Tarzan grows from a boy to a man, and the challenges he faces increase in difficulty. There are also five bonus levels to keep you hopping.

In this classic linear-action game, Tarzan swings, springs, climbs, and

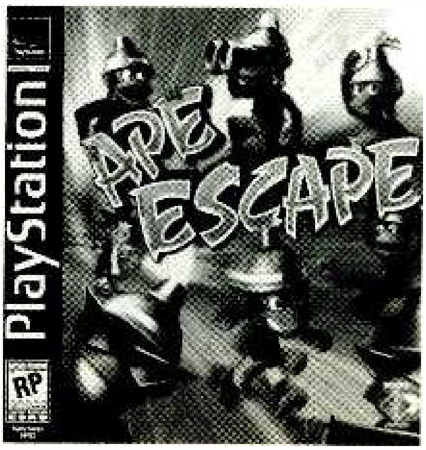
surfs his way through the jungle. He's armed with a knife, spear, "power fruits" to throw at his enemies, and Jane's trusty parasol. The hero must outwit or out-fight the enemies he confronts. As he moves through the game, players collect rewards: tokens that add a life for every 100 collected on one level, Jane's sketches that award them a bonus level, and all six letters in Tarzan's name that allow players to view film footage.

Tarzan is an entertaining game that kept our young (nine-, six-, and four-year-old) testers mesmerized for hours on end, and amused us as well. Although the game is fun, it is nothing out of the ordinary in and of itself. What makes it special is the Disney animation and Phil Collins' songs. Anyone who enjoyed seeing *Tarzan* in the theater will appreciate this charming game.

Ape Escape

Also from Sony Computer Entertainment America (do we sense a trend here?) is *Ape Escape*, the first PlayStation game that *requires* the Dual Shock Analog Controller. Actually, other than the presence of monkeys (and, in reality, gorillas are not monkeys), the two games have little in common.

In *Ape Escape*, the bad guys are the monkeys, who wear blue, red, or yellow helmets to signify their level of intelligence and, hence, how difficult they'll be to capture. Their evil leader, Specter, wears a white helmet that grants him super-intelligence. He has warped the band of monkeys through time in an attempt to change the



course of history so that monkeys rule the world, and humans are confined to the "Amusement Park." Sounds a bit like *Planet of the Apes*, doesn't it?

But don't count on any gun-toting Charlton Heston to come to the aid of humankind. It's up to your character, the brave and stalwart Spike, to capture the wayward monkeys and send them back to the present. He must also rescue his best friend, Jake, whose mind is under Specter's control. Spike is aided by the Professor, who invented the Time Station that started all the trouble in the first place, and his able assistant Natalie. These two allies keep Spike armed with an array of ape-catching gadgetry. Sounds a bit like James Bond and Q, doesn't it?

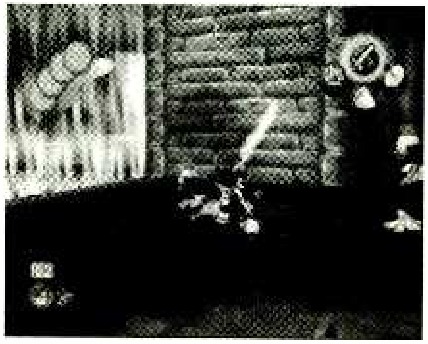
Spike's basic arsenal consists of a Stun Club that can be used to knock down and temporarily incapacitate monkeys and other bad guys, plus a Time Net that captures the monkeys and sends them back through the Time Station to the present-day Professor's lab. Other tools include a water net, monkey radar, a row boat, a tank, a slingshot, a remote-control car, and a sky flyer. Up to four of these items can be accessed from the Gadget Screen at any given time.

There's a training room to help you get used to all of Spike's moves and gadgets, and there's a Warp Room that lets you travel through time. Each level of the game takes place in a different time zone, and you encounter dinosaurs and various other strange creatures in your travels through such places as the Lost Land, New Freezeland, Futurama, Medieval Mayhem, and the Mysterious Age.

There are more than 200 individual monkeys that must be captured and returned to the present. Each of them has a name and some personality trait to set it apart from the others ("Ah-Choo, afraid of dinosaurs." and "Coco, can handstand for days."). Sounds a bit like the latest craze, *Pokemon*, doesn't it?

Ape Escape might be derivative, but it presents some challenging game action. The 3-D graphics create a series of "realistic" fantasy landscapes. The Dual Shock Analog Controller furthers the sense of realism, as it shakes and rumbles to mimic the game action.

Both *Tarzan* and *Ape Escape* can provide hours of entertainment for the entire family. *Tarzan* will hold more appeal to the younger set. The animation sequences are endearing, the characters are cute, and the game itself is easier to play, particularly with Tarzan's pal Terk giving verbal pointers. There are fewer tools and moves to learn, and play is linear; our two youngest testers quickly mastered the basics. *Ape Escape* requires more hand-eye coordination and some time and effort to learn. Spike has so many gadgets at his disposal, and each level is a complex three-dimensional world with plenty of hiding places for the monkeys to use. Each monkey reacts differently, depending upon its helmet color and personality. Even the grownups needed time to learn how to use the Time Net; the youngest kids weren't able to handle it at all.



With either game, however, be sure to allot plenty of time for monkeying around with the PlayStation!

GIZMO NEWS

Paid (to Watch) Advertising

Earn money at home! AllAdvantage.com doesn't require any envelope stuffing. The Palo Alto, California-based company is offering a unique form of advertising in which potential customers are actually paid money simply for viewing ads when they're online.

When you sign up with AllAdvantage, you agree to let the company scroll a "viewbar" on your screen every few minutes. The company keeps track of how much time you spend online with the banner-style ad activated and pays you 50 cents for every hour up to $20 a month.

Granted, $20 a month won't pay your rent or even put gas in your car. But that's just the beginning. Get your friends to join, and you can earn more money. And, as more advertisers sign on, your "salary" will rise. Those advertisers are the ones who are paying, after all.

AllAdvantage hopes to take advantage of the increased bandwidth that will allow folks to watch TV over the Internet. Why not watch on your PC—and get paid for doing so—instead of watching earning-free on TV?

The scheme is an elegant example of cutting out the middleman. Instead of paying various media outlets—television, radio, newspapers, magazines—to carry their pitches, advertisers can simply pay AllAdvantage, which then passes on some of those ad dollars to you.

Advertisers will know precisely who is seeing their ads. They'll not only know how many peo-ple are logged on and for how many hours, but they'll be supplied with viewer-identification information.

Right now, there is no way that

AllAdvantage can determine whether or not you're even sitting in front of the PC or just leaving it on to rack up those billable hours. But it's predicted that in the future iris-scanning devices could tell if you were present and paying attention.

Personally, we prefer to do our TV viewing from the comfort of our couch, remote control in hand to mute the volume during commercials. If we don't earn 50 cents for watching *ER*, we can live with it. But if AllAdvantage's new advertising method catches on with advertisers, might it sound the death knell for free TV and radio and inexpensive print media? There are only so many ad dollars to go around, and if they don't go to traditional media, will those media begin charging for their services? We will just have to wait and see how well this advertising approach pays off

Court Rules in Favor of MP3 Devices

Dealing a blow to the Recording Industry Association of America (RIAA), the Ninth U.S. Circuit Court of Appeals in San Francisco ruled that Diamond Multimedia Systems' Rio PMP300 MP3 portable digital music player is not primarily a "digital audio recording device" and thus is not subject to the restrictions of the "1992 Audio Home Recording Act." The judge's decision stated that "The Rio's operation was consistent with the act's main purpose—the facilitation of personal use."

The decision not only allows MP3 players to be marketed this year, but it opens the door to changes in the way music is created and distributed by effectively removing the RIAA's strict control over content. To smooth the transition, a group called the Secure Digital Music Initiative (SDMI)—made up of representatives from the recording, software, hardware, and consumer-electronics industries—is developing a specification for devices that play copy-protected digital music, probably using a watermarking technology. In fact, the group is considering the same technology used to protect DVD-Audio content.

Once the specification is released, it will take some time for companies to come up with player designs, manufacture them, and get them to market. There should be several available for the Christmas selling season, with more to follow next year.

Microsoft Monkey Business

Well, it seems that we can't keep away from monkeys this month, any more than Microsoft can avoid lawsuits. Interestingly enough, the latest suit brought against the software giant revolves around—you guessed it—monkeys.

The problem stems from the search engine in Microsoft *Publisher 1998.* When you ask it to search for photos of monkeys, one of the five search results is a picture of an African-American couple sitting in a playground. This linking of black people with monkeys brought on cries of racism, including a lawsuit brought by John Elijah of San Diego, who found the image to be "racist" and "an insult." The suit that was filed in early July in U.S. District Court for the Southern District of California seeks over $75,000 in damages and restitution to anyone exposed to the image. Considering that more than four million copies of Microsoft *Publisher 1998* have been distributed, that's an awful lot of exposure.

According to Microsoft, the photo under dispute was linked by the program's search engine to several phrases, including "couples," "man," "monkey bars," "playground equipment," and "woman." When you search for any of those phrases—or even a part of one of those phrases—the photograph of the couple in the playground appears.

"We recognize [the inclusion of the photograph] as being insensitive," said Microsoft spokesman Greg Shaw, noting that the company has made a free fix available. But the general consensus among technology analysts is that such glitches are difficult to avoid, given the size and complexity of databases and the nuances of the English language.

Microsoft Game Blocker

For those seeking relief from other offensive sights and sounds on their PCs—namely extreme violence, nudity, and foul language in computer games—the next release of Microsoft's Windows operating system will include a "parental lock-out" feature. The option, which is based on the game's industry-determined content rating, will allow parents to block out certain games from the computer.

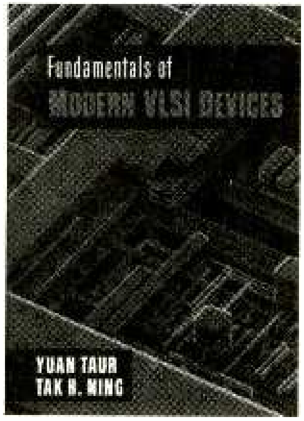
The Entertainment Software Rating Board and the Recreational Software Advisory Committee are the two main groups that rate games. Microsoft is trying to put their ratings into a database on which the *Windows Game Manager* would be based. Without the support of these groups, this feature cannot succeed. Microsoft would also like to see the ratings embedded in the game software itself, but to date no manufacturers have agreed to do so.

If the *Windows Game Manager* works out as planned, it will be available in all new Windows-based PCs and will be sold as an upgrade as well. It would be possible to add ratings from educational or religious groups also, and parents could even rate games on their own, giving them even more control. ■

Electronics Library

FUNDAMENTALS OF MODERN VLSI DEVICES
by Yuan Taur and Tak H. Ning

The great advances made in VLSI technology in recent years have grown out of rapid developments in the design and fabrication of CMOS and bipolar devices. This book examines in detail the basic properties and design of these devices, including chip integration, and it discusses the various



factors that affect their performance.

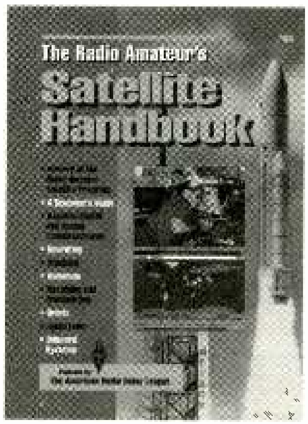
The authors begin with a thorough review of the relevant aspects of semiconductor physics and go on to describe the design of CMOS and bipolar devices and the optimization of these devices for VLSI applications. Issues such as power consumption and packing density that affect circuit performance and manufacturability are discussed. Scaling and the physical limits to scaling such devices are also covered.

Fundamentals Of Modern VLSI Devices costs $44.95 and is published by Cambridge University Press, 40 W. 20th Street, New York, NY 10011; Tel. 800-872-7423; Web: www.cup.org.

THE RADIO AMATEUR'S SATELLITE HANDBOOK
by Martin Davidoff

Perfect for beginners as well as experienced satellite enthusiasts, this comprehensive book is the new standard for ham-radio operators who want to experience the thrill of contacting other stations through an orbiting spacecraft. The author, an expert in the field, covers every aspect of the amateur satellite program, including tracking (with an emphasis on software and how to use it), station equipment and antennas, and operating tips and techniques. Also discussed are the unique aspects of the analog and digital ham satellites, plus complete details on current and future ham satellites—including extensive coverage of AMSAT's Phase 3D.

In addition, the handbook covers the SAREX (US Shuttle amateur in space) program and operation from the Russian space station Mir. The detailed appendices include a list of the dates and frequencies of all amateur spacecraft beginning in 1961, profiles of all the active amateur spacecraft, Internet sites of interest, and amateur-satellite-related FCC rules and regulations. Sample problems help the reader solve exercises involving satel-

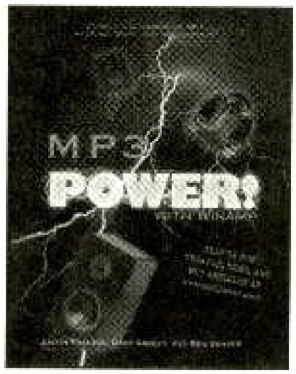


lite orbits and tracking.

The Radio Amateur's Satellite Handbook costs $22 and is published by American Radio Relay League, 225 Main Street, Newington, CT 06111-1494; Tel: 888-277-5289 or 860-594-0200; Web: www.arrl.org.

MP3 POWER! WITH WINAMP
by Justin Frankel, Dave Greely, and Ben Sawyer

Mastering MP3—compressed digital audio—requires a lot of work, and this book is designed to help demystify a technology that everyone is hearing about. It helps novices and experts alike maximize the potential of this new Internet technology. The authors offer unique and complete coverage of MP3 technology and *Winamp* technical specifications and optimizations. They also show users how to create



MP3 files from existing CDs and how to find MP3 files on the Internet.

Using *Winamp*'s SHOUTcast server technology and detailed instructions in the book, readers will also learn how to create a personal Internet radio station. In addition, the book includes interviews with leading MP3 users and proponents, including Chuck D of the rap group Public Enemy. The companion CD-ROM contains a varied collection of MP3 tools and utilities, as well as licensed music clips, courtesy of EMusic (*www.emusic.com*)—from well-known artists such as They Might Be Giants.

MP3 Power! With Winamp costs $29.95 and is published by Muska & Lipman Publishing, 2645 Erie, Ste. 41, Cincinnati, OH 45208; Tel. 513-924-9300; Web: www.muskalipman.com.

(Continued on page 88)

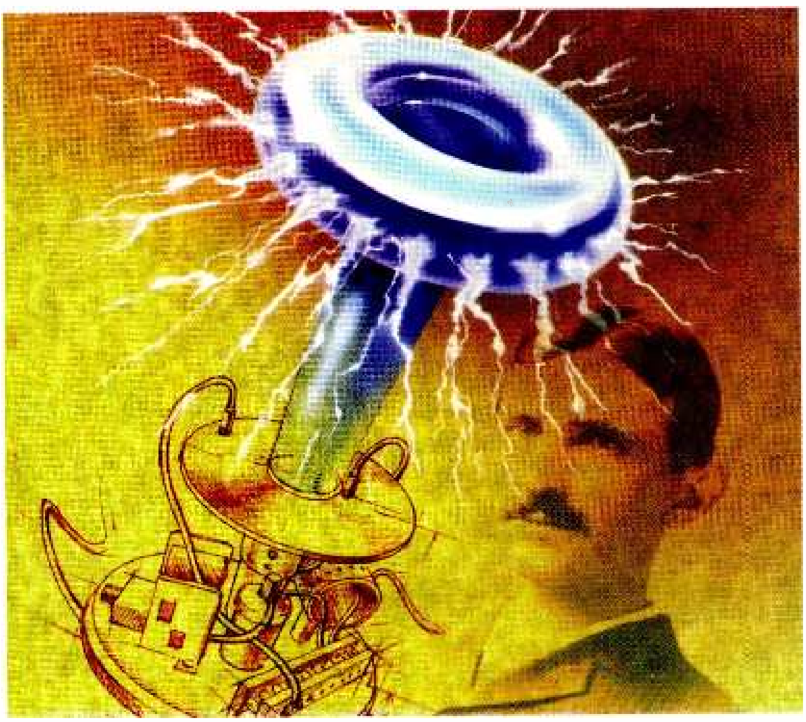
SOLID-STATE TESLA COIL

CHARLES D. RAKES

Wield the power of lightning with this modern design that would make Nikola himself proud.

One hundred years ago, from a mountain top in Colorado, Nikola Tesla transmitted electrical power with his famous Tesla coil for a distance of 25 miles without wires. That high voltage experiment in the wireless transmission of power is as fascinating today as it was back then. The majority of the Tesla coils being built today are of conventional design, depending on the use of line-operated step-up transformers to generate the necessary high voltage for the Tesla coil's primary circuit. And rightfully so. After all, they are based on a time-proven design, but it can be very dangerous or even fatal if the Tesla coil's primary is accidentally touched!

Our solid-state DC Tesla coil eliminates the line-operated, high-voltage transformer, making it less dangerous to operate and experiment with. However, there's still the possibility of shock if the primary tuning capacitor is accidentally touched while the circuit is in operation or *even when the power is turned off.*



There is one other aspect of our Tesla coil that is different from the conventional design, and that's the DC part. In a standard coil design, the maximum spark length obtained from the secondary coil is primarily determined, in an efficient system, by the AC-input power to the Tesla system. In a DC coil, the input energy is applied in steps and stored in the primary's tuning capacitor until the capacitor's voltage reaches a level sufficient to jump the spark gap. The DC coil doesn't spew out a continuous spray of sparks like the conventional coil but sends out snappy sparks in a slow motion, machine-gun like manner. Our DC Tesla coil only consumes a few watts of power but can output a 6- to 8-inch spark to ground.

About the Circuit. The schematic diagram of the *Solid-State Tesla Coil* is shown in Fig. 1. The circuit is built around a 555 oscillator/timer (IC1); a pair of IRF9130 P-channel HexFETs (Q1 and Q2); a gaggle of diodes, both 1N4007 and 1N5401 types (D1–D94); three transformers—T1, a 25-VCT, 2-amp unit, and T2 and T3, a pair of auto ignition coils; a couple of hand-wound coils (L1 and L2); and several support components (resistors, capacitors, switches, *etc.*).

Power for the circuit is furnished by a 25-volt, 2-amp transformer (T1), a full-wave rectifier (comprised of D1 and D2), and two filter capacitors (C4 and C5). Essential to the operation of the circuit are IC1, Q1, and Q2. Integrated circuit IC1 is configured as a low-frequency pulse-generator, whose operating frequency is determined by the values of R1, R2, and C2. The output of IC1 at pin 3 is fed to a voltage-divider network comprised of R3 and R4, at the junction formed by those two components. From that point, the voltage divides along two paths and is used to drive the two P-channel HexFETs (Q1 and Q2). The pulsing output of IC1 causes the HexFETs to turn on and off in unison. As the HexFETs—which operate like heavy-duty toggle switches—alternate between full

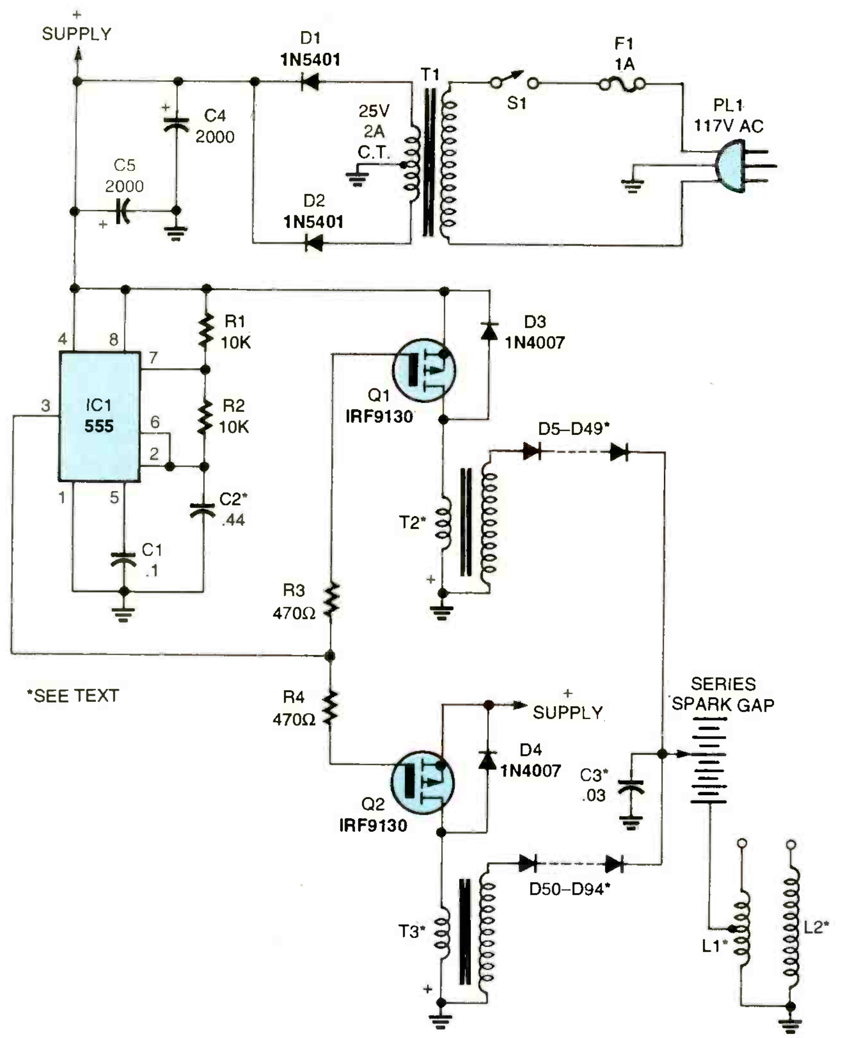


Fig. 1. The Solid-State Tesla Coil is comprised of a 555 oscillator/timer, a pair of IRF9130 P-channel HexFETs, a gaggle of diodes, three transformers, a couple of hand-wound coils, and several support components, as illustrated by this schematic diagram.

conduction and cutoff, a series of voltage spikes is sent to a pair of auto ignition coils (T2 and T3), producing a relatively high instantaneous peak voltage across the primaries of T2 and T3. The rising and collapsing voltage across the primaries of the ignition coils causes a very high pulsating voltage to be induced into the secondaries of T2 and T3.

The output of each ignition coil (at its secondary winding) is fed through identical diode strings—each comprised of 45 series-connected 1-amp, 1000-PIV silicon diodes (D5 through D49 for Q1 and D50 through D94 for Q2)—to a summing node at the junction of D49 and D94. The summed voltage causes C3 (the primary tuning and energy-storage capacitor, which is tied to the summing junction) to begin charging. The high DC voltage that's stored in C3 is fed through a series of spark gaps to supply an oscillating source of energy to the primary coil of the Tesla system, L1.

Inductor L1 is tuned to the natural resonance frequency of the secondary coil (L2) by adjusting the inductance of L1 via a movable tap. Adjusting the primary coil to the natural resonance frequency of the secondary coil is the secret to any successful Tesla coil system.

Construction. The author's prototype of the Solid-State Tesla Coil was put together as several subassemblies—perfboard (which contains the majority of the electronic components), driver, spark-gap, pancake-coil (L1, the primary coil), tower-coil (L2, the secondary coil), tuning/energy-storage assembly (C3), and a high-voltage-rectifier assembly. The majority of the subassemblies were then mounted to a round—15-inch diameter by 1-inch thick—baseboard, cut from pine-

PARTS LIST FOR THE SOLID-STATE TESLA COIL

SEMICONDUCTORS

IC1—555 oscillator/timer, integrated circuit
Q1, Q2—IRF9130 P-channel HexFET (Mouser part # 570-IRF9130)
D1, D2—1N5401 or similar 3-amp, 100-PIV, silicon rectifier diode
D3–D94—1N4007 or similar 1-amp, 1000-PIV, silicon rectifier diode

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1, R2—10,000-ohm
R3, R4—470-ohm

CAPACITORS

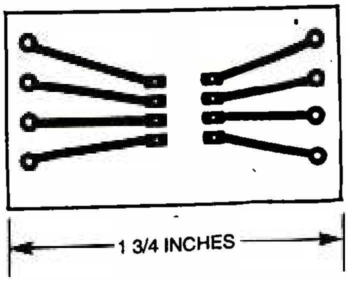
C1—0.1-µF, ceramic-disc
C2—0.44-µF, ceramic disc (see text)
C3—0.03-µF (see text)
C4, C5—2000-µF, 40-WVDC, electrolytic

INDUCTORS

T1—25-volt CT, 2-amp step-down transformer (RadioShack #27301512)
T2, T3—Auto ignition coil (Wells type LU800)
L1—See text
L2—See text

ADDITIONAL PARTS AND MATERIALS

F1—1-amp fuse
S1—SPST toggle switch
SPARK GAP—See text
Perfboard material, IC socket, alligator clips, 1-inch pine-board stock, ⅜-inch fiber board material, 1-inch ¼-20 bolts, ¼-20 nuts, 2-inch ¼-20 bolts, 1½-inch long × ⅜-inch diameter compression springs, #28 enamel-coated copper wire, #6 bare copper wire, 4-inch drain pipe, 4-inch end caps, 2-inch PVC pipe, 2-inch end caps, 0.062 aluminum flashing material (see text), feedthrough insulator, banana jacks, banana plugs, small metal box, 6-inch diameter galvanized adjustable elbows (see text), wood screws, 6-32 hardware, solder lug, test lead wire, jumper wire, solder, additional hardware, *etc.*



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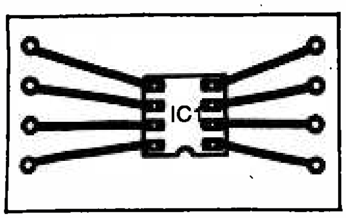


B

Fig. 2. The author's prototype of the Solid-State Tesla Coil was put together as several sub-assemblies. Most of the electronic components were hard-wired on a small section of perfboard, which also held a small printed-circuit card that was prepared especially for IC1. A template for that foil pattern as well as a parts-placement diagram is shown here.

board stock.

Begin by cutting the pine-board stock to the required dimension. After cutting the pine-board stock, a 2-inch PVC end cap was mounted open-end up to the center of the round baseboard. The two ignition coils were then mounted to the baseboard using a pair of L-brackets; plumber's tape can be used to secure the L brackets to the ignition coils. Or, if you prefer, large screw-type hose clamps can be used to secure the L-brackets to their respective ignition coils. After securing the ignition coils in position, mount T1 to the baseboard.

