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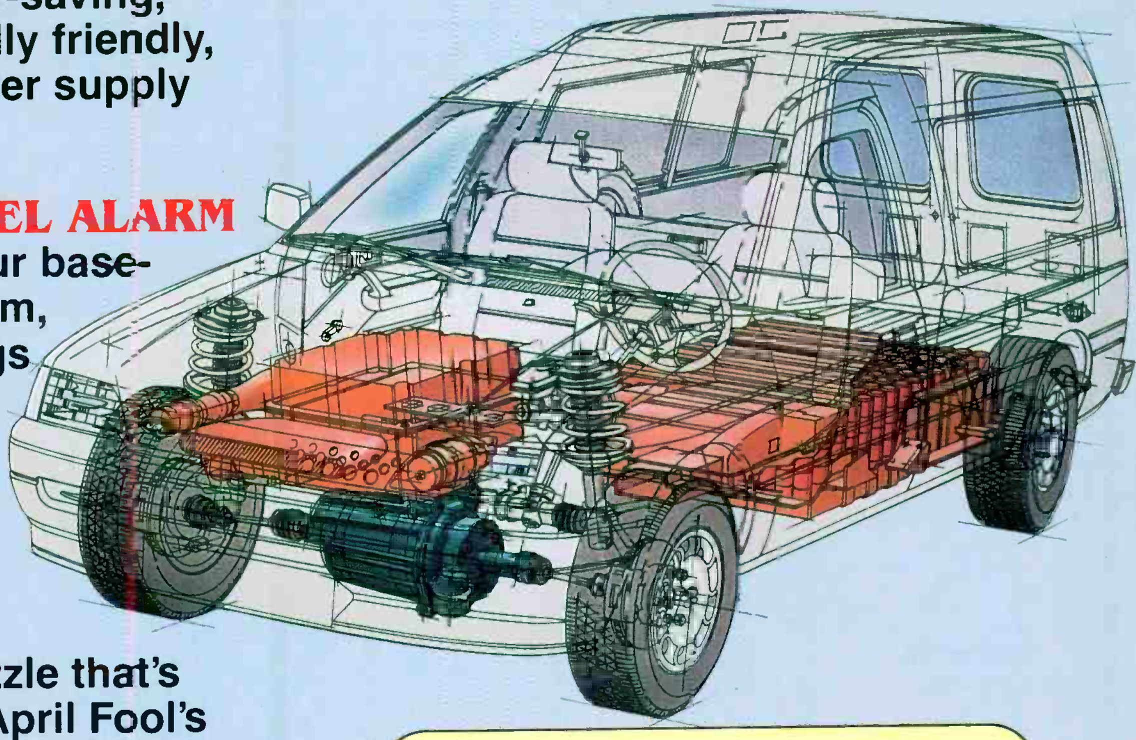

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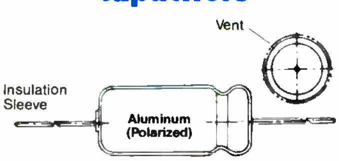

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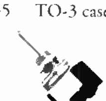

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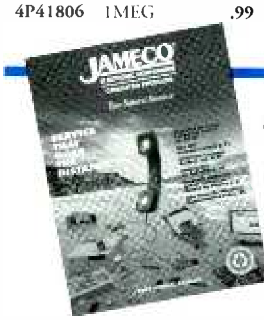

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EDITORIAL

TOMORROW'S ELECTRIC CARS

This month, **Popular Electronics** turns its attention to a topic that has spurred much debate. That debate has been over the future of the gasoline-powered automobile.

The argument has revolved around topics such as jobs, dependence on foreign oil, the environment, and more. Alternative fuels such as electricity have been proposed, but, considering the automobile's role in Americann culture, there is much doubt that many U.S. consumers would even consider an electric substitute.

But the U.S. is not the entire world—and there is a demand in Europe and Japan for less-polluting vehicles. Further, California, which in itself makes up roughly 11% of the U.S. market for automobiles, has mandated that, by 2003, at least 10% of the cars that an automaker sells in that state must be "zero polluting vehicles" that produce *NO* tail-pipe emissions. The only current technology that is capable of producing such a car is electric.

The race is now on to produce a viable electric car. In Detroit, and around the world, automakers are hard at work in their labs. In "The EV Revolution Revs Up" (see page 31), we look at the various electric-car technologies that are undergoing development, which problems have been overcome, and which problems must still be surmounted.

But technology is one thing, emotion is another. No matter what marvels make it possible, no one will buy an electric car if it is uncomfortable, unappealing, or disagreeably unusual. We had the opportunity to take some of the first electric prototypes out for a spin. Some of what we found was comfortingly familiar; some was disconcertingly strange. For a full report on our findings, turn to "Plug In, Turn On, Drive Out" (on page 5 in the "Gizmo" section).

Carl Laron
Editor

LETTERS

IGNITING SOME INTEREST

J.M.N.'s letter (**Popular Electronics**, January 1993) in response to the article "Build a High Energy Ignition System for Your Car" must be based strictly on theory. It certainly doesn't agree with my experience over the past 25 years.

I first started to build capacitor discharge (CD) ignition systems for my own, and my friends' and family's, cars before suitable transformer cores were commonly available. I wound those simple transformers on old fly-back transformer cores salvaged from defunct TV sets. I don't recall the year, but the latest revision to my schematic is dated August 3, 1971, and I had CD units in several vehicles prior to that. I couldn't locate the required capacitor at that time, and paralleled three 0.47-µF units for a total of 1.41 µF.

I removed one of those units from a 1976 Honda that I recently sold. The Honda had 185,000 miles on it, and had the CD unit in it since it was new. I replaced the points once—not because they wore out, but because the rubbing block wore to the point that it no longer insulated the points from the ground. At 10,000 miles, I installed a set of plugs called "Fire Injectors," which I bought from J.C. Whitney, that were similar in design to an aircraft spark plug, with a massive center electrode and four ground electrodes. I removed them at over 100,000 miles because the center electrode had become square and the outside electrodes had eroded too badly to fire reliably. They were guaranteed for the life of the vehicle, and J.C. Whitney refunded my original purchase price!

The only coil that I can recall failing was sold by Mallory specifically for use in CD systems, not original equipment coils. The capacitor-discharge unit was an addition. The distributor cap, rotor, coil, ignition wires, etc. will withstand a CD system, if they are in good condition. I found that all those items normally last longer with the CD system. Plug life is dramatically extended.

Two basic facts should be kept in mind when thinking about ignition systems. First, an electric arc will occur at the smallest gap in the circuit. That should be the spark plug gap, compensating for cylinder compression. Don't worry about the capability of the remainder of the system. Second, erosion of plug points, as well as rotors and distributor caps, is caused by the electric arc. Burning of the fuel has no effect on any component except plugs, and minimal effect there.

A Kettering system generates a damped wave form, resulting in many electrical pulses each time the points open, to erode the plugs, rotor, and distributor cap electrodes. The first electrical pulse should ignite the fuel mixture; the remainder only waste energy and cause erosion. A CD system gives essentially one pulse. Points carry a heavy load in the Kettering system and practically none with a CD system. Consequently, point replacement becomes a thing of the past, provided a little lubrication is used on the rubbing block once in a while. Point-dwell time loses its significance with the CD system. The points need only be closed long enough to discharge the trigger capacitor. (In fact, a delay is built into the trigger circuit to elevate false firings caused by point bounce.) Only the point opening has any real significance in the CD system.

I have no way to measure impedance at the coil, or at any other point in the system (and couldn't care less). But try a simple test with your Kettering system and then with a CD system. Hold a piece of tissue paper between the points of a plug and fire a Kettering system through the tissue paper until it ignites. Then try it with a CD system. Note which one will ignite the paper sooner. After all, the plug's only job is to build a fire in the cylinder!

As for emissions, each cylinder will fire more reliably with the CD system. Although it's important, the fuel/air ratio becomes less critical with reliable ignition. All factors being equal, the CD ignition system will lower emissions.

J.M.N.'s last statement is almost true: "Some conventional electronically switched ignitions with suitable high-performance coils can produce sparks of sufficient voltage, current, and duration to rival some capacitive discharge ignitions." Perhaps so; I just have not seen them. What I have seen are excessively overpriced systems—for instance, price tags of over $200 for a so-called "igniter" that can often be replaced with about $10 worth of parts!

I personally solved all the ignition problems in my vehicles—I switched to diesel fuel!
T.E.B.
Benson, AZ

THE PLUS SIDE OF SURPLUS GEAR

Just a note to let you know how much I enjoy reading *DX Listening* and *Antique Radio* in **Popular Electronics**. Since retiring from the Air Force, I've had plenty of time to tune through the bands. There are some really nice, sophisticated, store-bought receivers on the market, but I prefer to use surplus military gear.

My best receiver is a Hammarlund SP600, but my favorites are the ARC-5 (also called (SCR-274) Command sets, which get their share of monitoring the airways. I presently have a BC-454 (3–6 MHz) and a BC-455 (6–9 MHz) that, after a few new tubes and capacitors, work quite well. The dynamotors are a little bit noisy, but operating these old sets in their original configuration is part of the fun. My latest project has been an RAL-7 receiver (3–23 MHz) that was removed from a WW2 submarine. It is a TRF (tuned radio frequency) radio that requires patience in tuning. Once you get the hang of it, however, it's a very sensitive receiver.

All of my receivers are tube types that demand a wide range of voltages. I quickly tired of jerry-rigging the required voltage for each radio. I recently completed three power supplies that can proved 0–30 volts at 15 amps, 0–450 volts at 145 mA, and 0–95 volts at 280 mA. All have Variac's in the primaries to provide any voltage that I need.

I would like to contact other readers who are interested in surplus radios—particularly the ARC-5 system. If any readers have receivers, dynamotors, and tubes for sale or barter (I have some ARC-1 and ARC-3 components to trade), I'd like to hear from them. I also need operators/service manuals for the ARC-5/SCR-274 and RAL receveivers and the BC-221-P frequency meter.

Thanks, and keep up the good work!
John D. Broussard
312 Builbeau Street
Breaux Bridge, LA 70517

HAVES & NEEDS

Under the "Needs" portion of this heading: I am trying to find a circuit diagram and PC-board layout for a Superscope tape recorder model C-76, serial number U131989, built by Marantz. I really like this recorder because it has a built-in AC power supply. Thanks in advance to anyone who can help.

As for the "Haves" portion: I have a Heathkit VTVM Model IM-21 which I will be glad to send to anyone who will reimburse the packing and shipping charges. The manual is included.
Don F. Lehman
378 Fairway Drive
Columbus, OH 43214-1848 ■

GIZMO®

A CHRONICLE OF CONSUMER ELECTRONICS

APRIL 1993

VOLUME 6, NUMBER 4

Plug In, Turn On, Drive Out

THE NEW ELECTRIC CARS: A TEST DRIVE. Manufactured by the world's leading car automotive manufacturers. Prices: N/A.

This month, we're taking a slight departure from our normal coverage, where we provide a hands-on look at consumer-electronics equipment that you can buy today. None of the electric cars that we'll be looking at is available—at least not yet. But electric cars are coming—whether we like it or not. We'll give you an idea of what they might be like when they arrive for real.

Most automotive enthusiasts we've talked to are not happy with the idea of electric cars. How can a battery-powered car provide the deep rumble of a internal-combustion power plant? How can an electric car be refueled in five minutes to provide a 200-mile cruising range?

They're missing the point. For a rundown on the issues and the technology of electric cars, see the article "The EV Revolution Revs Up" elsewhere in this issue. For a hands-on test report, read on.

We got our opportunity to drive and ride in electric cars in late 1992 at the International Congress on Transportation Electronics. The biennial technical conference is co-sponsored by the Institute of Electrical and Electronic Engineers (IEEE) and the Society of Automotive Engineers (SAE).

A cold drizzle, occasionally mixed with sleet, was falling on the day that the press and other guests assembled at the Ford Motor Company Proving Grounds in Dearborn. Although the conditions forced the maximum speed limit to be posted at 35 miles per hour, the inclement weather was advantageous from a reviewer's point of view, for reasons that we'll discuss later.

There was a wide variety of cars at the demonstration. Some we got to drive; others we could only ride as passengers.

Still others we could only look at. We were surprised at the number of cars being shown. The nine cars and vans available for demonstration included models from Chrysler, Saturn, Ford, Geo, Nissan, Opel, Toyota, Volkswagen, and Chubu Electric Power Co.

We were surprised that so many of the electric cars were, for the most part, quite normal-looking. No electric cars are, after all, commercially available, and most reports we have read have made it clear that it will be some time before the bugs are worked out. Yet California, the world's largest automotive market, has spurred automakers into action by requiring that by 1998, ZEV's, or zero-emission vehicles, will have to make up 2 percent of the sales of any automaker who wants to continue doing business in the state. By 2003, 10

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This month in GIZMO®

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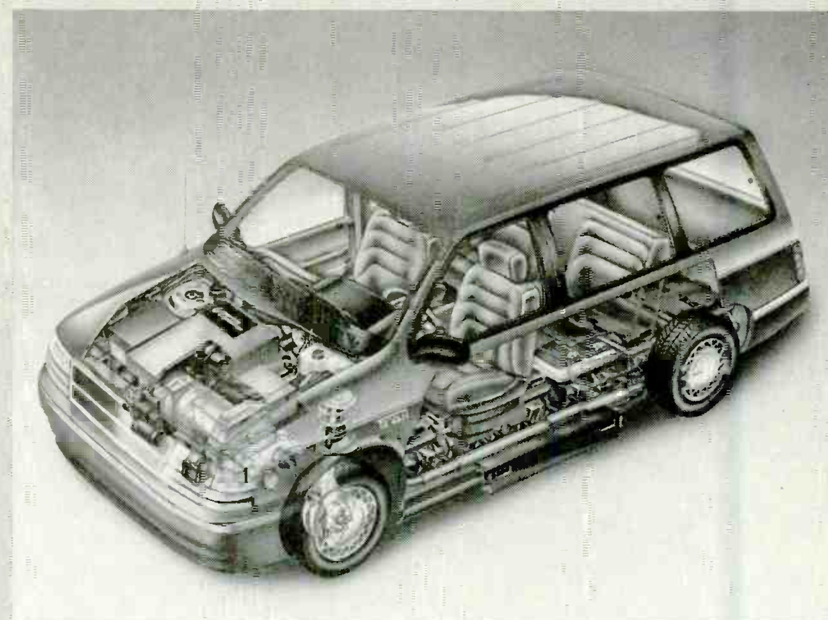


Chrysler's TEVan is a Plymouth Voyager that is retrofitted for electric operation. The batteries mount under the van's floorboards.

The Dream Mini, from Chubu Electric Power Co. of Japan, struck us as being more like a bicycle than a car. It will certainly get you from place to place, but not quickly or comfortably.

percent of the cars that automakers sell in California will have to be electric.

As we waited in a line of other journalists for our opportunity to ride in the cars, what first struck us was that they were disconcertingly quiet. They were so quiet as they pulled up to the tent under which we stood, that some people were heard suggesting that electric cars should have built-in noisemakers to enhance pedestrian safety—something like the annoying beep that trucks use to signal that they're in reverse gear. Let's hope not.

On the road—or on the track, in our case—the cars begin to sound more normal. Although there's no "vroom" from the motor, the road noise is sufficient to take away the eerie feeling of an absolutely quiet car. To be honest, it wasn't too exciting being a passenger. Since the cars were, for the most part, ordinary production cars that had been converted from gasoline to electric power, the test rides were pretty close to taking a ride in a taxi. The conversion was done more neatly in some cars than in others, but otherwise, things were very much like a gas-powered car. Replacing the gas gauges were panel meters showing the state of charge and the voltage and current being used by the car.

As we moved from car to car, a couple of things struck us. First, because it was a chilly day, we quickly noticed that none of the cars had any heat. We could understand why. The last thing that any manufacturer would want during a press demonstration would be for its car to run out of "gas." What bothered us a little more was that each car had a little towel inside to wipe the fog off the interior windows. We remember, as children, riding in the back seat of our parents' car on rainy days. Every once in a while we'd hear the command, "Wipe off the back window," as a rag got tossed into the back seat. We thought those days were gone forever, thanks to electric rear-window defrosters. Even our first car, which exemplified austerity, had a fan to defog the rear window.

Keep in mind that the regular-looking cars we tested were actually high-tech "chop-shop jobs"—standard cars that had been retrofitted with electric motors—and some compromises had to be made. The final versions of the electric vehicles will be streamlined for greater efficiency, will feature high-pressure tires for lower road

SPECIFICATIONS FOR ELECTRIC TEST VEHICLES

VEHICLE	DIMENSIONS (L × W × H) (inches)	WHEEL-BASE	DRAG COEFF.	CURB WEIGHT (lbs)	MAX. PAYLOAD (lbs)	MOTOR TYPE	HORSE-POWER	TRANS-MISSION	TOP SPEED (mph)	ACCEL. TIME	BATTERY TYPE	CHARGE TIME (hours)	BATTERY WEIGHT (lbs)	RANGE (miles)
TEVan Chrysler Corp.	176×72×68	112	N/A	5075	825	DC	35 cont 65 peak	Auto or Manual	65	0–60/25 sec.	180-Volt Nickel-Iron	6-8	1800	80
DREAM MINI Chubu Electric Power Co.	97×55×56	65	0.39	1142	242	Brushless DC (two)	8	None	48	0–38/10 sec	Sealed Ni-CD	8-10	398	72
SATURN Demi, APS, GM, Motorola, and others	179×69×51	101	0.3	2090	660	Advanced DC (two)	200	5-Speed	120	0–84/10 sec	Ni-CD or Zinc-Oxygen	8	1540	210
ECOSTAR Ford Motor Company	166×65×63	101	0.35	3100	850	3-phase AC induction	75	Single Speed Integrated	70 (governed)	0–50/12 sec	Lead-Acid or Sodium-Sulfur	4-5	800	100
STORM General Motors Corp.	N/A	N/A	N/A	N/A	N/A	AC induction (two)	114	None	75 (governed)	0–60/8 sec	Lead-Acid	6-8	870	70
NISSAN FEV Nissan Motor Co.	156×67×51	96	0.19	1980	N/A	3-phase AC induction (two)	54	N/A	78	0–66/10 sec	Ni-CD and Solar Cells	0.25*	440	150
ASTRA IMPULSE Opel AG	171×68×59	101	0.33	2057	880	AC induction	114	Fixed Reduction	72	0–54/10 sec	Lead-Acid	2-8	869	42
TOWN ACE VAN Toyota Motor Corp.	172×66×76	88	N/A	2860	330	3-phase AC Induction	50	4-Spd Manual	51	0–50/10 sec	Lead Acid	8	1474	96
JETTA CITY STROMER Volkswagen AG	173×64×56	98	0.37	2032	726	Shunt-wound DC	20	4-Spd Manual	63	0–30/10 sec	Sodium-Sulfur	14	607	90

* With super-charge system

resistance, and will incorporate other modifications to boost the juice from a battery-powered engine. The demonstration cars hadn't been designed from the ground up for efficiency; to compensate for reduced engine power, they were stripped of most of the "niceties"—heat, air-conditioning, and the like—that drivers consider necessities.

Once we got behind the wheel, the differences between electric cars and gas-powered ones became more apparent. In the cars we drove, the gear shift was replaced by a simpler version with three selections: forward, neutral, and reverse. In some cars, the gear selector was replaced by buttons. Also, when you turn the "ignition" key, it seems that nothing happens. That's because you're not starting the car, just turning it on.

When you step on the accelerator pedal, however, the car springs to life. Although the speed limit on the track was set at 35 miles per hour for safety (and wasn't enforced), we could definitely get a feeling for the cars' peppiness. All of the cars we drove could accelerate rapidly. Some of the ride-only models could not.

Some electric cars have only one forward gear, so you don't hear the engine revving and then slowing down as a gasoline-powered car does when it shifts gears. Other electric cars have more standard 4- or 5-speed transmissions—but because the motors are so quiet, the shifting noise isn't noticeable because the wind and road noise masks it.

So as not to waste any power, electric cars have regenerative braking systems. That is, the brakes turn the energy in the car's motion back into electricity to charge the batteries. In most of the cars, braking was accomplished with a standard brake pedal. In others, every time you took your foot off the accelerator, the car started braking. Although it was a little disconcerting, at first, to be able to stop the car with the accelerator, we got used to it—and began to like it—quickly.

In one car, we were able to adjust the regeneration with a potentiometer. At one extreme, taking your foot off the accelerator didn't cause any braking—the brake pedal was used for all braking. At the other extreme, the car would come to a rapid halt as soon as the accelerator was released. We liked having the option, but car manufactures will probably not give drivers the same choice. That's because they want to make electric cars as much like their gasoline-powered counterparts as possible. Manufactures feel that if the cars are to sell, consumers must feel completely comfortable with them.

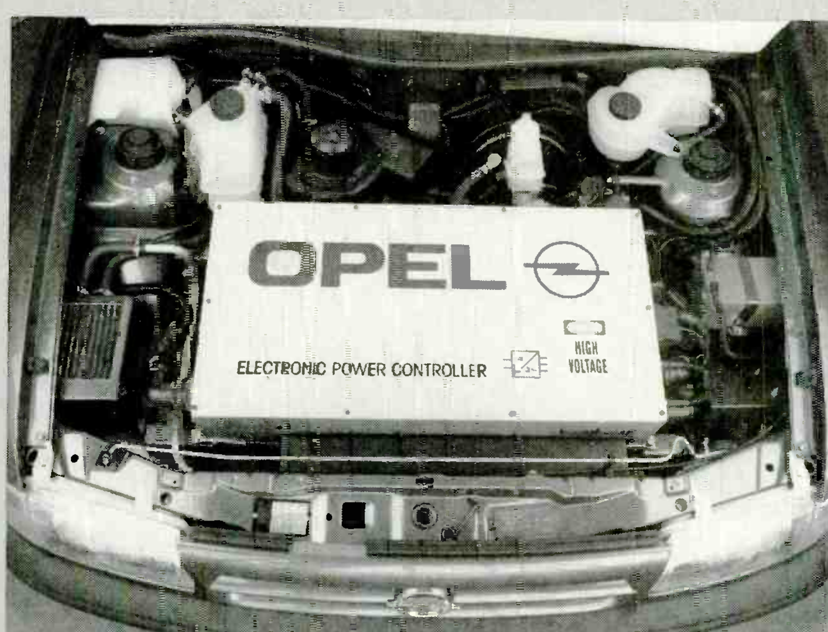
Another way that the cars we drove differed from "normal" is that, once stopped, they didn't move when the brake pedal was released. It would be a simple matter for a manufacture to build in a default creep (idle-in-gear) speed so that the cars will seem to behave just like gasoline-powered vehicles.

In terms of performance, the demonstration electric cars did behave like traditional vehicles, and we were quite impressed. They didn't strike us as being anything like golf carts—something that detractors of electric cars use as an example of why electric cars will never replace gas-powered vehicles.

The smallest car, however, *was* something like a golf cart. The Dream Mini, from the Chubu Electric Power Company of Japan, was designed to combine the "mobility of a motorcycle with the stability and comfort of a conventional four-wheel compact car." Well, the two-seater was anything but comfortable! Mini is an appropriate name—our knees were squashed tightly and uncomfortably in the car, the smallest one we have ever been in. It was also the loudest of the cars—both from the motors and from the road noise.

The largest of the cars was Chrysler's TEVan, which was basically a retrofitted Dodge Caravan/Plymouth Voyager, and just about as boring. The gasoline powertrain was replaced with an electric drive and a battery pack—nickel-iron bat-

We wouldn't like to get in a race with this Saturn, retrofitted by Demi, APS, GM, Motorola, and others. It can accelerate from zero to 84 miles per hour in ten seconds.



Under the hood of the Astra Impulse from Opel AG.

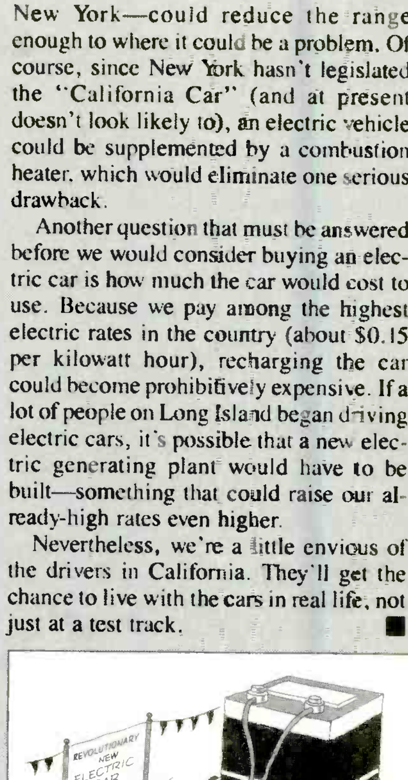
teries mounted under the floorboards.

The fastest car, without question, was a Saturn that was developed by a collaboration of the Arizona Public Service Company (APS), battery researchers Dreisbach Electromotive, Inc. (DEMI), Motorola, Saturn Corp., and Advanced DC Motors. The car, which has a top speed of 120 miles per hour, can accelerate from 0 to 84 mph in ten seconds—something that any auto enthusiast has to love. It was designed primarily as a test platform for DEMI's zinc-air batteries, but the car that we rode in was powered by nickel-cadmium batteries. The controller in the car was built by Motorola.

Will we be buying any of these cars anytime soon? Well, probably not. Even though we have a short commute, the addition of battery-powered equipment such as defrosters, windshield wipers, headlights, and heaters—all required equipment in New York—could reduce the range enough to where it could be a problem. Of course, since New York hasn't legislated the "California Car" (and at present doesn't look likely to), an electric vehicle could be supplemented by a combustion heater, which would eliminate one serious drawback.

Another question that must be answered before we would consider buying an electric car is how much the car would cost to use. Because we pay among the highest electric rates in the country (about $0.15 per kilowatt hour), recharging the car could become prohibitively expensive. If a lot of people on Long Island began driving electric cars, it's possible that a new electric generating plant would have to be built—something that could raise our already-high rates even higher.

Nevertheless, we're a little envious of the drivers in California. They'll get the chance to live with the cars in real life, not just at a test track. ■



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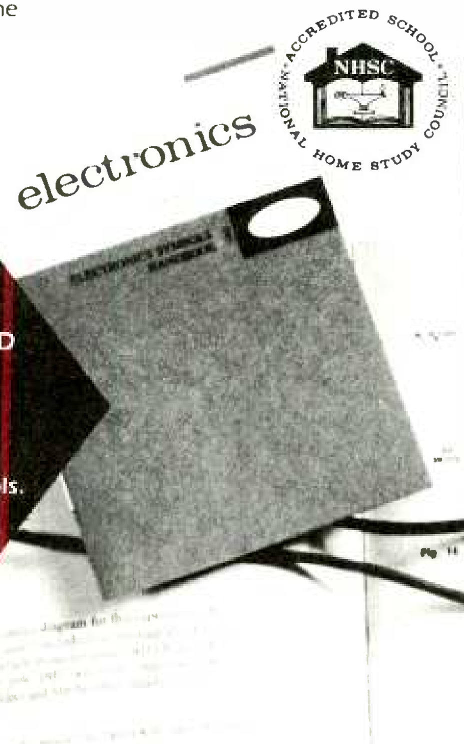

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Going by the Book

DIGITAL BOOK SYSTEM (DBS-1). Manufactured by Franklin Electronic Publishers, Inc., 122 Burrs Road, Mt. Holly, NJ 08060. Price: $199.95.

CIRCLE 51 ON FREE INFORMATION CARD

For as long as we can remember, technocrats, faced with new information technologies, have predicted the imminent demise of ink and paper. On-line services will replace daily newspapers as well as weekly and monthly magazines. Entire encyclopedia sets will be stored on a single CD-ROM disc. Computer-based notepads, as well as laptop computers, will take the place of a pencil and notebook. Multimedia learning experiences will enhance the educational process. Record-keeping will no longer require file cabinets full of paper, thanks to computer memory.