Next prepare the perfboard assembly. In the author's prototype, the perfboard assembly, which measures 3½ × 5 inches, contains all of the electronic components, except T1–T3, Q1, Q2, F1, S1, D3–D94, and the remaining high-voltage components. Interconnections between the various perfboard components were accomplished through point-to-point wiring techniques in typical breadboard fashion. Note: Although not really necessary, IC1 was mounted to a small printed-circuit board, measuring 1 × 1¾ inches, which was then mounted to the perfboard and wired into the circuit. A template for that simple foil pattern is shown in Fig. 2A, and the corresponding parts-placement diagram is shown in Fig. 2B.

Whether or not you decide to use that foil pattern, assemble the electronic portion of the circuit on the perfboard, guided by the schematic diagram (Fig. 1). A general layout for the Solid-State Tesla Coil's perfboard assembly—on which R1–R4, C1, C2, C3, C5, D1, D2, and IC1 (with or without printed-circuit board) are mounted—is shown in Fig. 3. Note that although C2—a 0.44-µF capacitor—is shown as a single component, it is actually a pair of parallel-connected 0.22-µF units.

Once completed, check the board for construction errors, and if all seems OK, mount the perfboard assembly to the baseboard. The perfboard assembly was mounted above T1, supported by a pair of 2¾- × 1½-inch wood blocks, as illustrated in Fig. 4. When that's completed, prepare the driver assembly.

The driver assembly is comprised of the two HexFETs (Q1 and Q2) and a pair of diodes (D3 and D4) mounted to individual heatsinks that were fabricated from two 3½- × 4-inch pieces of .062-inch aluminum. Diodes D3 and D4 were mounted directly connected across the source and drain terminals of the HexFETs on the opposite sides of their respective heatsinks. On completion of the driver assembly, check your work for construction errors. If all seems OK, mount the two HexFET/diode-mounted heatsinks to the baseboard on either side of the perfboard assembly, as shown in Fig. 4.

What remains are the pancake-coil assembly (L1), the tower-coil assembly (L2), the tuning and energy storage assembly (which revolves around C3), the series spark-gap assembly, and the high-voltage-rectifier assembly (comprised of D5–D94). Those assemblies, which were fabricated from readily available parts and materials, can be assembled in any sequence desired. But, let's start with the simplest item—the dual high-voltage-rectifier strings. Begin the next phase of construction by cutting the leads of the ninety 1N4007 diodes to a length of /-inch. After cutting the leads, solder the diodes together anode-to-cathode to form two 45-diode strings (with a total length of about 22-inches)—one for each transformer output. (The overall string length isn't critical so anything close will do.)

Afterward, the two diode strings

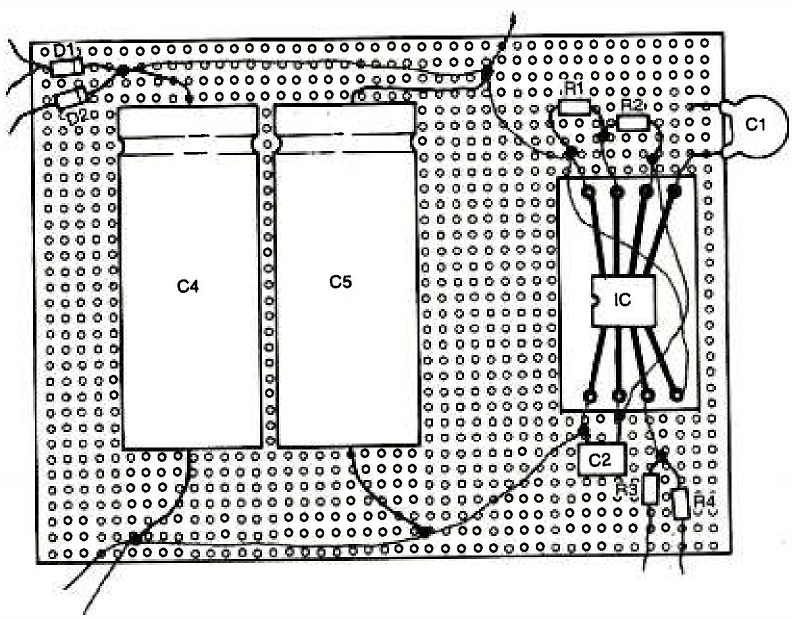


Fig. 3. Although there is nothing critical about the layout of the perfboard assembly, general layout for that portion of the circuit is shown here. When assembling this portion of the circuit keep in mind that C2 is actually two parallel-connected capacitors (see text for details).

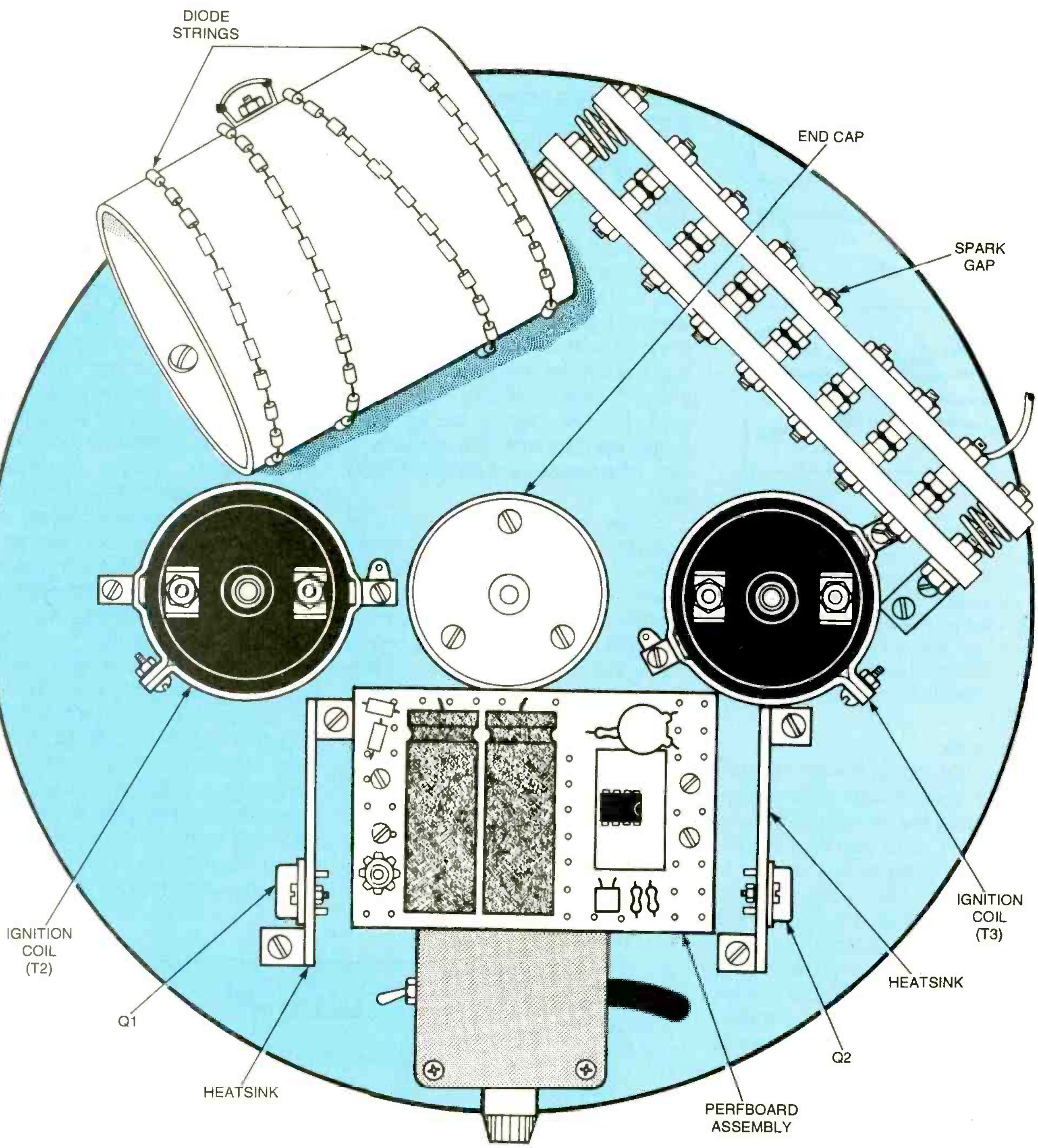


Fig. 4. The perfboard assembly was mounted suspended above T1 and supported by a pair of 2¾- × 1½-inch wood blocks that were on a 12-inch circular baseboard, as illustrated here.

were wound on a 5-inch length of 4-inch diameter PVC pipe and joined at their cathode ends at a junction formed from 6-32 hardware and solder lugs mounted to a convenient location on the 4-inch PVC pipe (see Fig. 4). Hot-melt glue was then used to hold everything in place. The diode assembly was then mounted to the baseboard atop a 2-inch porcelain insulator. If a porcelain insulator isn't available, a suitable support can be fashioned from a piece of hardwood or plastic.

Pancake-Coil Fabrication. The pancake coil was formed on a ¼-inch thick piece of Plexiglas material (which serves as a base and provides support for the primary) that was cut into a 12-inch diameter circle (see Fig. 5). If Plexiglas isn't readily available, just about any other type of plastic material, fiberboard, or even wood can be used. After cutting the base into shape, cut a 4½-inch hole into its center. Starting at the edge of the center hole in the coil base, wind 10¾ turns (about 24 feet) of number 6 bare copper wire onto the base to form L1. The 10fl turns of L1 should be spaced to evenly cover the coil's Plexiglas form.

Note: If number 6 copper wire

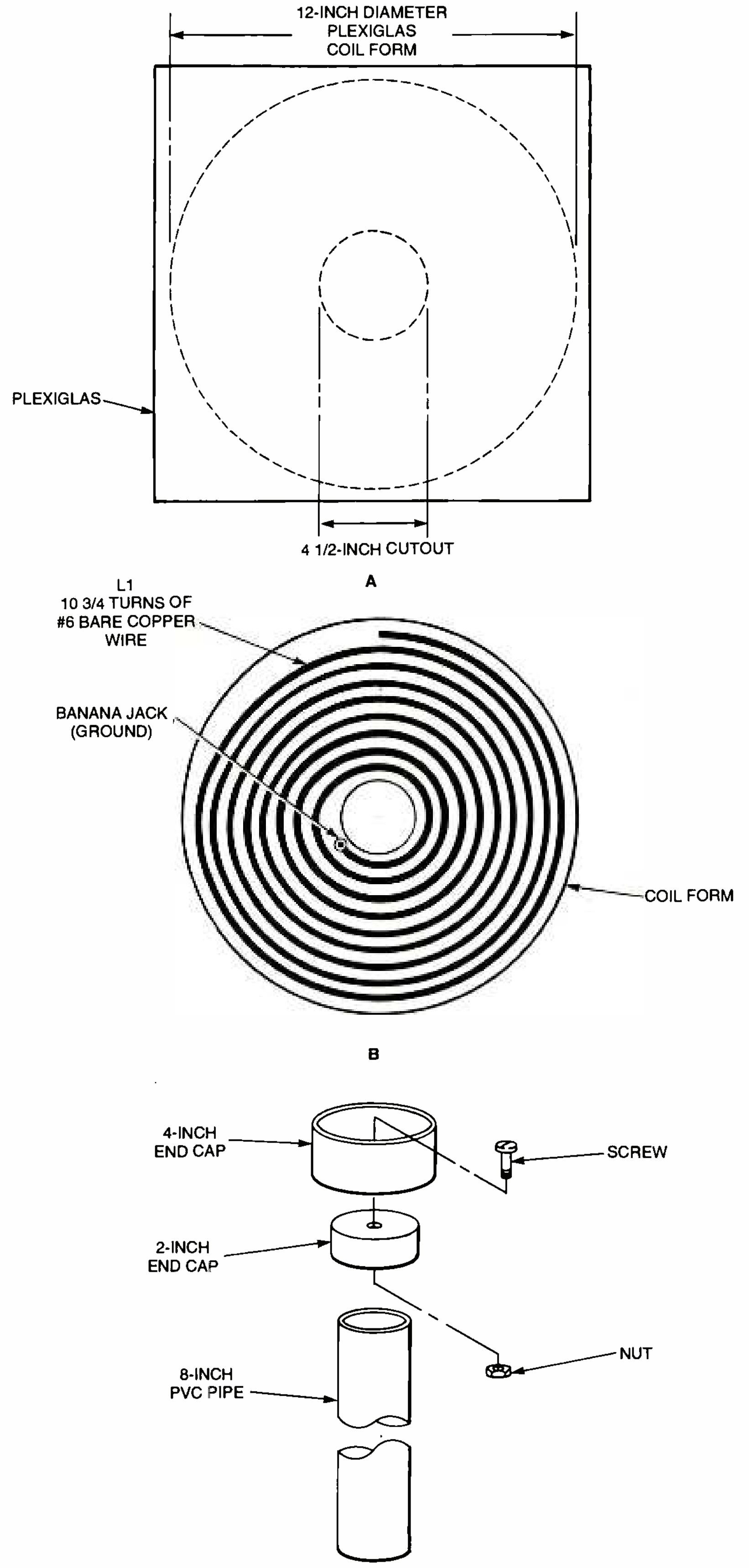


Fig. 5. The pancake coil—comprised of 10¾ turns of number 6 bare copper wire—was formed on a ¼-inch thick piece of Plexiglas material that was cut into a 12-inch diameter circle.

isn't available, any copper wire close in size will do (but, remember, bigger is better because current flows in the outer surface of the wire in a Tesla system). Don't be too concerned if the coil doesn't turn out picture perfect; winding the primary coil can be the most challenging part of building the Tesla coil. When finished, secure the coil in place with epoxy or hot glue.

Drill a hole in the Plexiglas base at the end of the inside turn and mount a banana jack for the ground end of L1 and L2. Connect the end of the inside winding to the banana jack and connect an 8-inch length of test lead wire to the jack and a banana plug to the other end.

After that, epoxy or hot glue a 4-inch PVC end cap to the center of the primary coil's base. The open rim of the end cap should be flush with the top of the Plexiglas base. Drill a hole in the center of the end cap large enough to clear a number 8-32 screw. Then using the same bit, drill a hole in the center of a 2-inch PVC end cap and bolt the two- and four-inch end caps together.

If the end caps are rounded on top, fill the gap where the two caps meet with epoxy or hot glue. The glue acts as a filler and adds to the stability of the coil support stand. Cut an 8-inch length of 2-inch PVC tubing. The 8-inch tube serves as a support for the two coils (L1 and L2) in the final assembly.

Tower-Coil Fabrication. The tower (or secondary) coil, L2, was wound on a piece of PVC pipe. Figure 6 gives details of fabricating the tower-coil assembly. Begin by cutting the a section of 4-inch diameter PVC pipe to a length of 18½-inches (as shown in Fig. 6A). Then, temporarily place end caps on each end of the coil form (as shown in Fig. 6B) to make sure they fit snugly. Once the fit is confirmed, remove the end caps and then (again referring to Fig. 6B) drill a hole in the coil form of sufficient size to accommodate a 6-32 screw, about fl inch up from the bottom of the form. That hole is to serve as a tie point for the ground end of L2.

Next, drill another hole about ½-

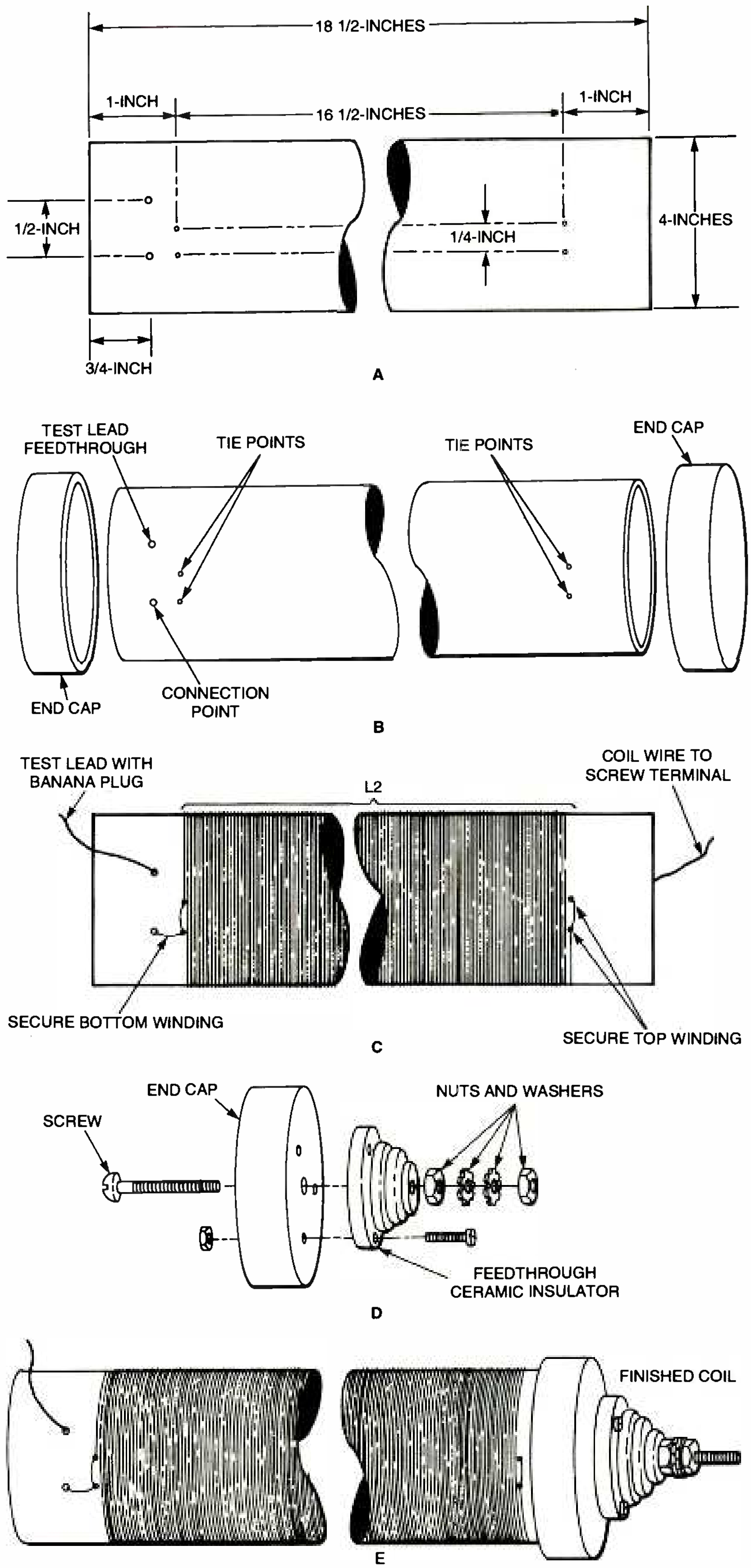


Fig. 6. The tower (or secondary) coil was wound on an 18½-inch length of PVC pipe. Shown here are fabrication details of the tower-coil assembly.

inch off to the side of that hole just large enough for a test-lead wire to pass through. Make a mark one-inch up from the bottom of the coil and in line with the first hole. Drill two very small holes (just large enough to pass #28 wire through) about ¼ inch apart and horizontally in line with the bottom. That allows the bottom end of L2 to pass through the coil form and attach to a solder lug held in place with the 6-32 hardware. From that point, make another mark 16½ inches directly above it. At that mark, drill two more small holes about ¼-inch apart and horizontally in a line to allow the top end of L2 to pass through and connect to the top terminal.

Once all the preparations for the coil form are complete, wind the coil—which is comprised of about 1400 feet of neatly wound number 28 enamel-coated wire—guided by Fig. 6C. Winding the coil by hand can take a couple of hours, but if a lathe is handy, the job can be completed in about thirty minutes. However you wind the coil, be careful to fill the space between the marks with an even and neat solenoidal winding of number 28 enamel-covered copper wire. Leave about six-inches of wire at each end of the winding for making connections. Spray several coats of Krylon (or similar) clear acrylic on the coil for added insulation and protection against moisture. Don't overdo the acrylic spray: Two coats are sufficient.

Take a 4-inch PVC end cap and mount a feed-through ceramic insulator to the top of the cap (as illustrated in Fig. 6D). Place a solder lug on the terminal (screw head) inside the end cap and connect the top winding of L2 to the lug. Place the end cap on the coil form. At the bottom end of the coil, connect the ground end of L2 to the solder lug mounted to the form with 6-32 hardware. To the same solder lug, connect a 3-inch length of test-lead wire with a banana plug attached. The plug goes into the banana jack that's mounted on L1's base to tie L2's bottom winding to circuit ground. Figure 6E shows how the coil should look when completed.

Building the Capacitor. Capacitor C3 is a homemade unit comprised of 33 sheets of aluminum flashing and 34 sheets of plastic material sandwiched between a couple of pieces of pine board (which we'll hereafter refer to as a clamp).

Begin this phase of construction by manufacturing the capacitor clamp. The capacitor clamp is comprised of a pair of $15 \times 11\frac{1}{4}$-inch end pieces cut from 2-inch thick length of pine wood, a $13\frac{1}{2} \times 11\frac{1}{4}$-inch piece of $\frac{3}{8}$-inch thick fiber board, and two 8-inch $\times \frac{1}{2}$-inch carriage bolts (see Fig. 7 for details). After cutting the pine and fiber boards to the dimensions indicated in Fig. 7 and drilling holes as required, glue the fiber board section to the bottom of the capacitor clamp, as shown. When the clamp is ready, prepare the capacitor's dielectric and electrical plates.

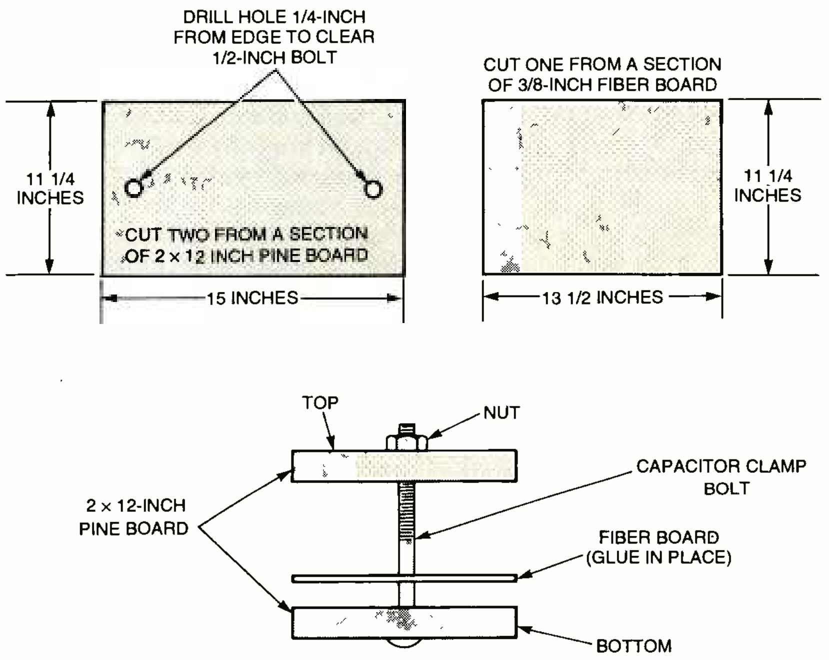


Fig. 7. Capacitor C3 is a homemade unit comprised of sheets of aluminum flashing and plastic material sandwiched between a couple of pieces of pine board, which we'll hereafter refer to as a clamp. Details of the clamp's construction are shown here.

The electrical plates for the capacitor were fabricated from a roll of 14-inch wide aluminum flashing, although aluminum foil can also be used. Figure 8A shows construction details for the plate (aluminum) section of C3. Start by cutting 33 sheets of flashing to 10×14 inches. After that, prepare the capacitor's dielectric. The dielectric (see Fig. 8B) is comprised of 34 sheets of 0.06-inch thick polyethylene material cut to 11×13-inches. Other types of plastic materials can also be used as the dielectric, as long as their insulating properties are sufficient to withstand the applied voltage. **Note:** Glass is not a suitable substitute.

Assemble the capacitor by placing one of the plastic sheets on the base of the clamp board. Position the first aluminum sheet, as shown in Fig. 8C, over the plastic sheet with a $\frac{1}{2}$-inch border on three sides, as illustrated. Place another plastic sheet over the aluminum sheet and position the second aluminum plate over that sheet of plastic facing out the opposite side with the same $\frac{1}{2}$-inch border. Continue the process until all materials are used. When finished, there should be 17 sheets of aluminum facing out one side and 16 facing out the other side.

Place the top clamp board in position and tighten the two nuts until all of the plates are flat. The aluminum plates on each side of the capacitor are then bolted together in several sections. To that end, punch or drill holes through 3 to 4 of the protruding aluminum tabs sticking out each side and clamp them together with 6-32

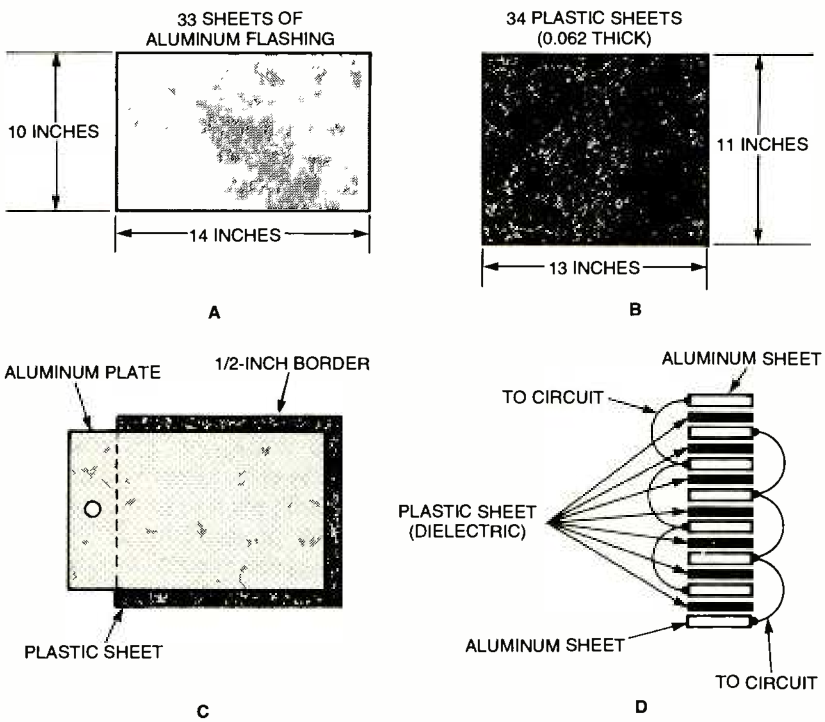


Fig. 8. Capacitor C3 is comprised of 33 plates fabricated from a roll of 14-inch wide aluminum flashing. The dielectric for C3 consists of 34 sheets of 0.06-inch thick polyethylene material cut to 11 × 13-inches. The plate and dielectric materials were then interleaved, as shown here, and the assembly held together with the homemade clamp.

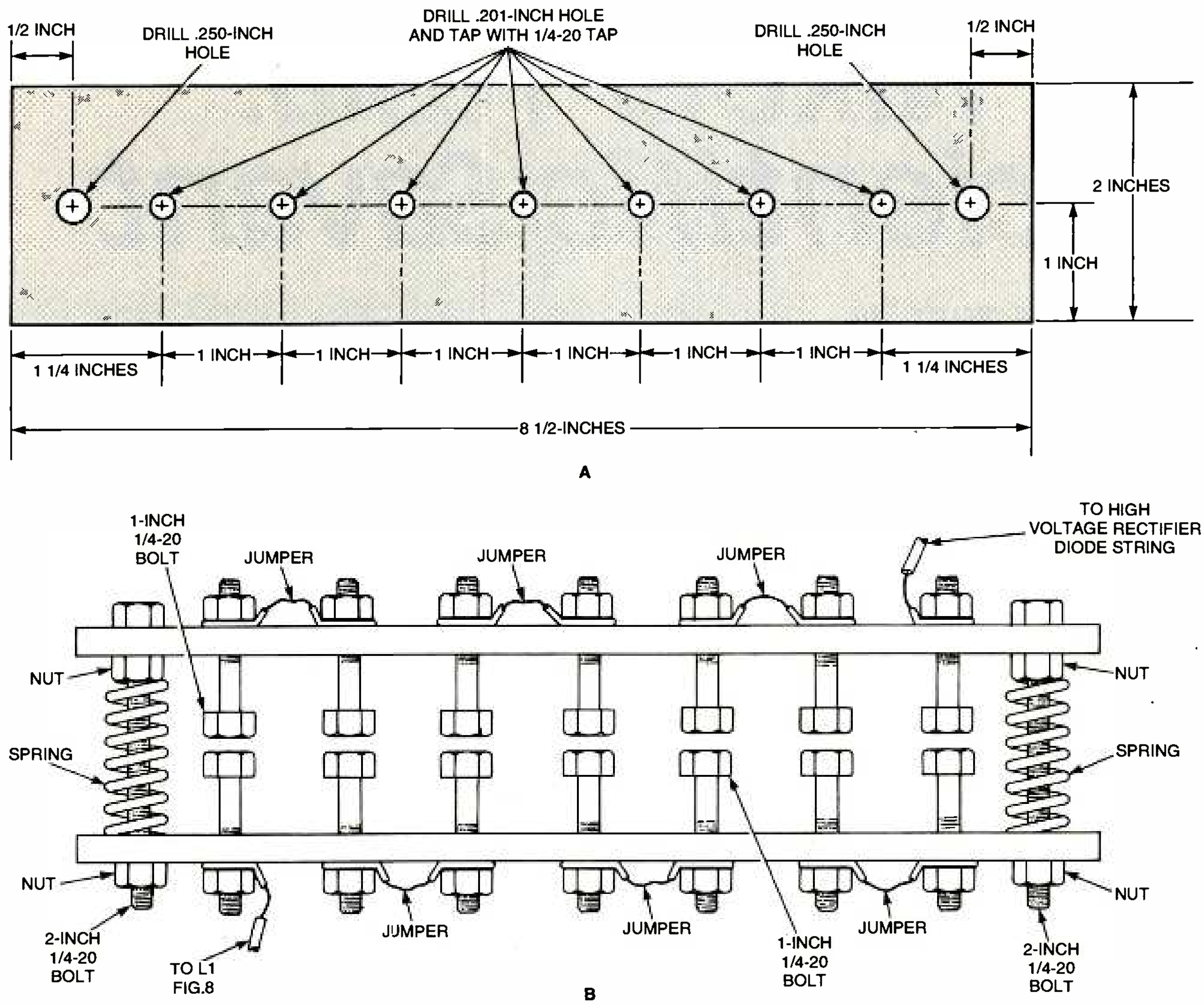


Fig. 9. The spark gap for the Solid-State Tesla Coil is a multi-stage, spark-gap arrangement, comprised of two pieces of fiber board and 16 bolts and nuts. Details for fabricating the multi-stage spark gap are shown here.

hardware and a solder lug. When all aluminum tabs are clamped in sections, tie all of the sections on one side together; then repeat the procedure on the other side (as indicated in Fig. 8D). The capacitor can then be hard wired to the circuit or connected with clip leads.

The Spark Gap. The spark gap for the Solid-State Tesla Coil is actually a multi-stage, spark-gap (multi-gap) arrangement, in which seven gaps are connected in series to allow maximum gap adjustment. The multi-gap arrangement is comprised of two pieces of fiber board, and 16 bolts and nuts. Details for fabricating the multi-stage spark gap are given in Fig. 9. Fabricate the multi-gap assembly by first cutting two pieces of 3/8-inch fiberboard to 8 1/2 × 2 inches, and drilling two 1/4-inch (0.250) holes in each end of each board (see Fig. 9A).

Follow that by drilling the remaining seven holes in the two boards using a 0.201-diameter drill bit; tap each of the seven holes with a 1/4-20 tap. Screw all 14 (seven in each side) 1-inch 1/4-20 bolts into place. Make sure each bolt is screwed all of the way in the board up to its shoulder. Connect the gaps together in series with jumpers as shown in Fig. 9B. Assemble the two halves with two, 2-inch 1/4-20 bolts and matching nuts. Place two compression springs over each bolt and place the other half of the gap assembly into position. Add the two outside adjustment nuts, set each gap to about 20 to 30 thousandths of an inch. Then attach the multi-gap assembly to the baseboard with two "L" brackets (refer back to Fig. 4).

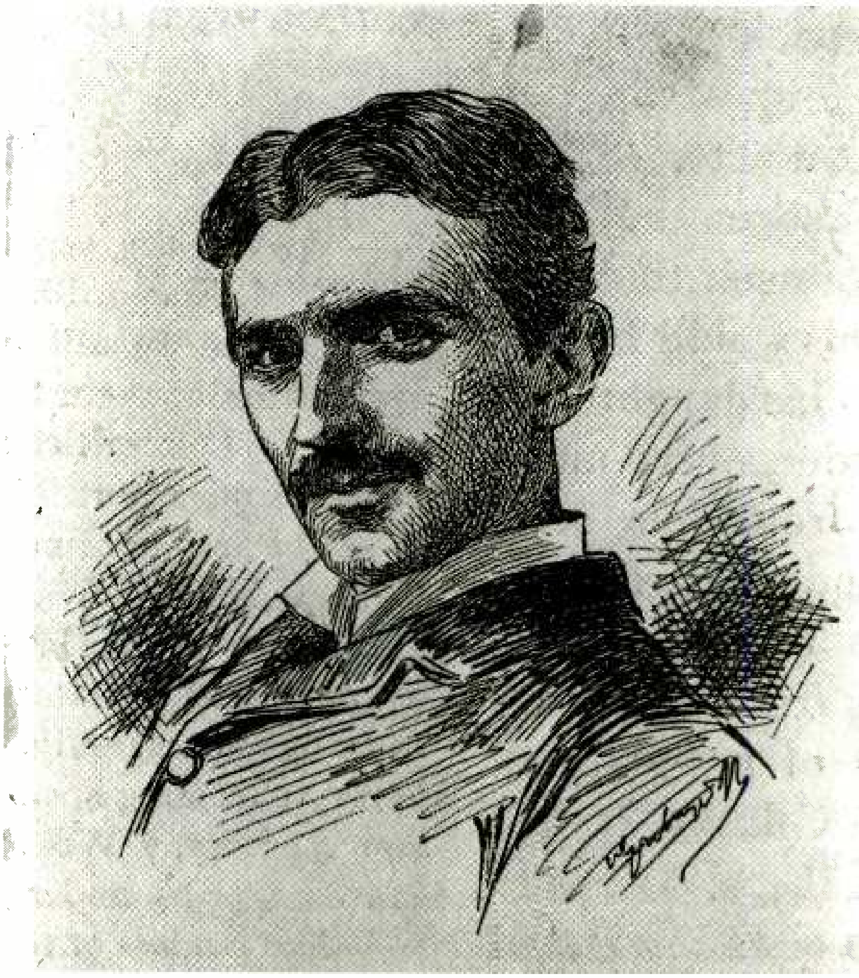
There is one final item to be added to the Tesla Coil—a top-loading capacitor—which helps to increase the output voltage and spark length considerably. The top-loading capacitor was constructed from four 6-inch-diameter galvanized adjustable (stovepipe) elbows connected together in a circle. Stovepipe elbows can be purchased at almost any large hardware-type store. After fabricating

(Continued on page 89)

Nikola Tesla: Scientific Savant

Calling Tesla merely "an inventor" would be like referring to Frederic Chopin as simply "a piano player."

JAMES P. RYBAK



What would cause a person to refuse a Nobel Prize? A 1915 Reuters dispatch from London stated, albeit unofficially, that Nikola Tesla and Thomas Edison had been chosen to share that year's Nobel Prize in physics. Numerous magazines and newspapers throughout the world published this report as fact. However, the awards were never made either to Tesla or to Edison. The complete story is not known, but many believe that Nicola Tesla may have refused to accept the award.

Tesla was very much in need of the $20,000, which would have been his half of the cash award accompanying the Nobel Prize. His work had resulted in the creation of fortunes for many others; but he, himself, lived much of his later life in near poverty and he would die penniless. If Tesla did decline the Nobel Prize, it likely was a matter of principle that precipitated his decision to refuse this prestigious honor. From Tesla's perspective, Edison was merely an "inventor" who devised useful applications of science. Tesla, meanwhile, considered himself a "discoverer" of new scientific principles and only, incidentally, an inventor. In Tesla's mind, the importance of the discoverer far outweighed that of the inventor.

Others believe that it was Edison who refused the award. Perhaps he was still angry that Tesla had quit working for the Edison Company and had aligned himself with Edison's arch competitor, Westinghouse.

Two years later, Tesla initially refused to accept the Edison Medal that the American Institute of Electrical Engineers (AIEE) planned to award him for his outstanding work in the development of alternating current theory and applications. Perhaps Tesla was miffed because it had taken the AIEE almost thirty years to recognize the significance of his work. Perhaps, too, Tesla was insulted to be given an award named after the person who had so strongly opposed the adoption of alternating current power distribution systems and who, Tesla believed, had reneged on a promise to pay him a large amount of money for solving important technical problems. In any event, it was clear that awards meant nothing to Tesla. It took an AIEE official several visits together with much coaxing and pleading before he could get Tesla to agree reluctantly to accept the Edison Medal. Tesla then almost failed to appear at the award ceremony.

Who was this man, this pioneer

whom many obviously have admired for the past century? Join us for a look at this savant's life and his accomplishments. As you'll see, forgetting Tesla is unforgivable for electronics activists. We owe him much.

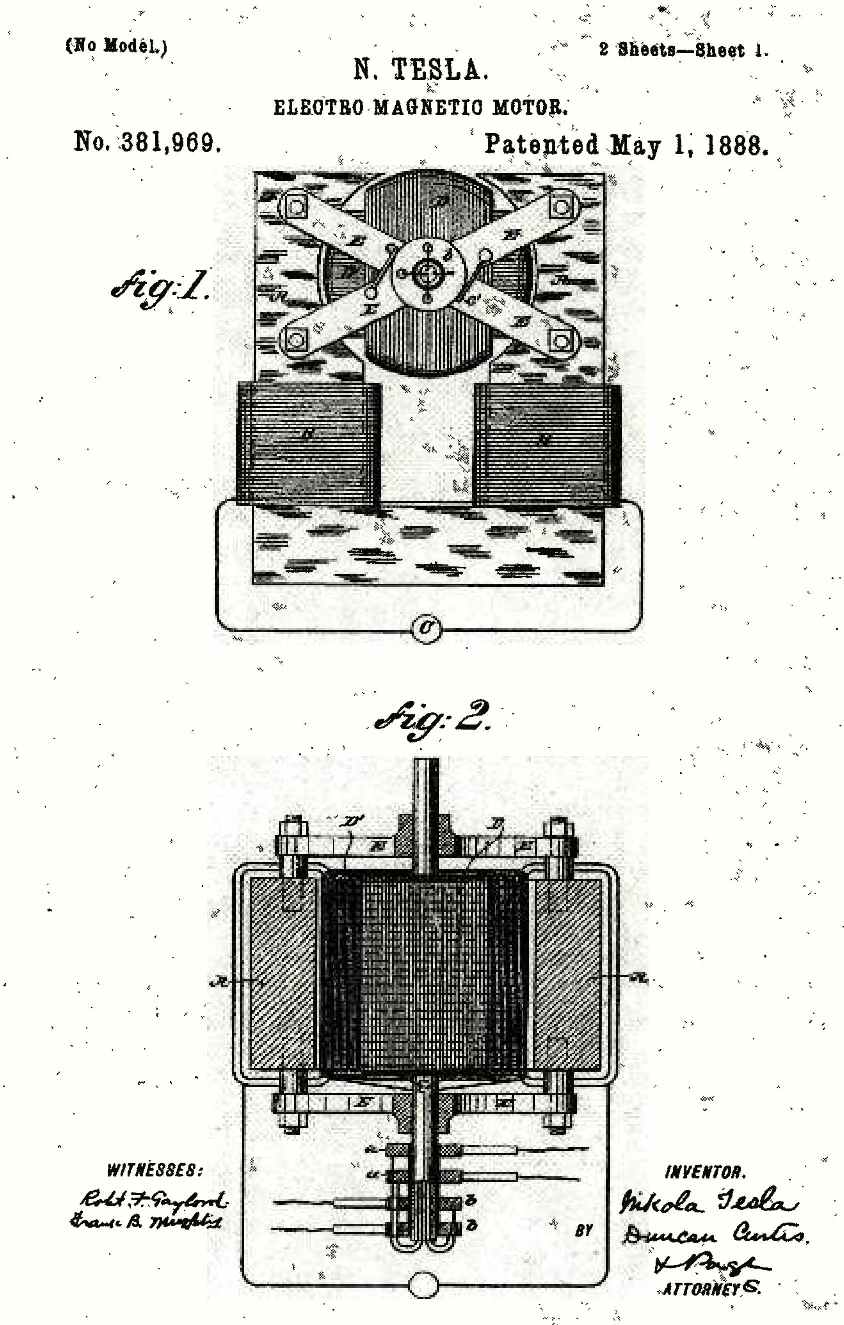
Early Days. Nikola Tesla was born in 1856 to Serbian parents who lived in a Croatian village in the southern part of the Austro-Hungarian Empire. His father had abandoned a military career to become a priest in the Serbian Orthodox Church. Although Nikola's mother had received no formal education, she was bright and had an exceptional memory. Tesla always credited his mother as the source of his intellectual abilities.

Mathematics was Nikola Tesla's favorite subject in school and the one in which he truly excelled. When given a problem to solve, he needed neither a blackboard nor a sheet of paper. Tesla had the extraordinary ability to visualize in his mind all the steps needed to solve the problem, just as though he had written them down. The ability to visualize mathematical problems and engineering designs clearly in his mind was of great value to Tesla throughout his life

As a child, Nikola loved to read and retained knowledge extremely well. He also learned several foreign languages. This enabled him to read far more than what was written in his native Serbo-Croatian. Young Tesla loved to devise complex mechanical devices in his mind and then build them from whatever materials were at hand.

While in what we would call high school and the first years of college, Tesla studied so intensely that his health was seriously affected. His father feared that engineering, which required many years of intense study and to which young Nikola aspired, would further jeopardize his son's well being. The elder Tesla urged the boy to enter the ministry because that profession required a less demanding program of study. Periodic episodes of severe illness due to overwork would plague Tesla throughout his life.

Although further weakened when he contracted malaria, Nikola successfully completed the four-year Higher Real Gymnasium (college) program in Croatia in only three years. It was during this time that Tesla became unalterably determined that he wanted to devote his life to electrical experimentation.



Tesla's second AC patent, granted in 1888, was for a then-groundbreaking induction motor.

Upon his return home, Tesla's parents were alarmed by their son's demanding career choice and by the unrelenting pace at which he continued to pursue his studies. His health was still very much at risk, and they again insisted that he become a priest, not an engineer. Very quickly, Nikola experienced the additional discouragement of contacting cholera and receiving his draft notice for army service.

Tesla now became despondent and was almost at death's door. He knew that if he survived the cholera, he would have to serve time in the army and then study for the priesthood. He felt he had nothing to live for. Upon realizing this, Nikola's father relented and gave permission for his son to study electrical engineering.

Tesla slowly began to regain his health. His father then sent him off for a year's rest to further recover his health. During this time, the elder Tesla used the influence of relatives to get his son's military obligation cancelled.

Committed to Developing AC. In 1875, Tesla went to the city of Gratz, Austria to study electrical engineering. There he still continued to overwork himself and again jeopardized his health. It was at this time that Tesla realized the inherent limitations of DC motors and generators due to the sparking associated with commutator action (the switching of current polarity in a motor to keep the armature coil moving). This discovery clearly convinced Tesla of the need to develop alternating current motors and generators that would not need commutators.

Developing the details of how this goal could be accomplished occupied much of Tesla's time for the next several years. He rejected the claim of his professor who taught the courses on motors and generators that the development of AC motors and generators was an "impossible idea."

It was "instinct" that told Tesla his professor was wrong. Tesla's instincts were almost always correct when it came to solving scientific problems. Nonetheless, progress toward his goal did not come quickly.

Following some additional engineering study in Prague, Tesla went to Budapest in 1881 where a family friend had offered him a job at the new telephone central station that was being started. Tesla's design, computational, and estimating abilities soon attracted the attention of his supervisors. When the telephone exchange was completed, Tesla was placed in charge of its operation. Once again, Tesla worked excessively and his health rapidly declined. Exhaustion soon forced him to quit his job.

The Key AC Concept. In February of 1882, shortly after recovering his health, the solution to the alternating current problem came to Tesla. He now could visualize clearly in his mind how he would use alternating currents to create a rotating magnetic field. This was the key concept needed to produce a practical AC motor.

Tesla created the rotating magnetic field by using two circuits in which the currents were out of phase with each other. Others had tried to develop AC motors using only one circuit, but their approach could not produce continuous rotation of the motor. Nikola Tesla's two-phase system successfully eliminated the need for a commutator.

The work Tesla had begun was far from completed, however. He now developed designs for dynamos (generators), motors, transformers, and the other devices needed for alternating-current power systems. Tesla extended his rotating magnetic field idea to include currents of three, four, and six different phases. Nikola Tesla had developed in his mind a true polyphase power system. He also believed that he could even build a successful single-phase AC motor.

The telephone company in Budapest where Tesla had worked prior to his illness and to which he had hoped to return was sold. The same family friend who had helped Nikola get his job in Budapest now helped him obtain a job in Paris with the Continental Edison Company, which was licensed to make DC motors, generators, and lighting equipment under Edison's patents.

Tesla tried to interest every likely person he could find in Paris to help him develop his polyphase AC system. He did not have to worry about people stealing his ideas as no one showed any real interest in them at all.

Tesla was assigned to a special project in Germany. Here he used his spare time to build a two-phase generator and a two-phase motor. Tesla did the close tolerance machining work himself. There were no working drawings on paper. Tesla had all the details clearly fixed in his mind. When he first tested the AC machines in 1883, they functioned extremely well. His theory was correct.

Upon returning to Paris after successfully completing the project in Germany, Tesla became dissatisfied with his immediate supervisors. He had been promised a generous bonus for his successful work in Germany but that bonus was never given. Indignant, Tesla decided not to show the Company officials his two-phase system in operation and resigned his position.

Tesla Meets Edison. Continental Edison's manager, Charles Batchelor, was an associate and good friend of Thomas A. Edison. Batchelor was impressed with Tesla and urged him to go to the United States to work directly with Edison.

Tesla welcomed this suggestion together with a letter of introduction to Edison that Batchelor is said to have written for him. Batchelor's

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letter to Edison reportedly stated "I know two great men and you are one of them; the other is this young man." Tesla sold his personal possessions to pay for the train and ship tickets he needed and left for New York in 1884.

Because his wallet and extra clothes were lost during his travels, Tesla arrived in the United States with little more than the four cents in his pocket and the clothes on his back. Fortunately, Tesla had a friend in New York with whom he could stay temporarily.

While Tesla was very favorably impressed with Edison when the two men first met, the reverse was not true. Edison had very little formal education and did his inventing by trial and error experimentation, whereas Tesla solved all his technical problems mentally and did virtually no experimentation. Perhaps an even greater barrier was that Edison was an unshakable proponent of DC power systems and was strongly opposed to the development of AC systems. Tesla was firmly convinced of the superiority of AC. Despite these fundamental differences, Edison gave Tesla a job, likely on the basis of Batchelor's recommendation.

Edison quickly saw that Tesla consistently put in long hours and made many valuable contributions. When Tesla suggested that he could improve the efficiency and lower the operating cost of the DC dynamos the Edison firm manufactured, the plant manager reportedly told him "There's fifty thousand dollars in it for you if you can do it."

During the following months, Tesla designed twenty-four new types of DC dynamos. He replaced the previously used long field magnets with more efficient shorter ones and added some important automatic controls. The machines performed as Tesla had promised and the Edison firm took out numerous new patents.

In the spring of 1885, when Tesla asked for the fifty thousand dollars he believed he had been promised and had earned, Edison's reply was "Tesla, you don't understand our American humor." Furious because he received not an extra dime beyond his $18 per week salary for all the successes he had produced, Tesla immediately quit his job with Edison.

The Tesla Electric Company. Tesla now was unable to find an engineering job and was forced to work as a laborer. In early 1887, Tesla's abilities and stories about his AC developments attracted the attention of the foreman of the labor crew on which Tesla worked. The foreman also was working far below his own level of training and was sympathetic to Tesla's situation. He introduced Tesla to A. K. Brown of the Western Union Telegraph Company. In April of 1887, Brown and a friend provided the money to create the "Tesla Electric Company." By coincidence, Tesla's new laboratory was located within sight of Edison's facility.

Quickly, Tesla built not only the two-phase AC generator and the induction motor he had built in Europe but also the other machines he had designed in his mind while in Budapest. While concentrating on single-phase, two-phase, and three-phase systems, he also experimented with four- and six-phase devices. Tesla also developed the mathematical theory needed to explain the operation of his AC systems so that others could and would both understand and accept his work.

After having proven that his AC systems were practical, Tesla applied for a number of fundamental patents. These were granted to him in 1888. Word of Tesla's accomplishments and genius spread quickly. On May 16, 1888, Tesla was invited to present a lecture entitled "A New System of Alternate Current Motors and Transformers" at an AIEE meeting in New York. He now was a recognized and accepted member of the electrical engineering "establishment."

George Westinghouse was a far-sighted individual who already had made a fortune in Pittsburgh manufacturing his air brake for trains as well as a variety of electrical devices he had invented. He recognized the major advantages which AC power systems held over DC and he saw huge commercial potential in the work Tesla had done.

The DC electrical systems favored by Edison could not be used to distribute power farther than about one-half mile from the generator due to the excessive voltage drops that resulted from the resistance of the power lines and the large currents that flowed through the lines. AC voltages, however, are stepped-up at the generator using transformers, thereby reducing both the current and the transmission losses. The result is a substantially increased distribution range. Transformers then convert the AC voltages to safe levels at the point where the power is utilized.

An Alliance with Westinghouse. Shortly after Tesla gave his AIEE lecture, he was contacted by Westinghouse who wished to see the AC equipment in person. The two men had many interests in common and immediately formed a good relationship. Westinghouse quickly offered Tesla one million dollars for his AC patents. He also invited Tesla to come to Pittsburgh for a year at a "high" salary as a consultant. Tesla quickly agreed. Half of the one million dollars went to A. K. Brown and his partner who had financed Tesla's work but Tesla still was now rich beyond his wildest dreams.

Problems developed when Westinghouse's engineers tried to use Tesla's designs to produce small, single-phase motors. In addition, the priorities and urgencies associated with manufacturing AC power systems for sale were different from Tesla's research priorities. Furthermore, Tesla was adamant that his AC machines worked most efficiently at a frequency of 60 Hz (then "cycles per second") while Westinghouse's engineers had been used to working with frequencies of 133 Hz.

Dissatisfied with working for others, Tesla returned to his New York laboratory. He was now independently wealthy and wanted to return to his research. He rejected a very lucrative offer by Westinghouse to remain in Pittsburgh on a permanent basis. Soon after leaving Pittsburgh, Tesla was granted U.S. citizenship.

High-Frequency AC. Aware that

the electromagnetic spectrum extends all the way up to visible light and beyond, Tesla now investigated the behavior of his circuits at higher frequencies. Part of his work would result in transformers, which we, today, call "Tesla coils." Another part of this work would result in tuned circuits.

While developing his mathematical AC circuit theory, Tesla became aware of the roles played by inductance and capacitance in producing electrical resonance. He found that he could produce extremely high voltages with frequencies measured in tens or hundreds of kHz by adding the appropriate amount of capacitance to the primary of an air core transformer. (While iron cores make 60-Hz transformers perform well, they severely degrade transformer performance at high frequencies.) A spark gap discharge connected to the transformer's primary winding resulted in an oscillator which produced high-frequency, high-voltage discharges.

As he predicted by theory and confirmed by experiment, Tesla quickly established that high-frequency AC current flows along the surface of the human body rather than through it. Thus, no electrical shock is felt. As early as 1890, he recognized the therapeutic value high-frequency electric fields could produce in the human body. The effect became known as "diathermy."

Tesla gave his first public lecture and demonstration concerning his high-frequency work to the AIEE in May of 1891. In addition to producing long electrical sparks from his fingertips, Tesla created electrical sheets of flame and caused sealed tubes of gas (Geissler tubes) to glow even though there was no direct electrical connection to the tubes. This spectacular demonstration, coupled with his AIEE lecture on polyphase AC power systems three years earlier, established Tesla as a premier scientist and engineer.