Well, we all know the fallacy of the latter prediction. In today's automated offices, the file cabinets are still there—holding reams of computer-generated documents. While on-line services, CD-ROM drives, and portable computers have made inroads among business people and computer enthusiasts, mainstream America still buys their daily papers and their favorite magazines (luckily for us!). Students—even those in schools that have adopted multimedia learning systems—still take notes on paper. Millions of book lovers still read for education and for pleasure. (We definitely fall into that category. We love bookstores and libraries, and we thoroughly enjoy the look and feel of a hefty hardcover.)

Most book lovers loathe the idea of replacing paper with electronics. That attitude is understandable, but somewhat backward in light of today's technologies. As confirmed Gizmologists as well as book lovers, we aren't willing to make such absolute judgments. The fact of the matter, according to the Association of American Publishers, is that 90% of all printed material already is in digital form—manuscripts are typed on PC's, edited on-screen, and layouts set on a page by computer. That digitization sets the stage for easy transfer to various digital media, not just printed books and magazines. And, while we doubt that we would ever want to read the latest bestseller on an electronic device, today's children, raised on videogames and television instead of the adventures of Nancy Drew or the Hardy Boys, might not develop the same emotional attachment to books.

We don't think that printed books face any immediate threat of extinction—at least not from any electronic device that we've seen. But the time is ripe for electronic information sources as a supplement to the written word.

Franklin Electronic Publishing would surely agree. Long a pioneer in the field of hand-held information devices, including pocket-sized dictionaries, encyclopedias, and bibles, Franklin's latest entry has the potential to replace all of those devices—as well as electronic organizers, language translators, financial planners, cookbooks, and travel guides—with a single pocket-sized device. The *Digital Book System (model DBS-1)*, or DBS, might be called an electronic reader or player. It has the ability to read a variety of digital books in the form of integrated-circuit ROM (IC-ROM) cards. The DBS holds two cards simultaneously, and allows instant communication between the two.

The Digital Book System, viewed from the front, looks like any other electronic information device. Measuring 5 × 3-1/4 × 1/2 inches, and weighing in at less than five ounces, about a third of the front face is used for its five-line display. The 40 × 160 continuous pixel supertwist display has graphics capability and shows various type styles and capabilities. Below the display are a row of function keys, a QWERTY-style keypad, and a gold-rimmed key that acts as a CTRL key.

The screen's contrast is controlled by a thumb wheel on the left side of the unit. That placement turned out to be a bit inconvenient. We managed to accidentally brush against the thumb wheel, turning the contrast way down and making us think the batteries had worn out!

It's when you turn the Digital Book System over that it gives a clue to its real self. Two shallow, rectangular compartments on the back of the unit each accept a digital book, or IC-ROM card. A contact strip that runs along the right side of each compartment accesses the data contained on each card. Installing the cards is no more difficult than removing the cover of the battery compartment (which is also on the back of the unit).

The function of the Digital Book System at any given time depends entirely upon which books are installed. The unit comes with two: the *Merriam Webster Dictionary Plus*, which contains spelling, definitions, and synonyms and *Word Games*, a collection of ten games ranging from the standard (Anagrams, Hangman) to the high-tech (Letris, a word-based spinoff of the videogame "Tetris"). It's possible to "communicate" between the two; for instance, you can highlight a word that appears in the game card, switch to the dictionary card, and that word will automatically appear, ready for you to look up its definition at the press of a button. However, not all digital books can receive words, and most of them can only handle one or two words at a time.

One function remains the same regardless of the books you have installed. The notepad function stores up to 60 lines of text, allowing you to type and edit your own notes. It's also possible to highlight information from a digital book and copy it directly to the notepad. The notepad has word-processor-type functions that allow you to define blocks of text and then move, delete, or copy them; insert lines; move up or down by the page; and erase characters. You can also "send" a word from the note-

pad to the dictionary to look up its meaning.

If you're a regular reader of this column, you're no stranger to "electronic" or "digital" books. We've covered Sony's Data Discman as well as a variety of CD-ROM volumes. Franklin's Digital Book System represents a whole new (and, of course, incompatible) species. CD-ROM's (and Data Discs) are "read" via a laser as the disc spins within the player. The Digital Book System is a solid-state unit that uses a memory card that Franklin calls IC-ROM.

There are several advantages to IC-ROM. First, the IC-ROM system requires no moving parts to read the data, making it cheaper to produce and less prone to breakdowns. The solid-state hardware also allows a much smaller, faster, and more reliable information-retrieval system. Finally, the IC-ROM-based DBS uses much less power than that required by portable CD-ROM players; it gets 60 hours of use from the four lithium (CR2032) batteries that are included.

The drawbacks are that less data can be stored on IC-ROM cards than on CD-ROM's, which hold roughly 700 megabytes, and Sony's data discs (about 200 megabytes). CD-ROM's and data discs—but not IC-ROM's—also provide digital audio and graphics for multimedia applications.

It's only in direct comparison to CD-ROM's or data discs that anyone would suggest that the IC-ROM cards were short on memory. In fact, each IC-ROM card holds 45 megabytes of memory, which is the approximate equivalent of ten printed Bibles. That's a significant amount of data in itself, and the Digital Book System holds two such cartridges simultaneously. For the uses that Franklin has in mind, the IC-ROM cards have more than sufficient memory.

As we go to press, three books are available on IC-ROM: the dictionary and word game books that are included with the DBS, and the *Video Companion*.

The *Merriam-Webster Dictionary Plus* provides 274,000 definitions, 496,000 synonyms, and spelling corrections for more than 83,000 words. You can type a word in the way it sounds ("frend," for instance) and the device will provide a list of correctly spelled options ("friend," "frond," "freed," etc.). Pressing the gold control key and T activates the thesaurus function, which in this book is actually a more detailed definition (or, according to the manual, "a general definition shared by a list of synonyms.") In this case, the dictionary definition of "friend" was "person one likes;" the thesaurus meaning was "a person with whom one is on good, and usually, familiar terms." Pressing the gold key and S calls up a list of synonyms, in this case "acquaintance, confidant, familiar, intimate, mate." You can highlight a word within the definition and look up its meaning by pressing the ENTER key or simultaneously pressing the gold key and D. You can also call up a list of homonyms by pressing the gold key and C—C for "confusable words," meaning they sound alike but don't mean the same thing, and the dictionary would call up a list of the homonyms and their respective meanings. As you move through various functions, the dictionary keeps track of your progress. You can backtrack through the steps you've taken using the BACK key. You can also press the LIST key to see a list of the last 26 words that you've looked up.

We have a few complaints about the dictionary. In the example used above ("friend") our dog-eared paperback version of *The Random House Dictionary* provided the following definitions: "1. a person attached to another by feelings of affection or personal regard; 2. a patron or

A First Edition Digital Book

The Video Companion Digital book, about the size of a matchbook, snaps easily into the back of the Digital Book system.

The *Video Companion* digital book ($59.95), the ideal thing to bring along to Blockbuster Video on a Saturday evening when all the new releases have long since been checked out. It provides information about almost 7000 movies that are available on video tape. You can scroll through an alphabetical list of all those movies, or can use several different search methods. The easiest is to enter the movie's title. The *Video Companion* then provides the release date, the length, the director, the cast, a list of keywords (which are the basis of another search method), a summary of the plot, and lists of other credits and any Academy Awards or nominations.

The other search methods are only slightly more difficult, and can be more fun. You can search by cast, director, keywords, other credits, country of origin, MPAA rating, academy award, year, and critic rating. If you're in the mood to look at, say, any film with Michelle Pfieffer in it, you can opt to search out films by cast members, and type in her name. (You'd better know that "Pfieffer" starts with a "P," however. Franklin's automatic spell corrector doesn't work with this digital book, so typing in "Fifer" won't cut it.) The *Video Companion* comes up with 14 matches for Pfieffer, Michelle, and that's where the fun part comes in. We knew she was in *The Fabulous Baker Boys* and *Frankie & Johnny*, but *Amazon Women On The Moon* was a surprise to us. From the title, we expected a B-movie from early in her career, but the synopsis informed us that it was a "series of twenty comedy sketches by five different directors, loosely linked by a running parody of 1950's sci-fi films. Our video store didn't carry it, however.

Keywords are words that denote the theme, location, genre, historical period, types of characters—in general, words that might be used to describe a film. The more than 1200 keywords include animals, religious groups, events, fictional and historical people, general settings, occupations, languages, and more. Yet, it can be difficult to find a movie using only keywords. For instance, in our search for *The Wizard of Oz*, we tried typing in wizard, tornado, munchkin, Toto, Dorothy, and Oz, with no luck. Typing in "witch" gave us a list of 49 films. Then, using the *Video Companion's* extensive cross-referencing abilities, we added another keyword—"Kansas"—which narrowed it down to just one listing: *The Wizard of Oz*.

It's also possible to search for films starring two or more actors—Katherine Hepburn and Spencer Tracy, for instance—or to go between search categories to find, for instance, films set in Africa and starring Humphrey Bogart. We came up with *African Queen* and *Casablanca* in our heads; the *Video Companion* also listed *Beat the Devil* and *Sahara*. We enjoyed trying to come up with strange combinations, such as films rated "G" that include cannibalism (*Hansel and Gretel* and *The Time Machine*).

The Video Companion can serve as the basis of various trivia games. In fact, you just might decide to stay home and play with the *Video Companion* digital book instead of renting a video! ■

supporter; 3. a person who is not hostile: 4. (*cap.*) a member of the Society of Friends: Quaker; 5. *make friends with* to become a friend to." It also listed three synonyms: acquaintance, companion, and comrade. The thesaurus that's built into our XyWrite word-processing program provided more than 40 synonyms, including pal, buddy, chum, cohort, colleague, companion, comrade, crony, and partner. It also bothered us that the dictionary didn't recognize some of the more obscure words used in the game card.

Other than those obscure words, our only complaint about *Word Games* is that we spent too much time playing them! Ten games are included. The familiar ones include anagrams, cryptoquotes, and jumbles. In "letter poker" you're dealt a hand of letters and make bets depending on how long a word you think you can spell, using the rules of draw poker (you can discard unwanted cards and receive new ones). In "Letris"—our favorite—you must guide falling letters into vertical or horizontal words without letting any stack reach the top of the screen. Each game offers various levels of difficulty—some allow you to change the length of the words, others the complexity of the word list, others, the speed of play. We found ourselves continually challenged by each game we tried.

Of course, not many people will buy the Digital Book System just to play word games. The third IC-ROM release, the *Video Companion*, is described in the box on page 14. Franklin is planning to release DBS books on cooking, nutrition, gardening, nursing, business, religion, and foreign languages. At least 17 titles should be available by the time you read this, and 50 should be released by the end of the year. Those include a personal organizer and *Fantasy Baseball*, which allows you to create your own super ball teams using real players throughout the entire history of the sport.

Franklin seems to be targeting the medical profession with many of their earliest planned Digital Book releases. For instance, *Medical Letter Handbook of Adverse Drug Interaction* ($99) provides interactions for up to 20 drugs at a time, and can instantly cross reference any medical term in *Stedman's Medical Dictionary*. Other upcoming medical titles include the Washington University *Manual of Therapeutics*, the *Physician's Desk Reference*, and McGraw-Hill's *Harrison's Principles of Internal Medicine*.

Other non-consumer applications are being considered by Franklin, which sees a market for digital books containing more specialized databases, such as compilations of technical and business related information. Such IC-ROM's could include part numbers or product codes used by large corporations, complete lists of car components along with troubleshooting and installation guidelines for auto dealers and mechanics, or the complete National Electrical Code for electricians. To encourage such applications, Franklin is encouraging such applications with OEM arrangements, liberal licensing policies, and DBS development kits.

For consumers, we see the most promise in travel applications. On a European trip, we'd like to pair a language translator digital book with a travelers guide. While on the plane, we could play word games or *Fantasy Baseball*, since extra IC-ROM cards can be stored in the included carrying case. For car trips, we'd like to see a card that provided maps and travel routes, and lists of such services as hotels, restaurants, and gas stations—and maybe a trivia game to keep passengers from getting bored.

The possibilities are endless. If Franklin can keep the card prices low and the selection high, the Digital Book System, with its speed, small size, ease of use, and two-book capability, looks to be winner. ■

"A paper clip . . . it's like a bent piece of wire"

Just Say Play

VCR VOICE VOICE-POWERED PROGRAMMER AND UNIVERSAL REMOTE. Manufactured by Voice Powered Technology, Inc., 19725 Sherman Way, Canoga Park, CA 91306; Tel: 800-788-0800. Price: $169.

Even confirmed Gizmologists must admit that, in some cases, low-tech works best. Case in point: The easiest, most efficient way to get a point across is to simply come out and say what you mean. Need a bit of sweetener in your coffee? Saying "please pass the sugar" should do the trick. By vocalizing a simple, reasonable question, request, or command, you can generally count on a positive response. Wouldn't it be nice if you could use that tried-and-true approach to control complex consumer-electronics gear?

That's the basic premise behind *Voice Powered Technology's VCR Voice*, a hand-held, voice-controlled remote for VCR timer programming, that also serves as a universal remote for TV's and cable boxes. The device, which features proprietary VoiceLogic hardware and software, can be programmed to recognize specific commands from as many as four different people, and to control two separate TV/VCR/cable-box setups. Once it's programmed, all you need to do to record a television show (*Cheers*, in this example) is simply tell the VCR Voice the channel, day, and start and stop times by saying "Four, Thursday, nine PM, nine-thirty PM." Make sure there's a tape in the VCR and that its power is off, and then leave the VCR Voice positioned within range. At the proper times, the remote sends signals to begin and end recording. It works even if you're watching another show at the time. There's no need to set the source, or switch the TV to channel 3 (or 4)—the device does that automatically. Even the most technologically inept folks should be able to handle that!

According to surveys quoted by Voice Powered Technology, there are an awful lot of technologically-impaired people out there—eight out of ten of whom haven't figured out how to program their VCR's in the standard manner. "Setting the controls to record a show at a different time—while they are asleep or away from home—is too difficult for most." That translates to a potential market of some 50-million Americans for a device that lets them use their voices to tell their VCR's who's boss.

Frankly, we think those figures are grossly inflated. (This country is in big trouble if they're accurate.) Granted, early VCR models fully deserved their user-unfriendly reputations, and manufacturers deserve full blame for incredibly poor design. But things have changed since then. Today's VCR's, with their on-screen programming menus and prompts, couldn't be much simpler to program. Most of the units that we've tested don't even require a glance at the user's manual. It's possible that many of the people surveyed are still using ten-year-old models, or that their first attempts at programming left them unwilling ever to try it again. But we firmly believe that anyone who can read should be able to set timer recordings on any VCR with on-screen programming. (In our own decidedly unscientific sampling of about 20 family members and friends, we found three who couldn't program a VCR. Two of those can't really be counted: One simply had never owned a VCR and the other has a defective VCR that is unable to recognize the stations assignments used by her cable box. The third person had tried it once, unsuccessfully, without consulting the manual, and never bothered to try it again.)

Even if the 50-million figure is overestimated, we are willing to concede that there are a lot of people out there who—be it through lack of confidence or lack of ability—have trouble programming their VCR's. Many more can't fathom the video-source connections (switch to channel 3, hit TV/VCR, etc.). Unfortunately, those same people are likely to also experience trouble programming the VCR Voice.

When you take the unit out of the box, the first thing you see is an instruction booklet called "Set-Up" that's subtitled "3 Simple Steps to Set Up Your New VCR Voice Programmer." Thumbing through it, we wondered why 42 pages were needed for explaining those "Easy as A-B-C" steps (training the programmer to respond to your voice, teaching it to replace your other remote controls, and verifying it learned the lessons in steps A and B). We also wondered why underneath Booklet 1 they needed to include Booklet 2 ("Using") and Booklet 3 ("Extra Help"). Actually, the Using guide is one accordion-pleated sheet with seven 3 × 8-inch pages. The 70-page Extra Help book (with a cartoon of Albert Einstein saying "It's relatively easy" on the cover) had us a bit worried, although we were fairly sure we could get by without consulting it. We were wrong.

We got off to a good start. It's very easy to teach the device to recognize your vocal commands. The top portion of the VCR Voice, which houses the microphone, a large display, and an infrared transmitter that wraps from the top of the unit to its rear, slopes forward. That configuration allows you to hold the VCR Voice directly in front of your face while speaking, and still be able to read the display and send commands to the VCR.

A button labeled TRAIN is pressed to begin the voice-training process. A list of words—the days of the weeks, numbers one through twelve, "o'clock" and "thirty," AM and PM, and basic VCR commands (play, stop, pause, etc.)—appear, one after another, on the display. That's your cue to hold down the RECORD side of the VCR/RECORD rocker switch that's situated just below the microphone, and clearly speak each word into the microphone. It's recommended that you do this in a quiet room, with no obtrusive background noises, to avoid confusing the device. At that point, the device is digitally recording your commands and storing them in memory. In daily use, it compares what it hears against what is in memory. Any extraneous sounds can, therefore, lead to problems.

The second step is to train the VCR Voice to act as a universal remote for your VCR, TV, and cable box (if applicable). A cover at the bottom end of the VCR Voice slides down to reveal the set-up buttons.

CIRCLE 52 ON FREE INFORMATION CARD

Four arrow keys, which are labeled REW, PLAY, FFWD, and PAUSE, call up and scroll through various options on the unit's display. The SET UP key initiates the process, and the STOP button is used to correct errors during setup.

Training is accomplished by setting the VCR Voice head-to-head with each original remote, beginning with the TV's. The SET UP key is pressed until "TV" appears in the display. Then, pressing the right arrow causes various television functions to be displayed. When it says "power" you must press the POWER (ON/OFF) key on your television's remote. As each cue appears in the display, you press the related button on the original remote. That process "teaches" the VCR Voice to operate the functions of your television; the same basic method is used for the VCR and cable-box remotes.

That sounds pretty straightforward. The problem occurs when your gear falls under the heading "Important Equipment Exceptions," where you are asked if you have a TV remote that allows you to select video inputs so you must press a button labeled video or TV/video to view a tape. If that's the case (as it was for us), you're instructed to "go directly to page 38 of Booklet 3 and follow steps 4–16 in the directions for TV Remotes with Separate Video and TV Inputs for Watching Tapes." Those directions were somewhat more complex.

Other special cases covered in Booklet 3 include TV and VCR remotes with separate ON and OFF buttons, combination TV/VCR units, VCR remotes with SEARCH buttons, Zenith VCR remotes, and cable boxes with an OFF button but no ON button. Another section in Booklet 3 covers special configurations of your video gear.

Finally, in step C, a "Quick-Check" process is used to confirm that the VCR Voice has proper control over your video equipment. In ten steps, you test to make sure that the device actually does power up your equipment, change channels, and alter the volume.

Once the basic programming is complete, you can customize the device for up to four users. Each person who intends to use the device must follow the vocal training in step A. Once that's done, you can program-in each user's name. The unit's clock and calendar have been preset at the factory. If, for some reason, the date and time are wrong, this is the time to set them correctly—a simple procedure. And if your TV or VCR have a button that you use frequently that isn't found on the VCR Voice (last channel recall or search, for instance), you can program its FEATURE button to activate that function.

Now, you're ready to use the thing! (Phew!)

On the programmed VCR Voice unit, the standard screen will show the user's name in the top left corner, the day and time in mid-screen, and the system number (1 or 2—remember, you can program the device to operate two complete video systems). To either side of the oval VCR/RECORD toggle button are VCR-ON and TV-ON buttons. Below those are channel and volume up and down toggle keys; pressing the center of the volume control mutes the sound. Below those are two buttons marked TRAIN and REVIEW. Rounding out the front controls is a STOP button situated on the cover that hides the setup controls.

To operate the VCR, after pressing the VCR ON key, you simply hold the unit about eight inches from your mouth, press down the VCR side of the VCR/RECORD button, and speak your command clearly: "Play." The command will appear on the VCR Voice's display, and, assuming there's a tape in the VCR, it will begin to play. To record a program that's on now, you press down the RECORD side, and say the channel number and the day. When the prompt "start time" appears, say "start" and recording will begin. To record a program that's on sometime in the future, you must also state the start and end times. The REVIEW button lets you confirm the program; the DELETE key (located in the hidden compartment with the setup keys) can be used to erase any erroneous programs.

Then make sure that the VCR is turned off and the VCR Voice programmer is placed so that it has an unobstructed view of the VCR. Because of the way its infrared panel wraps around from front to back, you can either leave it on top of the VCR so that it extends about two inches over the front edge, or you can set it on a coffee table facing the VCR. The taping symbol appears on the screen 24 hours before recording is to begin, and flashes a half hour before. Five minutes before record time, a minute-by-minute countdown is displayed and the remote periodically emits a beep. If you are watching another show when recording begins, the VCR Voice handles all the source switching automatically. Unless, of course, your set-up resembles ours.

In one of our test setups, source switching presented a problem because the TV had four source options: antenna, cable, VCR, and S-video. To get from the antenna to the video (VCR) inputs, it's necessary to press the source selector twice. The VCR Voice couldn't do that automatically, but we programmed its FEATURE button so that we could switch it ourselves, manually.

Our second video setup was more straightforward—a TV and VCR hooked together via their antenna jacks—so we anticipated no problems programming it, although we had noticed during the initial programming that the user's manual made frequent mention of special instructions for those who use a single universal remote to control several video devices. That's the case with our second set up, but those special instructions turned out to be simple: Make sure you press the TV button on the universal remote before you begin training the VCR Voice to control your TV. There's no need to re-record your voice commands for the second set up; you skip directly to step B. By now, we considered ourselves pros at this, and figured we'd have it done in no time. Sure enough, in less than ten minutes, all systems were go.

We quickly discovered a quirk, however. The VCR Voice worked fine when it came to switching from TV mode to VCR—we said "play" and the unit switched the TV to channel 3, the source to VCR, and began play back. It was when we said "stop" that the problem arose. The programmer stops the tape and immediately switches the source back to TV—but the TV is on channel 3, showing just snow. We'd prefer that it would either leave the VCR as the source or, if it must switch back to antenna, use some sort of channel-recall to switch back to the last channel watched on the TV.

All those set-up difficulties aside, the VCR Voice does work as promised, with one major provision. The user's guide tells

(Continued on page 21)

Honey, I Shrunk the Camcorder

VM-H39A Hi-8 CAMCORDER. Manufactured by Hitachi Home Electronics, 3890 Steve Reynolds Blvd., Norcross, GA 30093. Price: $1799.95

When we first saw *Hitachi's VM-H39A*, it was not only the world's smallest and lightest Hi-8 camcorder, but the world's lightest camcorder of any format. By the time you read this, that might not be true any longer—manufacturers are continually shaving a fraction of an ounce or a fraction of an inch off their units. A year ago, Gizmo devoted an issue to "small wonders." Back then, the world's smallest and lightest high-band camcorder was more than 4 ounces heavier.

Hitachi's latest entry is, indeed, remarkably small. It measures approximately 3¼×4×9½ inches. Although it's considerably fatter, it's about the length and width of a VHS tape. That's small enough to fit in the pocket of a winter coat. Its weight of 1.3 pounds is light enough not to be much of a bother.

Back in the days when full-size camcorders were the rage, it was common to point out that there was a certain advantage to a camcorder's heft—the inertia of a heavy unit helped the user hold it steady. Although that's true, you don't find many people pointing it out any longer—especially not in Gizmo. Small, light camcorders like the VM-H39A are so convenient that they're much more likely to get used. Since no one wants to lug around big full-size VHS camcorders, they're more likely to remain home in the closet.

It's also true that small, light camcorders are difficult to hold steady. Especially at maximum zoom, where every movement is magnified, the natural shaking of the user's hand can become quite distracting. That's why electronic image stabilization, or EIS, has become so important.

Hitachi's EIS system compensates for motion electronically at the expense of resolution. In the EIS mode, only a portion of the CCD image sensor—the device that converts what it "sees" into electrical signals that are recorded on tape—is used to generate the image that is recorded on tape. The "unused" portion of the image sensor serves as a safety buffer. If your hand shakes—and thus causes the image to fall on a different portion of the CCD—the camera looks at the shifted image rather than on the CCD's center.

The very slight, usually imperceptible, decrease in resolution is a small price to pay for Hitachi's EIS system, which has the advantage of adding very little weight to the camcorder. It is also far more rugged than stabilization systems that mechanically compensate for movement. The EIS is especially important with Hitachi's latest camcorder because of the high zoom ratio it provides: With magnification of 64×, every movement is greatly exaggerated.

The VM-H39A is comfortable to hold, although it is not as well balanced as other camcorders we have used. The right hand slips though an adjustable strap and around the side-mounted battery; the index and middle fingers reach the zoom rocker switch, while the thumb controls the record/pause button. The only other controls on the right-hand side of the unit are two small slide switches. One turns on the microphone's wind filter, and the other allows you to record in a standard 8mm mode with a high-band tape. (In the Auto mode, the camcorder automatically detects the tape in use and records in the appropriate mode.)

On the left-hand side of the camcorder are seven controls: six pushbuttons and a focusing wheel. Each button is subtly different, either in its texture, shape, or the shape of the surrounding indentation, so it is possible to find the right control without taking your eyes off what you're doing.

The EIS button activates the camcorder's electronic image stabilization. A small shaking-hand icon is displayed in the viewfinder whenever that mode is selected. EIS worked very well for many situations: recording while walking, or shooting from a moving car, for example. It's not to be used all the time, though; the camcorder will try to compensate for intentional motions, too.

The ZOOM MODE button lets you select one of three modes offered. When powered up, the camcorder is, by default, in Mode 1, in which the zoom can be increased optically up to ×8. Continuously pressing the power-zoom rocker switch will enlarge the image digitally up to a ×16. The viewfinder lets you know that you're zooming digitally by showing the zoom ratio (×8, ×9, and so on) in the viewfinder.

Press the ZOOM MODE BUTTON and you enter Zoom Mode 2, in which the digital zoom can be advanced to 64×. This feature is somewhat of a gimmick. When the digital zoom is pushed that far forward, the picture resolution is decreased significantly, and starts to take on a mosaic look. Hitachi, knowing this, doesn't put much emphasis on the feature. In fact, the labeling on the side of the camcorder states "×16 Digital Zoom." The manual hints that the extreme zoom is for "special effects."

A second press of the ZOOM MODE button puts you in a 16×9 version of zoom Mode 2. That lets you shoot videos that can be played back on the wide-screen TV's that are just becoming available. They can also be played back on our 4×3 TV's of today, although the picture's proportions will be distorted.

A D. FILTER button scrolls through three special-effect modes. The first lets the camcorder shoot in black-and-white. If that doesn't give the old-time look you're after, you can switch to Sepia Mode, which records video with a reddish-brown tint, much like early photographs. A Sunset Mode emphasizes reds, giving even mundane sunsets a spectacular look.

Three fade-in and fade-out modes are provided. The first fades to or from white. The second provides a wipe to black—two curtains of black wipe from the top and bottom toward the center of the picture. A Zoom Fade mode zooms in as the picture fades to white.

To correct the exposure when your subject is standing in front of a strong light, a B. LIGHT button must be held down. We found it to be a little inconvenient, and would prefer to have the compensation be alternately turned on and off with successive pushes. We also found that the results that we saw in the viewfinder didn't accurately reflect what we recorded, where the compensation was more pronounced.

Otherwise, we liked the viewfinder, which is a color LCD panel. As you might expect, the color LCD viewfinder cannot provide the resolution of a black-and-white viewfinder, but it is easier to use while shooting low-contrast scenes where the color information can be vital.

On the rear panel of the VM-H39A—where the battery mounts in most traditional camcorders—are the rest of the operating controls. They include the power and cassette-eject switches, and standard VCR-type operating controls for playback. A DATE button brings the date, time, or both up on the screen for recording. (A lithium battery backs up the clock and calendar. The date and time are adjusted with the unit's VCR controls.) Various information, including a linear time counter, can be brought up in the viewfinder with a touch of the DISPLAY button. A second push turns the counter memory on, so that you can quickly return to your starting point.