Tesla Demonstrates Wireless. At the Spring 1893 meeting of the National Electric Light Association in St. Louis, Tesla gave his first public demonstration of the wireless transmission of electrical energy and, thereby, the feasibility of wireless communication. On one side of the stage, Tesla had a tuned circuit consisting of a bank of Leyden jar capacitors and a coil. The tuned circuit was connected to a spark gap and a 5-kVA power-distribution transformer. A vertical wire (antenna) extended from the coil to the ceiling. This arrangement formed his "transmitter."

On the other side of the stage Tesla had his "receiver," which consisted of another, identical tuned circuit with a vertical wire extending to the ceiling. A gas-filled Geissler tube was connected to this tuned circuit in place of the spark gap used with the transmitter.

No wires connected the transmitter and receiver. When Tesla applied power to the transmitter, the Geissler tube in the receiver glowed brightly. This demonstration occurred two years before Marconi went to London with his wireless telegraphy equipment. Soon, Tesla was routinely causing gas-filled tubes to light in a manner that predicted the development much later by others of neon signs and fluorescent lamps.

At this same time, a grand example of the value of Tesla's polyphase AC system was being undertaken. The concept of harnessing the energy of Niagara Falls and using it to generate electricity had been discussed for some time. Now the technology existed to achieve this goal. If the power of Niagara were to be used to generate DC, the area over which this potentially huge amount of electricity could be distributed would be very small. Even Buffalo, only 22 miles away, could not be served if DC were generated.

Both the Westinghouse Electric Company and the General Electric Company (successor to the Edison General Electric Company) submitted proposals in 1893 to install a Tesla polyphase system. GE, now a firm believer in AC since Edison no longer controlled the restructured company, had obtained a license to use Westinghouse's Tesla patents.

Westinghouse won the contract for the generating plant at Niagara while GE was chosen to build the transmission line to, as well as the distribution system within, Buffalo. The plant was delivering power in 1895, and the transmission line was completed the following year. Tesla's stature as a technological hero was reinforced once again.

From 1891 until 1893, Tesla lived the life of a celebrity. He was in constant demand at scientific and high society gatherings both in the U.S. and abroad. Lectures and spectacular demonstrations were given in both London and Paris. Now Europe, too, fully appreciated the magnitude of Tesla's accomplishments. Tesla then abandoned the active celebrity life, because it kept him from the research he loved. However, he had become attracted to the trappings of affluence and would endeavor to maintain that image for the rest of his life, even when he clearly could not afford to do so.

The previous successes Tesla had achieved in making sealed tubes of gas glow when in the vicinity of his high-frequency, high-voltage transformers demonstrated that wireless transmission of electrical energy over short distances was possible. Now Tesla wanted to develop that concept further—much further. He envisioned transmitting energy without wires, not only for communicating, but also for powering lights and motors around the world.

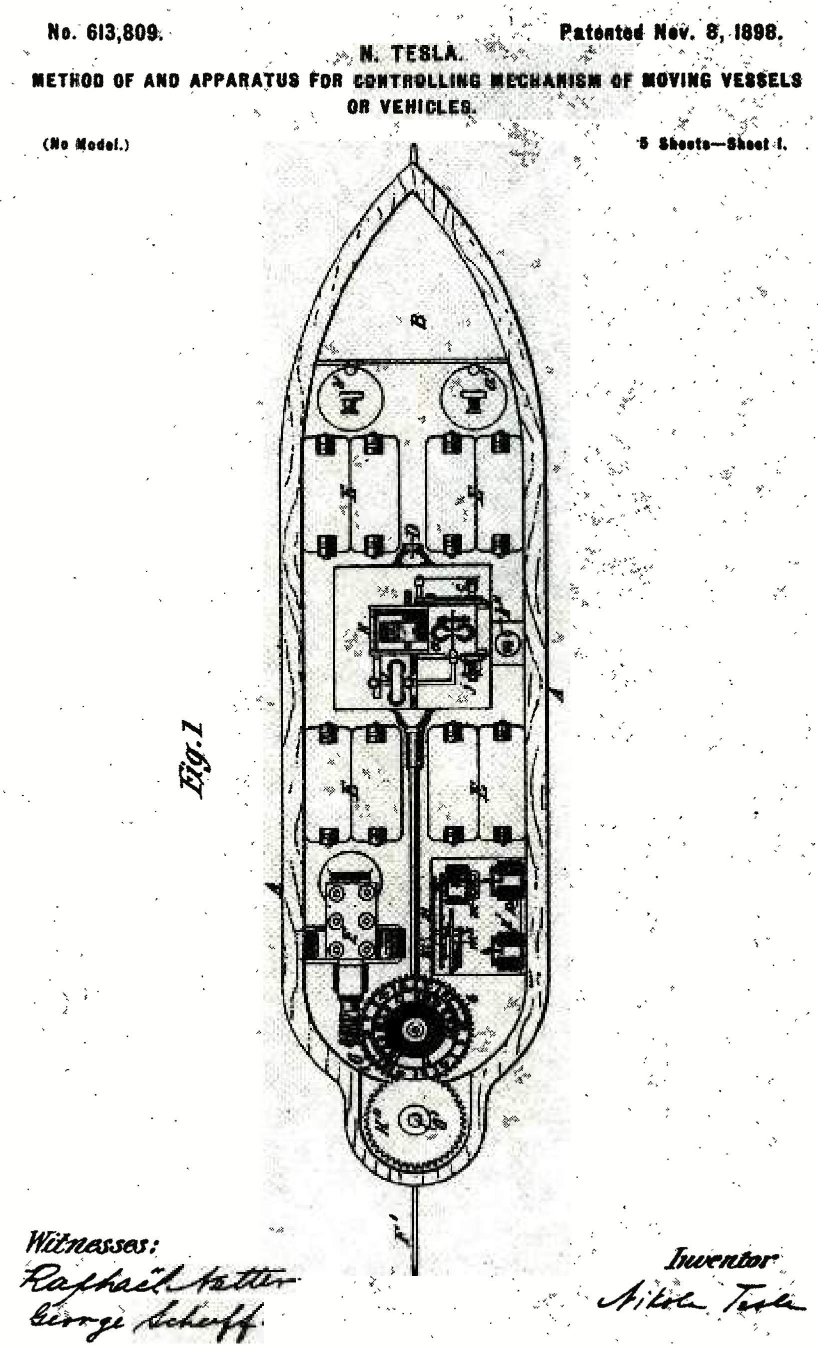
During the winter of 1894-95, Tesla built a transmitter at his laboratory together with a portable receiving station to test his latest plan. Successful wireless transmission was achieved over short distances. Then tragedy struck. Just as he was preparing to make the first public demonstration of his wireless transmission system, fire completely destroyed Tesla's laboratory together with all his equipment and records. Tesla was devastated. Virtually all his money had been invested in his work. Nothing had been insured.

With funds personally provided by the man who had organized the Niagara power plant project, Tesla painstakingly reconstructed his laboratory. He resumed the wireless transmission tests with his transmitter and portable receiver in the spring of 1897. The receiver was operated on a boat traveling up the Hudson

River, successfully demonstrating the feasibility of wireless transmission at distances of 25 miles. Tesla's two fundamental wireless patents (645,576 and 649,621) were issued in September of 1897. In 1943, the U.S. Supreme Court would rule that this work of Tesla's, together with related, independent achievements by Oliver Lodge and John Stone, anticipated Marconi's work. As a result, Marconi's important 1904 wireless patent was declared invalid.

First RC Boat. A year later, in September of 1898, Tesla startled visitors to the Electrical Exhibition at New York's Madison Square Garden by demonstrating the world's first radio-controlled boat using what he called his "mind-powered" or "Teleautomatic" system. Tesla remotely controlled a 3-foot long iron-clad boat through a variety of maneuvers in front of large audiences every night for a week. To demonstrate its simplicity of operation, Tesla permitted volunteers from the audience to operate the controls. Patent number 613,809 was awarded to Tesla for this invention. His goal was to sell a similar remotely operated submarine to the U.S. Navy for use in the Spanish-American War. Tesla hated war and felt his invention could save lives. The Navy was not interested.

Tesla had long been the beneficiary of good press coverage concerning his numerous previous inventions. Now he attempted to enlist assistance of the press to create public support with the hope of pressuring the Navy into using his invention. Tesla's written announcement concerning his "mind-powered" submarine together with his responses at a press conference were too fantastic, even for the press of that day which normally thrived on sensationalism. As a result, Tesla found himself criticized in print by some of the members of the press for, what seemed to them as, his exaggerated claims and blatant attempts at headline-seeking. Nonetheless, the journalists still found Tesla's activities to be of great interest to the public. However, as Tesla continued to announce what seemed to be ever more fantastic plans,

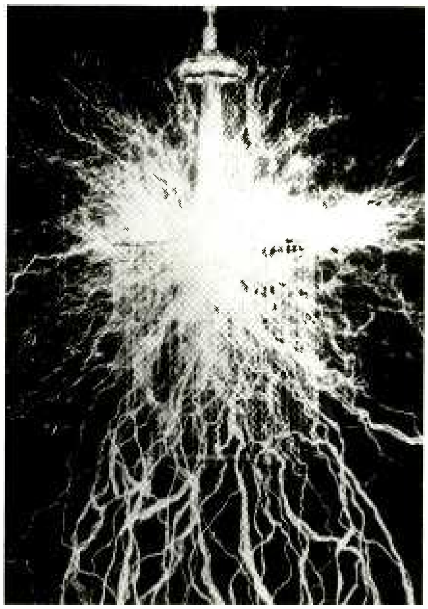


In 1898 Tesla demonstrated the world's first radio-controlled boat, and received another patent for a device that would survive him in some form for decades.

the enthusiasm of the press became tempered with skepticism.

Tesla was anxious to proceed with his planned project to beat Marconi in establishing a world-wide wireless communication system, as well as one for the global distribution of electrical power. The problem, again, was money until a wealthy friend loaned him $10,000. Now Tesla built a high-frequency oscillator, which generated 4 million volts, but the sparks produced were too large and violent for his New York City laboratory. More space was needed.

Off to Colorado. Leonard E. Curtis, a former Westinghouse lawyer who now was associated with the Colorado Springs Electric Company, invited Tesla to move his laboratory to Colorado. Curtis promised Tesla the use of land east of Colorado Springs



Shown here is the breathtaking discharge from Tesla's "magnifying transmitter" in Colorado Springs. (Courtesy of the Smithsonian Institution.)

as well as all the electricity he needed, both free of charge. John Jacob Astor, owner of the Waldorf-Astoria Hotel where Tesla now lived and had dined for years, provided the $30,000 needed to make the move and set up a laboratory.

Tesla arrived in Colorado Springs in May of 1899. Within three months, he built a laboratory complete with a tower and mast topped by a 3-foot copper sphere reaching 200 feet into the sky. A giant high-frequency oscillator, which Tesla called his "magnifying transmitter," also was readied. This magnifying transmitter incorporated a resonant transformer designed to electrically excite the earth and was optimized for maximum wireless transmission of energy. Tesla had carloads of laboratory equipment together with several assistants sent to him from New York.

Using a receiver connected to the earth to monitor the effects of the large number of lightning discharges that occurred in the region daily during the summer, Tesla reached a dramatic conclusion. He now was sure that the earth was filled with fluid electrical charges. Tesla believed that when this electricity is disturbed by repeated electrical discharges occurring at the proper time interval, resonant low frequency electrical waves of tremendous magnitude are produced.

Tesla had produced similar resonance effects in his electrical circuits. He reasoned that he could cause resonant waves in the earth with his high-voltage discharges. Tesla also believed that these waves would provide large amounts of electrical energy that could be tapped throughout the world.

Tesla's nighttime initial test of his new magnifying transmitter went well. Lightning bolts 135 feet in length surged from the top of the mast, and the resulting thunder crashes were heard 15 miles away. Then came silence and darkness.

At first, Tesla thought that his assistant had turned off the power. Finding that not to be the case, he telephoned the power company to demand that his power be restored. The curt reply from the power company was that his experiment had destroyed their generator. All of Colorado Springs was in darkness. A standby generator soon restored power to the city, but Tesla was told that his power would be restored only if and when he repaired their damaged generator.

One evening when the monitoring receiver was connected to the earth to listen for distant thunderstorms, Tesla heard three pulses in quick succession. He knew that these sounds were not characteristic of thunderstorms and declared that they must be of extraterrestrial origin. Later he concluded that the signals had not come from just any planet but that they had come from Mars!

On January 7, 1900, Tesla left Colorado Springs for New York. He had spent $100,000 in eight months and now was out of money. He intended to return to Colorado to conduct additional experiments once his finances were in better order, but this plan was never realized.

During his time in Colorado, Tesla performed many interesting experiments and learned much from them. However, there is no evidence that he succeeded in transmitting any significant amount of power over long distances without wires.

When he reached New York, Tesla was ridiculed by reporters for his claim of having heard extraterrestrial signals. Shortly afterward, he wrote a seemingly fantastic, metaphysical magazine article entitled "The Problem of Increasing Human Energy," which did little to help his believability in the minds of most people. His own extravagant claims and predictions again were eroding his credibility. Not every prediction in this article was preposterous, however. One prediction described the "radar" systems that were not developed by others until almost 40 years later.

During this same time, Tesla filed for and was granted several patents involving the use of cryogenic techniques for the underground transmission of high voltages. These anticipated similar developments that would later take place in the 1970s, both in the U.S. and abroad.

The Wardenclyffe Project. Tesla needed badly to obtain new financing for what would be his most ambitious project: a giant tower and laboratory with which he planned to establish worldwide wireless communication. There he also expected to refine his plans for wire-

No doubt Tesla's most ambitious project, the tower at Wardenclyffe was designed to establish worldwide communication—no small feat for the dawn of the 20th century. Unfortunately, Tesla lost the tower to creditors in 1915.

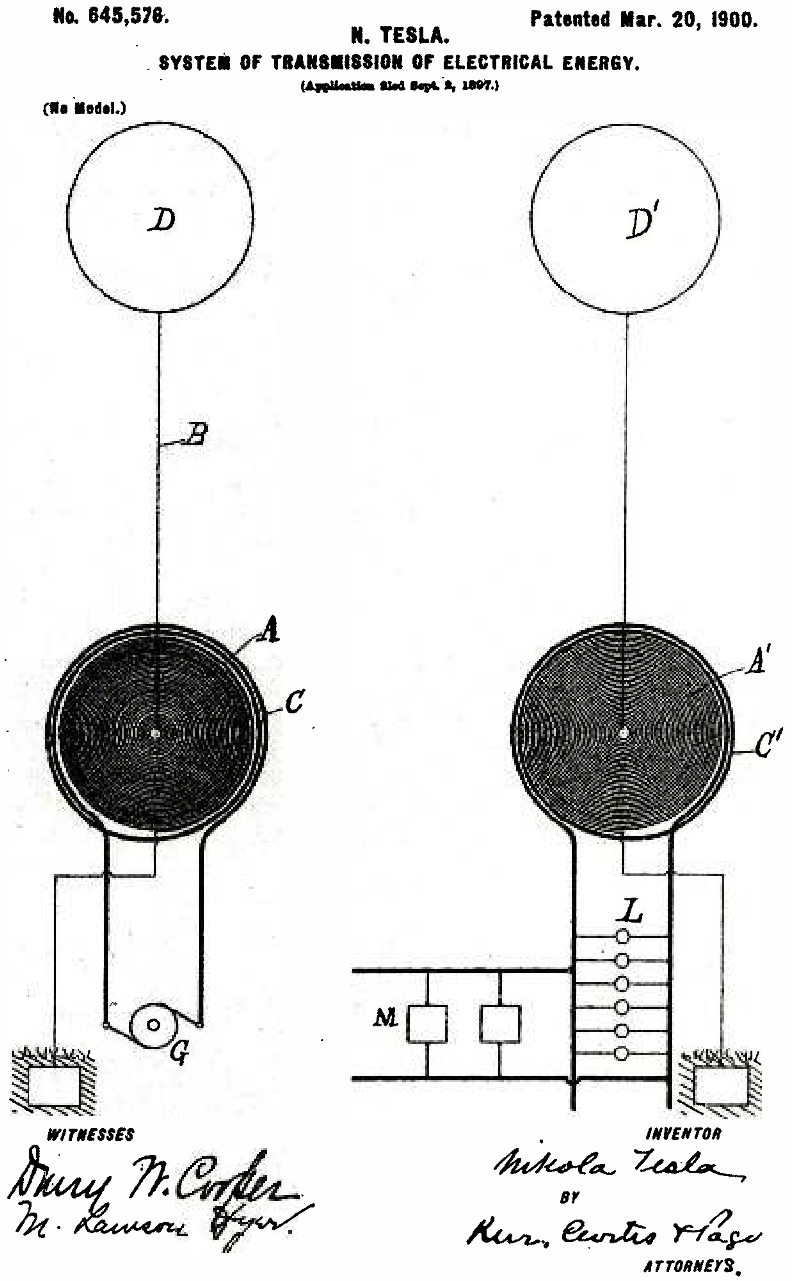
less electrical power distribution. Neither Westinghouse nor Astor was willing to loan Tesla the money he needed. J. Pierpont Morgan, however, did provide $150,000 to build the tower and other needed facilities at Wardenclyffe, Long Island in exchange for control of some patents Tesla still had.

Although Tesla wanted something taller, the finances available limited him to the construction of a tower 187 feet high with a hemispherical dome 68 feet in diameter. The Wardenclyffe project was still under construction in December of 1901 when Marconi succeeded in sending wireless telegraph signals across the Atlantic using much simpler equipment and facilities than what Tesla was proposing. Tesla contended that Marconi's equipment violated many of his (Tesla's) patents. Nonetheless, Tesla's plan was looking more and more extravagant.

Rapidly rising prices together with an overly ambitious design made it impossible for Tesla's Wardenclyffe project to be completed as planned. Creditors constantly hounded him and, despite Tesla's best efforts, additional financing could not be found. Negative rumors concerning the status of Tesla's remaining patents together with growing skepticism concerning his fantastic predictions made people wary. Tesla became despondent.

By 1906, virtually all construction at the Wardenclyffe site had stopped due to Tesla's inability to pay his bills. The high-voltage oscillator had been completed, but lack of funds made it difficult for Tesla to test it. When he did, however, people throughout Long Island and as far away as Connecticut could observe the bright flashes in the nighttime sky. However, no wireless transmission of messages or electrical power ever occurred from Wardenclyffe.

In 1915, Tesla finally lost Wardenclyffe to creditors. The tower was dynamited for its scrap value in 1917. Despite this huge setback, Tesla never gave up his ideas concerning wireless power transmission and broadcasting. Coincidentally, the years 1915 and 1917 also were the years of Tesla's alleged selection for the Nobel Prize and his receipt of the Edison Award, respectively.



The US Supreme Court in 1943 declared Marconi's important wireless patent of 1904 invalid due, in part, to this earlier patent of Tesla's.

Down, Not Out. While Tesla was dejected due to his inability to complete the Wardenclyffe project, his mind still produced many far-sighted ideas. He designed a VTOL (vertical takeoff and landing) aircraft during 1907-08. A turbine placed at the center of the aircraft had a propeller mounted above, as in a helicopter, for takeoffs and landings. Once airborne, the pilot operated a lever that moved the propeller to the front of the craft, as in a conventional airplane. Tesla did not build a prototype of this VTOL but was awarded patents on its design. In 1908, Tesla publicly described the limitations of propeller driven airplanes and predicted the development of jet aircraft.

Tesla filed for patents in 1909 on a powerful and lightweight "bladeless turbine," which appeared to have the potential to revolutionize the design of prime movers in terms of horsepower produced per pound of weight. Tesla's turbine consisted of a series of horizontally stacked, closely spaced disks attached to a shaft and enclosed in a sealed chamber. A fluid (liquid or gas) under pressure entered the sealed chamber at the periphery of the disks. Viscosity caused the disks to rotate as the fluid moved in circular paths toward the shaft where it exited the turbine.

Successful small models of the turbine were built, but the inadequate materials then available together with Tesla's serious financial problems prevented his development of larger versions. Several firms paid for the rights to refine Tesla's turbine design, but their efforts were largely unsuccessful. The two patents Tesla was awarded on his turbine design in 1909 are still being studied today by engineers trying to develop this far-sighted design.

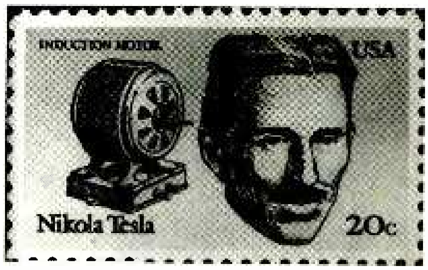
The Gernsback Connection. Shortly before the Wardenclyffe tower was demolished, a man named Hugo Gernsback renewed an old acquaintanceship with Tesla. Gernsback was editor of the magazine *The Electrical Experi-menter* that had evolved from his earlier publication, *Modern Electrics.* Both were similar in many respects to the two magazines, *Popular Electronics* and *Electronics Now*, currently published monthly by Gernsback Publications, Inc. During his lifetime, Gernsback would publish a variety of magazines devoted to electrical technology and related topics.

As a youngster in Luxembourg, Hugo Gernsback had first heard of Tesla and had become fascinated by his accomplishments. Fixed in Gernsback's mind was the photograph of Tesla he had seen which showed high frequency arcs of current passing through the electrical inventor's body. His admiration for Tesla would continue lifelong. Gernsback immigrated to the U.S. in 1903, at the age of 19, after having studied electronics in Europe. The two met briefly in 1908 but Gernsback had followed the press reports of Tesla's activities.

A legitimate scientist and electrical inventor in his own right, Hugo Gernsback was awarded 37 patents during his life. Most people, however, recognize him as the "Father of Modern Science Fiction." Gernsback authored a number of science fiction (or "scientifiction" as he initially called them) stories. He is better known, however, for publishing the science fiction works of many other popular authors in the various magazines he headed between 1910 and his death in 1967.

In 1916, Gernsback asked Tesla to edit a major article on the magnifying transmitter and the Wardenclyffe project. The article was published in the March 1916 issue of *The Electrical Experimenter.* Tesla needed the modest amount of money Gernsback paid him for this work. Gernsback, in turn, was pleased to publish this article about a device and project which, if Tesla had been successful, would have turned many science fiction predictions into reality.

In 1919, Tesla wrote a 6-part series entitled "My Inventions," which Gernsback also published in *The Electrical Experimenter.* Articles by or about Tesla still fascinated Gernsback's readers.



In 1983, the United States honored Tesla with a postage stamp.

Tesla continued to spawn new ideas in his mind. However, as time went on, more and more of these ideas seemed in the realm of science fiction and some appeared even to violate the known laws of nature. Several of his more fantasy-like ideas included a machine for capturing and utilizing the energy of cosmic rays, a technique for communicating with other planets, and a particle-beam weapon for destroying a fleet of 10,000 enemy aircraft at a distance of 250 miles.

Some of Tesla's ideas were more practical, and occasionally he was able to sell to others the rights to develop these concepts. Designs for an automobile speedometer and a locomotive headlight were particularly innovative and practical. These sales provided him with a small amount of money but, due to his many staggering debts, he lived in near-poverty for the rest of his life. Despite his chronic financial problems, Tesla always tried to project a personal image of sophistication and elegance.

Tesla was saved from complete destitution in 1934 when the Westinghouse Corporation agreed to pay his hotel rent together with a monthly stipend to serve as a "consultant." In exchange, Tesla agreed to drop his complaint that Westinghouse had violated his wireless patents. The government of Yugoslavia charitably awarded Tesla a pension of $600 per month in 1937. Anxious creditors eagerly awaited the monthly arrival of these funds.

Tesla became virtually a total recluse and an extreme eccentric in his last years. His main contacts were with the city's pigeons that he cared for and fed. Tesla died alone in a small hotel room on January 7, 1943 at the age of 86.

The New York City cathedral in which Tesla's funeral service was held was packed with over two thousand mourners. Tributes from political and scientific notables, including three Nobel Prize Laureates, poured in from around the world.

Still a great admirer of this world famous scientist and inventor, Hugo Gernsback was among the first to be notified of Tesla's death. Gernsback arranged to have a death mask made and covered with copper. The mask was kept it in Gernsback's office as a personal remembrance of this scientific savant.

Hugo Gernsback firmly believed that Nikola Tesla was the world's greatest inventor of all time—bar none. His admiration for Tesla is best summarized by the following tribute Gernsback wrote in the January 1919 issue of *The Electrical Experimenter*:

> "If you mean the man who really invented, in other words, *originated* and discovered—not merely *improved* what

(Continued on page 88)

Using RF Splitters and Combiners

JOSEPH J. CARR

If you work with RF circuits and systems, then there is a good chance that you'll someday find yourself in need of either a splitter or combiner. The principal difference between power combiners and power splitters is in their applications—otherwise they are identical circuits. A combiner is a passive electronic device that linearly mixes two or more signal sources into a common port. The combiner is not a mixer because it is linear and thus does not produce additional frequency products. A splitter, on the other hand, performs exactly the opposite function of a combiner; *i.e.*, it directs RF power from a single input source to two or more loads.

SPLITTER/COMBINER CHARACTERISTICS

Splitter/combiners (Fig. 1) are typically passive electronic networks that provide one common port (Port S) and two or more independent ports (Port A and Port B). When power is applied to the common port and delivered to the independent ports, the circuit operates as a splitter. When power is applied to the independent ports and the combination of individual signals is added linearly at the common port, the circuit behaves as a combiner. Such devices typically provide a 0-degree phase shift between ports.

A splitter delivers equal amplitude signals to the respective independent ports. Also in the splitter mode, except for the purely resistive network (Fig. 2), there is a high degree of isolation between the independent ports. The minimum theoretical splitter mode insertion loss (see Table 1) occurs because the power is split into N different channels, and it is calculated from:

$$\text{Insertion Loss (dB)} = 10 \log_{10} (N)$$

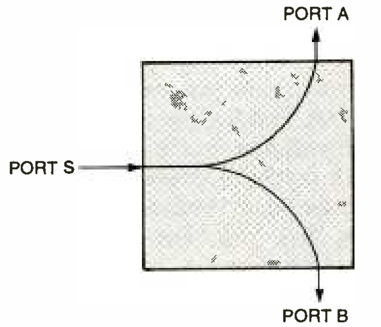


Fig. 1. Splitter/combiners are typically passive electronic networks that provide one common port and two or more independent ports. Shown here is a 3-port splitter/combiner.

where N is the number of independent ports.