Two title pages, each one with up to two 16-character lines, can be stored in the camcorder memory, which is also backed up by the lithium battery.

Unless you have an 8mm VCR, you'll have to connect your VCR to your TV to watch your videos. When playing back your recordings, you'll most likely use the VM-H39A's tiny remote control. The remote can also control the recording functions of the camcorder.

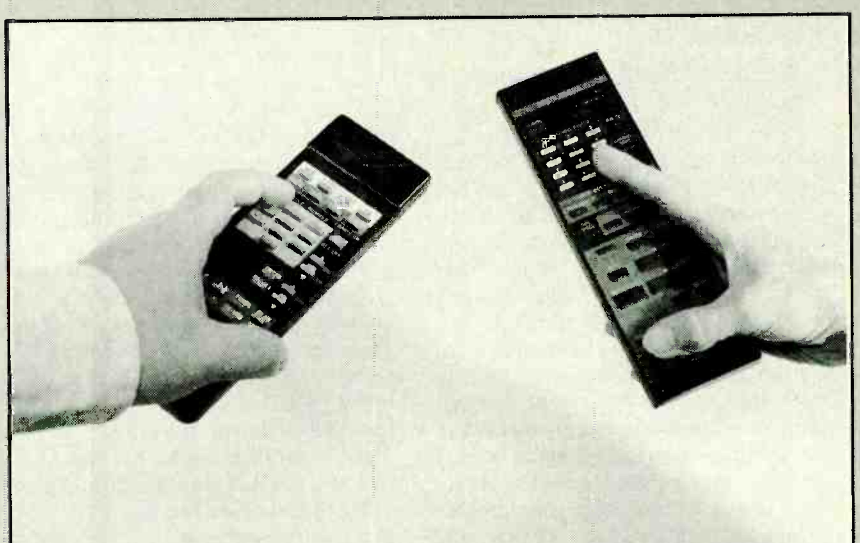
Although the VM-H39A boasts a light sensitivity of 2 lux, a hot shoe for attaching a video light is featured. Our evaluation sample did not include the light.

Considering that Hitachi's VM-H39A claims to be the lightest and smallest camcorder, surprisingly few compromises were made to this high-band unit. Manual exposure control might be present in a larger camera, as would such frills as more wipe patterns. The placement of the battery, under the hand strap, might cause problems for small hands if a higher-capacity battery is used. Neither represents a big trade-off for such a small package.

The 8mm format is the format of choice for home videographers. With equipment like the VM-H39A, it's no wonder. ■

Dueling Clickers

DUAL-REMOTE STEREO COLOR TELEVISION MODEL 4193-27A. Manufactured by Gotcha Video Products, Inc., 4/1 April Way, Happy Valley, CA 94111. Price: $999.99.



CIRCLE 4/1 ON FREE INFORMATION CARD

The age of remote-controlled home-entertainment equipment has one unfortunate offspring: the Remote-Hog. You know the type. Just about every family has one, unfortunately. Not content to consult the TV listings, he flips endlessly through the channels, never pausing when someone else in the room suggests "That looks interesting." Not content to mute the volume during commercials, he flips stations until some program catches his eye, and then doesn't switch back in time to catch the original program being watched.

If you live with such a person—or recognize yourself in the description—*Gotcha Video Products Model 4193-27A Dual-Remote Color Television* could change the way your family views TV. It might even—by arming a previously powerless viewer—totally change what psychologists refer to as "the dynamics of the family."

The 27-inch set (a 31-inch model is also available) provides all of the features you'd expect on a mid-range TV of the 1990's. Those include a fashionably-flat "Smooth Plane" picture tube, and Gotcha's patent-pending "Embellished Bass Booster" (EBB) and "Super-Pigment-Enhanced Coloration System" (SPECS) technologies. Audio and video parameters and functions, including bass, treble, color, tint, contrast, volume, channel, and mute, are adjusted using on-screen menus—accessed via the *two* remote controls that come with the set.

Those dual remotes are an attention getter, but anyone can buy a universal remote to supplement the one that came with a standard TV. What makes the Model 4193-27A truly unique is the circuitry that enables the set to interpret, display, and keep track of the commands from each remote. The set doesn't simply let two viewers battle it out with individual remotes. The on-screen menus change color, from standard white to either blue or hot pink, depending upon which remote's command is being acted upon. That allows viewers to see at a glance who is doing what with their respective remote controls. The remotes themselves also are color-coded blue and pink (perhaps Gotcha Video is anticipating a battle of the sexes played out on the video field).

But that's not the end of it. A proprietary microprocessor chip keeps score of the remote action. "Players" are scored on two factors: speed and duration. You get points for being the first to get a command across. But you also score when your command is allowed to remain for a user-specified period of time. For instance, in a battle over a movie on Channel 11 and a football game on Channel 7, Player A might score two points for selecting Channel 11 first. Then Player B comes and switches to the game. The action goes back and forth between the two channels until Player A throws down his clicker in disgust. Player B, whose football game remains on screen for the next two and a half hours, emerges the clear winner.

You can also score points with the picture-in-picture (PIP) function, which provides four different PIP sizes. The larger the insert picture, and the closer it is to the middle of the main picture, the more points you earn.

Truly competitive types will enjoy the on-screen score-keeping feature. It's possible to get an on-screen tally of the remote-control scores for the past hour, day, week, or month. Various types of charts let you see at a glance who's ahead now, and how each player's performance has changed over time.

In our tests of the dual-remote TV, we allowed two married couples and a pair of pre-teen brothers to try it for ten days. Both couples started out with the wives complaining that their husbands monopolized the clicker, and never let them view their programs of choice. At the end of the ten days, the situation had dramatically changed for both couples, but in entirely different ways.

In the first case, it took only one evening for the husband to get a first-hand taste of being subjected to selfish clicker control. Over the next several days, the two of them battled it out, managing to reach a stalemate by the end of a week. At the end of the trial period, faced once again with a single remote, the first couple reports that they share control of it, and do significantly less channel flipping than in the past. Now, they report, that he learned what it was like to be subjected to his type of clicker control, he immediately changed his selfish ways.

The second couple quickly discovered a streak of competitiveness of which they were previously unaware. It took the wife a couple of days to get the hang of using the remote (her husband, after all, had the advantage of years of practice). Once she caught on, they found themselves evenly matched, and have been enjoying their clicker duels even more than just watching television shows. They plan to buy themselves a dual-remote TV for their next anniversary.

The boys' test was less successful, with each evening's viewing ending in a wrestling match in less than a half hour. Their parents were forced to step in and ended all television privileges on the third day of the trial. It would appear that a certain level of maturity is a prerequisite to using the dual-remote TV.

Gotcha Video is planning to market a series of games on digitally encoded videotape, including word games, trivia contests, and the like. The games can be downloaded into the TV's memory using any VHS VCR. The color-coded remotes will serve as game controllers.

Already available are additional, color-coded (yellow and green) remotes. Up to four can be used with each Model 4193-27A television. Perhaps the extra ones could be used when friends came over for dinner and a game. We certainly wouldn't recommend arming the kids with them, however! ■

VCR REMOTE

(Continued from page 8)

you to mute the volume before using vocal commands to change channels, and that advice should be applied to all spoken commands. The VCR Voice often experiences trouble hearing you if any background noise is present. That includes music, conversation, and television programming. It's a natural reaction to shout at it, or move the microphone closer to your mouth, but that won't work. The best response is elicited by exactly replicating the conditions present when you trained the device to recognize your voice—holding it eight inches from your mouth, speaking in a normal tone of voice, and making sure there's no distracting background noise.

The VCR Voice has a few features that we particularly enjoyed. Our favorite is the commercial zapper. By saying "Zap it!" during playback, the VCR Voice programmer commands the VCR to fast forward through 60 seconds of tape, allowing you to skip past one long or two short commercials. And, while most TV functions are controlled using buttons, it's possible to change the channel verbally. Pressing the center of the CHANNEL switch causes the screen to prompt you to say the channel number. Saying the number causes the channel to change. Finally, we liked the unit's LCD readout, which verifies the function you've selected, and conveniently provides the day and time for those of us who can't see across the room to the VCR's front-panel display.

Unfortunately, for a device aimed at technophobes, the VCR Voice is quite difficult to set up initially—certainly incredibly more difficult than programming the timer on a VCR. The difficulties that we experienced would reduce a true technophobe to tears, at the least. (And that's assuming that they don't accidentally hit a wrong button, as we did during the initial programming routine, which caused the entire device to lock up. We had to reset the unit and start from scratch, including recording the voice commands.) We'd imagine that the VCR Voice will get the most use in homes occupied by at least one technically adept person and one or more folks who have trouble with electronics. In fact, all of the illustrations in the manual show "Dad" programming the device while Mom and the kids cheer him on. Once the initial programming is complete, anyone should be able to train the device to recognize their voice, and then to use spoken commands to program the VCR for timer recordings. ■

ELECTRONICS WISH LIST

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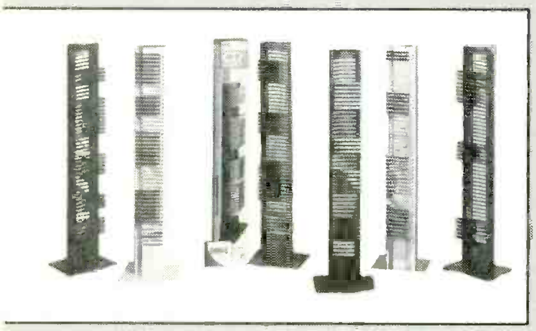
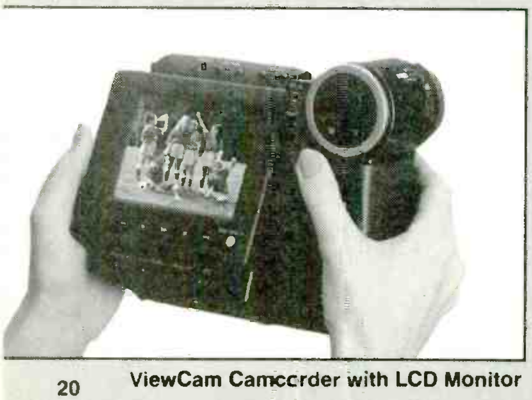


CD Storage Rack

CD Skyscraper

The *CD Storage Tower* from *Bib America* (10497 Centennial Road, Littleton, CO 80127) can be used either with its detachable base as a floor-standing model, or without the base for wall mounting. Each CD Storage Tower holds 50 CD's, and two units can be fitted back-to-back to expand the storage capacity to 100 discs. The storage slots allow the titles to be easily viewed and the discs to be quickly removed. The towers are available in matte black, white, silver-gray, blue, and red. And, as if that's not enough, a free "Chronicles Anthology" series CD from Polygram Records, containing songs by the Allman Brothers, Roy Buchanan, John Mayall, and Rod Stewart, is included. Price: $99.95.

CIRCLE 55 ON FREE INFORMATION CARD



ViewCam Camcorder with LCD Monitor

Picture-Window Camcorder

Instead of squinting through a conventional viewfinder, videographers equipped with *Sharp Electronics Corporation's* (Sharp Plaza, Mahwah, NJ 07430-2135) Hi8 *VL-HL100U ViewCam* can watch the action on a built-in, four-inch, color LCD monitor. The anti-glare LCD panel makes viewing possible even outdoors on sunny days. Playback can be done on the spot, with no need to hook up to an external monitor. The LCD panel can rotate 180° vertically for easy high- and low-angle shots. A remote control provides even more versatility. An electronic image-stabilization system compensates for the slight hand movements that naturally occur while recording with a palm-sized camcorder. The ViewCam also uses a digital memory to take digital still snapshots at intervals of five seconds. Those photos can be edited together with the camcorders strobe function for special effects. Other features include hi-fi stereo sound recording, 8× zoom, index search, auto-focus, auto-color adjustment, and neuro-auto iris. Price: N/A.

CIRCLE 56 ON FREE INFORMATION CARD

A Hands-on Electronics REPORT

CIRCLE 120 ON FREE INFORMATION CARD

Xantech Fone Link Remote Control

Control your home-entertainment system from outdoors or through walls with the Fone Link cordless-telephone programmable interface.

Every so often, a new gadget appears on the market that is worthy of a Hands-On Report solely because of its uniqueness. It doesn't have to use any new or unusual technology, but it does have to do something new and different using common techniques. The Model 710 Fone Link Cordless Telephone Programmable Interface, from the Video Link division of the Xantech Corporation (12950 Bradley Avenue, Sylmar, CA 91342; Tel. 818-362-0353) is just such a device.

The Fone Link, which lists for $199, turns your cordless telephone into a remote control. To illustrate, suppose you are listening to your home stereo from in your backyard. Intense sunlight would prevent you from using your stereo's infrared (IR) remote outdoors, even if you have a clear line-of-sight view of the stereo equipment. And normally you wouldn't have a clear view of your stereo anyway—there's usually at least one wall between you and the stereo. Because cordless phones use RF frequencies, which do not require a line-of-sight between the remote and appliance, the Fone Link lets you adjust volume, change radio stations, change CD's, etc., from wherever you like. The Fone Link also lets you start, stop, and record on a VCR while watching a TV in another room.

The Fone Link plugs into your telephone line and your cordless phone plugs into the Fone Link. Inside the Fone Link is microprocessor-controlled circuitry that can learn the commands issued from your IR remotes. The front panel of the Fone Link contains an IR emitter array that outputs the commands learned from your remotes. Up to 11 functions can be learned, and the Fone Link also incorporates some interesting features that will eliminate problems caused by certain cordless phones and certain remotes. Let's now take a closer look at the Fone Link.

Using the Fone Link. The front panel of the Fone Link contains five LED indicators, three IR emitters, and an IR receiver. On the back panel is a "stretch" control (which we'll talk about later), a power input jack, an output jack, three pushbuttons, and two telephone jacks.

Setting up the Fone Link is very easy. However, the IR emitters on the front panel of the Fone Link must face the device that you wish to control. If that's not convenient, there is an output jack on the back of the Fone Link for an optional external infrared emitter. The external emitter can then be mounted on the front panel of the device you wish to control, letting you place the Fone Link wherever you like. External emitters might also be necessary if you wish to control more than one device, especially if the devices are not close together.

Next you hook up the included AC adapter and plug the Fone Link into your phone jack and your cordless phone into the Fone Link. That done, the Fone Link is ready for use. Now when you press the off-hook (or talk) button on your phone, the phone is first set up as a remote control. To test your phone to see if it's still working as a phone, you must press the asterisk (*) button after taking the phone off-hook (after pressing the talk button); you should then hear a dial tone and the phone should work normally. To disable remote-control operation, you simply press the asterisk button again. When you are done using the remote, you put the phone back on-hook (press the talk button again).

We found that programming the Fone Link is very simple. First you press a reset button on the back of the unit to clear any codes that might be stored in memory. Next you press the program button on the back of the unit, and a "program" LED on the front

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panel lights up. When you press the button on your phone that you want to use to control a specific function, a "learning" LED on the Fone Link lights up. While pointing your remote control at the Fone Link's front panel, you press and hold down the button on the remote that you want the Fone Link to learn. Doing that causes the Program LED to flash. Once the Fone Link learns the command, the Learning LED turns off. Additional commands are learned in the same fashion, and when learning is complete, you push the program button again and the program LED turns off. If any problems occur during programming, an "error" LED lights up to alert you to that fact.

Now when you push the talk button on your phone, the number buttons correspond to the commands that you programmed them for. While the commands are being sent, an "output" LED flashes on the front panel. To use the phone to call someone, you simply press the asterisk button to get a dial tone. If someone calls you while the phone/remote is idle, it rings normally and you must press the talk button and then the asterisk button to answer. If someone calls you while you are using the phone as a remote, you will hear it ring from the ear piece instead, and you must go back on-hook, then off-hook again, and then press the asterisk button to answer. It's actually much simpler than it sounds. Stickers included with the Fone Link can be placed on your phone's handset to indicate which functions are assigned to which buttons.

One limitation of the Fone Link is that you can only have as many programmed functions as there are keys on a standard handset. Since you can program each of your phone's buttons except, of course, the asterisk, you can program 11 functions in all. That means a little advance planning can save some headaches later. For instance, if you programmed all of your receiver's station presets, you'd probably use up most of the telephone buttons. Instead, it would be better to program your receiver's station-preset scan (if it has one), leaving more buttons for other commands. Also, the power button on any particular piece of equipment is not especially important to program—you can always turn off the power when you go inside. Try to keep those sort of things in mind when programming the Fone Link.

A delete button on the back of the Fone Link lets you remove or replace single functions. To remove all programming, you must press the reset button.

Special Features. As mentioned before, the Fone Link has some special features that will eliminate problems cased by certain cordless phones and certain remotes. For example, while most cordless phones will emit a DTMF tone for as long as the button is held down, some phones will emit only a brief tone no matter how long the button is held down. That would be very inconvenient if the button were being used to adjust volume, because you would have to press the button several times to significantly raise or lower it. That was the case with the Sony cordless phone we used to test the Fone Link.

For that reason, the Fone Link incorporates a "3/6 stretch" feature. What that does is output the commands programmed on the phone's 3 and 6 buttons for an extended or stretched length of time. Although the 3 and 6 buttons can be used for any function, it's best if you program them for volume-up and -down. There is a potentiometer on the back of the Fone Link that adjusts the length of the 3/6 stretched tones to cause a smaller or larger change in volume for each press of the 3 or 6 button.

The Fone Link has 64K of ROM; that leaves almost 6K for memorizing each of the 11 functions. (We remember when home computers had less memory than that!) However, some remotes will output a code that requires more than 6K. In that case, the Error LED will flash after you try to program the code. All you have to do in that case is repeat the programming procedure for the same phone button. On the second pass, the Fone Link provides four times the memory for that function. Generally, if one button on a remote needs the extended memory, it is very likely that the others will, too.

Wrapping it Up. During our testing the Fone Link worked without any problems, and the instruction manual was clearly written and easy to understand—which is something of a rarity these days. Included with it is everything you need to use it, such as a modular cord, AC adapter, and stickers for labeling your phone. Of course, the unit does not come with a cordless phone—you have to provide that.

We actually had a need for the Fone Link while we were writing its review. You see, there was this special on TV that included several different segments, one of which we wanted to record. The only VCR was downstairs, but we were upstairs writing the review where there was only a TV to monitor the show for the anticipated segment. So we set up the Fone Link downstairs with the VCR's "record" function memorized. When the segment we were interested in came on, we were able to start the VCR recording from a cordless phone upstairs.

For more information on the Fone Link you can contact the company directly (using the address or telephone number presented at the beginning of this article), or circle No. 120 on the Free Information card. ■

PRODUCT TEST REPORTS

By Len Feldman

Pioneer Elite PD-75 Compact Disc Player

As CD players get better and better, manufacturers scramble to discover additional design features and convenience features that will "separate them from the pack." Perhaps the most interesting and innovative feature of this top-of-the-line unit from Pioneer (2265 E. 220th St., Long

The Pioneer Elite PD-75 CD player.

Beach, CA 90810), is what they call their "Stable Platter Mechanism." In most CD players, once the disc tray closes, the disc itself is supported only at its center. Pioneer claims, with some justification, that this mode of disc suspension can cause subtle sonic imperfections because of external vibration and jitter. That can result in sufficient misreading of data to cause data interpolation, as opposed to accurate data reading, or even accurate error correction.

Pioneer's solution to that problem is astonishingly simple: Mount the laser pickup assembly above the spinning disc rather than underneath, as in most players, so that the entire disc can be supported by a platter whose diameter is equal to that of the disc itself. Of course, that arrangement requires that discs be inserted in the disc tray with the label side down and that takes some getting used to. If you inadvertently mount the disc with label side up (as we did when first attempting to use this unit), no harm will be done—the player will simply reject the disc.

Vibration is further eliminated by the use of a low-vibration, linear, motor and by the use of a rigid, multi-layered honeycomb chassis consisting of a steel chassis with excellent shielding and a special plastic honeycomb base. Other design features include Pioneer's 1-bit direct linear-conversion system (which strives to eliminate so-called "zero cross" and low-level distortion), balanced outputs, a discrete push-pull power supply, and shielded printed-circuit boards.

As for user-convenience features, they abound as well. You can access any given track directly, or search for a particular track in either direction. Audible manual search is also possible, as is index search for those discs that have been supplied with index numbers within a given track. Playback can also be started from a desired elapsed time on the disc. Up to 24 different tracks of a CD can be programmed to play in any desired order, and if the disc is left in the player, program contents will be stored for about 3 days, even if power is turned off. You can even program the CD player to pause between selections; a useful feature when recording selections from a CD onto tape. Repeat play and random play can also be selected.

CONTROLS

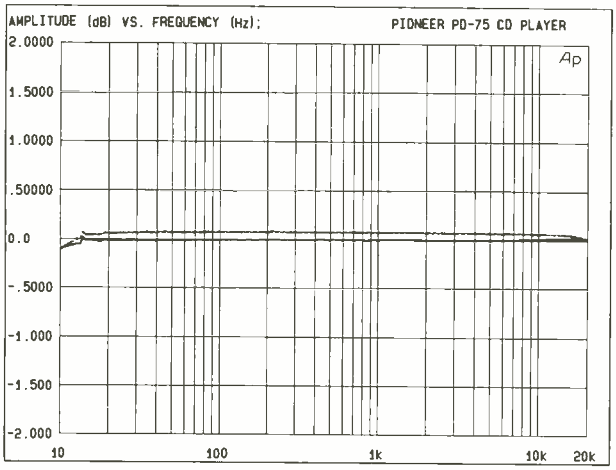
Since many of the more sophisticated control functions of the PD-75 are accessed via its supplied remote control, the front-panel layout of the unit remains relatively simple and uncluttered. The power switch is located at the lower left of the panel, and nearby are a display on/off switch and an output selector that chooses either analog or digital outputs. The massive, solid, disc tray occupies the center section of the panel, and above it is a display area. Various time displays that can be brought up on this display (in addition to the track number and index number) include elapsed time of the current track, remaining time of the current track, total remaining time for the disc, and total playing time of the disc. During programmed playback, the remaining time of the programmed tracks can be displayed, as well as the number of programmed tracks and their total playing time.

To the right of the display area and the disc drawer are the stop and track search buttons, and below them, the open/close tray, play, and pause buttons,

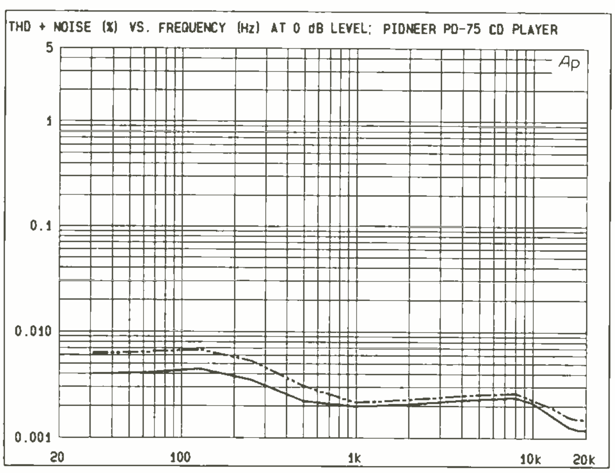
TEST RESULTS—PIONEER ELITE PD-75 CD PLAYER

Specification	Manufacturer's Claim	PE Measured
Frequency Response	2 Hz to 20 kHz	Confirmed
S/N ratio	112 dB	115 dB
EIAJ dynamic range	98 dB	99.8 dB
Channel separation	108 dB	128 dB @ 1 kHz
Harmonic distortion	0.0018%	0.0014%
Output Voltage	2.0 volts	Confirmed
Max. program steps	24	Confirmed
Dimensions (WxHxD)	18 1/16 × 5 1/8 × 13 inches	Confirmed
Power requirements	120V 60 Hz, 30 W	28 watts
Weight	26 lbs. 7 oz. (12 kg)	Confirmed

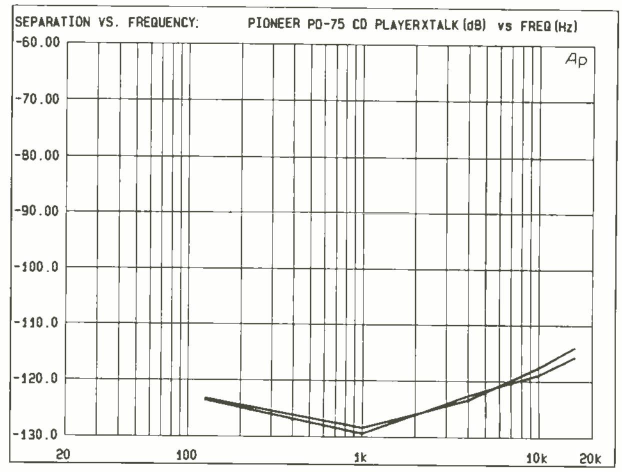
Suggested retail price: $1200.00.



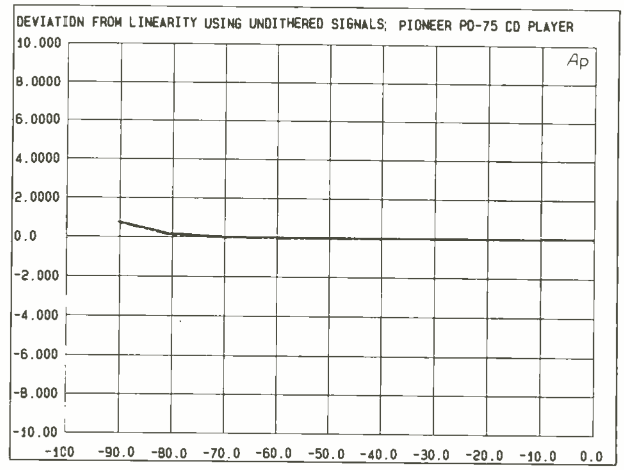
The frequency response of the PD-75 was virtually flat from well below 20 Hz to 20 kHz. Further, there was no evidence of ripple in the response at the treble end of the spectrum—a condition often found in less-expensive CD players.



Unlike many CD players, which exhibit a rise in noise and distortion at high frequencies, this unit showed a reduced level of harmonic distortion at the treble end of the spectrum.



Separation between channels was excellent, measuring nearly 130 dB for mid-frequencies and remaining well above 110 dB even at 16 kHz, the highest test frequency used.



Even at the extremely low level of −90 dB, linearity was within 0.5 dB of perfect.

the last two of which are equipped with indicator lights. The remote control, in addition to duplicating the controls found on the front panel, is equipped with track number buttons (1–10, +10, and >20), index buttons, manual search buttons, a program button, the random play and repeat buttons, a time button (for calling up the different time displays already described), and a clear button that is used to erase all or portions of memorized programming.

The rear panel of the PD-75 incorporates a pair of analog outputs as well as optical and coaxial digital outputs and balanced XLR connectors. If you own a Pioneer cassette deck, a CD-deck synchro jack found on the rear panel can be used to synchronize that deck with the CD player.

TEST RESULTS

The frequency response of this CD player was virtually flat from well below 20 Hz to 20 kHz. Nor was there any evidence of ripple in the response at the treble end of the spectrum—a condition often found in less-expensive CD players. There was less than 0.1-dB difference in output levels between channels.

Unlike many CD players, which exhibit a rise in noise and distortion at high frequencies, this Pioneer player actually showed a reduced level of harmonic distortion at the treble end of the spectrum. At mid-frequencies, THD plus noise was approximately 0.002%.

Often, the analog output stages of CD players tend to add some distortion when reproducing signals from CD's at maximum recorded levels (0 dB). Not so in the case of the Pioneer PD-75. An examination of THD-plus-noise versus recorded signal level for a 1-kHz test tone showed that distortion-plus-noise varied from around −97 dB to −95 dB below maximum recorded level for all signal levels below about −10 dB, and those readings increased only very marginally as higher recorded levels were reproduced; a −97-dB reading represents an equivalent distortion percentage of 0.0014%, while a −95-dB reading corresponds to a percentage of 0.0018%.

To separate the distortion components from the noise contribution, we also ran a spectrum analysis of the output of the CD player while it reproduced a full-scale 1-kHz signal, nulling out the fundamental itself. Significant harmonic components were seen at 2 kHz and 3 kHz, but they were each fully 100 dB below maximum recorded level. Calculating the equivalent overall distortion from those two "spikes" resulted in a figure of only 0.0014%.

Separation between channels was excellent, measuring nearly 130 dB for mid-frequencies and remaining well above 110 dB even at 16 kHz, the highest test frequency used. The signal-to-noise ratio measured 115 dB, while EIAJ dynamic range was nearly 100 dB. An examination of noise versus frequency revealed that the minor noise contributions from the power-supply components were down some 124 dB below maximum recorded level.

Low-level linearity is one of the most important criteria by which a CD player (or any digital audio device) should be judged. The Pioneer PD-75 proved to have excellent low-level linearity, thanks to its error-free 1-bit D/A conversion system. We examined the deviation from perfect linearity for signals in the range from 0 to −90 dB. Even at the extremely low level of −90 dB, linearity was within 0.5 dB of perfect. Then, using dithered signals in the range from −70 dB to −100 dB, we found that linearity was virtually perfect down to that extremely low −100 dB level.

HANDS-ON TESTS

We listened to a variety of CD program material using this superb-sounding CD player. As an experiment, we mounted duplicate CD's in this player and in another competing player that we had always regarded as a reference standard. Quite surprisingly, we could hear a subtle different between the two players: We could clearly discern better stereo imaging; a cleaner fade away of soft, reverberant sounds; and, in general, a more transparent kind of music reproduction that, to our ears at least, seemed more faithful to the original live music performance.

Of course, these sorts of subtle improvements in CD player quality are not attained at low cost. Whether or not the high price ($1200) of the PD-75 seems justified to you will depend entirely upon how much of an astute listener you are and how much you are willing to spend for that last increment of sonic excellence.

For more information on the Pioneer Elite PD-75 CD player, contact the manufacturer directly, or circle No. 119 on the Free Information Card. ■

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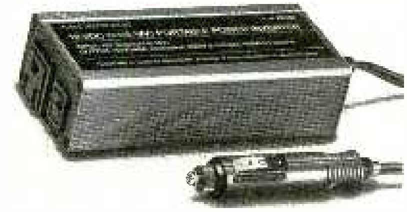

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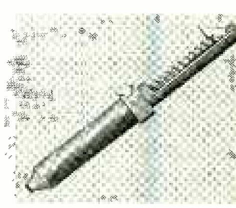

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Electric vehicles are headed our way—here's how they're shaping up

THE EV REVOLUTION REVS UP

In twentieth-century America, the gas-guzzling automobile is the undisputed King of the Road. Sure, there have been periodic calls for change—for cleaner-burning fuels, for more efficient carburetors, and even for getting rid of the internal-combustion engine altogether—but only in the wake of crises such as the fuel shortages of the 1970's. Recently, the loudest demands for change have come from the state of California.

Up to now, there has never been a serious challenger to the gas-powered car. Designs for electric cars have been bandied about for decades, but have always been shrugged off as the pipe dreams of folks whose heads are perpetually in the clouds.

In light of that attitude, it's interesting to note that two of the all-time most successful inventors of practical, yet highly visionary devices—Thomas Edison and Henry Ford—were early proponents of electric-powered vehicles. Edison held patents for two versions of a "propelling mechanism for electric vehicles" and for an electric automobile. Mrs. Henry Ford drove an electric car built by Detroit Electric, a company that targeted female drivers looking to avoid the mess and fuss of gas- and steam-powered engines, and whose ads contained endorsements by both Edison and Ford. But, faced with the superior power, longer driving range, and convenient refueling of gas-powered vehicles, the electric car was soon left in the dust, along with the horse-drawn carriage. The era of the standard car had begun with a vengeance.

The Age of the Gas-Guzzler. As cars powered by internal-combustion engines became ever more popular, a tremendous infrastructure arose to meet the demands for fuel, roads, repairs, and spare parts. A portion of that infrastructure can be seen everywhere—from highways, bridges, tunnels, and road-maintenance crews to car dealers, gas stations, body shops, auto-parts stores, car-stereo installers, and junkyards. The less visible, but just as vital end of the infrastructure includes the oil importers and refineries, and the manufacturing plants where engines, tires, glass, and everything else that goes into a car or truck are made.

As gas-powered vehicles became firmly entrenched in our lives, powerful lobbies used their political clout to become even more powerful—even going so far as to have the popular public trolley system in Los Angeles ripped up. Now, it seems that California is out to get them back—with new laws that require automakers to sell electric cars.

BY TERI SCADUTO AND BRIAN C. FENTON

It's not surprising that car makers have shown little interest in the development of alternative-fuel or electric vehicles, even in the face of increasing environmental woes. Designing an electric vehicle (EV) that can match the driving range, operating cost, convenience, and sticker price of internal-combustion vehicles, creating the new infrastructure to support it, and convincing the public to buy it, is no easy task. Why mess with a winning formula, particularly when the development of new automotive technologies is such an expensive and risky undertaking?

Certainly nothing in the recent history of the automotive industry would suggest that the Big Three would initiate such an undertaking of their own volition. Challenged in the 1970's to produce smaller, safer, more energy-efficient vehicles, their response was "It can't be done!" They eventually changed their tune, but not until the Japanese automobile makers proved that it could.

Not all the foot-dragging blame can be placed upon Detroit. In fact, while the automotive industry has taken steps to curb fuel consumption, drivers have not done their part. According to a paper presented by Philip S. Myers of the University of Wisconsin, Madison at Convergence '92, a joint electronics- and automotive-engineering conference, "... despite nearly doubling fuel economy of automobiles between 1970 and 1988, gasoline consumption increased by more than 6 percent." That increase is due to the growing popularity of light trucks, larger passenger cars, and luxury cars, which are relatively inefficient. In addition, ". . . vehicle miles traveled have increased and, unless major changes in lifestyle are made, will continue to increase at a rapid rate." Consumers, even the most environmentally conscious of whom are not fond of major changes in lifestyle, have not created a demand for electric cars.

From Dreaming to Drawing Board. Now, however, that demand has been artificially created by federal and state governments, as well as the European community. In particular, the mandates of the Federal Clean Air Act of 1990 and the actions of the California Air Resources Board, or CARB, have provided an impetus toward the design of alternative-technology vehicles.

The Edison battery originally used in Mrs. Henry Ford's 1916 EV is still used on special occasions to power this 1922 Detroit Electric, on display at the Henry Ford Museum and Greenfield Village in Dearborn—a must stop for car, technology, and history buffs who find themselves in the Detroit area.

Nissan's sleek FEV—Future Electric Vehicle—bears little resemblance to it's Roaring '20's ancestor.

The infamous smog of Los Angeles places it at the head of the list of more than 100 cities that violate Federal Clean Air standards. CARB has decreed that in 1998, 2% of all vehicles weighing less than 3750 pounds that are sold in California must be zero-emissions vehicles (ZEV's), defined as vehicles that give off no tailpipe exhaust pollutants. That percentage increases in steps, capping at 10% in 2003. If an automaker doesn't meet the quota, it can lose the right to sell cars in the state.

California vehicle sales represent 11% of the total U.S. market; at 2.2 million vehicles a year, that's a market that can't be ignored. And several other states, mostly in the crowded Northeast, are moving toward adoption of CARB standards. Because the only imminently feasible cars that produce absolutely no exhaust emissions are electric-powered, the race to produce EV's is now on in Detroit, Japan, and Europe.

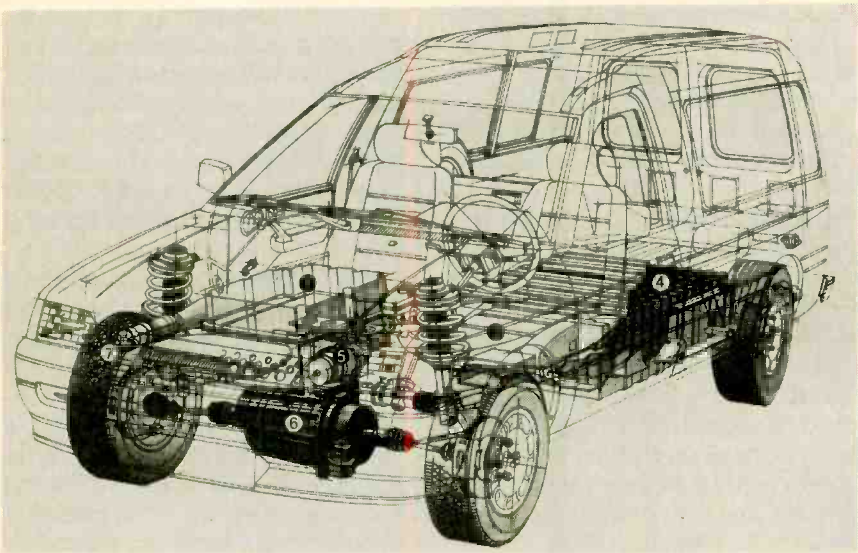
Suddenly, the dawning of EV's has moved from the realm of environmentalist dreaming to R&D labs in Detroit and around the world. The challenge they face is multifaceted: They must develop a battery that can provide sufficient power and driving range, has a long life, is affordable, and can be quickly and conveniently recharged. They must agree upon and encourage the necessary infrastructure to support such recharging, working with power utilities and the government. And they must come up with a product that not only meets government standards, but also appeals to consumers.

In this article, we examine the state of the art of electric vehicles—how they work, what's needed to keep them powered up, what the switch to EV's could mean to the environment, and how consumers might be convinced to buy them. For a close-up look at how it feels to drive EV's, take a look at this month's *Gizmo*, where we describe actual test drives of several models.

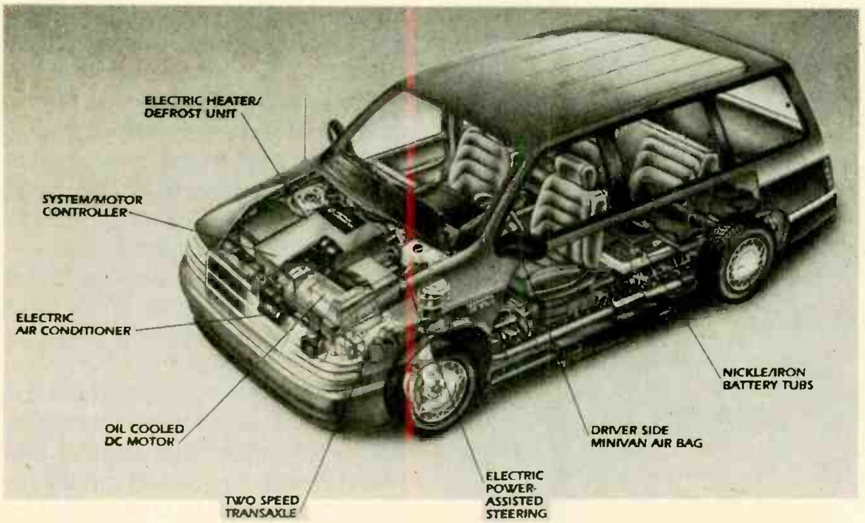
A Peak Under the Hood. Even at this early stage in their development, there is agreement on the EV's basic components: charger, battery, controller, motor, and drive train. A charger is needed to take AC power from a wall socket, convert it to DC, and charge up the battery. In the battery, that energy is stored until it is needed. A controller acts in the same capacity as a fuel injector in an internal-combustion engine; it converts the current back to AC and regulates its flow to the motor as indicated by the amount of pressure placed on the accelerator (formerly the gas pedal). The motor converts the electric energy to the power needed to rotate a shaft. The transmission in an EV—if one is used at all—is considerably simpler. In some, motors directly drive the wheels; in others, the transmission is a set of reduction gears. In reverse gear, the motor is simply run backward.

Despite agreement on the basic ingredients, each EV manufacturer has developed a distinctively different recipe. For instance, some EV designs feature a separate motor for each wheel of the car. Others have a central power plant. Motors come in several varieties, including conventional brush DC, permanent-magnet DC (PM DC), and AC induction. Currently used in golf carts, the brush DC motor is inexpensive and easy to control, but it has low motor speed, and the need to periodically replace the brushes. A PM DC motor is brushless and performs better, but it is also more expensive. The AC-induction motor is the current favorite because it can provide more power in a smaller package, has no brushes to fail, and has a flatter efficiency-versus-speed curve. But it is more expensive than a traditional brush DC (though less expensive than a PM DC) motor, and it requires power inverters and more complex controllers than either type of DC motor.

The controller in an electric vehicle monitors driver demand and other factors, determines the amount of electrical current needed, and sends the properly conditioned current to the motor. Semiconductor manufacturers worldwide are working to develop the best semiconductor device to drive an EV motor. The front runner to date is the insulated-gate bipolar transistor, or IGBT, which might best be described as a bipolar transistor with a MOSFET on its input. The IGBT combines the best features of a bipolar junction transistor (BJT)—high switching speed—and a MOSFET—low on-state loss.



The inner workings of Ford's EcoStar EV. 1—The power electronics center controls the flow of electricity, charges the battery and directs power to the drive motor (6); 2—the vehicle system controller monitors vehicle functions; 3—the power protection center combines protection and isolation functions for safety; 4—sodium-sulfur battery; 5—optional climate control system; 6—the three-phase AC drive motor delivers power to a single-speed, direct-coupled transaxle; and 7—external charger door.



Chrysler's TEVan electric minivan shows another possible EV configuration, with nickel-iron batteries, an oil-cooled DC motor, and two-speed transaxle.

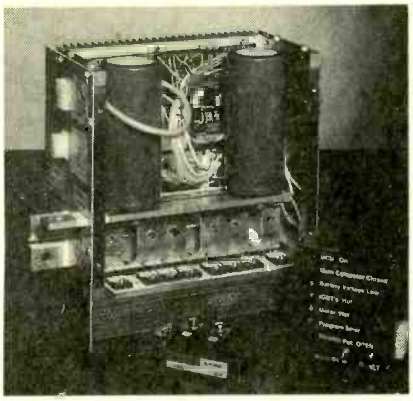
One of the major pluses of EV engines is that, with so few moving parts, they require little maintenance. (In fact, one manufacturer considered sealing the hood completely, but rejected that idea because they felt that owners of the first EV's would be eager to open the hood to show off their vehicles' innovative inner workings.) The EV itself is expected to last longer than gas-powered cars—with the exception of its battery.

EV Batteries. The electric-vehicle ingredient that presents the biggest challenge to developers is the battery. If EV's are to deliver the power and driving range that American drivers require, a suitable battery must have both a lot of energy per pound (a high specific energy) and the ability to quickly release that energy (high specific power).

The contenders are lead-acid (favored by GM and Opel), nickel-cadmium or Ni-Cd (the leader in Japan), and sodium-sulfur or Na-S (Ford's and Volkswagen's pick). Each battery has its advantages and drawbacks. Lead-acid batteries have high specific power; sodium-sulfur, high specific energy. Nickel-cadmium batteries rate even better than lead-acids in specific power, but they have two problems: They work best if they are completely run down before they are recharged, and they contain cadmium, a highly toxic element. Since most drivers would be uncomfortable driving their vehicles to the point that their batteries were almost fully discharged, charging stations will have to contain enough smarts to discharge Ni-Cd batteries before recharging them. Lead-acids, on the other hand, have the opposite problem: they can be ruined by being repeatedly fully discharged. Unless all manufacturers use the same kind of batteries, charging systems will have to be able to determine the batteries used and charge them appropriately.

All the battery types have two problems in common: They wear out relatively quickly, and the cost of replacement batteries is expected to be prohibitive. Manufacturers are considering such options as long-term battery leases to ease the cost burden to consumers.

In short, there isn't a battery in existence that comes close to the power-



The EV controller designed by Motorola as a prototype for the electric Saturn developed by Arizona Public Service and DEMI has the ability to handle up to 900 amps from a 150-volt battery source. It operates at 16 kHz to avoid noise.

GM's prototype EV, the Impact, has a tear-drop-shaped profile that reduces aerodynamic drag. The Impact's introduction has been delayed until the late 1990's, due to the "high level of uncertainty in the marketplace," according to GM.

generating capacity of an gasoline-based internal-combustion engine. Nor do industry insiders predict any startling battery innovations in time to meet the 1998 deadline. The battery problem is serious enough that the U.S. government has stepped in, joining Ford, Chrysler, and GM, and funding the United States Advanced Battery Consortium (USABC). Government laboratories are being put to use in developing a battery that's suitable for use in EV's.

Efficiency Experts. Because it's not likely that remarkably better batteries will exist in time for manufacturers to meet the 1998 deadline (especially when you consider that it takes four years to bring a new car from drawing board to showroom), designers will have to house those same batteries in a better car—a vehicle designed for efficiency from stem to stern.

As far as efficiency goes, electric motors are the hands-down winners over traditional, internal-combustion engines. The heat generated by combustion is vented out through with the exhaust or through the radiator. Friction in the engine and transmission is wasteful. An incredible amount of forward momentum is lost through braking, particularly in city driving. When you factor in all of the inefficiencies, a traditional automobile squanders 85% of the energy in gasoline in the form of heat! The internal-combustion engine itself has an efficiency of less than 20%. Electric motors, on the other hand, usually have efficiencies better than 90%.

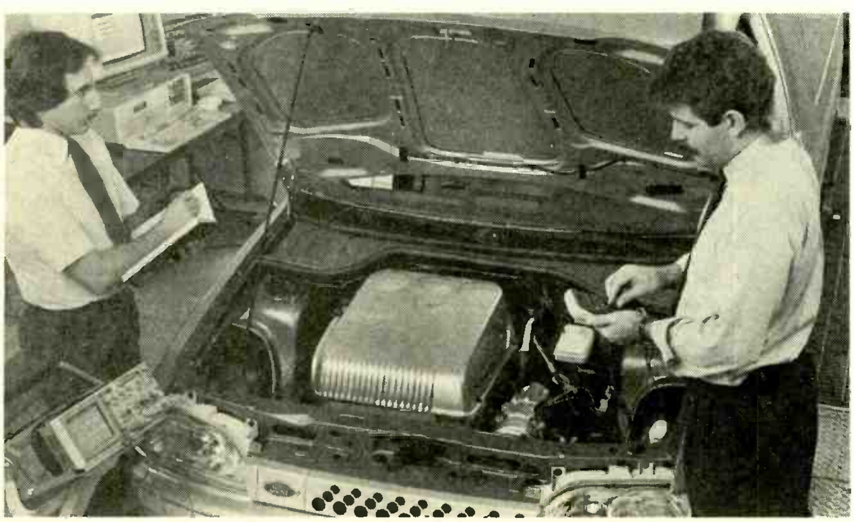
Unfortunately, a highly efficient motor that's based on an inefficient battery still isn't enough to cut it. EV's also require drastic reductions in aerodynamic drag and in rolling resistance. That means redesigning the body of the vehicle as well as the tires on which it rolls.

Aerodynamic drag, which can be defined as a force that opposes the motion of a vehicle and that increases as the square of the vehicles speed, can be reduced in three ways. Driving slower reduces air resistance—but also reduces a vehicle's appeal to drivers. Designers can also limit the vehicle's height and width, and reshape its body to make it more aerodynamically efficient. The usual overall drag coefficients for today's cars range between 0.3 and 0.4; for cars designed specifically as EV's, that figure generally hovers just below 0.2. That reduction was accomplished by streamlining the vehicles, including the usually overlooked underbody. (That's easier in an EV, which doesn't have a tailpipe and muffler hanging down.)

In standard tires, the energy that is expended as the tire flattens against the road is lost when the flattened section regains its shape as the tire turns. To reduce this "rolling resistance," a firmer tire is necessary, but comfort and handling must not be sacrificed. EV tires, which are inflated to approximately twice the pressure of standard tires without any noticeably adverse affect, have rolling resistance coefficients ranging from 0.004–0.007; for conventional tires, the range is 0.01–0.02.

Perhaps the cleverest efficiency booster comes in the form of the braking system used in EV's. Traditional cars lose all of the kinetic energy in their movement by turning it into heat in the brakes. Rather than simple friction brakes, EV's use *regenerative braking.* When you step on the brake pedal, the motor controller treats the motor as a generator. That slows the vehicle down and charges the batteries. Because regenerative braking is not effective at low speeds, an EV must have a traditional friction brake as well.

Although taken for granted in a car powered by an internal-combustion engine, heating and cooling demand energy that would greatly reduce the driving range of an EV. Car makers are exploring ways of reducing those needs. For example, vehi-



Ford engineers measure the output voltage of the current inverter going to the vehicle's electric motor. The inverter takes a signal and direct current from the battery and converts it to AC to run the motor.

cles could be heated or cooled to a comfortable level while they're being recharged, lessening the need for battery-powered temperature control. Solar-powered fans could keep cars cooler in the summer, reducing the need for air conditioning.

Creating a New Infrastructure. Car manufacturers have been able to produce electric cars that accelerate from 0–60 mph in 8 seconds, and reach speeds of more than 120 miles per hour. In short, cars that perform on a par with gas-powered vehicles. But those EV's can't perform without a support system.

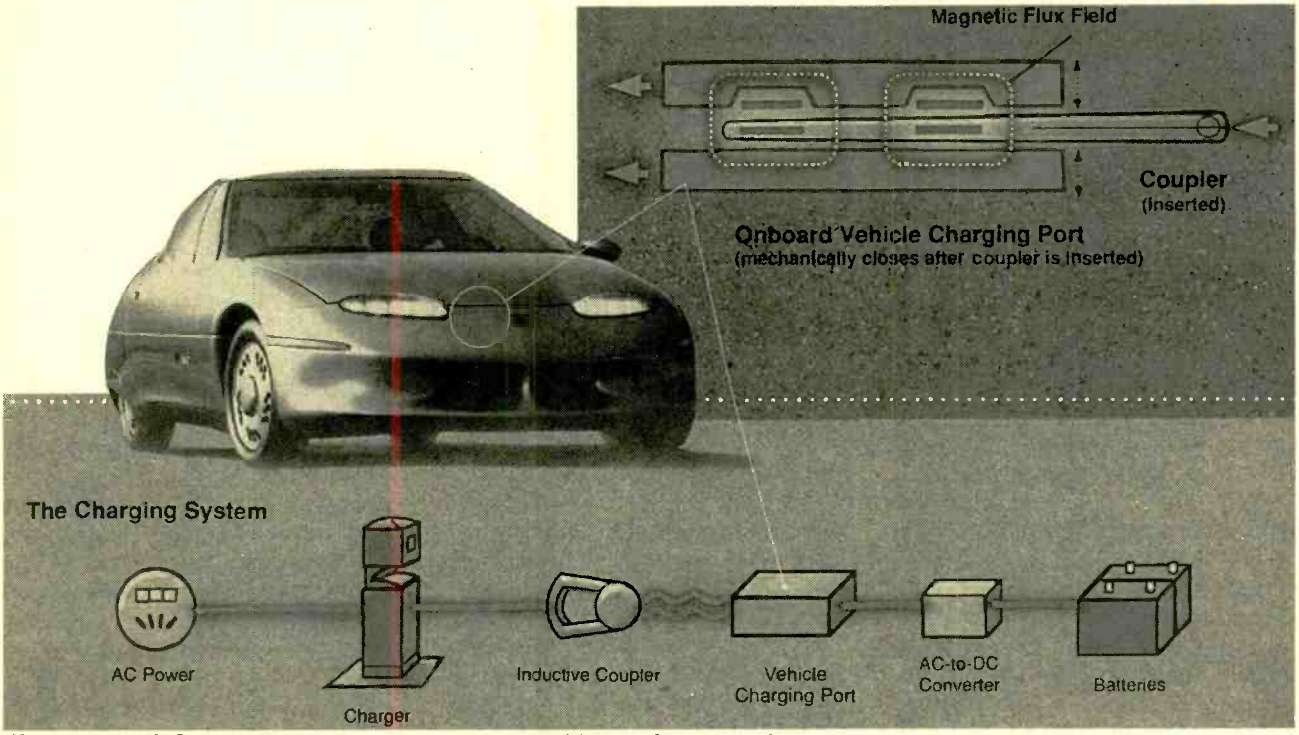
What is needed to make EV's a practical means of transportation is an infrastructure that will provide their drivers with convenient, cost-effective, quick ways to recharge their batteries, so that they can travel without fear of being stranded with a discharged battery. That infrastructure includes standardized charging hardware and procedures, facilities for recharging batteries (as well as for replacing and recycling worn batteries), appropriate means of power distribution, and, perhaps, a new rate structure. A trained work force of EV technicians capable of providing fast recharges and emergency road service is also essential. There are various options being considered, but standards must be set well before EV's hit the pavement.

There is general agreement that overnight recharging can be accomplished at home, using 240-volt household current for a period of about eight hours. That method has two main advantages: Power utilities have electricity to spare in the late-night, off-peak hours, and outfitting a garage with a recharger wouldn't be too costly or difficult.

Trouble begins in places like New York City, where very few people have private garages or carports in which to juice up. In cities across the U.S., more people park in driveways than in garages. And most homes have more than one car.

Curbside rechargers would be necessary for those people. And a network of quick-charge stations will be needed to serve as "gas stations" for EV's everywhere. There appears to be some agreement that such charging stations should have a familiar appearance, making EV drivers feel comfortable with them. EHV Corp has developed a curbside charger that looks just like a parking meter with a cable sticking out the back, and Nissan's prototype "EV Power Station" closely resembles a service station island housing a couple of gas pumps.

What has yet to be agreed upon, however, are the specifics. What will a safe, easy to use, home charger look like? Will cables be attached to public charging stations (where they would be at risk of breakage and vandalism), or be built into the vehicles themselves (where they would add weight and increase the price). What sort of communication is required between the vehicle and the power source? At public self-charging stations, how will payment be handled? There is also the question of how many quick-charge stations are needed, and how far apart they might be placed. To help settle these issues, and to help smooth out difficulties that might arise between organizations with conflicting interests, regular meetings of the Infrastructure Working Committee—a group of automakers, utilities, and other inter-



Hughes Aircraft Company's inductive charging system safely transfers energy from one point to another. The magnetic field replaces the common metal plug/socket used to plug-in appliances. The inductive-coupler charging system features an electronic "coil" that is completely encased in a five-inch round, plastic covered paddle. When the paddle is inserted into the charging port on the car, the magnetic fields intermingle to complete the circuit.

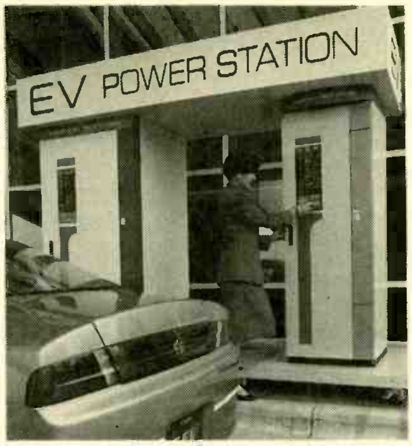
ested participants organized by the Electric Power Research Institute in Palo Alto, California—are held.

To the Source: the Utilities. It stands to reason that electric companies have a lot to gain from the introduction of EV's—increased revenues, much of it derived from the use of equipment that is currently being "wasted" during off-peak hours. It's also clear that urban residents of Los Angeles will benefit from reduced emissions and cleaner air. What isn't quite as clear is how users of EV's, and the rest of us, might end up paying for vehicles powered by electricity—not only in terms of money, but in terms of air pollution.

The actual cost of charging up an EV is expected to be roughly equivalent to, or perhaps a bit cheaper than, tanking up with gasoline. When electric vehicles are first introduced, their small number will place no strain on existing electrical power plants. However, should EV's catch on in a big way, and should quick recharges during the day become common practice, it's possible that utilities would have to expand or build new facilities—paid for, of course, by rate increases.