The splitter mode is used for a number of different purposes in RF circuits and/or test setups. It can be used to provide a number of in-phase output signals of equal amplitude, which change with the input signal applied to the common port. In the combiner mode, it can be used for vector addition or subtraction of signals. An example of such an application is when it's desirable to linearly mix the signals derived from, say, a sweep generator and marker generator or (as when doing intermodulation-distortion tests) from two identical CW signal generators.

A simple "Tee" connection can be used for splitting or combining, but there are problems with that approach. The impedance, for example, will be the parallel combination of all source impedances connected to the Tee junction; *e.g.*, the impedance will be Z/N when all impedances are equal. For example, if a 50-ohm impedance is used for all devices, then the impedance at the junction is 50/N. For the two-way Tee, a pair of 50-ohm loads will be seen as a single 25-ohm load at the common port.

Another problem with the Tee approach is that there is no isolation between ports. Changes at one port affect the other ports. For example, if there are three ports to the Tee junction, and one becomes short circuited, then all three of them appear shorted. The simplest, and least desirable, splitter/combiner is the resistive network, although it has the charm of being cheap and easy to build.

RESISTIVE SPLITTER/COMBINER

The simplest usable splitter/combiner circuit is the resistive network illustrated in Fig. 2. That circuit uses three resistors in a Y-network to provide three ports. It can also be extended to higher numbers of ports by adding more resistor legs. The value of each resistor is $R = R_O/N$, where R_O is the system impedance and N is the number of ports. For example, if the system impedance is 50 ohms,

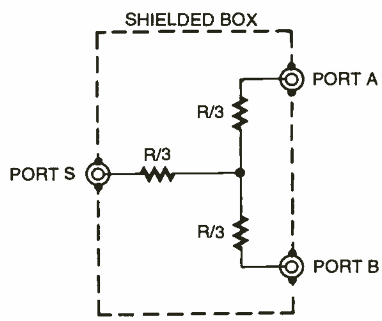


Fig. 2. The simplest usable splitter/combiner circuit is the resistive network, which uses three resistors in a Y-network configuration to provide three ports.

and three ports (as in Fig. 2) are required, then R = 16.67 ohms, and for 75 ohm systems R = 25 ohms.

The resistors used in the circuit must be non-inductive, limiting selection to carbon composition or metal-

TABLE 1—INSERTION LOSS

Ports (N)	Loss (dB)
2	3.0
3	4.8
4	6.0
5	7.0
6	7.8
7	8.5
8	9.0
10	10.0
12	10.8
16	12.0
20	13.0
22	13.4
24	13.8
36	15.6
48	16.8

film resistors (and not all metal-film types if VHF/UHF operation is intended!). If higher power than 2 watts is needed, then each arm of the Y-network can be made from multiple resistors in series or parallel.

The values 16.67 ohms and 25 ohms are not standard values, except perhaps in certain lines of 1% or less tolerance precision resistors. They can, however, be approximated using standard values. For example, only a small error is created when 15-ohm resistors are used in place of 16.67 ohms and 27 ohms is used in place of 25 ohms. Because resistors come with variations in their actual value, the amount of which is indicated by its tolerance rating (5%, 10%, 20%), we can often select from a collection of standard values to approximate the actual value needed.

It is also possible to approximate the values by using series or parallel combinations of standard-value resistors. For example, a pair of 51-ohm standard-value resistors in parallel will make a good match for 25 ohms. Similarly, three 51-ohm resistors in parallel will approximate 16.67 ohms.

The advantage of the resistive splitter/combiner is its broadband operation. The bandwidth can extend into the UHF region with discrete resistors, and into the gigahertz region if implemented with surface-mount resistors and appropriate printed-circuit technology. The upper-frequency limit in either case is set by the stray inductance and capacitance.

The disadvantages of that form of combiner are significant, and they include a relatively high insertion loss (on the order of −6 dB) and only about 6 dB of isolation between output ports. If those limitations are not important in a given application, then this form of splitter/combiner is ideally suited.

TRANSFORMER SPLITTER/COMBINER

Figure 3 shows a somewhat better form of splitter/combiner circuit. That circuit can be used from 500 kHz to over 1000 MHz if the proper transformers and capacitor are provided. In that circuit, Port S is the common port, while Port A and Port B are the independent ports. The network consists of a center-tapped inductor (L1) and a resistor (R1). The transformer, being center-tapped, has a 2:1 turns ratio between the two halves, and so provides an impedance across the "A"

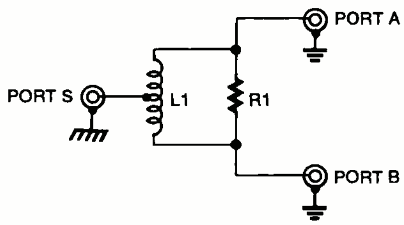


Fig. 3. This splitter/combiner circuit, consisting of a center-tapped inductor (L1) and a resistor (R1), can be used from 500 kHz to over 1000 MHz if the proper transformers and capacitor are integrated into the circuit.

and "B" ends that is four times the impedance from the center tap to either "A" or "B." Let's first examine the circuit behavior as a combiner.

Assume that equal amplitude signals are applied to Ports-A and B. Examine the signal at, say, Port A first. The RF power applied to Port A is split into two components, one flowing in R1 and the other in L1. The signal that travels to Port B via R1 is not phase shifted, thus it has a 0-degree relationship to the original signal at Port A. The other component is phase shifted 180 degrees by L1; so it arrives at Port B 180 degrees out-of-phase with the component flowing in R1 (the two components cancel each other).

If the amplitudes of the signal components are kept equal (which can be done by judicious selection of R1 and L1), then cancellation is complete. That cancellation causes a high degree of isolation between Ports A and B. Although it is possible to attain infinite cancellation, 20 to 60 dB is more reasonable in practical circuits.

MISMATCH LOSSES

It is important in any RF system to ensure impedance matching at all ports. However, in practical terms, it often happens that some degree of mismatch will occur. Let's examine a scenario of what happens when there is a mismatch loss at Port S.

Assume that a two-port network similar to Fig. 3 is connected such that a +10 dBm signal is applied to Port A. There is a mismatch loss of −20 dB at Port S, and the −3 dB normal loss between Port A and Port S found on all two-output port splitters.

Under a perfectly matched situation, the output signal level at Port S will be (+10 dBm) + (−3 dB) = +7 dBm. With the mismatch reflection of−20 dB, a signal of (−20 dB) + (+7 dBm) = −13 dBm is reflected to Ports-A and B. Because of the 3-dB port-to-port loss, signals of (−13 dBm −3 dB) = −16 dBm each arrive back at Ports A and B. The practical effect of the mismatch is that Ports A and B are no longer highly isolated from each other. There is a +10 dBm signal applied to Port A, and a −16 dBm signal at Port B, which means there is a (+10 dBm) − (−16 dBm) = 26 dB isolation figure, rather than infinite.

In general, with circuits such as that in Fig. 3, it is important to ensure an impedance match at Port S, although some mismatch can be tolerated at both Port A and Port B.

There is an imbalance of behavior between ports when a serious mismatch occurs at either Port A or B. Assume that Port S and Port B are properly and perfectly matched by 50-ohm loads, but Port A is short circuited (0 ohms). Because of the isolation, Port B is not affected by the short-circuit and continues to see a 50-ohm impedance. But the impedance seen by Port S is reduced 3:1. If it is normally 25 ohms (as when the other ports are at 50 ohms), then the effect of one shorted port is a two-thirds reduction to 25/3 = 8.333 ohms.

A variation on that theme is shown in Fig. 4. In that circuit, an inductor is used to match the impedance at Port S.

(Continued on page 87)

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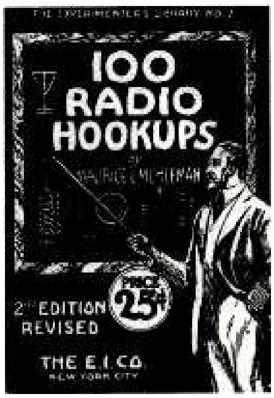

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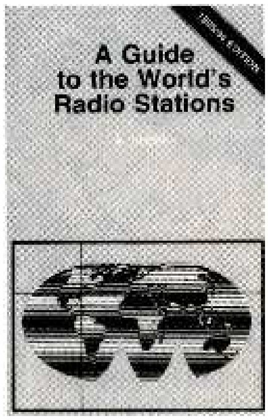

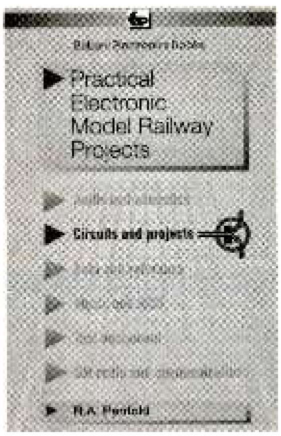

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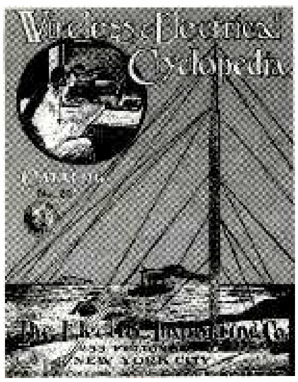

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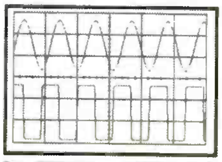

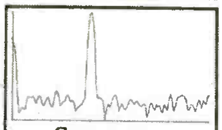

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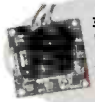

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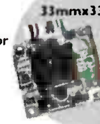

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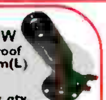

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Delay Sweep	YES	ALT-MAG	ALT-MAG	ALT-MAG
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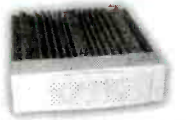

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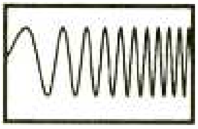

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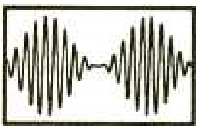

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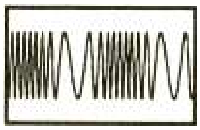

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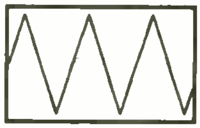

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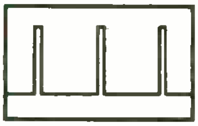

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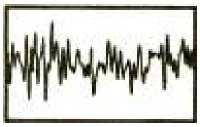

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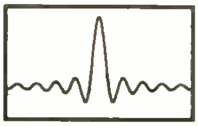

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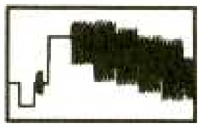

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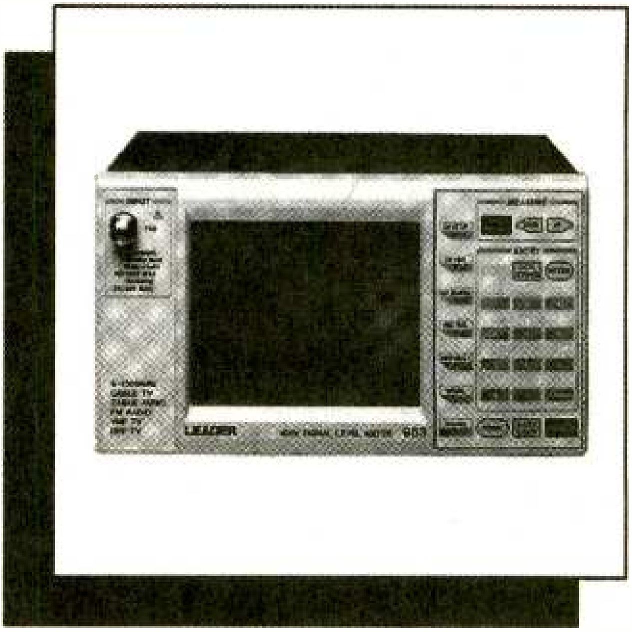

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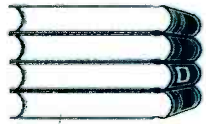

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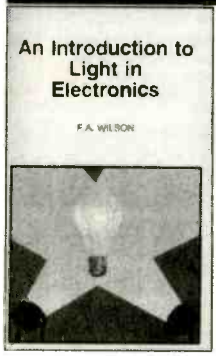

Taken for granted by us all perhaps, yet this book could not be read without it, light plays such an impressive role in daily life that we may be tempted to consider just how much we understand it. This book makes a good start into this fascinating and enlightening subject. It has been written with the general electronics enthusiast in mind.

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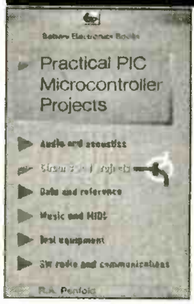
ET08

Practical PIC Microcontroller Projects



This book covers a wide range of PIC based projects, including such things as digitally controlled power supplies, transistor checkers, a simple capacitance meter, reaction tester, digital dice, digital locks, a stereo audio level meter, and MIDI pedals for use with electronic music systems. In most cases the circuits are very simple and they are easily constructed. Full component lists and software listings are provided. For more information about PICs we suggest you take a look at BP394 -- An Introduction to PIC Microcontrollers.

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ET10

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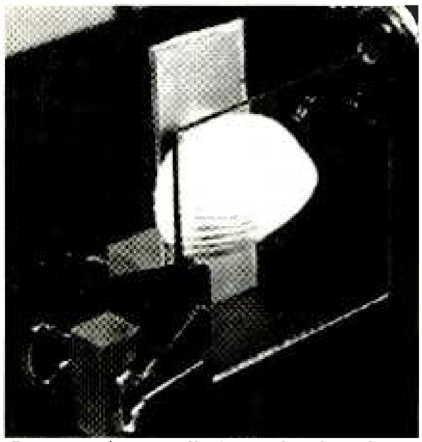
AMAZING SCIENCE

Laser-Diode Holography, Part 2

JOHN IOVINE

Last month, we began our exploration of laser-diode holography with a discussion of what holograms are and the history of laser-diode holography. We covered the use of laser pointers in holography, the effects of vibrations on holography and how to combat it, as well as other aspects of this fascinating subject. This time around, we're going to continue with a look at the types of film used in laser holography and developing that film, as well as go over some tricks and tips on how to improve the final product.



Because of its small size and light color, a seashell is an ideal first model for a holography experiment.

So without any further fanfare, let's jump right in and get our hands dirty. (**Note:** The figure numbering reflects a continuation of last month's column, so the first figure for this month is Fig. 7. Thus, any reference to Figs. 1 through 6 relate to the October 1999 column.)

FILM

A few major holographic-film suppliers (Agfa and Ilford come to mind) quit the holography film market. Currently there are a few out-of-country holographic-film suppliers. The holographic film that we'll be using for our experiments is BB640. The number 640 refers to the laser-light wavelength in nanometers (nm) to which the film emulsion is sensitized. Since HeNe lasers are tuned to 633 nm—only a hairs-breadth away from 640 nm—the film is well suited to capturing HeNe laser images. Diode lasers come in 650-nm and 640-nm wavelengths. The 640-nm unit is a little more expensive, but its output is brighter (to the human eye) than the 650-nm type.

The BB640, available in 2½-inch square glass plates, is easier to work with than film, because the units can be mounted directly on to the table. To hold the glass film in place, the plate is clipped on its side with a medium-size binding clip that is secured to the table with bar magnets (see Fig. 7).

SAFE LIGHT

Holographic film is sensitive to red light and relatively insensitive to green light. When setting up the isolation table to shoot a hologram, you need a green safelight to see what you are doing without exposing the holographic film. An inexpensive safelight can be fabricated using a green LED as a light source. The wavelength of the LED's output determines how "safe" it is for our application.

There is an easy way to check whether the LED light source is appropriate (safe). In a pitch-black room, remove a holographic film plate and illuminate the plate with the safelight for a minute or two. Then dump the plate into the developer. If the plate gathers density (was exposed), then the safelight isn't safe. On the other hand, if the film remains clear (transparent, *i.e.*, it didn't gather density), then the light source is safe.

Other options for a safelight include lime green night-lights, small-wattage green Christmas bulbs, and so on. You can get a tested green electroluminescent safelight from Images Company (PO Box 140742, Staten Island, NY 10314; Tel. 718-698-8305 or 718-982-6145; Web: *www.imagesco.com*).

MODEL CONSIDERATIONS

For your first model, choose something hard that won't bend, flex, or

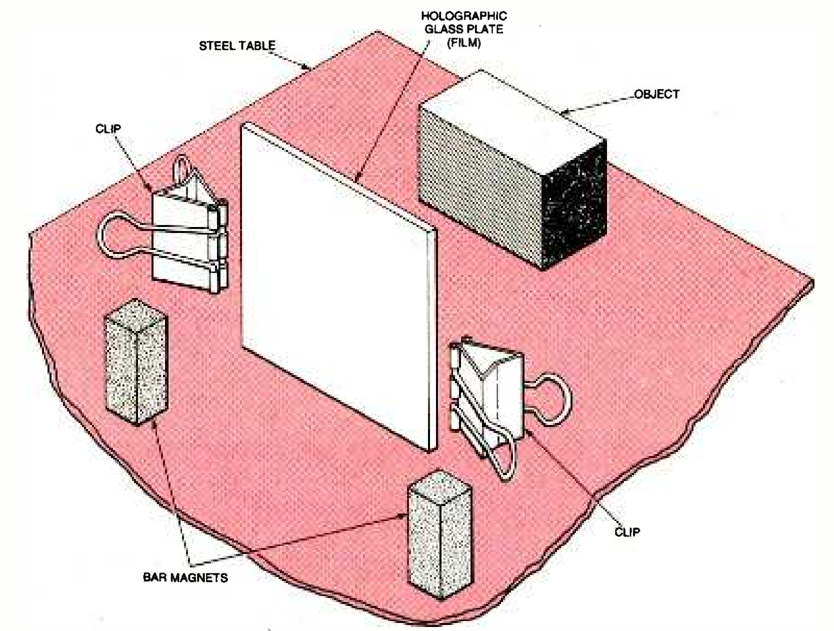


Fig. 7. A 2½-inch square glass plate, mounted directly on to the steel table with medium-size binding clips and bar magnets, serves as holographic film.

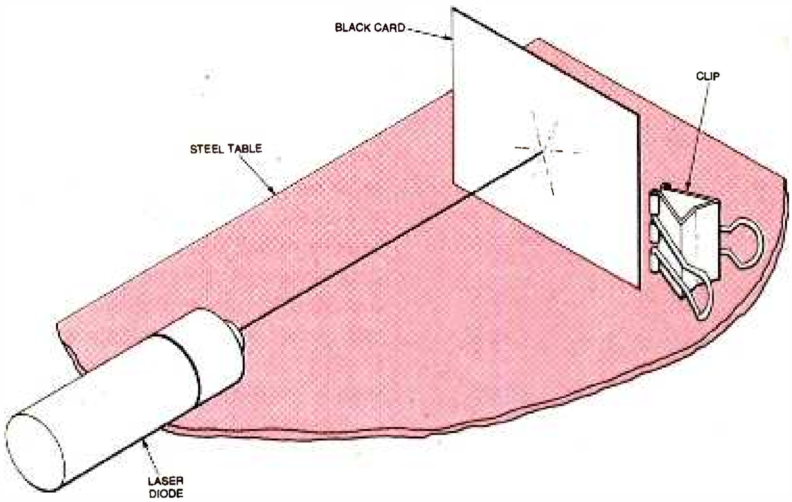


Fig. 8. A shutter card was made from a piece of black, non-glossy cardboard, measuring approximately 2½ × 2 inches, and a medium binding clip was attached to make the card freestanding. No magnets were used on the shutter-card binding clip, because doing so would make it more difficult to lift the shutter card without creating unnecessary vibrations.

move during exposure. Make sure it is light colored or white, and that it fits completely behind the film plate. For beginners, a light-colored seashell is recommend for the first holographic subject. The seashell can be glued to a magnet, placed on an optical mount, and optimally positioned.

The model should be placed as close to the film plate as possible without touching. That produces the brightest viewable hologram. Once you gain experience, you can move on to more complex models. For instance, I borrowed one of my son's hard rubber dinosaurs and spray painted a little flat white on the model to make it more reflective. After drying, the model was again placed as close as possible to the holographic plate (without touching).

BLACK SHUTTER CARD

A shutter card is used to block and unblock the laser beam to expose the holographic film plate (see "Exposing the Holographic Plate" for details on the proper use of a shutter card). You can make a shutter card from a black non-glossy piece (approximately 2½ × 2 inches) of cardboard. One medium-size binding clip on the side of the card makes it freestanding on the table (see Fig. 8). Do not use magnets on the shutter card's binding clip, because you need to be able to lift the shutter card easily without creating any unnecessary vibrations.

When exposing the holographic film, it's ill advised to just lift the card off the table and place it back down. Doing so could create vibrations that would prevent the hologram from forming. Instead, the shutter card is lifted gently off the table, held in position for a moment, still blocking the beam but not touching the table. Then the card is lifted completely out of the path of the laser beam.

The card is kept out of the path of the laser long enough to make a 60–90 second exposure. The shutter card is then reinserted into the path of the laser, ending the exposure. You do not have to be as careful when putting the card down. Once the laser beam is blocked, vibration doesn't matter.

WHITE CARD

A white card is a focusing aid that is placed where the film will eventually be positioned to make it easy to see the laser light when setting up the holographic equipment. The card can be fabricated from a white piece of cardboard approximately the same size as a film plate (2½-inches square), and made freestanding via a metal binding clip as was done with the shutter card. Arrange the components on the table as shown in Fig. 9.

Once the card is set up, move it or the radius mirror so that the beam spread completely fills the white card evenly. If it's difficult to see the laser light on the white card, turn off the room lights. Direct the spread laser light onto the white card, making sure that the beam strikes the card at a 30- to 45-degree angle.

Once the laser light fills the card evenly and completely, position the object you are shooting behind the card. Remove the white card, leaving the binding clip(s) in position. The laser light should now be illuminating the object. Look at the object from the laser side—that's the view of your finished hologram.

PARTS AND MATERIALS LIST

Laser pointer or diode, radius mirror (spreading optic), isolation table, film, BB640 2½-inch square holographic plates (2), ⅜ × ⅜ × 1-inch bar magnets (4), 0.9 × 0.9 × 0.4-inch rectangular magnets (2), 2½ × 1 × ¹⁄₁₆-inch steel plates, green safelight, developing chemicals (JD3 kit), medium-size binding clips, 2 × 2-inch black card, 2½ × 2½-inch white card, glue, small piece of carpet (or towel), small inner tube, three trays, quiet dark area.

Block the laser beam using the shutter card. With all the lights off, remove a film plate from its light-tight box. Holding the plate by its edges, close the film box and turn on your safelight. The film plate will appear transparent, but there is an emulsion on one side. Place the holographic plate in the binding clip(s) that were holding the white card. Using the safelight, make sure the bottom edge of the glass holographic plate is flush with the surface of the table. Check the bottom of the binding clip(s), too, which should be flush with the table surface to provide maximum stability.

EXPOSING THE HOLOGRAPHIC PLATE

The exact exposure time will vary with the strength of diode's output, wavelength, and beam spread. Start with 90 seconds; the exposure time can be increased or decreased according to the results observed when developing the plate.

To make the exposure, lift the shutter card off the isolation table, while keeping it in a position that still blocks the laser beam. Hold the card in that position for 10–15 seconds to let any vibration caused by lifting the card off the table die down. Then lift the card completely, allowing the laser to expose the plate. After the exposure time has

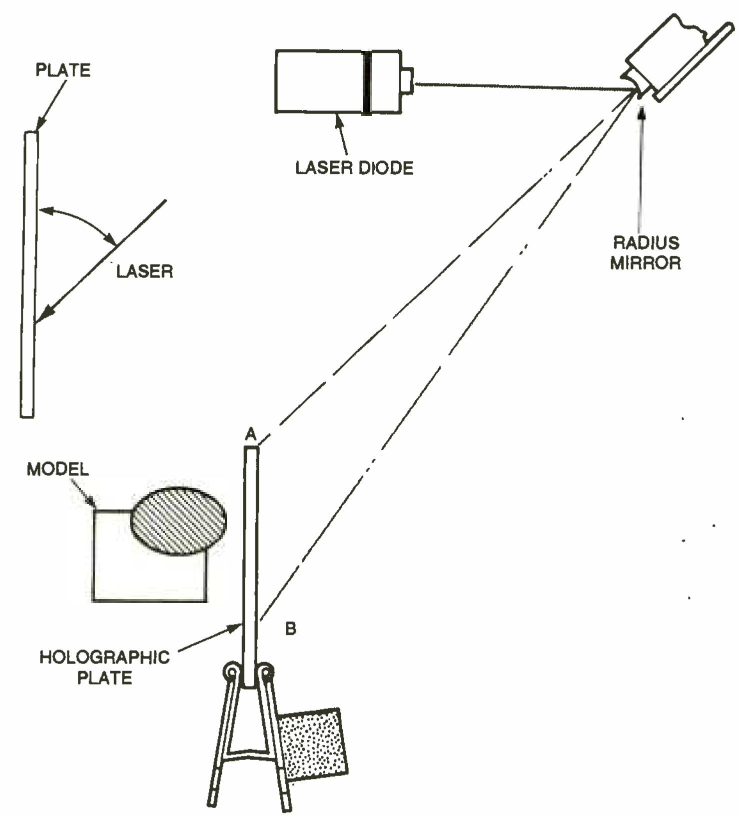


Fig. 9. A white piece of cardboard, approximately the same size as a film plate (2½ inches square), was used to help set up the table. The white card should be made freestanding using a metal binding clip, as was done for the shutter card.

elapsed, replace the shutter card in its laser-beam blocking position. The plate is now ready to be developed.

DEVELOPING

Developing holograms is as simple as developing black-and-white film. Good developing kits—either JD2 ($14.95) or JD3 ($14.95)—can be purchased from Photographers Formulary (PO Box 950, Condon, MT 59826; Tel. 800-922-5255). The developing chemicals are poisonous and can be absorbed through the skin. However, the people at Photographers Formulary tell me that the JD3 kit uses less toxic chemicals. In all cases, wear some sort of rubber gloves when mixing the chemicals and developing holograms. A safelight is also required to properly develop the holographic plate.

In setting up your developing system, place three small plastic trays, each large enough to hold a 2½-inch square glass plate, on a table. Tray 1 should contain developer chemicals, Tray 2 will hold distilled water, and Tray 3 should contain bleaching solution.