But there's another, less obvious, price that we might end up paying for electric-powered cars—an increase in the amount of pollutants created by electrical power generation. That varies considerably depending upon the type of fuel being used, with coal being the dirtiest and nuclear energy the cleanest. Unfortunately, 54% of the electricity generated in this country comes from burning coal, compared to 33% from nuclear and renewable sources such as hydropower, 9% from gas, and 4% from oil. So, while carbon monoxide, ozone, and volatile organic compounds found in smog would not be created by EV's, widespread use of EV's could cause a slight rise in the amount of sulfur dioxide in the atmosphere.

Proponents of EV's counter those claims by stressing that: First, EV's free us from dependence on foreign oil; second, those parts of the country where electricity is generated by nonpolluting sources (solar, hydro, nuclear) will experience an across-the-board reduction in pollutants; and third, that electric utilities are much



A

B

Nissan's prototype EV Power Station (a), which closely resembling an ordinary gas station island, features the company's Super Quick Charger that makes recharging as easy as (and neater than) filling the tank. The transfer line (cable) is in a compartment in the station. (b) A personalized computer card could be used to read the recharging requirements for any type of EV and to handle payments.

more efficient users of fossil fuels than are the internal-combustion engines found in toady's cars. It's easier to keep large, stationary power plants "tuned up," and to monitor their emissions, than it is to keep track of millions of privately-owned and -maintained automobiles.

The Big Sell. Car manufacturers, utilities, and other backers of electric vehicles must work out all those kinks, and present a united, standardized front to consumers if they hope to actually sell even enough cars to meet California's standards for 1998. Of course, there are always a few "early adopters" who will race out and buy an EV just to be the first on the block to own one. We would imagine that, particularly in southern California—with its unique combination of environmentally outspoken public figures, a large population of the extremely wealthy, and a really awful problem with smog—the first generation of EV's could become a sort of status symbol (even if it was parked in a four-car garage alongside a Range Rover, a Mercedes, a minivan, and a Rolls Royce). But before EV's can truly generate the mass appeal needed to sell enough cars to meet the CARB limits, several issues must be addressed.

Four factors influence car buyers' decision making: cost, convenience, performance (quality), and emotion. The first three are much more concrete and objective; the fourth, however, cannot be ignored. When shopping for standard, gas-powered cars, there are generally several models that offer virtually the same power, mileage, level of luxury, size, handling, and sticker price. The deciding factor is often emotional: One car is perceived to be "sexier" than another, or the desire to "buy American" wins out.

It's up to the manufacturers, the utilities, and state and federal governments to deliver EV's that inspire consumer confidence by providing the performance and convenience of similarly priced gas-powered vehicles, and to create the infrastructure required to serve them. To make the package more appealing, it's likely that various incentives will be offered to those who use EV's. Those might include dramatically reduced electric rates for overnight recharging, tax credits or sales-tax waivers for purchasers, subsidies for installing home chargers, and the use of highway lanes now reserved for buses or carpools only.

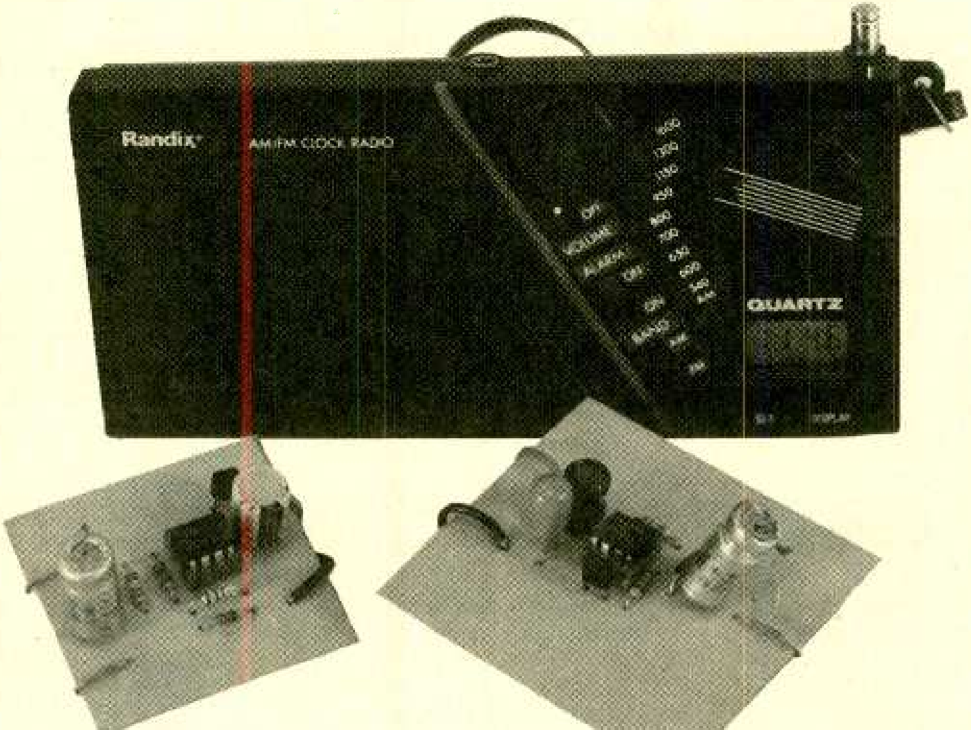
The next step is educating the public to reduce fear of the unknown. It's vital that any preconceived notions that EV's don't have enough range to meet the average driver's needs must be banished. In reality, polls of drivers

(Continued on page 88)

Solar Power Supplies for Portable Radios & Cassette Players

Build an environment-friendly, money-saving power supply for radios, cassette players, and more

BY ANTHONY J. CARISTI



If you make extensive use of portable radios or cassette players, you are well aware of the high cost of replacement batteries. Besides being expensive, batteries tend to expire right in the middle of your favorite music. The *Solar Power Supply* described in this article is designed to address that problem by providing a low-cost alternative to purchasing batteries, assuming that much of your listening is done during the daylight hours and in places where sunlight is available.

To accommodate different types of portable electronic equipment, two systems will be described; a switching (step-up) regulator and a linear (step-down) regulator. Each of the regulator circuits is used in conjunction with a solar-cell array, which converts light into electrical energy. The outputs of the circuits remain constant even with varying degrees of light intensity.

For special low-light operation, the builder can add more cells in series with the solar-cell array to compensate for that condition. For night-time or indoor use, if the solar array is placed close to bright lighting, the Solar Power Supply will be able to provide sufficient power to operate most portable devices.

Switching Regulator. Figure 1 shows the schematic diagram of the switching regulator, which can be configured to output 7.2 or 4.8 volts of regulated DC, depending on the resistor value selected for R1. By making R1 453k, which produces an output of 7.2 volts, the circuit can be used to operate radios that are normally powered from a 9-volt battery. By making R1 274k, which produces an output of 4.8-volts, the circuit can be used to operate devices that are normally powered from a 6-volt source (*i.e.*, two AA or C cells).

At the heart of the switching-regulator circuit is an MAX630CPA (Harris) micropower switching regulator (U1), which is designed to deliver 7.2 volts at 15 mA with an input of 3 volts. The switching regulator is fed from a solar-array, consisting of eight, 0.5-volt photovoltaic or solar cells, which output 4 volts. The 8-cell solar-array ensures that the circuit can provide sufficient power to operate the connected device when less than full Sun intensity is available.

With a typical load current of 15 mA at 7.2 volts, the power output of the circuit is 108 mW. Assuming that the

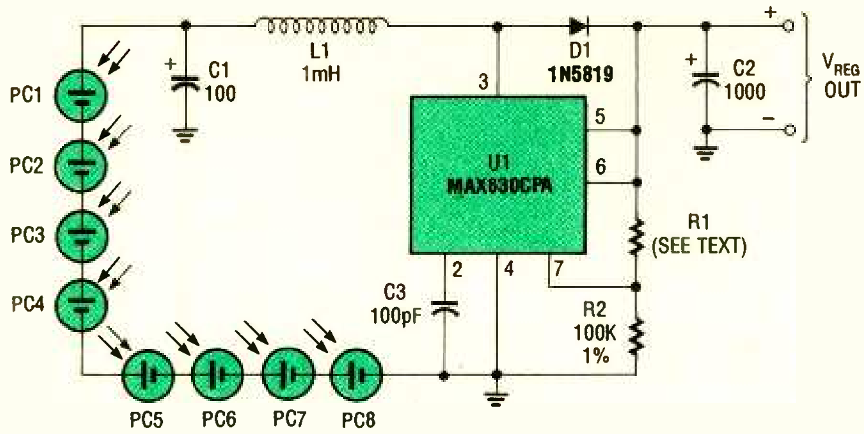


Fig. 1. Powered from an 8-cell solar array, the switching regulator can be configured to deliver 7.2 or 4.8 volts of regulated DC. At the heart of the circuit is an MAX630CPA micropower switching regulator (U1), a chip that's designed to deliver 7.2 volts at 15 mA with an input of 3 volts.

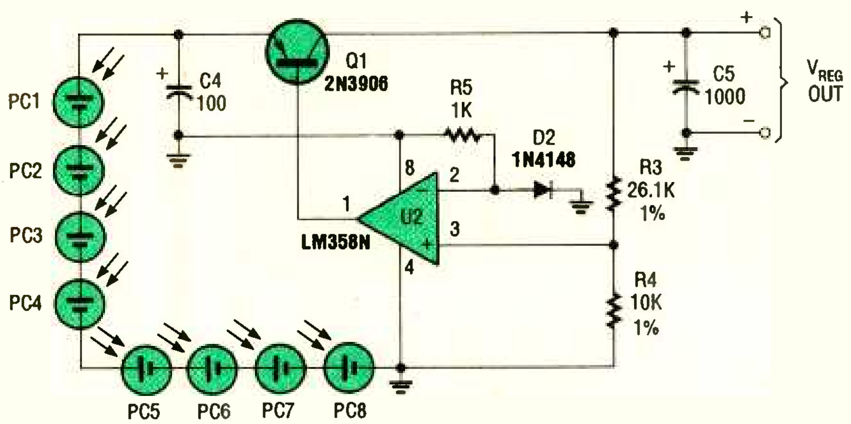


Fig. 2. This linear regulator circuit has at its heart a low-power op-amp, which controls a PNP transistor that's connected as a high-side switch between the array and the load.

circuit has an operating efficiency of 70%, power input is 154 mW. With an input of 3 volts, the solar-cell array must be able to deliver 51 mA to power the regulator circuit. With the specified resistor value, the circuit can provide 4.8 volts at 115 mA with an input of as little as 3.3 volts.

The calculations for a typical load driven by the circuit are as follows: A cassette player that draws 115 mA of current at 4.8 volts requires an input power of 552 mW. Using a conservative figure of 70% efficiency for the switching regulator, the current required from the solar-cell array is 239 mA. For this application 250- or 300-mA cells would be a good choice. If necessary, one way to attain greater current ratings than can be obtained from one solar cell is to connect two or more in parallel.

Linear Regulator. Some portable cassette players use two AA cells as the power source, and require an operating current of typically less than 125 mA. Although a step-down switching regulator can be designed for this application, a linear circuit is more efficient. Such a circuit is illustrated in Fig. 2. The heart of that regulator is a low-power op-amp, which controls a PNP transistor that's connected as a high-side switch between the cell array and load. The circuit's input/output voltage differential just 0.3 volt, which is lower than most fixed linear-regulator chips.

In the linear circuit, the negative input of the op-amp is biased at a reference voltage of 0.7 volts by means of R5 and D2. A voltage divider, composed of R3 and R4 and connected to the positive input of the op-amp, monitors the output voltage of the regulator. The output of the op-amp acts as a current sink for the base of Q1, and draws sufficient base current to maintain a relatively constant output voltage with variations in solar-cell voltage and load current.

As the output voltage of the solar-cell array changes with varying degrees of Sun intensity, the voltage at pin 1 of U2 moves up and down accordingly. As a result, the output of the supply remains at or close to 2.4 volts.

As discussed earlier, the current supplied by the solar-cell array is essentially equal to the current demanded by the radio or cassette player. For most 3-volt portable cassette players, the current is usually in the 125-mA range. One way to obtain a solar cell with that capacity is to parallel 100-mA cells with 50-mA cells, which would provide an extra margin of power to the system.

Construction. Both of the regulator circuits are extremely simple to build and can easily be hardwired on a small section of perfboard. But for a more professional look, you may wish to use printed-circuit construction. The board(s) can either be etched from the full-sized, printed-circuit templates shown in Figs. 3 and 4 (the switching and the linear regulators, respectively), or purchased from the source given in the Parts List.

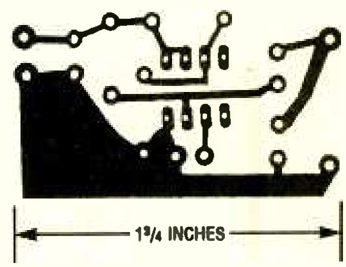


Fig. 3. The switching regulator was assembled on a small printed-circuit board. This full-sized, printed-circuit template can be used to etch your own board.

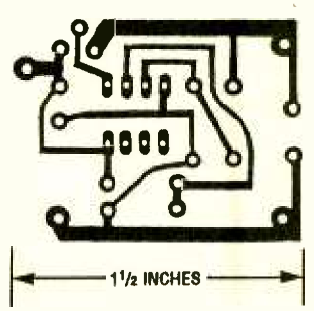


Fig. 4. The linear regulator was also assembled on a small section of printed-circuit board. Here is a template of that foil pattern.

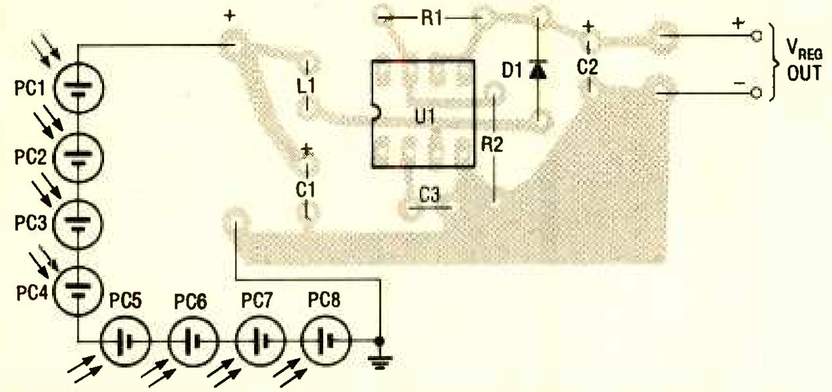


Fig. 5. When gathering the components for the switching-regulator board, be sure to use the parts specified in the Parts List, including the use of metal-film resistors where called for, and a Schottky diode.

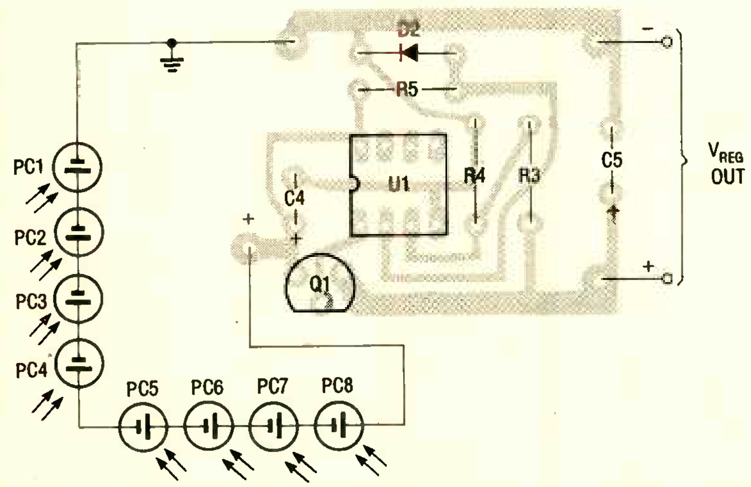


Fig. 6. Here is the parts-placement diagram for the linear-regulator circuit. When assembling this, as well as any other electronic project, make absolutely sure that all of the polarized components are properly oriented.

PARTS LIST FOR THE SWITCHING REGULATOR

SEMICONDUCTORS

U1—MAX630CPA switching regulator (Harris Semiconductors), integrated circuit
D1—1N5819 Schottky diode

RESISTORS

(All fixed resistors are ¼-watt, 1% units, unless otherwise specified.)
R1—453,000-ohm or 274,000-ohm, metal-film (see text)
R2—100,000-ohm, carbon, 5%

CAPACITORS

C1—100-µF, 10-WVDC, radial-lead electrolytic
C2—1000-µF, 10-WVDC, radial-lead electrolytic
C3—100-pF, 50-WVDC, ceramic-disc

ADDITIONAL PARTS AND MATERIALS

PC1–PC8—0.5-volt photocell (see text)
L1—1-mH, 200-mA choke, DC resistance 5 ohms or less
Printed-circuit materials, enclosure, wire, solder, hardware, etc.

When gathering the necessary components, be sure to use the parts specified in the Parts List. That includes using 1% metal-film resistors where called for, and a Schottky diode in the switching regulator. The inductor must be rated for twice the load current of the supply, and have a resistance of less than 5 ohms. The use of alternate components will result in less than optimum operation. Be very careful to orient all polarized components properly; just one part placed backwards on the board will render the circuit inoperative and may cause component damage.

Once you've obtained the specified parts, construction can be begin. Parts-placement diagrams for Figs. 3 and 4 are shown in Figs. 5 and 6, respectively. It is recommended that a socket be used for the DIP IC in each circuit. The use of sockets makes troubleshooting or servicing much easier should either ever be necessary.

When the circuit is completely assembled and wired, inspect it very carefully for shorts, opens, and cold solder joints (which may appear as dull blobs of solder). Any suspect joint should be redone by removing the old solder and applying new solder. It is far easier to correct construction problems at this stage than it is to do so later on should you discover that your project does not work.

Solar Cell Selection. In order to select the correct-size solar cells for the desired application, the current draw of the device to be operated must be known. That can be determined by actually measuring the current drawn by the device to be powered, with a DMM set to read DC milliamps, while the radio or cassette player is operated from a set of batteries or an AC adapter.

Using batteries as the power source is the preferred method for determining load current since it will provide a more accurate reading. While making the measurement, play the unit with the highest volume that you intend to use.

The easiest way to make this measurement is to obtain a power-adapter plug that the fits the external power jack of the unit to be powered, and use an external power source (batteries or AC adapter) to operate the unit. A DMM connected in series (as illustrated in Fig. 7) with one of the power leads and set to 200 mA DC will indicate the current drawn by the unit.

Because there is no standard power-supply connection scheme from one manufacturer to another, one must be very careful about power-supply polarity when performing this test. One way to check polarity of the jack on some units is to connect a pair of wires to the adapter plug, insert the plug into the jack, and use a DC voltmeter to check the polarity of the battery voltage appearing across the wires. That test requires batteries to be in the unit to provide voltage at the power jack, and will work if the plug does not automatically disconnect the batteries.

PARTS LIST FOR THE LINEAR REGULATOR

SEMICONDUCTORS

U2—LM358N dual low-power op-amp, integrated circuit
Q1—2N3906 general-purpose PNP silicon transistor
D2—1N4148 general-purpose silicon diode

RESISTORS

(All fixed resistors are ¼-watt, 1% units, unless otherwise specified.)
R3—26,100-ohm, metal-film
R4—10,000-ohm, metal-film
R5—1000-ohm, carbon, 5%

CAPACITORS

C4—100-µF, 10-WVDC, radial-lead electrolytic
C5—1000-µF, 10-WVDC, radial-lead electrolytic

ADDITIONAL PARTS AND MATERIALS

PC1–PC8—0.5-volt photocell (see text)
Printed-circuit materials, enclosure, wire, solder, hardware, etc.

Note: The following parts are available from A. Caristi, 69 White Pond Road, Waldwick, NJ 07463: PC board (specify linear or switching regulator), $5.00; U1, $11.50; U2, $2.75; L1, $5.50; D1, $2.00; metal-film-resistor kit (specify values), $2.00. Please add $3.00 postage/handling. New Jersey residents please add applicable sales tax.

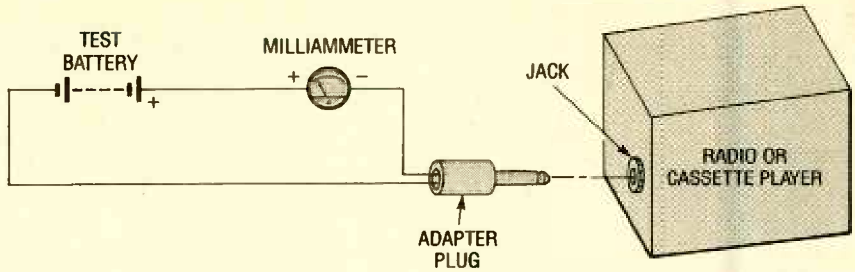


Fig. 7. The solar cell used in this project must be selected according to the current draw of the device to be operated. That can be determined by actually measuring the current drawn by the device using a DMM set to read DC milliamps, in a setup like that shown here.

TABLE 1—TYPICAL CURRENT REQUIREMENT FOR PORTABLE RADIO AND CASSETTE PLAYERS

Power Source/Drive	Volts	Mode	Load Current
2 AA cells/Walkman	3	Radio	25 mA
2 AA cells/Walkman	3	Tape	125 mA
4 AA/C cells/Radio & cassette	6	Radio	25 mA
4 AA/C cells/Radio & cassette	6	Tape	115 mA
9-volt battery	9	Radio	15 mA

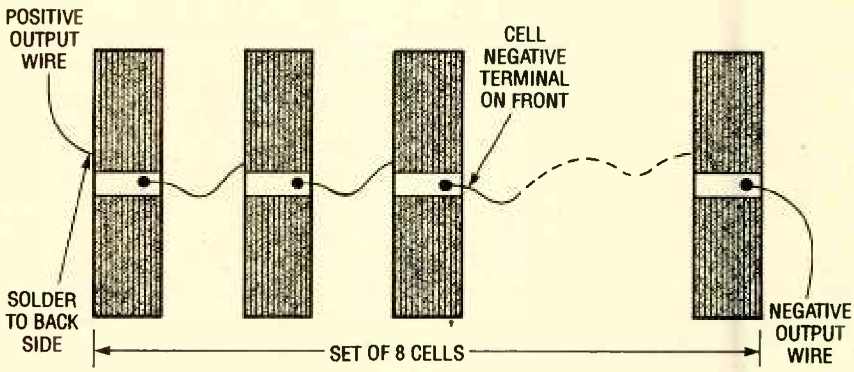


Fig. 8. This illustration shows the proper way to wire solar cells in series. The connections are made from the back of the cell (positive terminal) to the silver colored band on the front of the cell (negative terminal). The free ends of the 8-cell string is the connected to the circuit as shown in the schematic diagram.

Another way to verify polarity (if an AC adapter for the unit in question is available) is to plug the unit into a 117-volt AC receptacle and check the DC voltage at the output of the plug with a DC voltmeter.

Table 1 gives the approximate current drawn by several types of common portable radio and cassette equipment. Note that "radio only" operation requires significantly less current than cassette operation. That because the motor does not run when simply playing the radio. For 3-volt devices, the linear regulator circuit is the best candidate. For that type of circuit, the solar-cell array's output current should equal that of the unit to be powered.

For 6- and 9-volt devices, the step-up switching regulator in Fig. 4 is the preferred circuit. In that case, the required solar-cell current capacity must be calculated, using two simple equations. First calculate the radio/tape player power input in milliwatts:

$$\text{mW} = \text{V} \times \text{mA}$$

where V is the nominal regulated supply voltage (4.8 or 7.2 volts) and mA is the device's load current, which was measured previously.

Next calculate solar-cell current using a conservative estimate of 70% (0.7) for switching-regulator efficiency, and a minimum solar-array output voltage of 3 volts under hazy sunlight:

$$\text{Solar-array current} = \text{mW}/(0.7 \times 3)$$

where mW is the power input previously calculated. For example, for a typical cassette player that is powered by 4 AA cells and draws 115-mA load current:

$$\text{mW} = 4.8\text{V} \times 115\text{ mA} = 552$$

and:

$$\text{Solar-array current} = 552/(0.7 \times 3) = 263\text{ mA}$$

For the above example, a set of eight solar cells (rated at 300 mA) connected in series will be ideal for this application.

Solar-Cell Assembly. Solar cells may be obtained individually, or in groups connected in series to form an array. A typical solar cell, rated at 300 mA, is available from Radio Shack (part number 276-124). Another good source for solar cells is Edmund Scientific Co. (101 E. Gloucester Pike, Barrington, NJ 08007).

(Continued on page 88)

Build a TELEPHONE INTERCOM

Do you have a couple of old telephones sitting in your junkbox? This simple project will turn them into a useful intercom unit that works just like a real telephone system.

BY GREG SHERIDAN

Ever wondered how Commissioner Gordon managed to raise Batman effortlessly on the hotline? Or have you ever been curious to know how the White House/Kremlin hotline works? Both systems are probably very similar to the *Telephone Intercom* described in this article. The intercom consists of two ordinary telephones that are interconnected via a 2-wire interface circuit. The circuit, which features full-duplex operation (*i.e.*, simultaneous 2-way conversation), can also be used to test telephones, modems, DTMF decoders, and facsimile and answering machines.

A stripped-down version might also be used to make role-play training sessions more realistic at telephone counselling services. In fact, that is the purpose for which the circuit was initially designed.

To operate the Intercom, you simply lift one phone and the other phone rings. Lifting the second phone then stops the ringing and conversation can commence. The circuit does not reset until both telephone handsets are replaced. That prevents the first phone that's hung up from ringing until the second phone "clears." It also allows one party to hang up and continue the conversation on another extension on the line.

CAUTION: This Intercom must not be connected to telephone company lines. It is intended only for use on lines completely separate from Telephone company installations.

An Introduction to Telephones. A telephone in its on-hook (hung-up) state exhibits a capacitance and series resistance between both legs of the line. That's the ringing circuit (see Fig. 1). An AC ringing signal will pass and cause the telephone bell to ring or the "tone ringer" to warble. When the phone is taken off-hook, a DC loop (mainly resistive) is connected across the line and DC flows, fed from the telephone exchange. The exchange equipment detects the current flow and either stops the ring signal (for an incoming call) or sends a dial tone (for an outgoing call).

When a phone rings, the ringing signal is connected to one leg of the line and the return path is through the DC supply. When the telephone is idle, the line voltage is usually around 48 volts, although that's not critical. When the phone's handset is off-hook, a current of 20–30 mA (known as the loop current) flows through circuit. That current is sufficient to power the phone's transmitter (microphone), whether it is a modern electronic type with a built-in preamplifier or the original carbon-granule type. The loop current also powers any dialing circuitry.

Our circuit emulates the above conditions, which makes it compatible with just about all types of telephones. However, there are a couple of deviations from standard telephone practice. First, the circuit described herein uses a negative ground whereas telecommunications equipment generally use a positive ground. That convention was chosen to minimize electrolytic action in grounding stakes and the like, but is not applicable here.

The ring's voltage and frequency have also been altered to keep the

*This story first appeared in *Silicon Chip*, Australia (May, 1992), and is reprinted with permission.

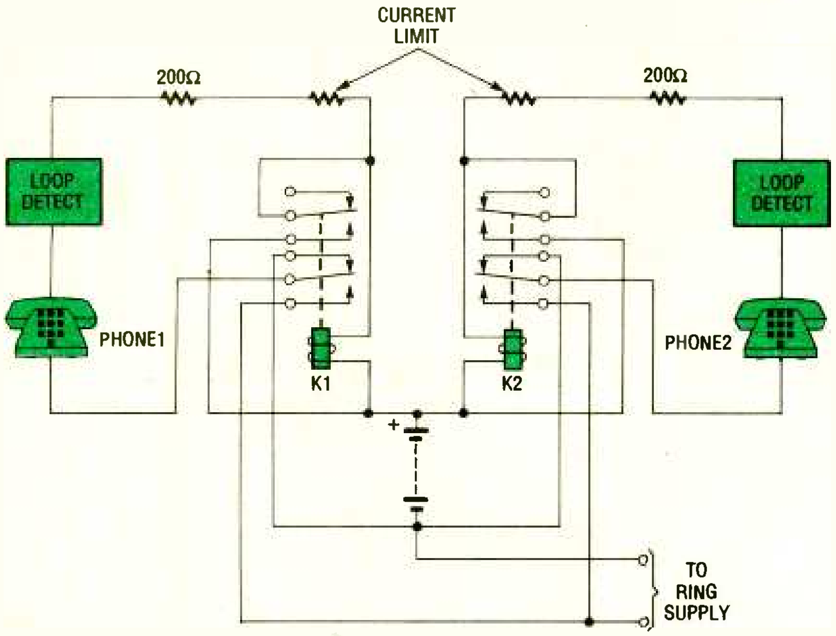


Fig. 1. The basic telephone-ringing circuit. When one phone is taken off-hook, the ring relays in the other loop close and a ringing signal is applied to the second phone.

project easy to build and the cost as low as possible. The normal ring signal is 75–90 volts rms at 25 Hz but, by experimentation, it was determined that that voltage and frequency are only required when driving older telephones with real bells.

Modern telephones usually rectify the incoming ring signal and regulate it to about 12 volts, which then becomes the power supply for the ringer chip. So, for those phones, the ring voltage and frequency are not critical. But, for applications where a higher ring voltage is required (generally the 800-series phones and their Bakelite predecessors), a larger ring transformer can be used.

Circuit Analysis. Figure 2 shows a complete schematic diagram of the Telephone Intercom. All of the required voltages are derived from two step-down power transformers. The first transformer (T1) provides a +12-volt rail (via D5 and U7) for the logic, plus around 46 volts DC, which is used as the telephone "speech" voltage. The second transformer (T2) produces around 90-volts peak-to-peak (nominally 30 volts rms), which is used as a ring signal.

The whole circuit uses only four CMOS chips and two optoisolators to provide the logic and generate the ringing signal. Let's see how it works.

A couple of Schmitt-trigger inverter stages (U1-a and U1-b) provide buffering and false triggering protection for phone 1. In the idle state, there is no DC flowing in the phone line, so U5's internal LED is off. Thus, pin 1 of U1-a is held high, which means that the output of U1-b (at pin 12) is also high. Similarly, if phone 2 is on-hook, pin 10 of U1-d will be high. Those logic highs are fed to pins 5 and 6 of AND gate U2-a, to pins 5 and 6 of NOR gate U3-a, to pin 13 of U2-c, and to pin 8 of U2-d.

Assuming that both phones are initially on-hook, the output of U2-a will also be high. That holds the RS flip-flop formed by U3-b and U3-c in the reset state, with its Q output (U3-b pin 10) low and its $\overline{Q}$ output (U3-c pin 11) high. The set input of the RS flip-flop (pin 13 of U3-c) is fed from pin 4 of U3-a, which is currently at logic 0.

If phone 1 is taken off-hook, current flows through U5's internal LED and turns on its internal transistor. That pulls pin 1 of U1-a low and thus pin 8 of U3-b (RESET) is also toggled low (via U1-b and U2-a), which means that the flip-flop can now be toggled. Similarly, if phone 2 is taken off-hook, pin 3 of U1-c goes low, and pin 8 of U3-b goes low via U1-d and U2-a. Gate U3-d detects any difference between the states of the two phones. When a difference is detected (*i.e.*, when one phone is taken off-hook), the output of U3-d at pin 3 goes high, turning on LED1 via transistor Q5 (actually, U2-a, U3-a, and U3-d together form an XOR gate to detect the different phone states).

In addition, when U3-d's output goes high, pin 3 of U2-b also goes high. Depending on which phone was taken off-hook, pin 11 of U2-c or pin 10 of U2-d goes high. (Note: U2 is a 4081 quad 2-input AND gate. When both inputs of a AND gate are high, the gate output will be high.) Let's assume that phone 1 has been taken off-hook. In that case, pin 10 of U2-d switches high and forward biases Q2. Transistor Q2 subsequently turns on, activating ring relay K2 whenever Q3 in the ring circuit turns on.

Similarly, if phone 2 is taken off-hook first, pin 11 of U2-c switches high and forward biases Q1. In other words, taking phone 1 off-hook closes K2 and rings the bell on the other phone, and *vice versa*.

Ring Circuit. Counter U4 and its support components form the ring timer circuit. It is normally held reset by U1-e, but is activated when pin 3 of U2-b goes high and pin 8 of U1-e switches low. That ensures that the counter is only one "clock tick" off the beginning of the ringing cycle, rather than having to wait for possibly up to two seconds for the ringing cycle to begin.

Gate U1-f (a oscillator stage comprised of one gate of a hex Schmitt trigger) clocks U4, which turns on Q3, activating ring relay K2 each time pins 2 and 7 (output 1 and output 3 on U4) go high. It also switches interrupt transistor Q4 (via output 2) to generate the required ring cadence. The exact operation of the ring cadence generator is described a little later on. Each time K2 is activated, its contacts close and the AC ring signal from transformer T2 flows through phone 2, D13, R4, R3, and C7.

If the calling phone goes back on-hook, pin 3 of U3-d goes low and the circuit reverts to the idle condition. Alternatively, if the called party answers, pin 4 of U3-a goes high and toggles the flip-flop comprised of U3-b and U3-c. That sets pin 11 of U3-c ($\overline{Q}$) low, which in turn, forces pin 3 of U2-b low, stopping the ring.

Conversation can now proceed, with the audio signal coupled via T3 (the 600:600-ohm telephone-coupling transformer). When one party

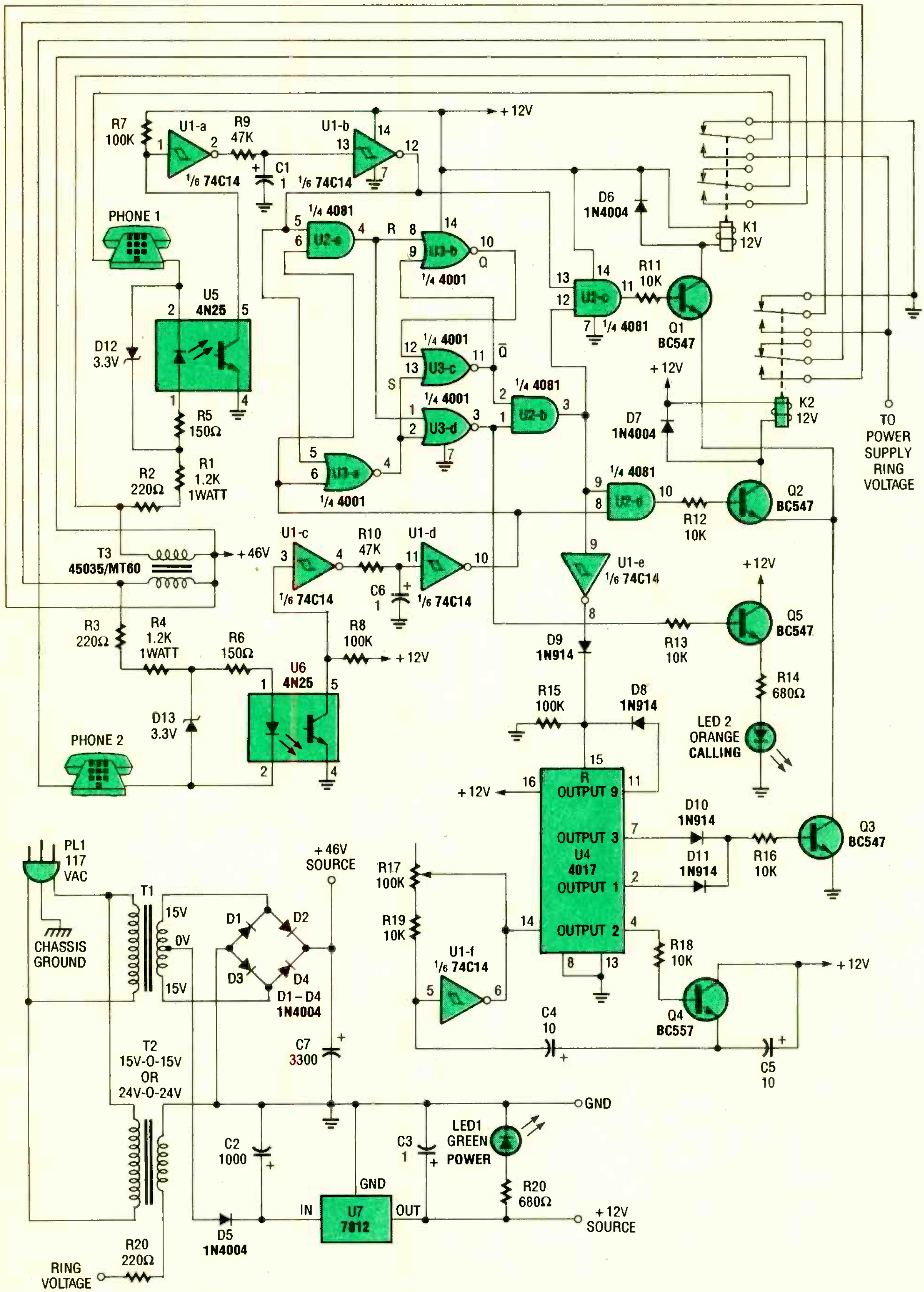


Fig. 2. The complete schematic diagram for the Telephone Intercom is shown here.

subsequently replaces the handset, pin 3 of U3-d goes high and attempts to ring the idle phone. Ringing will not proceed, however, because $\bar{Q}$ output of the flip-flop is set (low), thus depriving U2-b of the required logic high.

The flip-flop remains set until both handsets are replaced and U2-a resets the logic to its standby state. The Intercom is then ready for another call attempt.

Ring Sequence. The ring cadence can be easily customized to suit your application. This circuit was originally designed for use in Australia. There the standard ring has the following pattern: 400 ms on, 200 ms off, 400 ms on, 2 s off, and then repeats. To generate that sequence, we would normally require a 200-ms clock period and a counter with 15 outputs (*i.e.*, we would have to use two counter IC's in cascade). Another way is to use a single standard decade counter, the 4017, and add logic to make it suit the application.

In this circuit, U4 is fed from a 2.5-Hz clock (U1-f) which provides a period of 400-ms per step. However, as the output corresponding to the 200-ms off period goes high (output 2 at pin 4), the clock is doubled in speed to give the required 200-ms period. This is easily accomplished using PNP transistor Q4, which has a 10-µF capacitor (C5) wired between its emitter and collector.

In operation, Q4 is normally conducting and C5 is short circuited. However, when pin 4 of U4 goes high, it turns off Q4, placing C5 in series with C4 (another 10-µF capacitor in the clock's timing circuit).

Because the two capacitors are in series and of the same value, the total capacitance seen by U1-f is now halved. The clock, therefore, doubles its frequency, giving one 200-ms burst to step the counter past output 2. When output 3 (U4 pin 7) goes high, Q4 again turns on, and the clock reverts to its 400-ms period. Diode D8 resets the counter when pin 11 of U4 goes high to limit the off period to 2 s following the second 400-ms ring. The ring sequence is then repeated.

Although Fig. 2 shows the circuit arrangement for the Australian ring standard, you can easily customize the ring signal to suit your own requirements. For example, the clock fre-

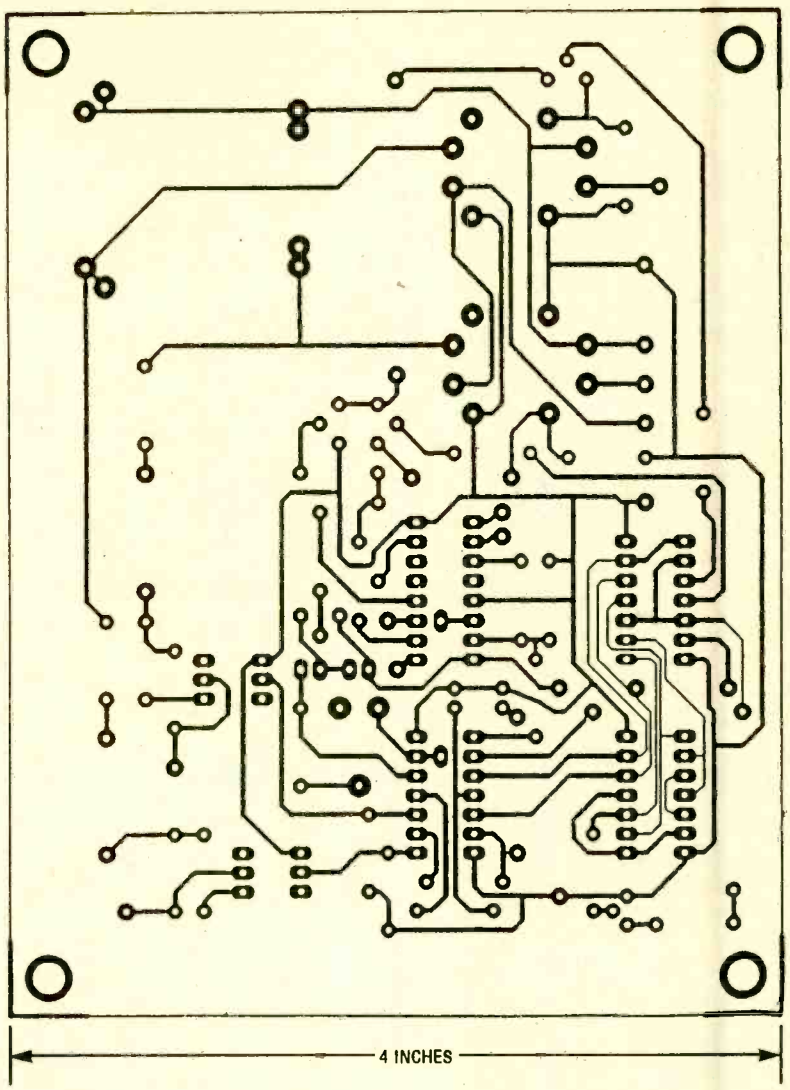
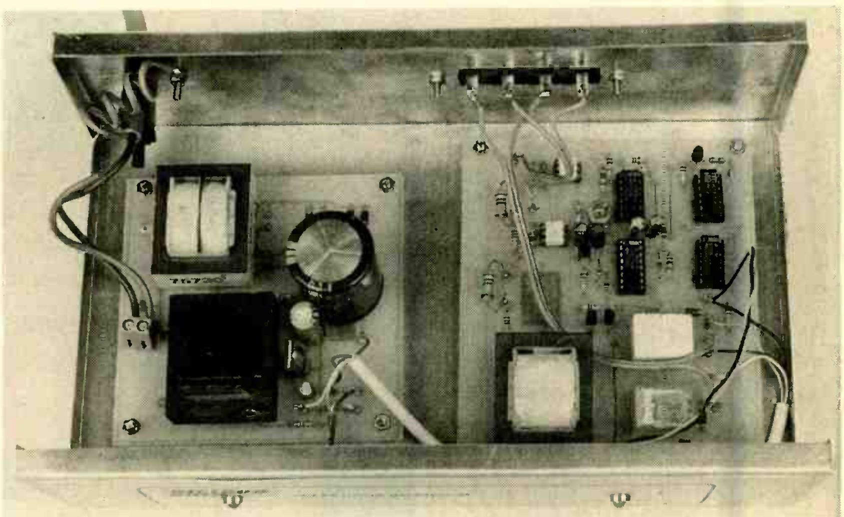


Fig. 3. Here is the full-size printed-circuit pattern for the Telephone Intercom's logic-circuit board.



The two printed-circuit boards are housed in a metal case. The boards are mounted in the case on 1/4-inch spacers and secured in place with machine screws and nuts. The screw terminals on the rear panel provide the connections for the lines to each telephone.

PARTS LIST FOR THE TELEPHONE INTERCOM

SEMICONDUCTORS

U1—74C14/40106 hex inverting Schmitt trigger, integrated circuit
U2—4081B quad two-input AND gate, integrated circuit
U3—4001B quad two-input NOR gate, integrated circuit
U4—4017B decade counter, integrated circuit
U5, U6—4N25 optoisolator/coupler, integrated circuit
Q1–Q3, Q5—BC547, ECG123AP, or similar general-purpose NPN silicon transistors
Q4—BC557, ECG159, or similar, general-purpose PNP silicon transistor
D1–D7—1N4004 1-amp, 400-PIV silicon rectifier diode
D8–D11—1N914 or 1N4148 general-purpose small-signal silicon diode
D12, D13—3.3-volt, 1-watt Zener diode
LED1—5mm green light-emitting diode
LED2—5mm orange light-emitting diode

RESISTORS

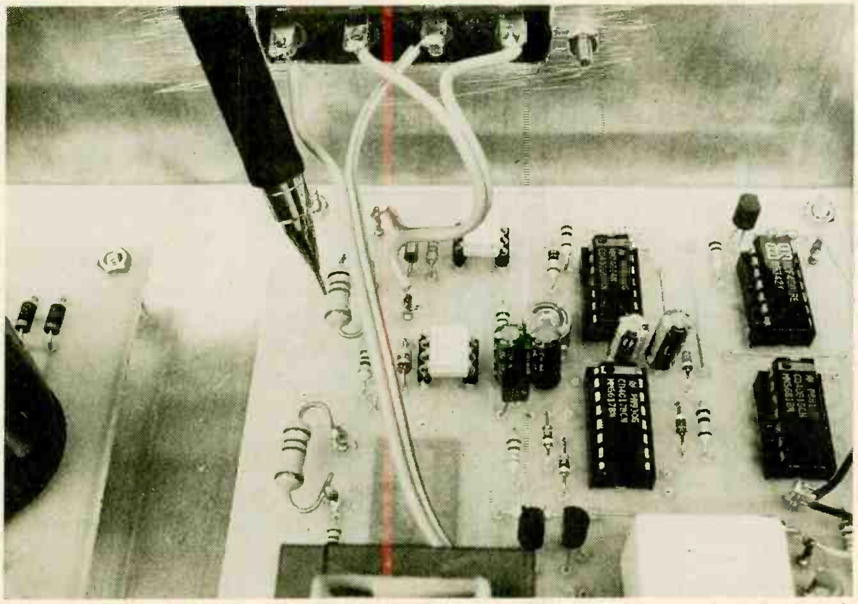
(All fixed resistors are ½-watt, 1% units, unless otherwise noted.)
R1, R4—1200-ohm, 1-watt
R2, R3, R20—220-ohm
R5, R6—150-ohm
R7, R8, R15—100,000-ohm
R9, R10—47,000-ohm
R11–R13, R16, R18, R19—10,000-ohm
R14, R20—680-ohm
R17—100,000-ohm, horizontal trimmer potentiometer

CAPACITORS

C1, C3, C6—1-µF, 25-WVDC, electrolytic
C2—1000-µF, 35-WVDC, electrolytic
C4, C5—10-µF, 25-WVDC, electrolytic
C7—3300-µF, 63-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

T1—30-volt center-tapped, 250-mA, PC-mount transformer
T2—30- or 48-volt, center-tapped, 250-mA, PC-mount transformer (see text)
T3—600:600-ohm telephone coupling transformer
K1, K2—12-volt DPDT relay
Printed-circuit materials, two telephones (see text), metal enclosure (see text), 3-terminal molded AC power plug with line cord, LED bezels, quad telephone-station cable, printed-circuit wiring pins, wire, solder, hardware, etc.



Note that R1 and R4 (the two 1.2k, 1-watt, loop-current limiting resistors) are mounted on PC-board wiring pins; that's done to make it easier to replace them should it be necessary to reduce their value for telephone lines of considerable length. Generally, you should aim for loop currents of 10–25mA. You can check that current by connecting your multimeter across each telephone while it is on-hook.

quency can be adjusted over a wide range via R17, or the ringing sequence can be changed by using different counter outputs. If you don't desire any "ring-ring" cadence, omit Q4 and replace C5 with a jumper.

Construction. Building the Telephone Intercom is straightforward, with most of the parts mounted on two printed-circuit boards. One board contains all the logic circuitry (see Fig. 3), while the second board (shown in Fig. 4) carries the power-supply components.

Editor's note: This project was originally designed in Australia. The boards were designed to accommodate components commonly available there. While identical or similar components are also commonly available here, in some cases—particularly the transformers and relays—pinouts and mechanical dimensions may vary. To accommodate domestic components, the board design may need to be modified somewhat. Alternately, those components can be mounted off-board and connections made via jumpers.

Etch the boards using any standard technique. Once the boards are dry, check them for damaged, missing, or incomplete traces. If all's well, drill the boards, making sure that the mounting holes for the large-lead components (transformers, capacitors, relays, etc.), are large enough.

Figures 5 and 6 are the parts-placement diagrams for the logic and power-supply boards (Figs. 3 and 4), respectively. Starting with the power-supply, begin construction by installing printed-circuit wiring pins at all external wiring points on the board, then install U7 (the 12-volt regulator), the capacitors (C2, C3, and C7), and the transformers (T1 and T2).

Moving to the logic board, install the five jumper wires before mounting any of the other parts (one jumper runs beneath two IC's). Once the jumpers are installed, install printed-circuit wiring pins at the external wiring points and install the remaining parts as shown, leaving the relays and transformer until last. It is recommended that sockets be provided for all of the DIP IC's. You should also install printed-circuit wiring pins at the mounting points for the two 1.2k cur-al case measuring approximately

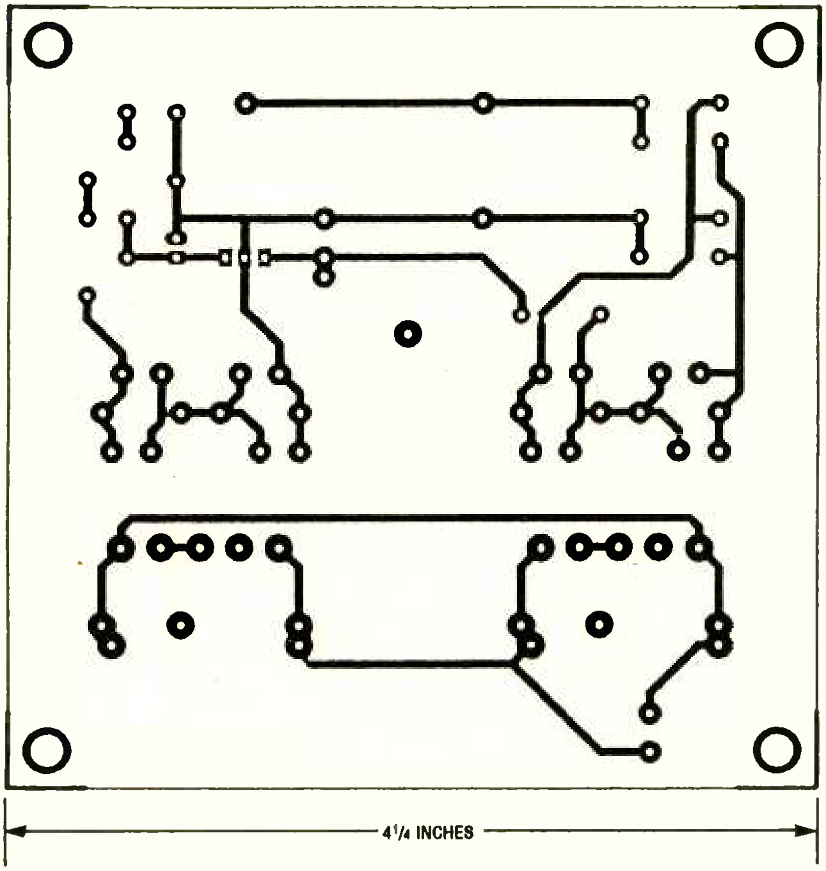


Fig. 4. The printed-circuit pattern for the intercom's power-supply board is shown here full size.

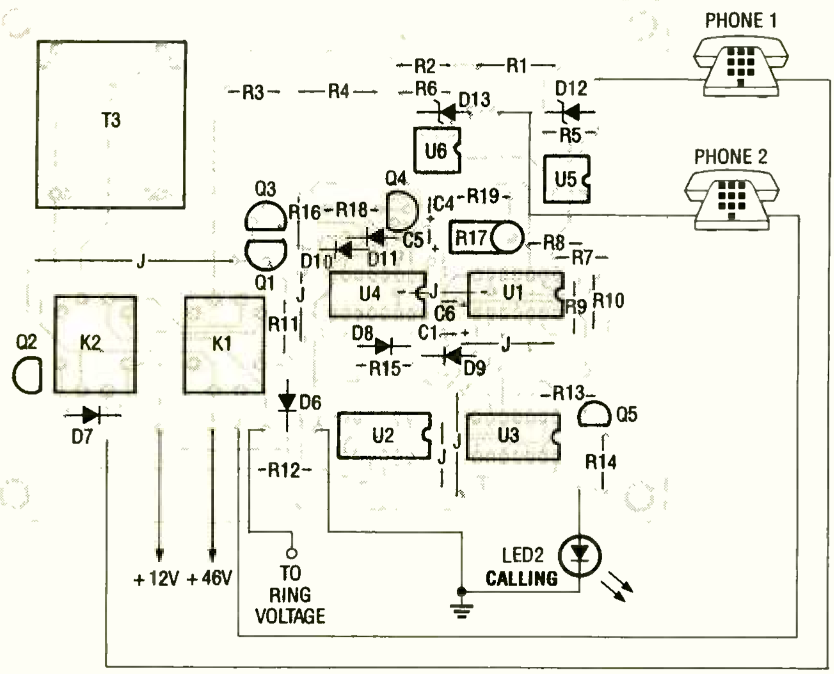


Fig. 5. This diagram shows the parts-placement and orientation for the Intercom's logic circuit board. Note that the two 1.2k, 1-watt current-limiting resistors (R1 and R4) are soldered to PC-board wiring pins (see text).

rent-limiting resistors, R1 and R4, since their values may have to be adjusted when the circuit is operational.

The prototype was housed in a metal 10¼ × 3⅛ × 6¼ inches. Begin preparing the enclosure by drilling mounting holes in the front panel for the two LED's; then drill the rear panel to accept the AC line-cord and its strain relief, a grounding-lug mounting screw, and the screw terminals for the telephone lines.

The two printed-circuit boards can be used as templates to mark out their mounting holes on the bottom of the case. Once all of the necessary holes have been drilled, secure the line cord to the case using the strain relief, and solder the hot and neutral leads to the power-supply board.

The ground lead is connected to the grounding lug on the rear panel. That lead should be made longer than the hot and neutral leads, so that it will be the last to break if the strain relief comes loose. Once the line-cord wiring has been completed, mount the two boards in the case on ¼-inch standoffs and secure them using screws, nuts, and star washers. The remainder of the wiring can now be completed as shown in Figs. 5 and 6. That includes a 4-wire connection between the two boards, plus wiring from the logic board to the front and rear panels. Quad-conductor telephone-station wire can be used to interconnect the two circuit boards.

Testing. Before applying power, go over the project carefully, checking for wiring errors; in particular, check that all parts are correctly oriented and that the line cord is held securely in place by the strain relief. If all seems well, switch on the power and check the supply voltages.

The output of U7 (the 12-volt regulator) should be at +12 volts, as should pin 14 of U1, U2, and U3, and pin 16 of U4. The positive terminal of C7 (the 3300-µF filter capacitor) should be at about +46 volts. Exercise caution when making these measurements, as line voltages are present on the underside of the power-supply board.

Assuming that the supply voltages check out, short pins 4 and 5 of one of the optoisolators (U5 and U6). One of ring relays should now begin operating, following the programmed ring sequence.

Trimmer potentiometer R17 can now be adjusted to give the correct

(Continued on page 89)

A NON-SERIOUS CIRCUIT

BY D. DEREK VERNER

Is it a parallel circuit or is it a series circuit? You'll have loads of fun watching your friends try to figure it out for themselves.