Start by placing the exposed plate in Tray 1. Agitate the chemicals by gently rocking the tray back and forth to keep fresh solution on the plate. The plate will gather density and appear to turn completely black. Don't worry—that's normal.

How quickly the plate gathers density in the developer is an indication of the exposure. If the plate goes black inside of a few seconds, it has been overexposed. To correct that, reduce the exposure time on the next run. On the other hand, if after two minutes the plate still hasn't gathered density, then it is underexposed and you need to increase your exposure time on the next run. If the plate has been properly exposed, it will gather enough density to appear 80–90% black after spending 1–2 minutes in the developer.

Whether your plate is over- or underexposed, continue the developing process. You may still have a hologram. If it is overexposed, snatch it from the developer when it's 80–90% dark. If under exposed, after 3 minutes in the developer the plate will have gathered as much density as it can, so press on to the next step in developing.

When the developing stage is complete, place the plate in Tray 2 (water) for 30 seconds to rinse away the developing solution. Although rinsing isn't mandatory, it will extend the life of the bleach. After the rinse, place the plate in Tray 3 (bleaching solution). Gently rock the tray back and forth as was done during the developing stage. Let the plate remain in the bleach bath until the plate becomes completely transparent (clear) again, which usually takes about a minute or so. Once the plate is clear, it is light safe. Normal

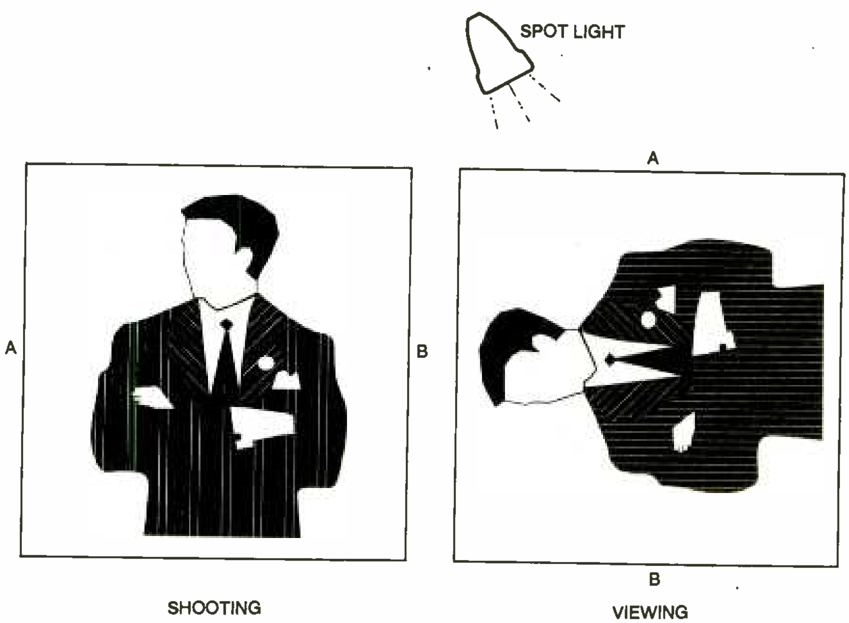


Fig. 10. If the model is placed right-side up when shooting the hologram with side lighting, then, when placed in the best vertical-viewing position, the model will appear on its side—as illustrated here.

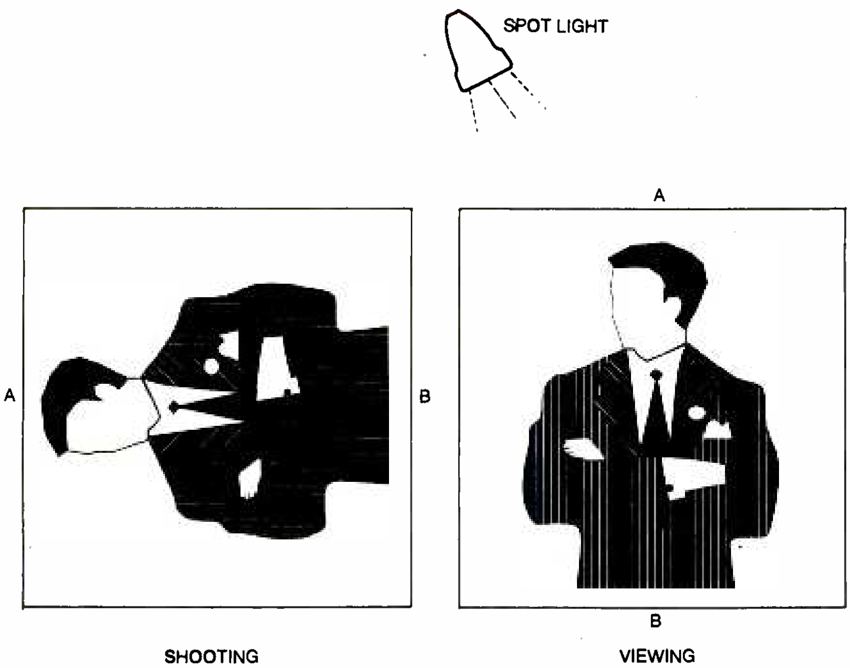


Fig. 11. To correct the problem outlined in Fig. 10, place the model on its side, with the top portion of the model pointed toward the "A" side of the plate, as shown here, to orientate the holographic image right-side up when viewing with a vertical light source.

lighting can then be turned on. Place the plate in the water tray. Bring the tray to a sink and run tap water at room temperature. Place the tray in the sink under the running tap water for about three minutes.

Afterwards remove the plate from the running water and stand it vertically against a wall to dry. The holographic image won't be visible until the hologram is completely dry. The plate can take 20 minutes to dry, so exercise a little patience.

VIEWING

Well, it's time to take a look at your hologram. The hologram we shot is a white-light reflection hologram, which means it is viewable in standard white light. The sun is the best light source to view holograms. For the best results with an artificial light, try a tungsten halogen lamp. Incandescent lamps can be used, but the image quality won't seem that good.

You may have to rotate the hologram a couple of times and vary the angle at which the light strikes the plate to find the best viewing angle. If the holographic plate is upside down (in reference to the angle of the laser light used to make the hologram) or sideways you may not see any image at all.

To improve the look of the hologram, place something black behind it.

TWO IMAGES

There are two images you can view from the hologram: virtual and real.

The *virtual image* appears correct to the human eye; and, should you move your head while viewing, the parallax and perspective of the image will remain correct.

In contrast to the virtual image is the *real image*, which can be observed by flipping the hologram around. The real image has a few peculiar properties. First the perspective is reversed. Parts of the object that should appear in the rear are in the front and *vice versa*. When you move your head to the left, the image appears to rotate in proportion to your movement, but you see more of the right side not the left side. The brain interprets that paradoxical visual information and causes the image to appear to swing around.

TROUBLESHOOTING

Of course, our description of the two images assumes everything went well. Here are some problems to watch for, though:

No Image—Correcting for a hologram without an image can seem very frustrating. Even though it may seem as if you don't have a starting point to begin evaluating the problem, you do. During development, did the film plate go black suddenly or did it gather density? If so, correct for proper exposure time as described in text and re-shoot. If exposure is correct, and you've established that none of the other checklist points in this troubleshooting section is to blame, then vibration may be preventing the hologram from forming. Find a quieter location.

Faint Image—Over- or under-exposed film can cause faint images. Another cause may be chlorides in tap water used to make your developing chemistry. Remix the developer using distilled water.

Weak and Faded Images—This problem may be encountered when the safelight being used really isn't safe. The safelight was fogging the film during setup and developing. Check the safelight as described earlier.

IMPROVING THE HOLOGRAM

The single-beam holographic setup that we've been discussing has a serious handicap—side lighting. To understand that phenomenon, trace the beam spread from the radius mirror to the holographic plate, look back to Fig. 9. In that diagram, the point where the beam spread first touches the plate is labeled point A, and the other end is point B.

Now, the light needed to reconstruct the holographic image must illuminate the hologram at the same angle that the spread laser beam struck the plate during exposure. If not, the orientation of the hologram will be off. Because most holograms are viewed with light that comes from above at a 45-degree angle, yet were made with side lighting or a beam that came from the side, the image will be seen as if on its side. Figure 10 shows why this is so, with respect to lighting points A and B.

To correct the side-lighting problem, place your model on its side, with its top portion toward point A of the plate, as shown in Fig. 11. That orientates the holographic image right-side up when viewing with a vertical light source.

You can mount a model for side illumination in a number of ways. The model can be glued to a small steel plate and then placed on its side using magnets, as illustrated in Fig. 12. Another method is to glue the object to a transparent piece of plastic sheet, measuring 3 × 3 × 1/4 inches, and then

(Continued on page 80)

Robotics Workshop

An Around-the-Web Look "Inside a Robot"

GORDON McCOMB

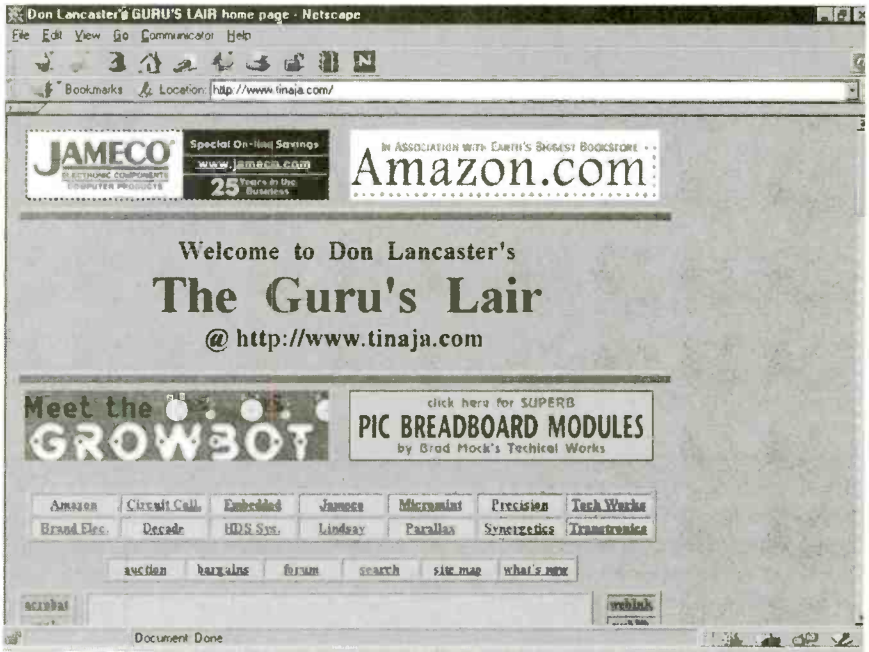
All things considered, the human body is a nearly perfect machine: it operates under its own power, can think for itself (most of the time!), can lift heavy loads, can move itself around, and it has built-in protective mechanisms. As a result, robots are often modeled after humans, if not in form, then at least in function. For decades, scientists and experimenters have tried to duplicate the human body, to create machines with power, intelligence, strength, mobility, and auto sensory mechanisms. That goal has not yet been realized, but perhaps may be some time in the future.

What exactly are the basic parts necessary for a machine to have before it can be given the title "robot"? In this column, we'll take a tour of the basic anatomy of a robot, and for extra measure we'll throw in some examples and additional information from the Web to assist you in further researching the subject.

MOBILE VERSUS STATIONARY

A *mobile* robot includes its own power system, brain, wheels (or legs), and manipulating devices such as claws or hands. The robot does not depend on any other mechanism or system to perform its tasks. It's complete, In and of itself.

Yet a machine need not be completely severed from a power or processing unit to be called a "robot." In a *stationary* robot, the mechanism that does the actual task (like weld a car door) is the robot itself; the support electronics or components may be—and often are—separate. The link between robot and control components might be a wire, a beam of infrared light, or even a radio signal. The Robot Home Pages listed in Table 1 provide a wide variety of robot styles, from completely self-contained mobile robots to stationary robot arms.



Don Lancaster's The Guru's Lair provides tons of information, including coverage of robotics.

TABLE 1—ROBOT HOME PAGES

Albert Project
home.earthlink.net/~johncutter/home.htm

Corky'z Robotz
www.geocities.com/SiliconValley/Park/1302/robotz.htm

Do Robots Dream
webhome.idirect.com/~bine/

Fighter Bots
members.tripod.com/RoBoJRR/Fights/thebots.html

Floppy the Robot
www.ohmslaw.com/robot.htm

Keith Soldavin's Robotics Page
www.personal.psu.edu/users/k/a/kas219/robot.htm

Ken Boone's Robotic Home Page
users.aol.com/kensrobots/kensrobots.html

Ringo's Robotic Page
www.geocities.com/CapeCanaveral/Cockpit/5418/index.html

Robotics Links
www.verinet.com/~dlc/botlinks.htm

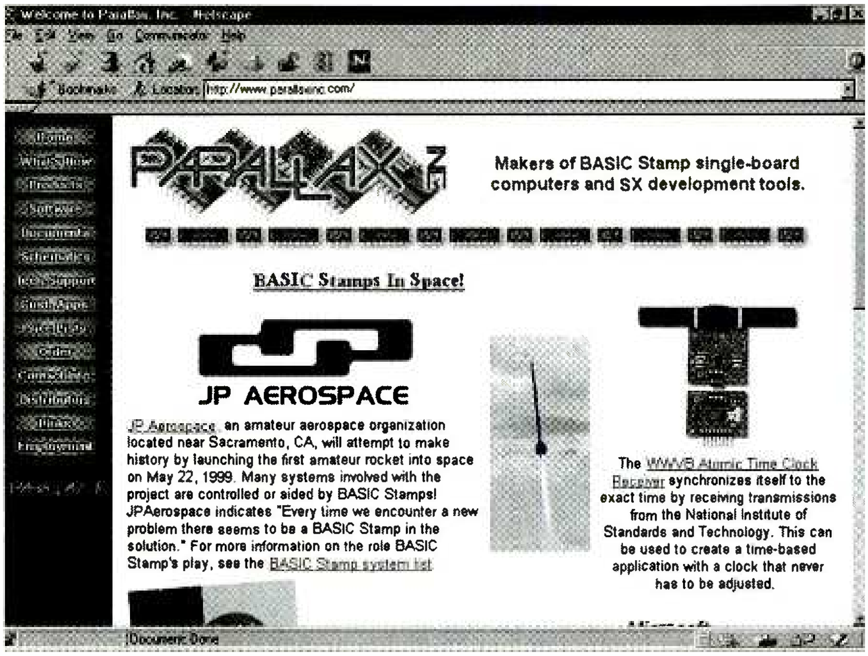
Robotics Project
home.earthlink.net/~apendragn/robot.htm

Robotics UK
www.geocities.com/SiliconValley/4845/

Robots and Stuff
204.233.101.40/robots/RobotsAndStuff.html

THE ROBOT BODY

Like the human body, the body of a robot contains all its vital parts. The body is the "superstructure" that prevents its electronic and mechanical innards from spilling out. Robot bodies go by many names, including *frame* and *chassis*, but the idea's the same.



Parallax Inc. offers Basic Stamp modules and programmers.

In nature, and in robotics, there are two general types of support frames: endoskeleton and exoskeleton. *Endoskeleton* support frames are common in nature—the skeletal structure is on the inside, the organs, muscles, body tissues, and skin are on the outside. The endoskeleton is a characteristic of vertebrates. *Exoskeleton* support frames are the "bones" on the outside of the organs and muscles. Common exoskeleton creatures are spiders, all shellfish such as lobsters and crabs, and an endless variety of insects.

Which is better? Both. It all depends on the living conditions of the animal and the way it eats and survives. For robots, endoskeleton systems are more popular, although combinations of the two are common. On the frame of the robot are attached motors, batteries, electronic-circuit boards, and other necessary components. In that way, the main support structure of the robot can be considered an exoskeleton, being outside the major organs.

The Seattle Robotics Society Web page is a virtual goldmine of robotics news and information.

Table 2 lists Web sites for educational construction kits, parts, and plans, which demonstrate ways to quickly create robot bodies using metal and plastic assembly parts that either snap or screw together.

ROBOT SIZE AND SHAPE

The size and shape of the robot can vary greatly, and size alone does not determine the intelligence of the machine, nor its capabilities. The overall shape of the robot is generally dictated by the internal components that make up the machine, but most designs fall into one of the following "categories":

Turtle. Turtle robots—or turtlebots—are simple and compact, designed primarily for "tabletop robotics." Turtlebots get their name because their bodies somewhat resemble the shell of a turtle.

Rover. Rover-type mobile robots are small automatons with wheels, often built on the chassis of a radio-controlled car. The radio-control aspect is usually used to operate the converted car/robot. Larger rovers include robots modeled after the R2-D2 functionoid of *Star Wars* fame.

Stationary. Stationary designs are used specifically with robotic arms, whether the arm is attached to a robot or is a stand-alone mechanism.

Android. Android robots are specifically modeled after the human form, and it is the type most people picture when talk turns to robots. Realistically, android designs are the most restrictive and least workable.

Table 3 lists Web sites to visit that offer commercial parts and robots for sale in either ready-to-go products or (more often) kit form.

ROBOT CONSTRUCTION MATERIALS

Hobby robots can be easily constructed from aluminum, plastic, or even wood—or a combination of all. Aluminum is perhaps the best all-around robot building material, because it is exceptionally strong for its weight. But, it's not as easy to work with as plastic, which is cheaper and lighter.

Bear in mind that effective use of

plastic requires some special tools, and availability of extruded pieces might be somewhat scarce unless you live near a well-stocked plastic specialty store. Mail order is an alternative.

BEAM robots are popular among both beginner and advanced robot builders as they are designed to use common, inexpensive materials. The Web sites listed in Table 4 are among many devoted to the BEAM design; most include a discussion of practical materials for robot building.

POWER SYSTEMS

Living organisms eat food, which is processed through the stomach and intestines to make fuel for the body. While you could probably design a digestive system for a robot, and feed it hamburgers and french fries, an easier way to generate power for a robot is to use batteries. Connect the batteries to the robot's motors, circuits, and other parts, and you're all set.

Batteries generate DC current and come in two distinct categories: rechargeable and non-rechargeable. *Non-rechargeable* batteries include the standard zinc and alkaline cells, as well as special-purpose lithium and mercury cells for calculators, smoke detectors, watches, and hearing aids. Non-rechargeable batteries find limited use in power-hungry robotics applications because replacing the batteries after a few hours or days can be an expensive proposition.

TABLE 2—EDUCATIONAL CONSTRUCTION KITS, PARTS, AND PLANS

Dave's LEGO Site
www.enteract.com/~dbaum/lego/

FischerTechnik
www.bkohg.com/fischer.html

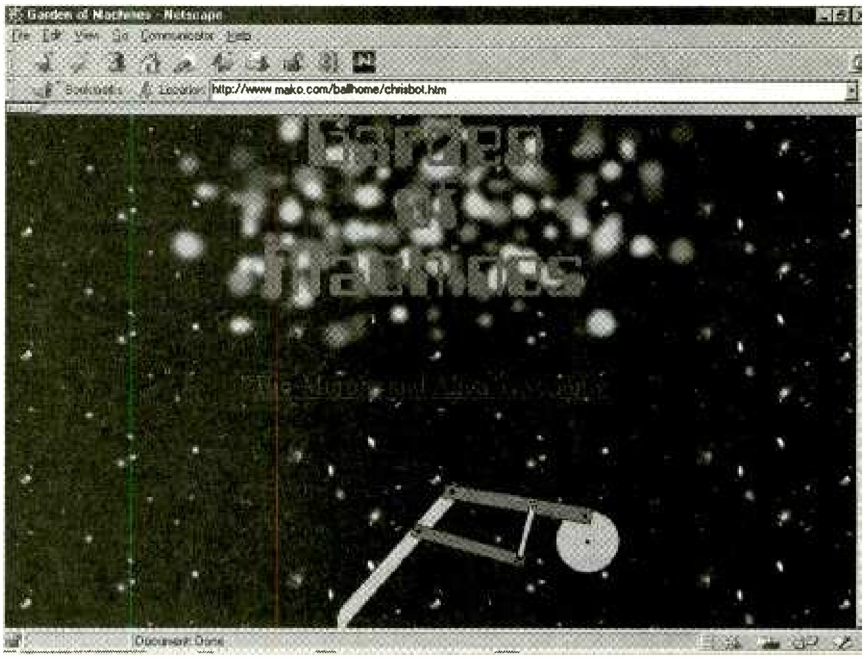
LEGO Mindstorms
www.legomindstorms.com

LEGO Robot Pages
www.cs.uu.nl/~markov/lego/

Pitsco
www.pitsco.com

RCX Command Center
www.cs.uu.nl/~markov/lego/rcxcc/index.html

ToyBots
www.daimi.aau.dk/~hhl/Toybots.html



The Garden of Machine's personal home page provides interesting background and how-to information on constructing robots with unusual locomotion systems.

Rechargeable batteries include nickel-cadmium (NiCd), gel-cell, sealed lead-acid cells, lithium-ion, and nickel-metal-hydride. NiCd batteries are a popular choice because they are relatively easy to find, come in popular household sizes ("D," "C," *etc.*), and are fairly cheap. Gel-cell and lead-acid batteries provide longer-lasting power; but they can be heavy and bulky, and some can leak caustic electrolytic fluid.

LOCOMOTION AND ARMATURE SYSTEMS

Wheels are the most popular method of providing robot mobility. There may be no animal on this earth that uses wheels to get around, but for robot builders, it's the simple and foolproof choice. Robots can have just about any number of wheels, although two is the most common. The robot is balanced on the two wheels by one or two free-rolling casters, or perhaps even a third swivel wheel. Four and six-wheel robots are also around.

A small percentage of robots are designed with *legs*. First, there is the question of the number of legs, and how the legs will provide stability when the robot is in motion or when it's standing still. Then there is the question of how the legs propel the robot forward and how to navigate a corner.

Tough questions, yes, but not insurmountable. Legged robots are a challenge to design and build, but they provide an extra level of mobility that wheeled robots can't muster. Wheel-based robots may have a difficult time navigating through rough terrain, but leg-based robots can easily walk right over small ditches and obstacles. I've found that robots with six legs (called a hexapod) are able to walk at brisk speeds without falling and are more than capable of turning corners, bounding over uneven terrain, and making the neighborhood dogs and cats run for cover.

The basic design of *track-driven* robots is fairly simple: two tracks, one on each side of the robot, act as giant wheels. The tracks turn, like wheels, and the robot lurches forward or backward. For maximum traction, each track is about as long as the robot itself. Track drive is practical for many reasons, not the least of which is the ability to mow through all sorts of obstacles, like rocks, ditches, and potholes. Given the right track material, traction is excellent, even on slippery surfaces like snow, wet concrete, or a clean kitchen floor.

The wheels, legs, and tracks of most robots are powered by DC motors. Two other forms of robotic motion are derived from hydraulic and pneumatic power. *Hydraulic* power uses oil or fluid pressure to move link-

TABLE 3—COMMERCIAL PARTS AND ROBOTS

Acroname Inc. Easier Robotics
www.acroname.com/robotics/robotics.html

Arrick Robotics
www.robotics.com/arobot/

CANtronics
cantronics.rzsoft.com

Cricket the Robot
home.earthlink.net/~henryarnold/

DonTronics
www.dontronics.com

Eletech
www.eletech.com

FutureBot Components
www.futurebots.com

HVW Technologies
www.hvwtech.com

Joker Robotics
www.joker-robotics.com

Lynxmotion Robot Kits
www.lynxmotion.com

Mekatronix
www.mekatronix.com

Mondo-tronics Robot Store
www.robotstore.com

Robosoft
www.robosoft.fr

Smart Robots
www.smartrobots.com

Zagros Robotics
www.zagrosrobotics.com

ages. Similarly, *pneumatic* power uses air pressure to move linkages. Pneumatic systems are cleaner than hydraulic systems, but all things considered, they aren't as powerful.

Both hydraulic and pneumatic systems must be pressurized to work, and the pressurization is most often accomplished through a pump. The pump is driven by an electric motor, so in a way, robots that use hydraulics or pneumatics are fundamentally electrical.

Hydraulic and pneumatic systems are rather difficult to effectively implement, but they provide an extra measure of power over motors. With a few hundred dollars in surplus pneumatic cylinders, hoses, fittings, solenoid valves, and a pressure supply (battery-powered pump, air tank, regulator), you could conceivably build a hobby robot that picks up chairs, bicycles, even your kid brother!

APPENDAGES

The ability to manipulate objects is a trait that has enabled humans, as well as a few other creatures in the animal kingdom, to manipulate the environment. Add a gripper to the end of the robot arm and you've created a complete arm/hand module that can be used in manipulating its environment.

Not all robot arms are modeled after the human appendage. Some look more like forklifts than arms, with a few using retractable push-rods to move a hand or gripper toward or away from the robot. Robot hands are commonly referred to as *grippers* or *end effectors.* Robot grippers come in a variety of styles; few are designed after the human counterpart. A functional robot claw can be built with just two fingers. The fingers close like a vise and can exert, if desired, a surprising amount of pressure.

Web sites that specialize in robotic power systems, locomotion, and armature concepts, including wheeled, walking, and hydraulic/pneumatic robots are listed in Table 5.

SENSORS

The more senses a robot has—*i.e.,* hearing, vision, or touch, *etc.*—the more it can interact with its environment. That makes the robot better able to go about its business on its own, which allows for more sophisticated tasks. *Sensitivity to sound* is the most common sensory system given to robots. Sound is easy to detect, and unless you're trying to listen for a specific kind of sound, circuits for sound detection are simple and straightforward.

Sensitivity to light is also common, but the kind of light is usually restricted to a slender band of infrared for the purpose of sensing the heat of a fire or for navigating through a room by way of an invisible light beam. Robot eyesight is a completely different matter. The visual scene must be electronically rendered into a form that the circuits on the robot can accept, and the machine must be programmed to understand and act on what it sees.