Every reader of this magazine is familiar with the difference between a parallel circuit and a series circuit. The parallel circuit shown in Fig. 1A allows independent control over each lamp: S1 turns I1 on or off independent of S2, while S2 operates I2 without regard to the position of S1. In the series circuit shown in Fig. 1B both switches must be closed in order to light the lamps, and if either is opened, both lamps go out. There is no independent control of the lamps.

That's where the Non-Serious Circuit comes in. The unit consists of two color-coded switches (one yellow, one red), and two bulbs of corresponding color. Since the components and wiring are clearly visible through the clear plastic box they are in, you can see that the switches and lamps are wired in series.

However, if you plug the unit in and flip a switch, only its like-colored lamp is affected! Flip the other switch and the other lamp goes off. At this point you'd be wondering what's going on here? As an experiment you might try switching the bulbs, but to no avail; the red switch still operates the red bulb, and the yellow switch controls the yellow bulb.

Very astute readers may have already figured out the circuit. If you haven't yet, don't feel too bad, this circuit has been known to confuse and mystify electronically sophisticated engineers. I built the first version of it when my son was studying parallel and series circuits in a technology class in junior high school. He brought it into class and asked his teacher why it didn't work properly. Believe me, the teacher almost went crazy trying to explain it. The secret is that each lamp and switch contains a concealed component.

How it Works. As can be seen in Fig. 2, the concealed components are rectifier diodes connected as shown. With both switches open there can be no current flow because the diodes wired across them block current in both directions.

Let's suppose we close S1. Let's also assume that during the first half-cycle of the power line's waveform current flows in a clockwise direction around the circuit. At I1 the current encounters D1, which blocks it so it travels through the lamp (I1) instead, lighting it (at half power). Next the current approaches I2, where D2 effectively shorts out the lamp. At S2 the current passes readily through D4 and on through S1, which is closed.

On the next half cycle when the current attempts to travel counterclockwise through the circuit it is simply blocked by D4. The overall effect is that lamp I1 appears lit and I2 is out. When S2 is closed as well, the current is AC and each lamp lights during the appropiate half cycle.

Parts Selection. You probably have all the parts necessary to build the Non-Serious Circuit in your junkbox. Any clear plastic box large enough to house the components will serve for the enclosure. The lamps can be any low-wattage AC bulbs with an intermediate-size brass base. Most American-made bulbs these days are made with aluminum bases that are not suitable for this project because it is hard to solder to the shell. If you use Christmas-tree bulbs, as I did, choose red and yellow ones as they light with more apparent brightness than blue or green when fed half-wave AC.

Although your hardware store probably also stocks a large selection of intermediate-size lamp sockets, the best choice is the brass shell removed from a composition-type Christmas-light string. That is because the shells cannot be "gimmicked" in any way that wouldn't be readily apparent.

The toggle switches must be of a type that can be easily disassembled. The ones shown are held together with two small screws. Although no-longer listed in their current catalog, it might be possible that your local Radio Shack has them still on the shelf as item 275-602 or in their toggle-switch assortment as item 275-322. However, any SPST switch that can be neatly disassembled and re-assembled will do.

The diodes can be 1N4002's or any

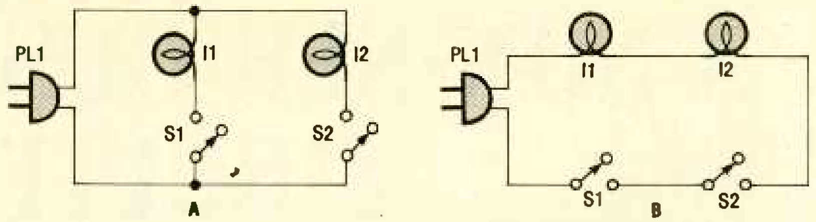


Fig. 1. The operation of a normal parallel circuit (A) or straightforward series circuit (B) is easy to figure out if you have a little knowledge of electronics.

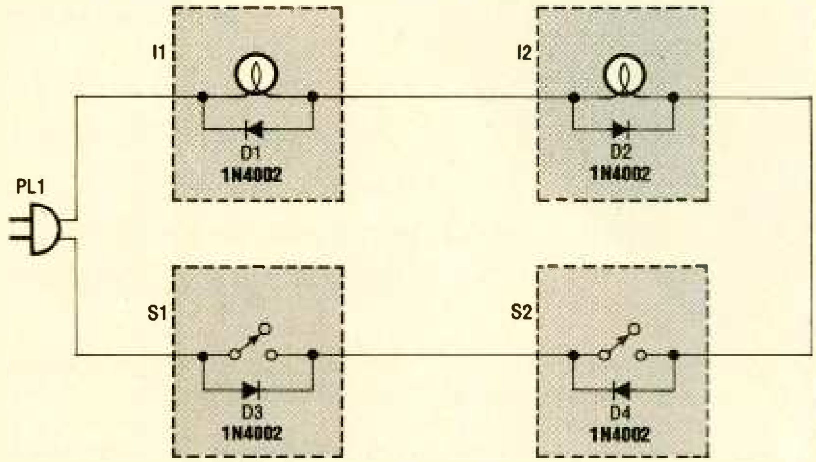
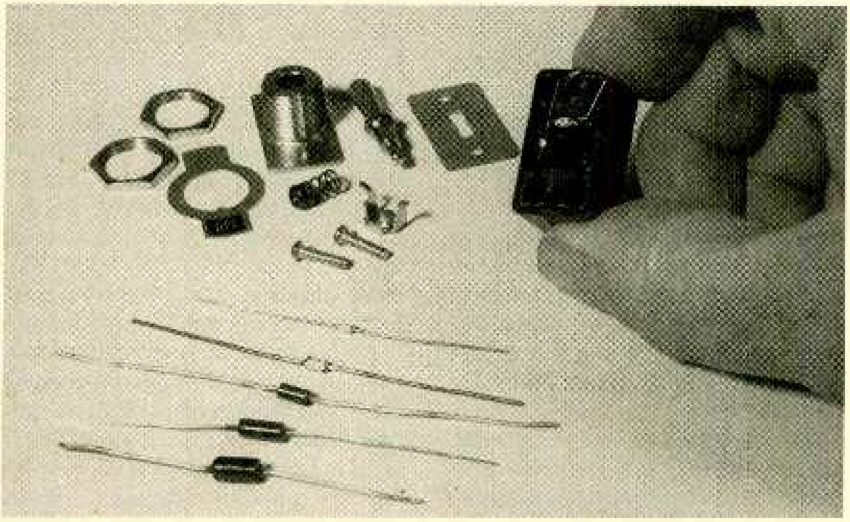


Fig. 2. This is the Non-Serious Circuit. If you follow each alternation of the AC line current around the loop for various settings of S1 and S2 you'll soon see how confusing the circuit would appear to the unsuspecting.


The diodes in the foreground are all capable of handling at least 1 amp at a peak reverse voltage of 100 volts. The smaller ones are easier to conceal inside the switch housing as shown.

others rated at least 1 amp at 100 PIV. These are generally available in the DO-14 size, which is less than a quarter-inch long. The smaller size makes it easier to conceal the diodes in the switches and lamp bases.

If you opt for the brass shells from some Christmas lights, you will have to devise a way to mount them so that the shell is not exposed (presenting a shock hazard). I epoxied mine into suitably countersunk holes in a small strip of acrylic plastic mounted inside the box by means of 6-32 screws. Slightly smaller holes in the top of the box allow the bulbs to be inserted, but prevent the shells from protruding outside the box.

To remove the bases from the lamps, you will need a propane torch and a pair of gas pliers. Wrap the bulb in a cloth with the base exposed and put on a pair of goggles. (Although I have never had a bulb break during this operation, it is always better to be safe than sorry.) Heat the base of the lamp in the flame of the torch, and with the pliers keep testing the bond by twisting it slightly. It shouldn't take much heat before the base loosens. As soon as it is free, turn off the torch and set the bulb down to cool. If the base and the bulb are still connected by wires soldered to the center contact and to the shell, carefully unsolder the connections.

With a penknife, scrape out the remnants of the composition material from the base of the lamp and from the interior of the shell. The material is brittle and can be easily removed. Clean the two exposed copper wires carefully by scraping or using fine sandpaper. Tinning the wires will make the next operation easier.

Clip the cathode lead of the diode (usually marked with a band), leaving about ¼ inch of lead. Wrap one of the wires from the lamp around the shortened lead close to the body of the component. Also wrap the lead with a short length of bare, tinned, solid hookup wire. Using a heat sink on the diode, solder the connection. Insert the stubby length of lead into the space between the evacuation tube and the remainder of the bulb. Take care not to fracture the fragile glass evacuation tube. Slip a small piece of spaghetti over the other wire from the lamp and solder it to the anode of the diode.

Examine the brass shell and locate the point on its rim where the wire was previously soldered. File a small notch in the rim large enough to clear the piece of hook-up wire installed in the previous step. Check the center con-

(Continued on page 93)

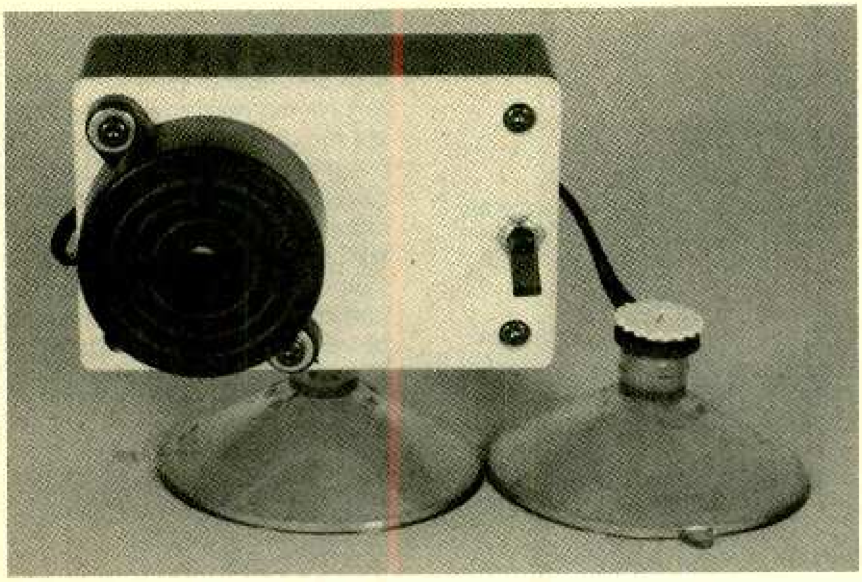
PARTS LIST FOR THE NON-SERIOUS CIRCUIT

SEMICONDUCTORS

D1–D4—1N4002 1-amp, 100-PIV, rectifying diode (see text)

ADDITIONAL PARTS AND MATERIALS

I1, I2—Christmas-light bulb
S1, S2—SPST power switch (see text)
PL1—AC linecord and plug
Clear-plastic case, two Christmas-light sockets, wire, solder, etc.



Build a Water-Level Alert

BY JOHN YACONO AND MARC SPIWAK

This neat little water-level alarm will prevent expensive water damage to your home, and also relieve you from having to mop up the floor when a bathtub overflows.

Filling up a nice hot bath and then soaking in it is something that many people look forward to, particularly after a hard day's work (is there any other kind?). However, mopping the floor after the bathtub has overflowed because you were on the phone or watching television at the time is something that most people would rather avoid. Our *Little Dipper* bathtub water-level monitor described in this article will help prevent you from ever having to mop up the bathroom floor.

Even if you are the type of person who has never let the tub overflow, the Little Dipper might still be for you. That's because you will no longer have to stand by the tub and watch it fill or keep running in and out to check the water level; you are free to do other things until you hear the buzzer. Of course, the Little Dipper can be used to monitor any water level—not just your bathtub. If, for instance, you have problems with water getting into your basement, you can set up a Little Dipper in the lower confines, and be notified the instant that water seeps in. We'll talk more about that kind of application later.

The Circuit. The Little Dipper circuit is pretty easy to understand, and even modify. The circuit (shown in Fig. 1) can be divided into two parts: an annunciator and a water detector. The water detector for the version shown has both a normal-sensitivity input, which is good for most applications, and a high-gain input.

The high-gain input can be useful for testing fluids with a very high resistivity, such as very pure water. Furthermore, it may be necessary to use the high-gain input if the 2N3904 NPN transistors that you use have a low gain: the H_{FE} (gain) of some 2N3904's can be below 100. The high-gain input overcomes the problems caused by weak transistors by combining Q1 and Q2 to form what is called a Darlington pair. Transistors connected in that configuration form a circuit with a gain that is the product of their individual gains. Typically, the gain of a 2N3904 ranges between 100 and 300, so the gain for the Darlington pair can range from 10,000 to 90,000; consequently, the overall gain will be more than adequate even if the gain of the two individual transistors falls below 100.

It's a good idea to test the effeciveness of both inputs to determine what you need for your particular application. If you decide to use the high-gain input, be sure to separate the probe leads—do not use twisted pair. If the gap between the input terminals that you use is bridged by fluid, the slight amount of current that flows through it will be greatly amplified. So Q1 will allow plenty of current to flow to the gate of the SCR to turn it on.

When the SCR turns on, it grounds the annunciator circuit, turning it on. Resistor R6 provides enough current to latch the SCR on when it is triggered. If you don't want the circuit to latch (for applications such as level detection), leave that resistor out. You may wish to place an SPST switch in series with the resistor so that you can enable the latching operation whenever desired.

The rest of the circuit is the annunciator, which was built from discrete components rather than an all-in-one buzzer for a couple of reasons. Buzzers tend to draw a lot of current. Using a buzzer would prevent the circuit from providing an unlatched mode of operation and tend to reduce battery life. The annunciator is built around a 555 timer set up as an oscillator. The IC drives a piezoelectric crystal at around 2 kHz to produce an alarming sound that can easily be heard from another room.

Construction. The Little Dipper circuit was built on a piece of perfboard using point-to-point wiring. You can follow Fig. 1 as a wiring guide. Some

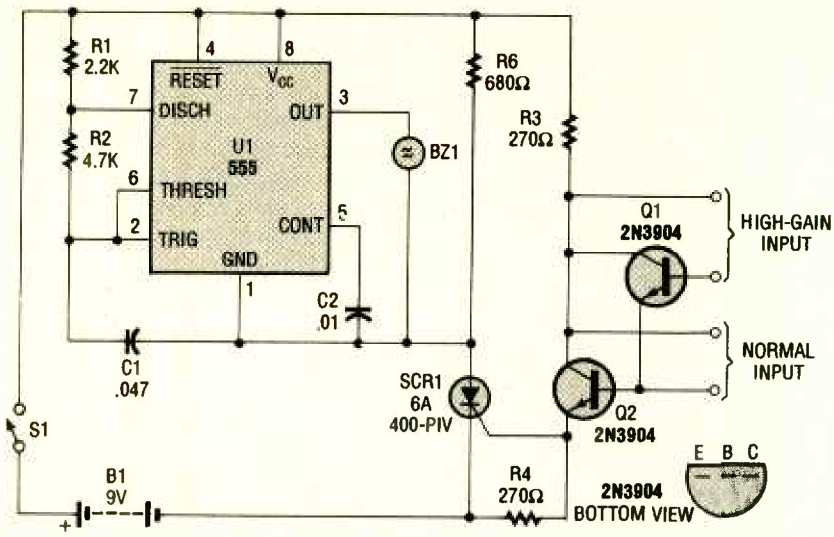


Fig. 1. The circuit can be broken down into two main portions: an annunciator and a water detector. The water detector has two inputs and the annunciator is made of discrete components and a 555 timer.

careful planning allowed the board, a 9-volt battery, and switch to fit inside a very small project case.

A suction cup was attached to the bottom of the unit to allow it to be secured on a corner of the tub away from the water. As mentioned before, the unit can be built using one or two transistors, depending on the sensitivity required. We included both transistors in the prototype, and then simply attached one of the probes to the base of the transistor that gave us the desired sensitivity, although we can easily change that selection at any time.

The 9-volt battery did present a problem. Because we wanted to use a project case that was already on hand, the battery had to fit in the case. By itself, the battery was no problem, but when the battery clip was attached it wouldn't fit in the case. So we simply drilled out the rivets that hold the two metal connectors onto the battery clip, and soldered leads directly to the sides of the connectors. That gave us approximately an ⅛-inch of additional space to play with, and the battery then fit in the case perfectly. It's a neat trick should you ever require that extra bit of space to fit a 9-volt battery.

Since we used the less sensitive input, a length of twin-lead wire connects the circuit board to the water probe, which is nothing more than two metal washers soldered to the ends of the wires and separated by an insulating washer. The three washers are secured to a suction cup with a plastic fastener. That allows the probe to be set at any convenient level in the bathtub, regardless of whether the tub is cast iron, fiberglass, etc.

We left the piezoelectric buzzer's crystal inside its resonating chamber and mounted the chamber on the cover of the project case. The chamber focuses the crystal's sound waves to make them much more audible from a distance.

PARTS LIST FOR THE LITTLE DIPPER

SEMICONDUCTORS

U1—555 oscillator/timer, integrated circuit
Q1, Q2—2N3904 general-purpose, small-signal, NPN silicon transistor
SCR1—6-amp, 400-PIV, silicon-controlled rectifier (Radio Shack 276-1067 or equivalent)

RESISTORS

(All resistors are ¼-watt 5% units.)
R1—2200-ohm
R2—4700-ohm
R3, R4—270-ohm
R5—680-ohm

ADDITIONAL PARTS AND MATERIALS

B1—9-volt, transistor-radio battery
BZ1—Piezoelectric element
C1—0.047-µF ceramic-disc capacitor
C2—0.01-µF ceramic-disc capacitor
S1—SPST toggle switch
Perfboard, battery clip, suction cups, washers, case and hardware, wire-wrap materials, etc.

Modifications. There are a couple of things that you might want to change, depending on your application. For example, if you are going to use the Little Dipper to monitor your basement for puddles, it's probably going to be on a permanent basis. In that case, you'll want to power the unit from an AC supply so that it can remain on at all times without fear of the battery dying. Just make sure that the power supply is not in danger of getting wet itself, and that the water probe lies flat on the floor.

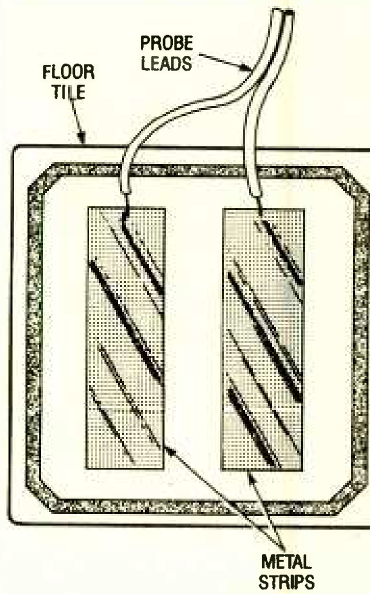


Fig. 2. A probe made from two metal strips mounted to the floor itself would be well suited as a puddle probe.

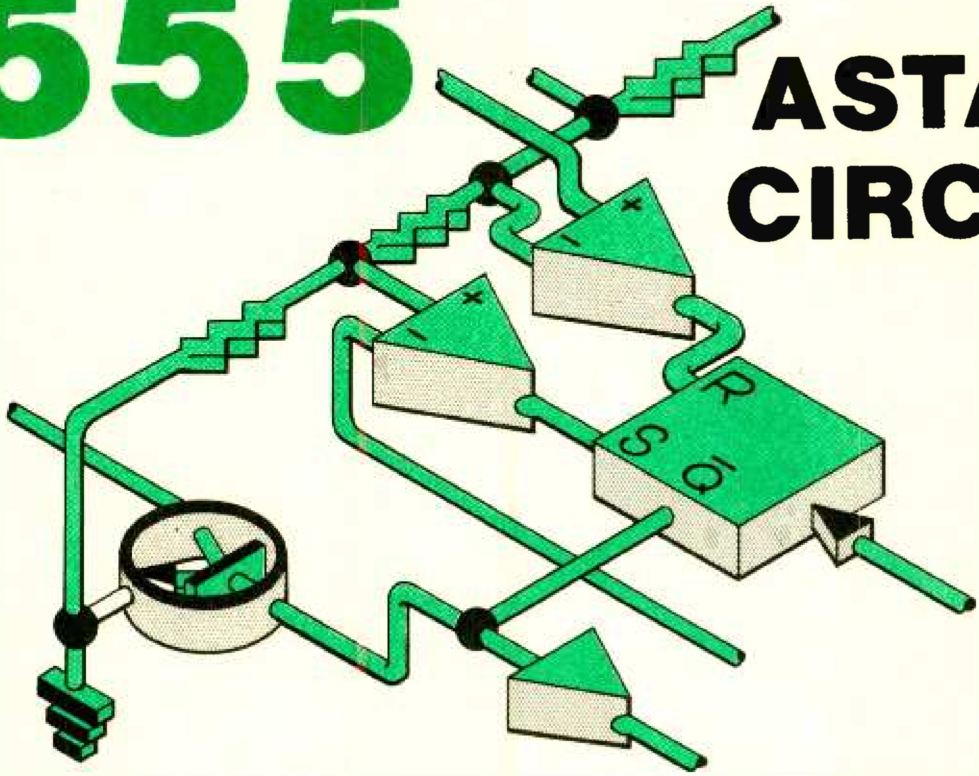
While the probe that we used for the prototype is best suited for bathtub monitoring, a better design for a puddle probe is shown in Fig. 2. The idea is to sense the puddle before it gets out of hand. Mount the metal strips directly on the floor and connect the circuit's probe leads to the strips.

Another potential problem with using the Little Dipper in a basement is that you may not hear the buzzer, depending on how far you are from it. If you'll be too far away to hear the alarm, it might be better if you run leads from the circuit to a buzzer located near you.

There's one other thing that you might want to do. With your own modifications to the circuit (wiring the output to a relay, etc.), you could actually

(Continued on page 92)

555 ASTABLE CIRCUITS



We explore how to use the popular 555 timer IC in practical oscillator applications.

BY RAY MARSTON

One of the most celebrated chips on the market is the 555 timer. Its simplicity and versatility have secured its success in industrial and hobbyist applications. Let's take a look at the 555 and discuss how to use it in practical astable (oscillator) circuits.

555 Astable Basics. The 555 timer IC can be easily used as the basis for an astable multivibrator or square-wave generator. Figure 1 shows a block diagram of the IC and the external connections needed to make it act in that manner. Note that the trigger input (pin 2) is shorted to the threshold terminal (pin 6), and that timing resistor R2 is wired between pin 6 and pin 7 (the discharge terminal).

When power is initially applied to this circuit, C1 is initially uncharged, so the IC's trigger input is low, which sets the output (pin 3) high and simultaneously switches Q1 off. Under this condition, C1 starts to charge exponentially towards the supply-rail voltage (V_{CC}) via R1 and R2. Eventually the voltage across C1 rises to ⅔'s of V_{CC}, at which point the IC's built-in threshold-voltage comparator activates and changes the state of the internal flip-flop, causing the pin 3 output to go low and Q1 to turn on.

That completes the astable's power-up cycle; all subsequent cycles may be regarded as oscillations, which occur as follows: As Q1 turns on at the end of the power-on cycle, it pulls discharge pin 7 low and starts to exponentially discharge C1 via R2 until the voltage across C1 falls to ⅓ of V_{CC}, at which point the trigger-voltage comparator toggles the internal flip-flop. That turns Q1 off again, causing C1 to charge exponentially via R1 and R2 until the voltage across C1 again rises to ⅔'s of V_{CC}, at which point Q1 turns on again, etc. This timing sequence then repeats *ad infinitum*, with C1 alternately charging via R1 and R2, and discharging via R2.

Regarding the circuit's actual timing, the period of the initial power-up pulse is:

$$1.1(R1+R2)C1$$

but on all subsequent cycles the high period (t1) will be:

$$t1=0.7(R1+R2)C1$$

and the low period (t2) will be:

$$t2=0.7R2C1$$

Note that (ignoring the power-up cycle) if R2 is very large relative to R1, the operating frequency is more or less set by R2 and C1. Also, the output will be an almost symmetrical square-wave and a near-linear triangle wave will appear across C1.

Figure 2 shows a practical version of the basic astable circuit together with its waveforms (after the power-up cycle). By the way, C2 is used to enhance the stability of the circuit which, with the component values shown, operates at about 1 kHz.

In practice, the values of R1 and R2 can be varied from 1k to several megohms; however, note that R1 greatly affects the circuit's current consumption since it is grounded via pin 7 during a portion of each cycle. Also note that the waveform's duty cycle can be tailored for an application by choosing suitable values for R1 and R2.

The circuit in Fig. 2 can be made more versatile by replacing R2 with a 10k resistor and a 100k potentiometer wired in series. Then the potentiometer can be used to vary the frequency from 650 Hz to 7.2 kHz. The frequency span can be further increased by selecting alternative values of C1 (perhaps via a multipole switch); the frequency range can be reduced by a decade by increasing C1's value by a factor of ten, and vice versa.

Duty-Cycle Control. As mentioned

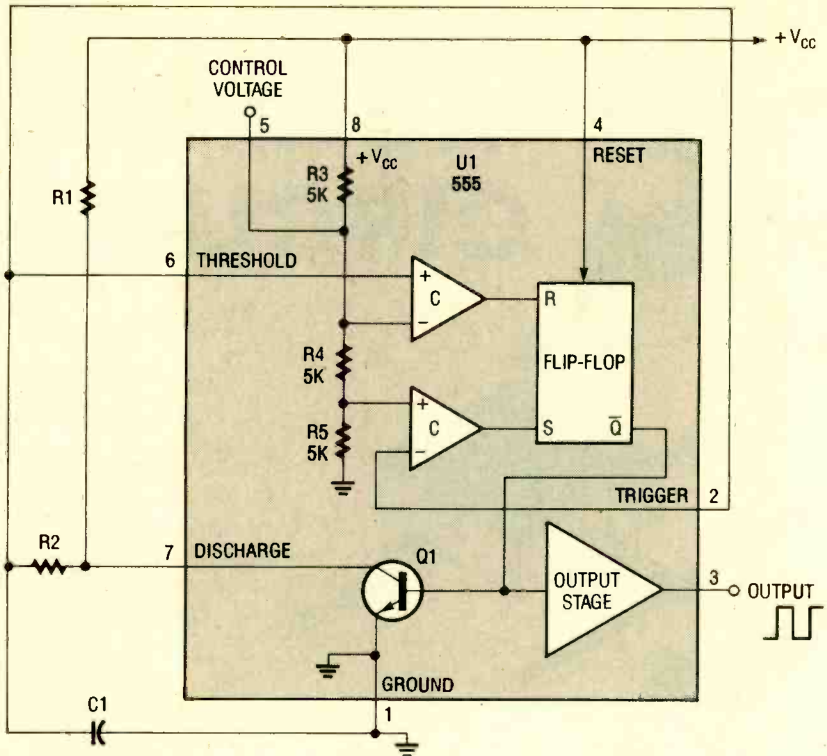
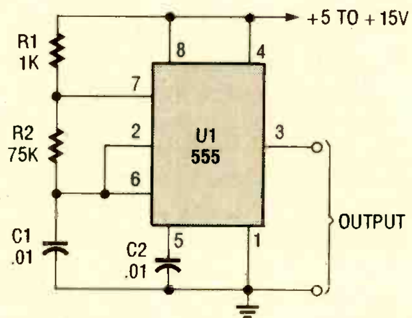


Fig. 1. This is a block diagram of the 555 IC, together with the external components necessary to use it as an astable multivibrator.



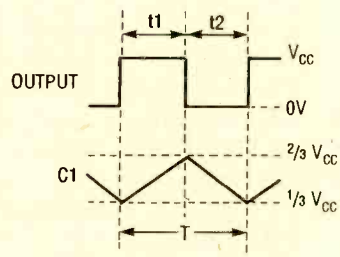


Fig. 2. This basic 1-kHz 555 astable multivibrator is free-running; once power is applied, it will oscillate.