In robotics, *sensitivity to touch* is most often confined to pressure sensors attached to the tips of fingers in the robot's hand. The more the fingers of the hand close around the object, the greater the pressure. The pressure information is relayed to the robot's brain, which then decides if the correct

TABLE 4—BEAM ROBOT DESIGN

BEAM Robotics
hometown.aol.com/kc8goq/index.html

BEAM Robotics
www.geocities.com/SouthBeach/6897/beam2.html

Solarbotics
www.solarbotics.com

TABLE 5—ROBOTIC POWER SYSTEMS

Climbing Robots in Portsmouth
www2.ee.port.ac.uk/~robotwww/mech.html

Gadget Master
www.pcgadgets.com

Garden of Machines
www.mako.com/ballhome/chrisbot.htm

Generating Arachnid Robot Gaits with Cyclic Genetic Algorithms
www.cs.indiana.edu/hyplan/gaparker/papers/SGA98/SGA98.html

Human-Machine Interaction
www.me.berkeley.edu/hel/hydrarm.html

Microprocessor-Controlled Autonomous Modular Walking Vehicle
real.uwaterloo.ca:80/~hexotica/

Mike's PIC Projects
members.aol.com/mmorrow476/home.html

RoboCat: A 4-CPU 4-Legged Walking Robot
home1.gte.net/tdickens/68hc11/robocat/robocat.html

Tech Center Labs
members.aol.com/gmayhak/tcl/bot.htm

Tri-Star Wheel
www.netinfo.com/~dcarlson/bkground.htm

Walking Robot
home.golden.net/~amiller/Microcore.htm

Working with Stepper Motors
www.eio.com/jasstep.htm

TABLE 6—ROBOT SENSORS

Homebrew Sonar Ranging System
www.wizard.org/sonardoc.html

Implementing Infrared Object Detection
www.seattlerobotics.org/guide/infrared.html

Piezo Film
www.msiusa.com/sensors.htm

Robot Base with Vision
www.joker-robotics.com/vision/mk3.E.html

Structured Light Vision
www.cyberg8t.com/pendragn/actlite.htm

Ultrasonic Imaging Project
business.netcom.co.uk/iceni/usl_project/

Ultrasonic Ranging System
www.qkits.com/public/qkits/qay60.htm

amount of pressure is being exerted.

There are a number of commercial products available that register pressure of one kind or another (piezo film is a common choice), but many are expensive. Simple pressure sensors can be constructed cheaply and quickly using ordinary mechanical switches. The senses of smell and taste aren't generally implemented in robot systems, though some security robots designed for industrial use are outfitted with a gas sensor that, in effect, smells the presence of toxic gases. Table 6 lists Web sites that discuss *robot sensors* for sound, touch, and vision applications.

INTELLIGENCE

There are smart robots and there are dumb robots, but the difference really has nothing to do with intelligence. Even considering the science of *artificial intelligence*, all self-contained autonomous robots are unintelligent, no matter how sophisticated the electronic brain that controls it. Intelligence is not a measure of computing capacity, but the ability to reason, to figure out how to do something by examining all the variables and choosing the best course of action, perhaps even coming up with something new.

The difference between dumb and smart depends on the ability to take two or more pieces of data and decide on a pre-programmed course of action. Usually, a *smart* robot is one that is controlled by a computer,

TABLE 7 MICROPROCESSORS AND EMBEDDED MICROCONTROLLERS

Artificially Intelligent Robots
www.ucc.gu.uwa.edu.au/~steve/

Basic Stamp FAQ
www.alwilliams.com/wd5gnr/stampfaq.htm

General Information on Intelligent Robots
arti.vub.ac.be/~cyrano/robot_general.html

List of Stamp Applications
www.hth.com/losa.htm

MIT Handyboard
lcs.www.media.mit.edu/groups/el/projects/handy-board/

Parallax—Basic Stamp
www.parallaxinc.com

Peter H. Anderson - Embedded Processor Control
www.phanderson.com

although some amazingly sophisticated actions can be built into an automaton that contains no central brain (the BEAM robots, described earlier, are a good example). A *dumb* robot is one that blindly goes about its task, never taking the time to analyze its actions and what impact they may have.

Using a computer as the brains of a robot provides a great deal of operating flexibility. To be effective, the computer must be connected to all the *control* and *feedback* components of the robot. These components include the drive motors, the motors that control the arm, a speech synthesizer, the pressure sensors, and so forth.

Web sites specializing in microprocessors and embedded microcontrollers will provide information on kits, assembled products, and plans for adding a brain to your robot. Such sites are listed in Table 7. ■

AMAZING SCIENCE

(continued from page 75)

to secure the plastic sheet to the table using two binding clips and magnets.

GOING FURTHER

Recall Frank DeFreitias, the hologram workshop teacher we mentioned last month? Recently, he learned that one experimenter created a hologram

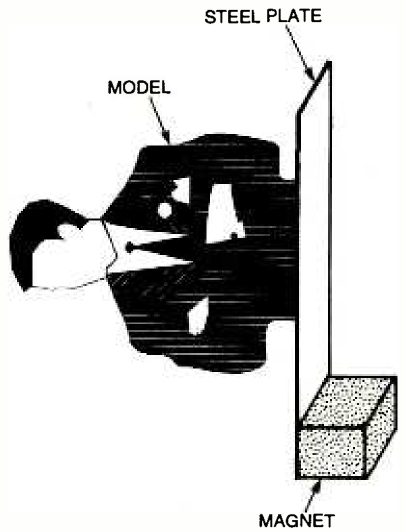


Fig. 12. Mounting the model for side illumination can be accomplished by glueing the model to a small steel plate and then placing it on its side using magnets.

with a depth of 7.5 feet. That's extremely deep for a hologram, considering the coherency length of a diode laser is only a few millimeters. What's happening?

It is my belief that laser light from a diode goes in and out of phase every millimeter or so. When in phase the light provides the sharp interference pattern needed for a hologram, but when out of phase it just contributes noise. So as one travels down the depth of the image, the laser light jumps back and forth between *in phase* and *out of phase*, yet the overall appearance of the holographic image is that it remains sharp.

If my belief is correct, the depth of field will no longer be limited by coherency length, but by the intensity of the laser light. Interesting stuff to consider if experimenting with "deep" holograms. Even more interesting is the possibility that for advanced, split-beam work, holographers may no longer have to match beam-path lengths. I haven't tried any split-beam work yet, but I plan to shortly.

To go further on your own, consider studying more basic techniques. If you'd like to peruse one of my books on the subject, check out *Homemade Holograms* (ISBN #0-8306-3460-6, McGraw-Hill 1990) or *Holography for Photographers* (ISBN # 0-240-80206-3, Focal Press 1997). For Web-based info, visit Frank DeFreitas' Internet Webseum of Holography at *www.holoworld.com*. ■

Neon-Lamp Circuits

CHARLES D. RAKES

This month we're going to play around with a number of neon-lamp circuits. The basic neon lamp has been around for some time, and today they are usually found working as indicators or pilot lamps in electronic equipment. In years past, however, when the vacuum tube ruled the electronic world, neon lamps and neon tubes were used as voltage regulators

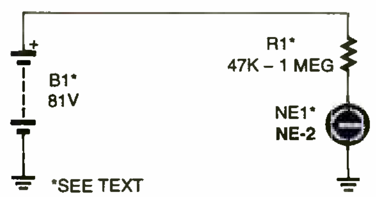


Fig. 1. The power source that we'll be using for neon-lamp experimentation is a stack of nine low-cost transistor batteries connected in series for a total source voltage of 81 volts.

to provide a near-constant voltage source for tube circuitry.

In addition, in the early days of TV, a special type of neon lamp was used to display—in a ghostly red glow—the crude images of the spinning-disc television system. But, at the *Circus*, we're allowed to experiment and build circuits just for the fun of it, and that's just what we are going to try and do with neon lamps this visit.

The most common and least expensive neon lamp available today is the NE-2, which can be had for less than half-a-buck. There are over a dozen variations of that basic neon lamp that offer a variety of characteristics. The "plain Jane" NE-2 has a breakdown voltage rating of 65 to 90 volts and a maximum current of 0.6 mA. The NE-2H, on the other hand, has a breakdown voltage of 95 to 135 volts and a maximum current of 1.9 mA, and yet still sells for less than half-a-buck. The other NE-2 family members fall somewhere in between those voltage and current specifications.

The most economical power source for neon-lamp experimentation is a stack of low-cost transistor batteries, see Fig. 1. **Note:** Although only a single battery symbol is used to indicate the power source, B1 actually represents a string of 9 or 10 series-connected units (for a source voltage of 81 or 90 volts). A stack of 9 or 10 nine-volt batteries will do for the standard NE-2, and the other NE-2 varieties can be operated by adding more 9-volt batteries in series. The batteries can be snapped together in a staggered row to obtain the desired output voltage.

Since the current demands of the neon lamp are so low, the battery life will be long. Just keep in mind that

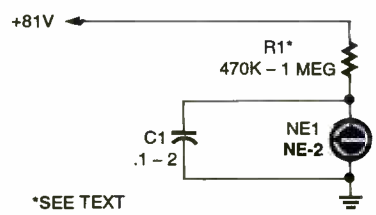


Fig. 2. One of the simplest oscillator circuits is the neon sawtooth generator, a schematic diagram of which is shown here.

PARTS LIST FOR THE SAWTOOTH GENERATOR (FIG. 2)

C1—0.1- to 2.0-µF, 100-volt capacitor
R1—470,000-ohm to 1-megohm, ¼-watt, 5% resistor (see text)
NE1—NE-2 neon lamp
Perfboard or breadboard materials, power source, wire, solder, hardware, *etc.*

you'll be working with voltages that could upset your carefree disposition, or even cause bodily harm. So be careful!

Resistor R1, in Fig. 1, is the neon lamp's current-limiting resistor. The minimum resistance for an NE-2 lamp is 100,000 ohms, and 47,000 for the NE-2H, while operating from a supply voltage no greater than 10% of the lamp's breakdown voltage. Higher operating currents greatly reduce the useful life of the lamp. The typical lamp-life expectancy is about 20,000 hours. That figure varies with the lamp's operating current.

SAWTOOTH GENERATOR

One of the simplest of all oscillator circuits is the neon sawtooth generator. A schematic diagram of such a circuit is shown in Fig. 2. When power is first applied to the Fig. 2 circuit, the capacitor (C1) begins to charge through R1. When the voltage across C1 reaches the neon lamp's breakdown voltage, the lamp (NE1) turns on discharging C1. The procedure is repeated over and over, producing a sawtooth waveform across the neon lamp. To the eye, the circuit is a simple neon flasher. Table 1 list various resistor/capacitor combinations and the expected frequencies generated by using those components.

TABLE 1—FREQUENCY SELECTION

C1	R1	FREQUENCY
0.1 µF	10-Meg.	1 Hz
0.22 µF	10-Meg	1/3 Hz
1 µF	10-Meg	1/10 Hz
0.1 µF	1-Meg.	10 Hz
0.22 µF	1-Meg.	3 Hz
1 µF	1-Meg.	1 Hz
0.1 µF	470K	20 Hz
0.22 Mf	470K	5 Hz
1 µF	470K	2 Hz

FREE-RUNNING OSCILLATOR

Our next entry, see Fig. 3, is a dual-lamp, free-running oscillator. The oscillator's operating frequency is approximately 2-Hz when a 0.1-µF capacitor is used for C1, 1-Hz with a 0.22-µF unit, and 0.5-Hz with a 1-µF component. Other combinations of component values can be substituted to either increase or decrease the oscillator's frequency. Larger component values lower the

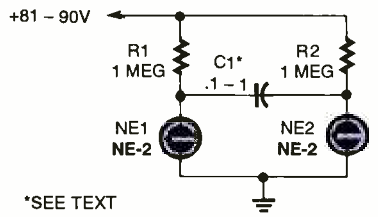


Fig. 3. This free-running oscillator, whose operation depends heavily on the two neon lamps (NE1 and NE2), has an operating frequency of approximately 2 Hz when a 0.1-µF capacitor is used for C1, 1 Hz with a 0.22-µF unit, and 0.5 Hz with a 1-µF component.

PARTS LIST FOR THE FREE-RUNNING OSCILLATOR (FIG. 3)

C1—0.1 to 1.0-µF, ceramic-disc capacitor
R1, R2—1-megohm, ¼-watt, 5% resistor
NE1, NE2—NE-2 neon lamp
Perfboard or breadboard materials, power source, wire, solder, hardware, *etc.*

oscillator's frequency and smaller values increase its frequency.

LATCHING CIRCUIT

Our next entry, see Fig. 4, uses a single neon lamp in an on/off latching circuit. The power source for the latching circuit must be adjusted to a voltage slightly below the neon's breakdown voltage, but above the lamp's operating voltage. A typical NE-2—operating at about 60 volts—breaks down at the 75-volt level. So a supply of 63 to 70 volts will do.

When power is applied to the circuit, C1—whose positive end is connected to the junction formed by S1 and S2—begins to charge through R3. Momentarily pressing S2 pulls the positive end of C1 low. The capacitor's

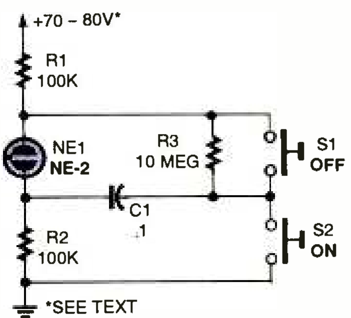


Fig. 4. Here a single neon lamp is pressed into service to help form an on/off latching circuit.

PARTS LIST FOR THE LATCHING CIRCUIT (FIG. 4)

C1—0.1-µF, ceramic-disc capacitor
R1, R2—100,000-ohm, ¼-watt, 5% resistor
R3—10,000,000-ohm, ¼-watt, 5% resistor
NE1—NE-2 neon lamp
Perfboard or breadboard materials, power source, wire, solder, hardware, *etc*

negative end is connected to the junction formed by R2 and NE1. At discharge, C1 sends a negative pulse to the bottom negative end of NE1. That causes the voltage across NE1 to raise above the lamp's breakdown voltage, turning NE1 on. On the other hand, momentarily closing S1 places C1 across NE1, thereby lowering the voltage across the lamp to a level below its holding or operating voltage, causing the lamp to turn off.

DUAL-LAMP LATCHING CIRCUIT

Our next circuit, shown in Fig. 5, carries the concept outlined in the previous circuit a step further by adding a second neon lamp along with additional support components to the circuit. The supply voltage for this latching circuit must be adjusted to a value below the breakdown voltage of both lamps. The two lamps should have about the same breakdown voltage.

Closing S1 causes NE1 to turn on, while extinguishing NE2; alternately, closing S2 causes NE2 to turn on as NE1 turns off.

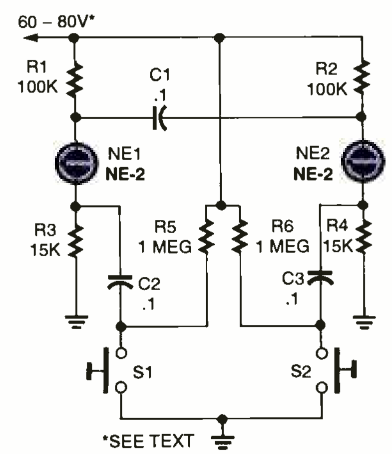


Fig. 5. This circuit configuration carries the concept outlined in Fig. 4 a step further by adding a second neon lamp along with additional support components to the circuit.

PARTS LIST FOR THE DUAL-LAMP LATCHING CIRCUIT (FIG. 5)

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1, R2—100,000-ohm
R3, R4—15,000-ohm
R5, R6—1-megohm

ADDITIONAL PARTS AND MATERIALS
C1–C3—0.1-µF, ceramic-disc capacitor
NE1, NE2—NE-2, neon lamp
S1, S2—Normally open pushbutton switch
Perfboard or breadboard materials, power source, wire, solder, hardware, *etc.*

CMOS DRIVER

Our next circuit, see Fig. 6, presses a single gate of a 4011 CMOS quad 2-input NAND gate into service to take control of the neon lamp's on/off operation. But, unlike the previous circuits, this one is fed from a negative supply. Potentiometer R4 is used to set the cir-

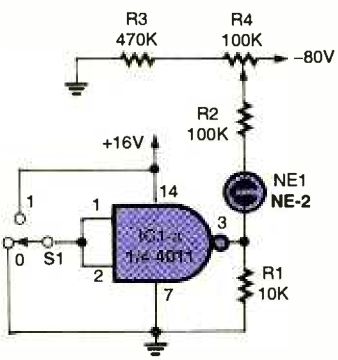


Fig. 6. The lamp driver shown here presses a single gate of a 4011 CMOS quad 2-input NAND gate into service to take control of the neon lamp's on/off operation.

PARTS LIST FOR THE CMOS LAMP DRIVER (FIG. 6)

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—10,000-ohm
R2—100,000-ohm
R3—470,000-ohm
R4—100,000-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS
IC1—4011 CMOS quad two-input NAND gate, integrated circuit
NE1—NE-2 neon lamp
Perfboard or breadboard materials, IC socket, power source, wire, solder, hardware, *etc.*

cuit's operating voltage slightly below the neon's breakdown voltage level. The difference in the neon's breakdown voltage and its operating voltage must not be greater than 15 volts, or the circuit will not work.

Setting S1 in the "0" position increases the neon's operating voltage by 16, turning it on, while placing S1 in the "1" position removes the voltage, turning NE1 off.

SEQUENTIAL DRIVER

Our next circuit takes the control theme of the our last circuit a bit further by introducing a 4017 CMOS decade counter/divider into the mix to produce the sequential neon-lamp driver circuit shown in Fig. 7. In that circuit, the 4017 (IC1) is connected in a "count-to-four-and-recycle" configuration that is set up to operate with an external clock—such as a simple 555-based oscillator or any similar fast-rising, positive, pulse-generator circuit.

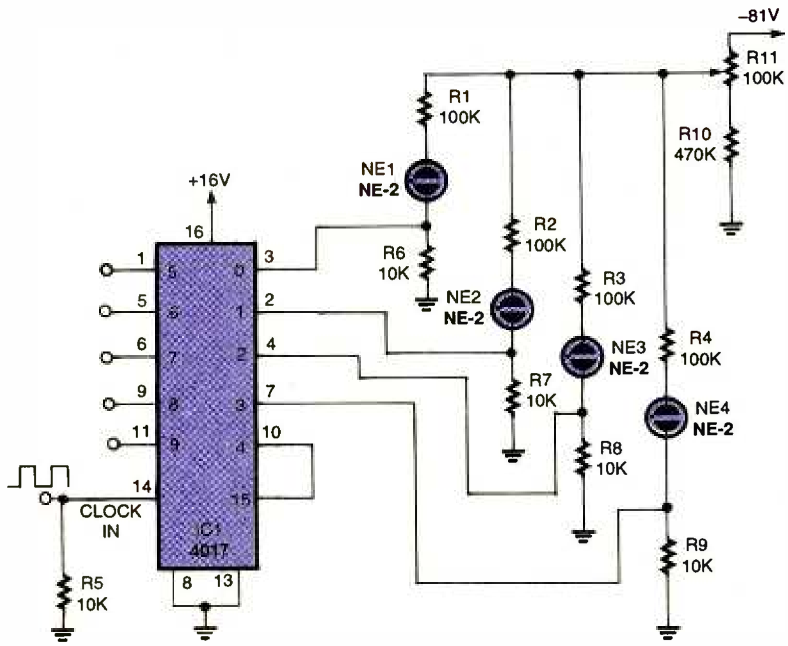


Fig. 7. Controlled by a 4017 CMOS decade counter/divider, the sequential neon-lamp driver circuit shown here is connected in a "count-to-four-and-recycle" configuration.

PARTS LIST FOR THE SEQUENTIAL DRIVER (FIG. 7)

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1–R4—100,000-ohm
R5–R9—10,000-ohm
R10—470,000-ohm
R11—100,000-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS
IC1—4017 CMOS decade counter/divider, integrated circuit
NE1–NE4—NE-2 neon lamp
Perfboard or breadboard materials, IC socket, power source, wire, solder, hardware, *etc.*

BREAKDOWN-VOLTAGE MATCHING CIRCUIT

In order for the Fig. 7 circuit to function properly, the four neon lamps must be matched to within a few volts at the breakdown-voltage level. To that end, a simple neon breakdown-voltage matching circuit is shown in Fig. 8. To use the matching circuit, simply place a neon lamp in test position 1 and increase the voltage via R3 until the lamp glows, and note the voltage at which breakdown occurs. Leave the lamp in position 1 and adjust R3 for a meter reading of about 40 volts or until the lamp extinguishes.

At that point, place another neon lamp in position 2 and increase the voltage until it turns on. As before, note the voltage at which breakdown

(Continued on page 85)

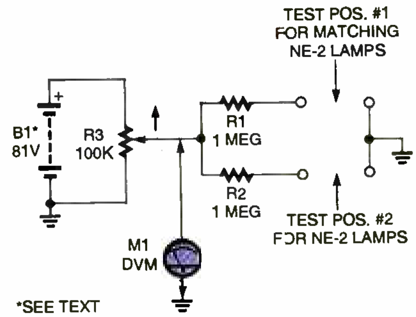


Fig. 8. This circuit can be used to compare and match the breakdown voltage levels of neon lamps.

PARTS LIST FOR THE BREAKDOWN VOLTAGE MATCHING CIRCUIT (FIG. 8)

R1, R2—1-megohm, ¼-watt, 5% resistor
R3—100,000-ohm potentiometer
B1—81-volt battery (see text)
Perfboard or breadboard materials, DVM, test terminals, IC socket, power source, wire, solder, hardware, *etc.*

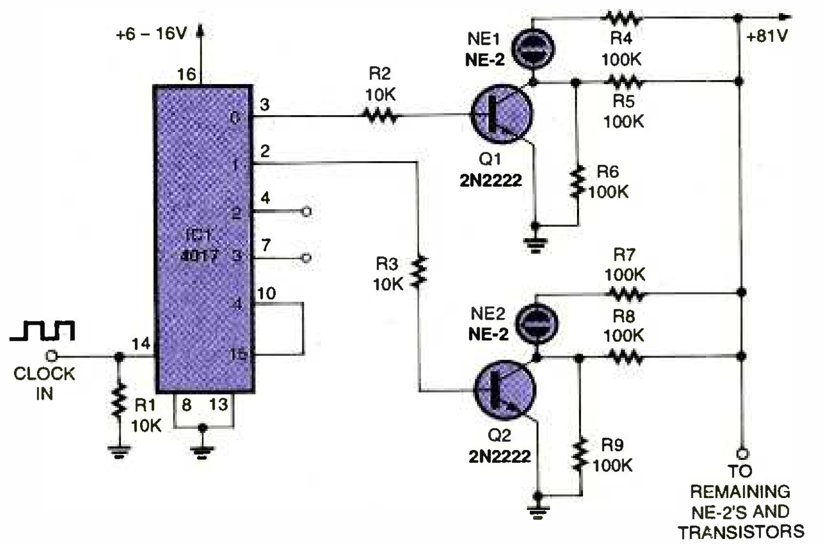


Fig. 9. The circuit in Fig. 7 can be expanded to drive a total of ten lamps by adding duplicate circuits to the remaining outputs of the 4017 and connecting the RESET *terminal (pin 15) of IC1 to ground.*

A Handy Handheld

MARC SAXON

When all is said and done, there's nothing quite as welcome as a good, basic, handheld scanner. Uniden designed just that when they created the BC120XLT.

The BC120XLT has 100 programmable channels, arranged in ten memory banks. That arrangement translates into 11 bands, including an aeronautical band and instant weather-band access. The basic frequency coverage is 29–54 MHz, 137–174 MHz, 406–512 MHz, plus 108–137 MHz aeronautical.

There are ten priority channels and a programmable search feature that allows the scanner to skip over unwanted data transmissions and birdies. The scanner also provides a preprogrammed service search for police, fire, emergency, aeronautical, and maritime frequencies. Scanning is at 100 channels per second, while searching lets users select either 100 or 300 frequencies per second.

Go to any channel directly via manual access and avoid stepping through other channels individually to get there. See every frequency in full via the backlit LCD display.

The Uniden BC120XLT comes with a rubberized antenna and BNC connector. Other included accessories are an AC adapter, belt clip, rechargeable battery, and earphone. The entire package weighs less than 13 ounces and measures about 2.5 by 2 by 6 inches (WDH).

This is a nifty little package that's easy to use, and it's available at all Uniden dealers.


The Uniden BC120XLT has 100 programmable channels, arranged in ten memory banks, including an aeronautical band and instant weather band access. The scanner also provides preprogrammed service search for police, fire, aeronautical, and maritime frequencies.

MIXED SIGNALS

According to our mail, there aren't too many things more annoying or confusing to the hobby scanner community than the various federal and local laws intended to thwart monitoring of cellular and cordless phones. Let's not forget that Uncle Sam, himself, is perhaps the world's most active and enthusiastic eavesdropper, with satellite and worldwide terrestrial facilities designed to overhear scrambled and unscrambled international private wireless telephone conversations, faxes, and other communications.

For the most part, the federal laws restricting hobby monitoring have been pushed through Congress by the wireless telephone industry, armed with highly emotional scare tactics citing the need for the public to have (at least the illusion of) privacy. Congress was duly impressed and provided rubber-stamp approval to every law proposed.

A lot of strange conversations are sent out over the airwaves, and most are in simple analog FM that may be easily monitored on many standard scanners. Of course, politicians didn't forget how a few bad eggs owning scanners taped several embarrassing cellular calls from a couple of high-profile Washington bigwigs, and then leaked the tapes to the news media. Nobody bothered to ask the wireless telephone industry why their equipment wasn't scrambled to begin with to ensure privacy. Assuring privacy came down to making it illegal to tune certain frequencies or to sell equipment capable of doing so.

Does such monitoring deserve to be illegal? The answer seems to vary, depending on the individual case. A year ago, a journalist pleaded not guilty to recording an angry cellular phone call between actors Tom Cruise and his wife, Nicole Kidman, and then selling the tape to a weekly tabloid newspaper.

Yet, last June, Massachusetts' highest court ruled that residents cannot expect privacy when talking on any telephone. The court ruled that State Police, without a warrant, could testify about a phone conversation they eavesdropped on involving a man accused of home invasion. In the call, while speaking to his girlfriend, the suspect implicated himself in the crime. The tape was not used at the trial. Justice Herbert Wilkins' opinion stated, "He had no reason to assume that the conversation would not be heard by a third party. A person cannot control conditions at the other end of a conversation. Any expectation of privacy in a telephone conversation is not objectively reasonable."

Although the wireless phone industry, celebrities, politicians, and criminals are most sensitive to wireless phone privacy issues, it seems that the public at large does not rate privacy very high on its list of reasons for using these devices. Despite warnings in most instruction manuals that eavesdroppers might hear these conversations, people continue to chat at great length about the most intimate and sordid details of their personal and business activities. Moreover, people loudly chat on cellphones while walking down the street; in public transportation; at concerts, movies, and sports arenas; and in elevators, stores, restaurants, and offices. It's become so irritating to bystanders that some communities are now passing laws restricting wireless phone use in certain public places.

So the public at large hardly seems to care about wireless phone privacy, and the industry wasn't required to provide secure equipment. The airwaves are a natural resource that belong to the public, which includes scanner hobbyists. Before the anti-scanner laws, millions of legal scanners were made and sold that are able to monitor these frequencies. Therefore, all the government has accomplished is take a bunch of hobbyists and cause many of them to do something illegal that used to be legal. Privacy has not been assured, and (except when someone foolishly makes and sells tapes), the laws are virtually impossible to enforce. Somewhere along the line, there's something illogical, unfair, and badly out of whack.

What do you think? Why not write and let us know.

MAILBAG

Cary, from Madison, WI, writes to ask if there is a way officers of different law-enforcement agencies can communicate with one another during (for instance) a high-speed vehicle pursuit involving several jurisdictions.

Frequency 45.86 MHz was established as a police intersystem channel back in the era when many agencies used the VHF low band. It's still authorized. However, later, 155.475 MHz was designated as a nationwide police emergency channel, and it remains available primarily to accommodate officers of different agencies communicating with one another during pursuits. I've monitored some interesting activity there, including combined-agency stake-outs; but I've also noted a few agencies using it as little more than an informal mobile frequency for non-official chit-chat.

What with many law-enforcement agencies having switched to UHF of late, their vehicles are no longer equipped for VHF high-band operation. This has reduced the ability of 155.475 MHz to effectively serve its intended national purpose. Still, it's worth monitoring for whatever interagency emergency activity it might occasionally produce. But, frankly, many agencies located adjacent to one another do not offer their mobile units the capability of communicating with one another. A typical example is here on Long Island, where **Popular Electronics** is published. Interstate 495 (the Long Island Expressway) mostly runs through two adjacent suburban counties, Nassau and Suffolk. The Nassau County PD vehicles use UHF-T band communications, while the Suffolk County PD has an 800-MHz trunked system. The police vehicles patrolling I-495 in each county can't talk to one another, even though many speeders, suspected DUIs, and other wanted drivers regularly travel between the two counties.

That's a wrap for this month. How about sharing your new frequencies with us, or submitting a scanner-related question or opinion? Your participation is needed so we can keep this the best scanner source around. Our mailing address is *Scanner Scene*, **Popular Electronics**, 500 Bi-County Blvd., Farmingdale, NY 11735. Our direct e-mail address is *sigintt@aol.com.* ■

CIRCUIT CIRCUS

(continued from page 83)

PARTS LIST FOR THE EXPANDED SEQUENTIAL DRIVER (FIG. 9)

IC1—4017 CMOS decade counter/divider, integrated circuit
Q1, Q2—2N2222 general-purpose NPN transistor
R1–R3—10,000-ohm, ¼-watt, 5% resistor
R4-R9—100,000-ohm, ¼-watt, 5% resistor
NE1, NE2—NE-2 neon lamp
Perfboard or breadboard materials, IC socket, power source, wire, solder, hardware, *etc.*

occurs, and continue on by substituting lamps in position 2 until four lamps are matched. If matches can not be made to the lamp in position 1, replace it with another lamp and start over.

The Fig. 7 circuit can be expanded to drive a total of ten lamps by adding duplicate circuits to the remaining outputs of the 4017 and connecting the RESET terminal (pin 15) of IC1 to ground. It can be a little tricky getting all of the neon lamps selected to fall within the voltage limits needed to operate properly, but it can be done. A much easier method is shown in our next sequential circuit.

EXPANDED SEQUENTIAL DRIVER

Using interfacing transistors between the 4017 and the neon lamps, as shown in Fig. 9, eliminates the lamp matching requirement. Just about any general-purpose NPN transistor can be used as long as it's rated for a collector-to-emitter voltage of 40 volts or more. The neon lamp now becomes the transistor's collector load and is powered from a positive 81-volt supply. In that circuit, maximum transistor and lamp current is limited to less than 1 mA by a 100K current-limiting resistor (either R4 or R7 in this circuit). Two additional 100K resistors are used as a voltage divider to limit the maximum voltage seen across the transistor.

As in the previous circuit, the number of lamps may be increased by adding transistor drivers and neon lamps to as many 4017 outputs as is desired. If a more brilliant light output is desired, the NE-2 neon lamps called out in the schematic diagram can be replaced by higher current NE-2H units. To bring the current level up, change R4 and R7 to 47K resistors and raise the supply voltage to 100 volts.

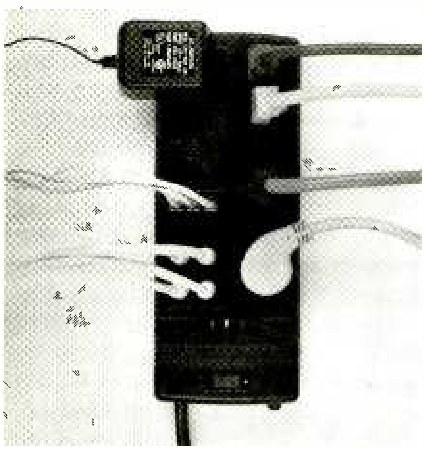
At the 100-volt supply level, the voltage at the transistor's collector is slightly higher than allowed by their specifications, but all the transistors that were tested in the circuit operated without a problem. In fact, all of the 2N2222s on hand endured a much higher test voltage and would see little strain in either of the lamp-driver circuits. In any case, just about any general-purpose NPN transistor with characteristics similar to the 2N2222, but with a higher collector-to-emitter voltage rating, can be used.

It's once again about time to close up shop and start thinking about what we're going to do here at the *Circus* next time. Anyway, between now and then think about using neon lamps in a modern-day electronic circuit or project and let me know about it. ■

NEW PRODUCTS

SURGE PROTECTOR

With many homes having at least one room filled with computers, stereos, or home theaters that are dependent on surge-sensitive microchips, protection is needed to help keep this expensive hi-tech equipment safe from harmful power spikes. The *Craftsman Premium Electronics Surge Protector (#82540)* offers a very high level of protection against these power surges for entire roomfuls of such equipment. Since a power surge, traveling down a power line outside the home, can cause a surge of up to 6000 volts in the electrical lines, it can overload these delicate microchips and power supplies.



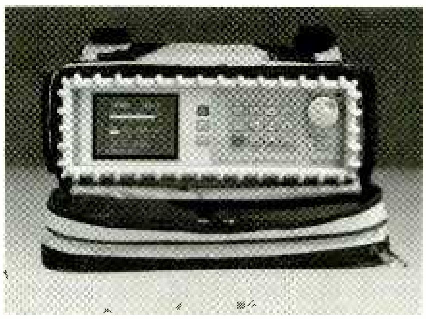
With a rating of 2500 joules, this surge protector provides special protection for computer modem lines, satellites, and cable TV. Not only does it offer nearly double the capacity of most other premium plug-in protectors, but it has three-stage and three-line protection, using three different kinds of protective components. This unit features eight plug-in receptacles, including two made-for-over-sized transformer plugs, and a 9-foot cord with a $^{1}/_{2}$-inch thick Slender Plug. The unit's audible alarm sounds if the surge protector has taken a significant voltage surge, and three lights indicate proper grounding, power on, and proper polarity.

The Craftsman Premium Electronics Surge Protector (#82540) costs $59.99. For more information, contact Sears Roebuck, Inc.; Tel. 800-390-8792 (information) or 800-377-7414 (sales).

CIRCLE 80 ON FREE INFORMATION CARD

TV LEVEL METER

Designed to perform measurements on analog and digital TV systems, the *PROLINK-3* combines a spectrum analyzer and a signal-level meter. It incorporates direct measurements for the evaluation of radio, TV, and data-signal quality. The unit also allows analog signals from any TV standard to be demodulated and identifies digital signals.



Portable, rugged, and easy to use, the instrument includes a powerful data-acquisition system (DATA LOGGER) with the capacity to evaluate up to 99 channels automatically. For measuring digital signals, it can incorporate an optional Bit Error Rate. Measurement results are shown on the easy-to-read screen.

The PROLINK-3 has a list price of $1996. For more information, contact NSC Industries, 2255-E Wyandotte Road, Willow Grove, PA 19090; Tel. 215-657-4690; Web: *www.promax.es.*

CIRCLE 81 ON FREE INFORMATION CARD

TRUE RMS AC MULTIMETER

The *Model 380973 True RMS AC Clamp-On DMM* measures AC/DC voltage to 600 volts and AC current to 600 amps. It also measures resistance, frequency, and capacitance; and it monitors audible continuity and test diodes. AC measurements cover a wide frequency (from 40 to 450 Hz) and basic DC accuracy is 0.75%.

Features include Data Hold and

Peak (Maximum) Hold, and there are indications for over range and low battery. Measurements are displayed on a 3fl-digit (3999 count) LCD. The unit, whose jaws open to 1.6 inches, measures 9 × 3 × 1.5 inches. It comes complete with test leads, a bead wire temperature probe, nine-volt battery, and case.

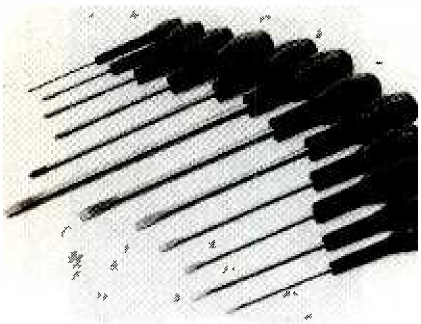
The Model 380973 True RMS AC Clamp-On DMM costs $169. For more information, contact Extech Instruments Corp., 335 Bear Hill Road, Waltham, MA 02451; Tel. 781-890-7440; Web: *www.extech.com.*

CIRCLE 82 ON FREE INFORMATION CARD

ERGONOMIC SCREWDRIVERS

The *Expert Screwdriver Line* features ergonomic handles for reduced hand fatigue and increased user comfort. The screwdrivers incorporate a twin-material cushioned rubber grip for improved turning torque and sure handling in harsh work environments. These tools feature vapor-blasted, precision-ground tips for increased torsional stability in screwhead recesses that helps to maintain safe, secure contact with the fastener heads.

Constructed of hot-forged, chrome vanadium steel, the screwdriver blades are nickel chrome-plated for



corrosion resistance and durability. The ergonomic grips are molded around the blade shaft for added strength. In addition to four screwdriver sets, over 40 Expert Screwdrivers are available individually.

The 5-Piece Expert Screwdriver Set (#83545) has an MSRP of $29.95, the 7-Piece Expert Screwdriver Set (#83567) has an MSRP of $69.30, the 12-Piece Expert Screwdriver Set (#83562) has an MSRP of $115.95, and the 11-Piece Expert TORX Set (#83541) has an MSRP of $81.15. For more information, contact S&K Hand Tool Corp., 3535 W. 47th Street, Chicago, IL 60632; Tel. 773-523-1300; Web: *www.skhandtool.com*.

CIRCLE 83 ON FREE INFORMATION CARD

INSULATION TESTER

Designed to test insulation at rated voltages into a maximum 1-mA load, the *Model AMB-5D Insulation Tester* measures test voltages of 250/500/1000 volts DC, has an AC voltage-monitoring range of up to 600 volts AC, and monitors 280-mA short-circuit continuity current. Among the features of the tester are auto-ranging (four ranges up to 4000 megohms) and auto-discharge. The 50-segment log-scaled analog display is easy to read on the large $3^3/_4$-digital LCD panel with a maximum reading of 4000. The LCD panel also displays both overrange and low-battery indications.

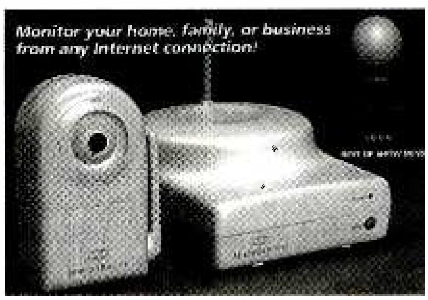
The easy-to-carry testing package is 7.8 × 5.46 ×3.7 inches and weighs only two pounds. The tester comes with test leads, batteries, and a user's manual.

The Model AMB-5D Insulation Tester costs $459.85. For more information, contact Amprobe, P.O. Box 329, 630 Merrick Road, Lynbrook, NY 11563; Tel. 516-593-5600; Web: *www.amprobe.com*.

CIRCLE 84 ON FREE INFORMATION CARD

INTERNET SECURITY DEVICE

Anyone with an Internet or e-mail connection can monitor his or her home, family, or business using the *MICROSENTINEL*. The MICROSENTINEL features a wireless camera and a motion detector that can be used with any Windows personal computer. It supports up to four small 2.4-GHz wireless color video cameras, each with a range of up to 700 feet.



The included security software can detect motion (a person entering a room); then record images, audio, or video; and optionally dial a phone number to notify users. The device can also record at designated times. The recordings can be automatically sent to any e-mail address or Web site, saved on the computer to be viewed later, or posted to the SDN Security Server Web site. In addition, while working at the computer, users can view the video of multiple activities such as the children with their nanny, pets in the backyard, or employees in the warehouse.

The MICROSENTINEL has an MSRP of $699. For more information, contact Security Data Networks, Inc., 5520 Dillard Drive, Corporate Suite 120, Cary, NC 27511; Tel. 800-747-9101 or 919-851-1778; Web: *www.sdn.com*.

CIRCLE 85 ON FREE INFORMATION CARD

COMM LINKS

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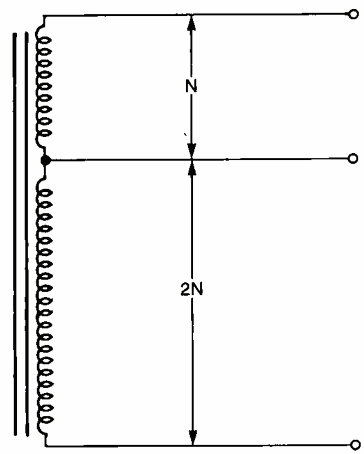


Fig. 4. A variation on the Fig. 3 circuit, in which an inductor is used to match the impedance at Port S, is shown here. The power splitting function is performed by center-tapped coil L1, with the input signal applied to the tap and the outputs taken from the ends.

The power splitting function is performed by coil L1. The coil is center tapped, with the input signal applied to the tap and the outputs taken from the ends. That transformer can be wound on either T-50-2 or T-50-6 toroidal cores for the HF bands, or a T-50-15 core for the AM BCB and medium-wave bands. Use 18 turns of #26 AWG wire for the HF bands and 22 turns for MW bands.

The resistor across the ends of L2 should be twice the system impedance. That means 100 ohms for 50-ohm systems, and 150 ohms for 75-ohm systems (standard values).

Some impedance transformation is needed if the system impedance is to be maintained, so L1 must be provided. The transformer is tapped, but not at the center. Figure 4 shows the relationship between the tap and the winding: the tap is located at the one-third point on the winding. If the bottom of the coil is grounded, then the tap is at the two-thirds point (2N turns), and the input is at the top (N + 2N turns). In other words, the tap is at two-thirds the overall length of the winding.

The capacitor usually has a value of 10 pF, although people with either a sweep generator or a CW RF signal generator can optimize performance by a 15-pF trimmer capacitor. Adjust the trimmer for flattest response across the entire band. ■

ELECTRONICS LIBRARY

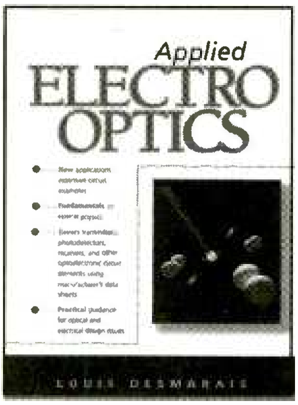
(continued from page 30)

APPLIED ELECTRO-OPTICS

by Louis Desmarais

An understanding of both the fundamentals of optics and electronics is essential to successfully build optoelectronic circuits. This "back-to-basics" guide provides engineers, designers, and technicians with a firm background in both optical physics and circuit design.

The book introduces the basic theory of optoelectronics, covering such topics as Maxwell's equations, reflection and refraction, and interference phenomenon. Each major element of an electro-optic system is discussed, including semiconductor light sources, optical transmitters, and optical receivers. After the theory is thoroughly covered, the book guides readers step by step through the practice of building circuits for a variety of applications, including CD players and infrared data transmission.



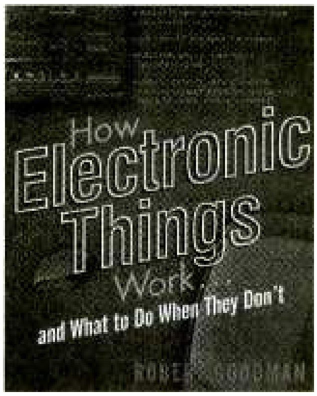
Applied Opto-Electronics costs $62.99 and is published by Prentice-Hall, One Lake Street, Upper Saddle River, NJ 07458; Tel. 800-811-0912; Web: www.phptr.com.

HOW ELECTRONIC THINGS WORK...AND WHAT TO DO WHEN THEY DON'T

by Robert Goodman

This is an everyperson's guide to electronics designed to help ordinary electronics users understand, live with, and maybe even learn to love the technology in our lives. Whatever your goal—saving on repair bills, maintaining your equipment, or making your own repairs, this book gives clear explanations of how things work.

The text is written in easy-to-understand language, and no technical experience is needed. There are clearly illustrated instructions on using test equipment to analyze and diagnose problems. Guidelines are provided on whether or not professional repair is needed. There are also tips on protecting expensive equipment from lightning and other electrical damage, as well as lubrication and maintenance suggestions.

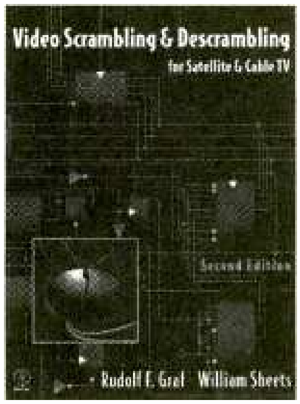


How Electronic Things Work...and What To Do When They Don't costs $62.99 and is published by McGraw-Hill, 1221 Avenue of the Americas, New York, NY 10020; Tel. 800-2MCGRAW; Web: www.books.mcgrawhill.com.

VIDEO SCRAMBLING & DESCRAMBLING FOR SATELLITE AND CABLE TV, 2nd EDITION

by Rudolf F. Graf and William Sheets

Video, audio, and computer hobbyists, technicians, and commercial TV personnel interested in satellite signals and programming will find this book an invaluable resource. This completely revised edition details the hows and whys of encoding and decoding video signals. Included is information on analog/digital conversion, phase-locked



loops, digital techniques, and IC data sheets.

The book provides an understanding of encoding/decoding systems and the theory and techniques of encryption and decryption. An overview is given of the rules and regulations governing the availability and use of satellite signals, antennas, and programming materials. Schematics and details for several encoder and decoder circuits and experiments are included.

Video Scrambling & Descrambling For Satellite and Cable TV, 2nd Edition costs $29.95 and is published by Newnes, Butterworth Heinemann, 225 Wildwood Avenue, Woburn, MA 01801; Tel. 800-366-2665 or 781-904-2500; Fax: 800-446-6250 or 781-904-2620; Web: www.bh.com/newnes. ■

NIKOLA TESLA

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> had already been invented by others, then without a shade of doubt, Nikola Tesla is the world's greatest inventor, not only at present but in all history.... His basic as well as revolutionary discoveries, for sheer audacity, have no equals in the annals of the intellectual world."

Countless others around the globe share Gernsback's feelings concerning Nikola Tesla. ■

PRODUCT TEST REPORT

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CONCLUSION

Any consideration of the CDR765 must involve price versus performance—and convenience, both compared with PC digital recording.

The CDR765 is unquestionably convenient. When "burning" CDs on a PC, the user has to deal with menus and application software, and, unless the PC has separate CD and CD-R drives, has to store the original CD tracks on the PC's hard drive before copying them. The time consumed depends on the speed of the CD drives and, in the case of two, whether they're linked by a fast SCSI connection (not often the case with Windows PCs).

Copying CDs on a PC can be faster than the maximum double-speed of the CDR765 (which is available only when you make a direct dub of an entire CD). But anyone who has ever used a cassette dubbing deck will feel comfortable with the CDR765—the only difference is getting used to the need to "finalize" the CD-R after recording (this process compiles its Table of Contents, so it may be "recognized" as an audio CD for playback).

Besides double-speed dubbing, the CDR765 offers many recording options, such as creating programmed compilations of singles with synchronized dubbing from the internal play-drive or an external source. When copying from sources with shorter play times, such as LP or cassette, the CDR765 will pause recording after 20 seconds without an incoming signal, so the user can flip the audio source. Additionally, the deck offers a choice of optical-digital, coaxial-digital, or analog inputs and outputs (plus a headphone jack). Both drives can be used in tandem for programmed play, or fed individually to separate sound systems.

Much of what the CDR765 does can be done more cheaply with PC-type CD-R drives, if not as easily. All Audio CD recorders and blanks are more expensive—and not just owing to the royalty level. Even with 3% tax, the price of Audio CD-Rs is disproportionate to that of PC blanks. This has to do with volume efficiencies and, to some extent, retail distribution. Audio CD-R sales volume is minuscule compared with that for PC blanks, which sell for cents. Meanwhile, only a handful of vendors offer Audio CD-Rs compared with heavy competition in the PC world. Additionally, Audio CD-Rs more often are carried by stereo-specialty retailers, who've got little incentive to discount them, given scant retail competition and the nature of the customer. All of the above applies even moreso to the new rewritable format.

For the record, we tried to "trick" the CDR765 into using cheaper PC blanks, something that was possible with earlier Philips CD-R decks by a variety of means. No dice—Philips got enough grief from the music industry over that previous loophole, so they made this deck bulletproof.

Despite the higher usage-costs involved, the CDR765 and other Audio CD-R decks will appeal to PC-phobes, anyone who simply wants to hit one button and go, or people who want their audio recording gear in the same room as their hi-fi system—not in the den with the PC. Cost objections are likely to vanish in the near future as Audio CD recorder hardware prices plummet, with Philips and Pioneer getting competition from Go-Video, Kenwood, and others. And any way you look at it, the price of a blank Audio CD-R is still cheap compared with buying a second CD.

For more information on the Philips CDR765 Dual-Drive CD-R/RW Recorder, contact Philips Consumer Electronics, 64 Perimeter Center East, Atlanta, GA 30346; Tel. 770-821-2400; Web: *www.philips.com*; or circle 50 on the Free Information Card. ■

TESLA COIL

(continued from page 39)

the top-loading capacitor, a metal strap is mounted to the unit and a hole drilled in the center, allowing it to be mounted atop L2.

Putting It All Together. Only operate the Tesla Coil when it is pluged into a grounded outlet! To do otherwise will result in poor performance and most likely cause shocks to the operator when touching the off/on switch.

Set the 8-inch length of 2-inch PVC pipe in the end cap mounted on the wood base. Set the L1 assembly on the pipe, and position L2 in place in the 4-inch end cap located in the middle of L1. Plug L2's ground into the jack on L1's base and connect that ground to circuit ground. Hook the capacitor up and attach the lead from the spark gap to one turn in from the outside turn of L1. Connect the output from the high voltage rectifiers and C3 to the spark gap including all seven gaps in series. Place the top loading capacitor on L2 with washers and holding nut. Check all of the connections between all major components against the schematic drawing in Fig. 1. If everything looks good, turn the power on and the spark gap should become active. Take a long clip lead and connect one end to circuit ground and clip the other end to a wooden yardstick. Bring that end near one side of the loading capacitor. Sparks will jump to the lead at a distance of 6 to 8 inches.

If not, the circuit probably needs to be tuned. Turn the power off and discharge C3. Move the lead on L1 in about fi turn and repeat the experiment. If the spark output increases, go another half turn in and see what happens. If the spark decreases, then go back half turn and check again. Keep experimenting with the tap location until the best output is obtained. The spark gap controls the amount of voltage reached across C3 before discharge and the maximum output spark. If the gaps are set too close, the discharge output will be much less in length but more often in occurrence. With the multi-series gap arrangement, experimenting with various gap settings is easy.

The best place to view the Tesla Coil's "fireworks" is in a darkened room. Hold one end of a fluorescent tube and bring it near the operating coil. If the coil is operating properly, the lamp should light with each discharge at two or three feet away from the coil. A clear incandescent lamp positioned close to L2 will produce a beautiful blue and yellow lightning array from the lamp's filament to the outer edge of the glass envelope. Just keep in mind that the voltage across C3 can hurt you, so be sure to discharge it before making any adjustments to the circuit. When not using the coil place a jumper lead across C3 as a safety measure. Good sparks always! ■

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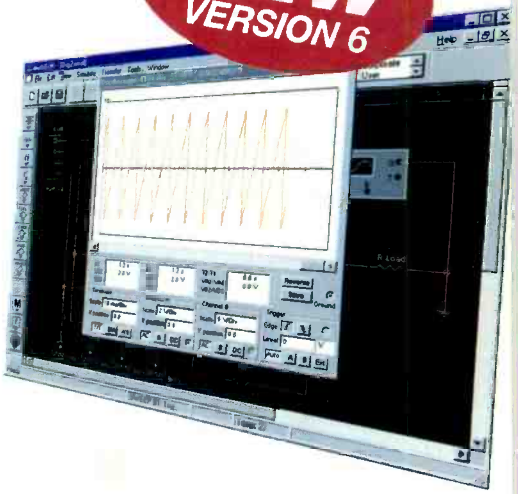

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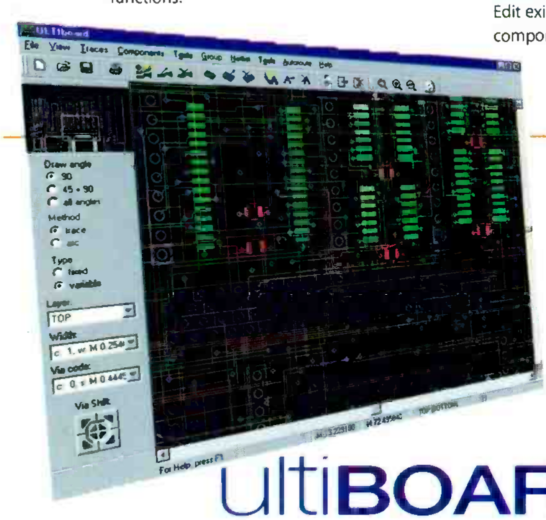

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