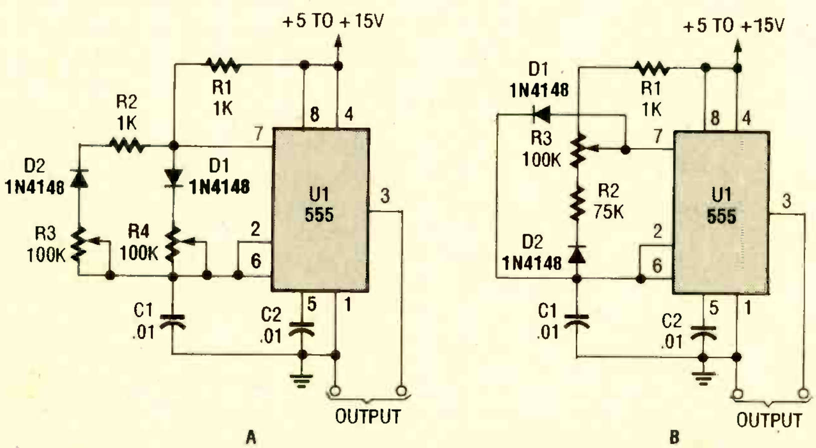


Fig. 3. The oscillator in A has been configured so its high and low periods are independently variable from 7µs to 750µs. The one in B is a 1.2-kHz unit with a duty cycle variable from 1% to 99%.

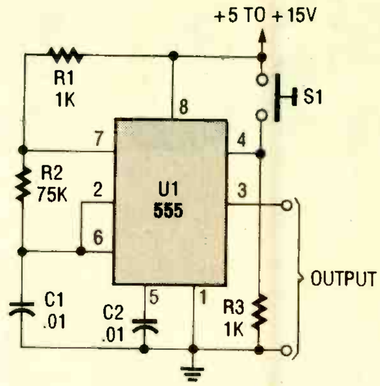


Fig. 4. This gated 1-kHz astable multivibrator permits press-to-turn-on operation.

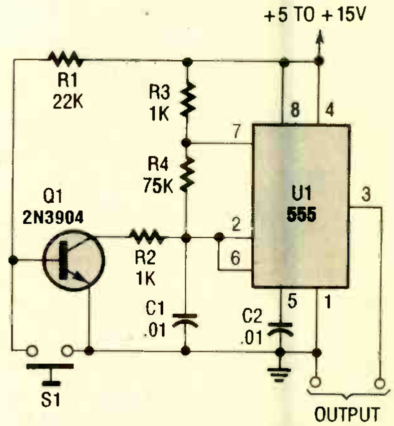


Fig. 5. Alternative gated 1-kHz astable with 'press-to turn-on' operation.

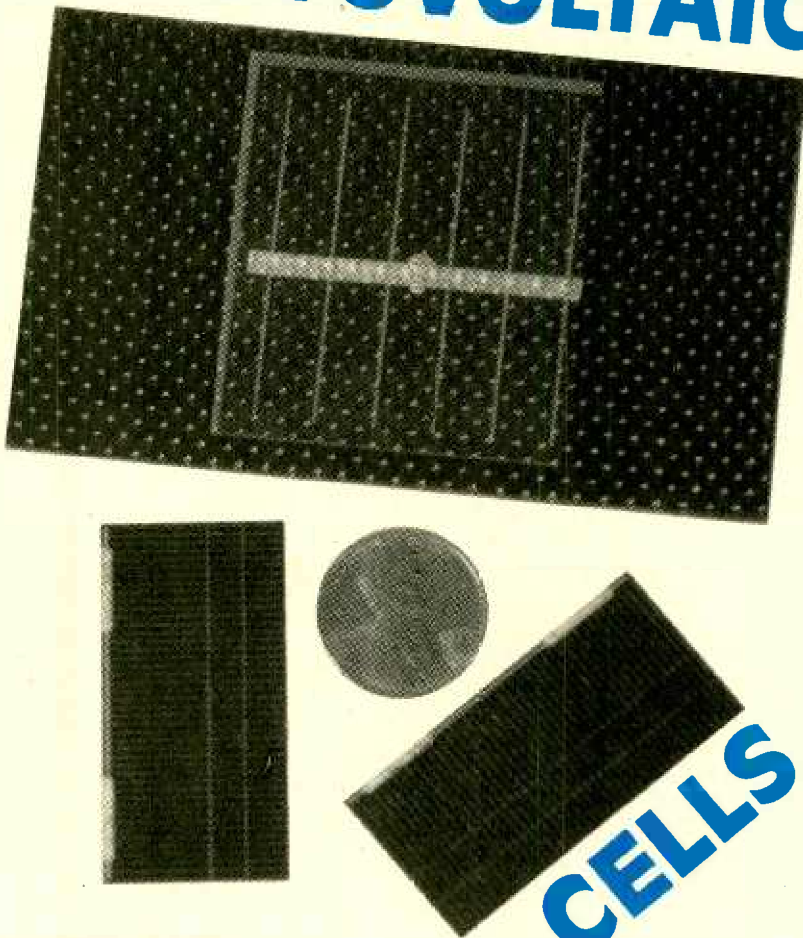
earlier the duty cycle of the circuit in Fig. 1 depends on the values of R1 and R2. Figures 3A and 3B show practical ways of making the duty cycle fully variable with the aid of steering diodes that automatically select alternate charge and discharge paths for C1.

The Fig. 3A circuit gives independent control of both the high and low periods. There, C1 charges via R1, R4, and D1, and discharges via R2, R3, and D2. The potentiometer values shown allow the high and low periods to to be varied over a 100:1 range (from 7µs to 750 µs). Keep in mind that the output frequency must vary as the high or low times are altered.

Figure 3B shows a way of altering the M/S ratio without significantly altering the circuit's operating frequency. There, the high period increases as the low period decreases, and vice versa, so the total period of each cycle (and thus the frequency) is constant. The most important feature of

(Continued on page 91)

All About PHOTOVOLTAIC CELLS



BY JOSEPH J. CARR

Learn about photovoltaic cells and how you can better use them in your projects.

Although it may not be readily apparent from their limited use, photovoltaic cells can fill a large number of modern-day needs. For example, one fellow that I met at a hamfest served in a missionary medical unit in the Sudanese desert. He told me that they charge automobile batteries from solar-cells for their communications equipment and, he averred, "that comm equipment was vital, we could die without it."

Another chap I know owns a "traditional" sailboat, (*i.e.*, one that has no electrical system. He generates battery power for his radio and navigation equipment using a solar-cell array.

Still another person I know created a small solar-powered three-home cable-TV system in the mountains of southwest Virginia. He needed 90 mA to run a wideband antenna amplifier at the head-end of a 800-foot long coaxial cable. The solution to the power problem was to use a 24-volt DC, 15-ampere-hour, gel-cell battery that is charged with a solar array that can produce nearly 1 ampere of DC when needed. This battery served for several years before needing service! If these examples make solar electric-power generation sound interesting, read on.

A basic Cell. A photovoltaic cell (also called photogalvanic cell or self-generating cell) is a device that generates an electrical potential when illuminated. Thus, if an illuminated photovoltaic cell is connected to a circuit, a current will flow from the cell through the circuit. The solar cell, which is used to generate electrical power, is perhaps the most common (or at least the most widely known) example of the photovoltaic cell. There are also instrumentation photovoltaic cells that are used to measure light levels rather than generate power.

Figure 1 shows three common symbols for the photovoltaic cell. The symbol in Fig. 1A is a standard PN diode symbol, with two arrows indicating light, aiming into it. This symbol is similar to that used for light emitting diodes (LED's), except for the direction of the two parallel arrows (in the LED symbol, the arrows are aimed outward, indicating an emitting device, as opposed to a sensor). It should be mentioned that this symbol typically denotes a "PN-junction" photovoltaic device (which we'll discuss later) in particular.

Another symbol is shown in Fig. 1B. This device is a battery symbol inside of a circle, with the greek letter lambda superimposed to indicate light sensitivity. We here at *Popluar Electronics* use a symbol similar to both, shown in Fig. 1C.

Metal/Semiconductor/Oxide Devices. There are two broad classes of photovoltaic devices. The earliest known group is formed from a metal/semiconductor bond. The other family is actually made up of special diodes.

In a metal/semiconductor device (like that shown in Fig. 2A), a metal disk of copper, gold, or platinum is coated with a layer of copper oxide, which is in turn covered with a semi-transparent layer of semiconductor material. The copper-oxide cell was invented prior to World War I by Bruno Lange, and eventually marketed by Westinghouse under the trade-name "Photox" cell.

A similar photovoltaic cell, made of

selenium, is shown in Fig. 2B. Cells like that were invented in the 1930's, and marketed by Weston Instruments under the trade name "Photronic" cell. In selenium cells, a thin layer of photosensitive selenium is coated onto an iron, steel, or aluminum plate.

In both forms of metal photovoltaic cell, the thin insulator (the copper-oxide or selenium) forms a barrier layer. When light illuminates the barrier layer, the impinging light photons are absorbed, and in the process free electrons are emitted. The existence of free electrons causes a difference of electrical potential to appear across the barrier layer.

As to the cells characteristics, the selenium layer is negative, while the thin metal side is positive. The cells produce an output potential in the range of 0.2- to 0.6-volts DC (0.45-volts DC with 2,000 foot-candles of illumination is a common standard). Photovoltaic cells designed for power applications produce between 20 and 90 milliwatts of DC power per square inch of photoactive surface exposed to light.

The selenium is sensitive to wavelengths from 300 to 700 nm, with its spectral response peaking near 560 nm. As with other sensors, it is common practice to alter the response of a selenium cell with special filters over the transparent window. For most instrumentation purposes, the selenium cell must be loaded with a resistor. Otherwise, it acts in a highly nonlinear manner.

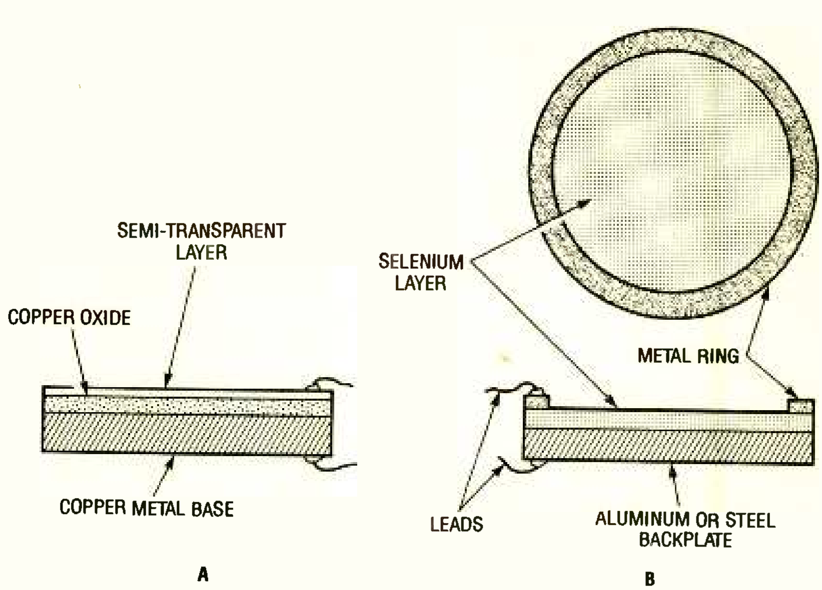


Fig. 2. Note how the oxide of the bottom layer of the metal/semiconductor-type cell in A is used as the middle layer. The selenium cell in B requires no middle layer.

Silicon PN Junctions. Perhaps one of the most successful forms of modern photovoltaic sensors is the PN-junction device. There are two recognized forms of PN photovoltaic sensors: heterojunction and homojunction. A heterojunction device uses two different materials to form a PN junction; an example is germanium/silicon (nGe-pSi) devices. Other types include thin-film pCu2-nCdS, pSi-nCdS, and pGe-nGaP devices. The latter two can be formulated to offer a wide response spectrum of 0.5 to 24μm. Most heterojunction devices were developed for solar power generation, but some are available as light sensors. Homojunction devices use but one type of material, of which the popular nSi-pSi device is an example.

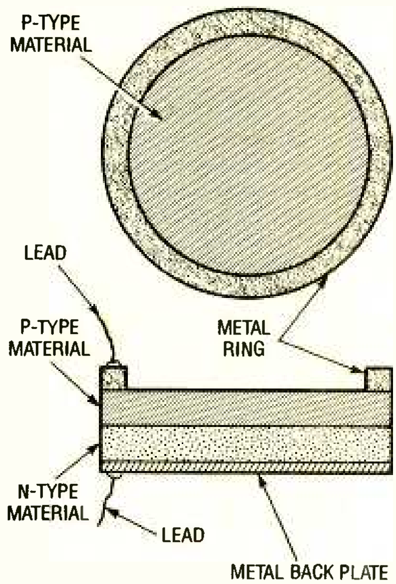


Fig. 3. PN-type cells look like metal/semiconductor cells in structure, but they are based on a standard PN junction.

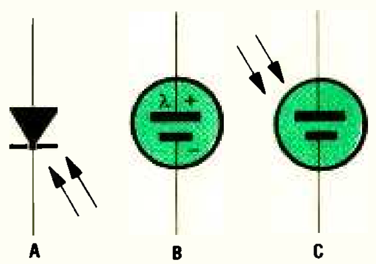


Fig. 1. These cell symbols are for a PN junction device (A), any photovoltaic cell (B), and any photovoltaic cell according to the style of this magazine (C).

The PN-junction photovoltaic cell works because there is an inherent electric field across the PN junction. When photons impinge on the PN junction, electron-hole pairs are created by the photons. The inherent electric field forces the positively charged holes to migrate towards the p-type material, and electrons to migrate to the n-type region. The migration results in an imbalance that creates a potential difference of several hundred millivolts. That potential is the open-circuit (no-load) voltage of the photovoltaic cell.

Figure 3 shows the structure of a silicon photovoltaic cell, which was discovered in 1958 by scientists working at Bell Telephone Laboratories. The silicon cell consists of a PN junction formed of P and N-type silicon. In the P-on-N form shown in Fig. 3A, a thin layer (about 0.5 mm) of arsenic-doped N-type silicon is deposited onto a metallic substrate to form the negative terminal of the cell. A P-type boron-doped layer is diffused into the silicon to form the surface to be exposed to light. The positive electrode is an annular ring deposited onto the exposed surface of the P-type silicon region. These cells output a potential of 0.27 to 0.6 volts under the illumination of 2,000 foot-candles. Response tends to peak at wavelengths around 900 nm.

An N-on-P silicon cell also exists in which a thin layer of phosphorous impurities are diffused into boron-doped p-type silicon. These cells show peak response near 800 nm.

To make a point, the spectral response of a "typical" silicon cell is shown in Fig. 4. Because of its response, the silicon photovoltaic cell is widely used in the visible-light region. The response is usable at ultraviolet wavelengths in the 400 nm range, but the response is quite poor, and exhibits a significant wavelength sensitivity. It peaks above 500 nm, and falls off gently to a wavelength around 900 nm, where it begins dropping off rapidly. As silicon only has a small amount of sensitivity in the near-infrared region, and none at all in the far infrared, different materials must be used for detecting IR wavelengths.

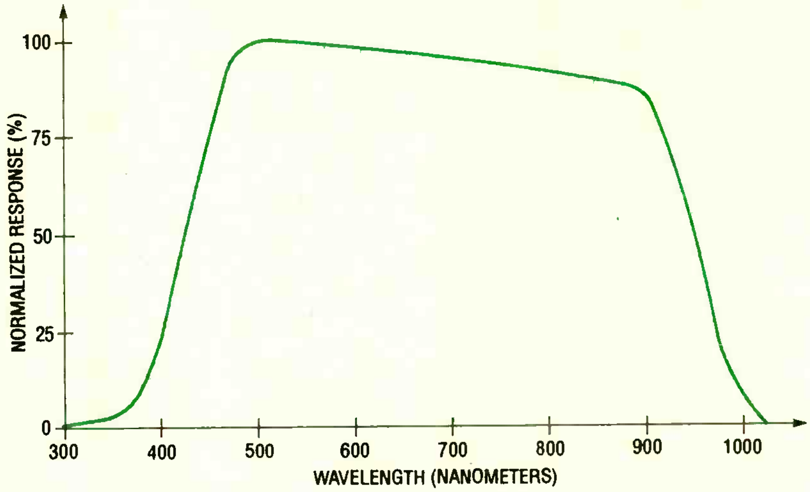


Fig. 4. As this generic silicon cell response shows, the cells have a bandwidth that's only usable over the visible-light spectrum.

Infrared Photovoltaic Sensors. Infrared sensors are designed to be sensitive to electromagnetic radiation in the infrared (IR) region (*i.e.*, at wavelengths longer than those of visible light). Because IR wavelengths can generate heat, it is sometimes necessary to cool IR sensors. Some sensors are operated at room temperature, which is about 27°C or 300°K (Note: 0°C = 273.16°K), but most of them require a cooler environment. A typical arrangement embeds the sensor in a Dewar flask (a dual-walled glass vacuum bottle) that is filled with liquid nitrogen to cool the sensor to 77°K. In other cases, dry-ice packs are used to cool the device to 196°K. Thermoelectric Peltier-effect cooling devices are also used. These devices are thermocouple piles made from dissimilar metallic or semiconductor sections that are excited by a DC current, causing one side to absorb heat, and the other to give up heat.

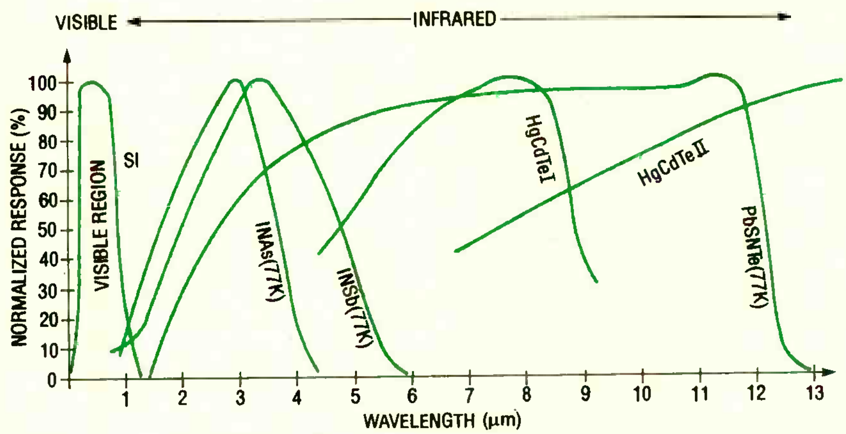


Fig. 5. Here we show the spectral response of different cells. Keep in mind that these are generic responses. Consult manufacturers literature for the response of specific products, as they may differ.

Germanium (Ge) is commonly used used in IR-sensitive metal/semiconductor cells at room temperature (300°K). The material exhibits a somewhat narrow response centered around 1500 nm (*i.e.*, 1.5 µm).

Indium-Arsenide (InAs) (with the spectral response shown in Fig. 5) is also used. The InAs cell is used at 300°K, as well as colder temperatures down to 77°K. The impedance of this type of cell tends to vary with temperature, being around 100 ohms at 300°K and up to 10 megohms at 77°K. The response time of the InAs cell is on the order of 1 µs.

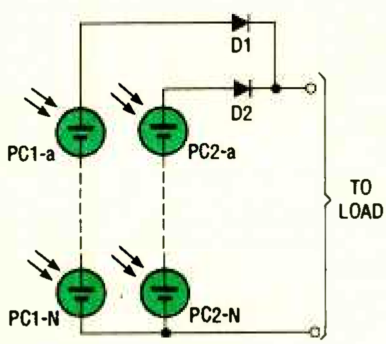


Fig. 6. When arrays of cells are connected in parallel to increase a system's overall current output, isolation diodes must be used.

Indium-Antinomide (InSb) is yet another material used. The InSb IR sensor offers a peak response at wavelengths around 3.5 µm when operated at 77°K (see Fig. 5). It has a response time similar to InAs cells (1 µs). The impedance of those cells varies with temperature, similarly to InAs, but over a considerably smaller range (20k to 50k).

Lead-Tin-Telluride (PbSnTe) has applications in the far infrared region of the spectrum (from 6 to 15 µm), and offers some response down to the near IR region around 2 µm as shown in Fig. 5. This material operates at 77°K, with response times down to the 50 to 100 nanosecond (ns) range.

The last material we'll present, Mercury-Cadmium-Telluride (HgCdTe), can operate at temperatures between 77°K and 120°K, in a spectrum over a range of 2 to 14 µm. Thus, HgCdTe cells can cover the entire IR spectrum from near-IR to far-IR. The actual response of any given cell can be custom tailored by changing

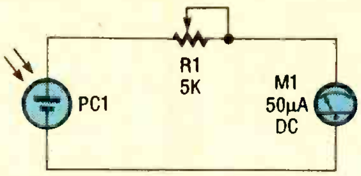


Fig. 7. Once calibrated, this simple light-meter circuit really works, and without the need for batteries.

the proportion of the three materials used (Hg, Cd, and Te). This phenomenon is shown in Fig. 5 by the two different HgCdTe curves labelled HgCdTe-I and HgCdTe- II.

Photovoltaic-Cell Characteristics. A photovoltaic cell is basically an electrical power source that converts light into voltage. It should not be surprising, therefore, to find that some of the characteristics of a photovoltaic cell are similar to the characteristics of other DC power supplies. Let's summarize them.

A cell's output voltage (V_{oc}) is usually measured open-circuit style (*i.e.*, with no load), and is defined as the output potential when the cell is illuminated by a standard 100-foot-candle light source. As mentioned before, the V_{oc} values for common photovoltaic cells are 0.2 to 0.45 volts for selenium cells, and 0.3 to 1.5 volts for silicon cells. Higher voltages can be produced by connecting two or more cells in series; cell arrays of 12 volts are common, while arrays of 24, 28, 32, and 120 volts are also available.

Because of internal resistance in the cell (see below), the output voltage drops from V_{oc} to a lower value called the "loaded output voltage" (V_{ol}) when current is drawn by an external load.

The output-current rating (I_o) is the short-circuit current produced under standard illumination conditions (100 foot-candles). Selenium cells vary from around 15 µA to almost 800 µA per cell, while silicon cells vary from about 5 mA to almost 40 mA per cell. Current rating is increased in an array of solar cells by connecting two or more cells (or series-connected groups of cells) in parallel. A high-current array is shown in Fig. 6. In this case, two cell arrays are used (PC1 and PC2), and an isolation diode is used for each array.

All electrical current sources possess a certain inherent internal resistance or source resistance (R_s). The resistance produces a voltage loss because a voltage drop is created across R_s when current is drawn, and this voltage drop must be deducted from the open-circuit output voltage in order to find the output voltage under load. The internal resistance can be calculated from:

$$R_s = V_{oc}/I_{sc}$$

where R_s is the internal resistance in ohms, V_{oc} is the open-circuit potential in volts, and I_{sc} is the short-circuit current in amperes.

Three factors affect the output power (P_o) available from a specific photovoltaic cell: the illumination

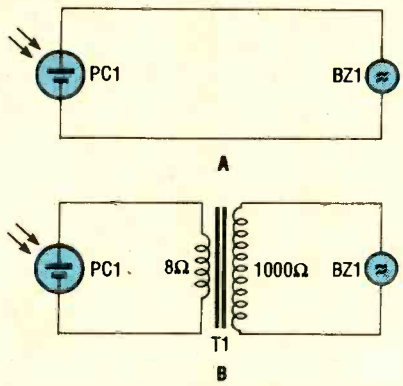


Fig. 8. It is possible to use photovoltaic cells to sound an alarm when the light level is high enough (A) or when a cell is pulsed (B).

level, the area exposed to the light, and the load resistance (R_L). The output power can be found from any of the following:

$$P_o = V_{ol}I_o$$
$$P_o = (V_{ol})^2/R_L$$
$$P_o = I^2R_L$$

The maximum power transfer between the photovoltaic cell and the load is found, as on any electrical power source, when the load resistance is matched to the internal resistance of the cell, or:

$$R_L = R_s$$

Now let's take a look at some applications circuits for photovoltaic devices, including both sensors and solar cells. Although the circuits use only one style of symbol, the same circuits work for PN-junction devices as well as metal/semiconductor devices.

Instrumentation/Communications. Of course, a power source is only useful if it can power something, and photovoltaic cells are no exception. That being so, let's take a look at some applications for the devices.

Figure 7 shows a cell in a basic light-meter circuit for use in photographic and other light-measurement applications. The photovoltaic cell is used to supply current to the circuit, which consists of a calibration resistor and a DC microammeter. The calibration resistor is adjusted to produce the desired meter deflection when exposed to some standard light-level.

Figure 8 shows two circuits that will work with small, low-voltage piezoelectric buzzers. These devices are widely used as annunciators in various applications, and are readily available at Radio Shack and similar outlets. When a photovoltaic cell is wired to a buzzer as shown in Fig. 8A,

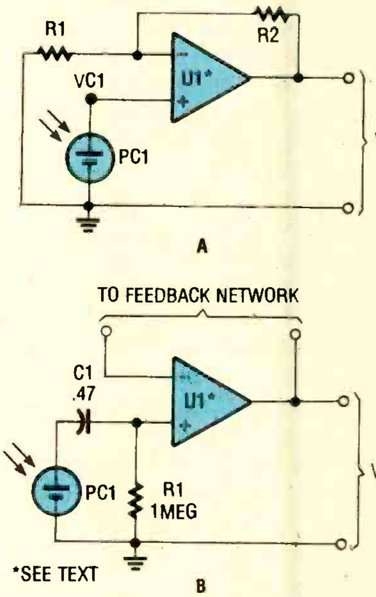


Fig. 9. You can use a photovoltaic cell to drive an operational amplifier so it will indicate the ambient light-level (A) or just changes in the ambient level (B).

the circuit acts as an alarm that will let the world know when the light level reaches a certain point (set by the characteristics of the components).

An alternate circuit, shown in Fig. 8B, makes use of a piezoelectric element (as opposed to a buzzer which consists of a piezoelectric element and on-board oscillator). The circuit can be used when the light level varies either naturally, is modulated, or is in-

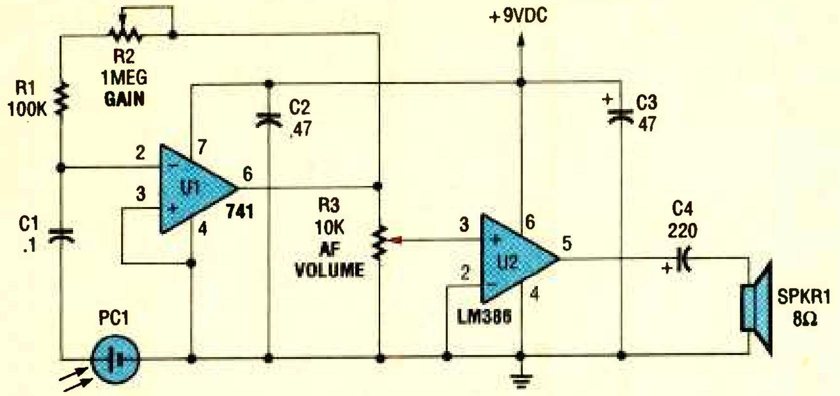


Fig. 10. This is an actual photovoltaic communications receiver. It demodulates AM light signals to recover the audio.

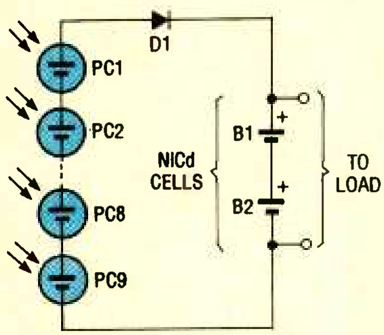


Fig. 11. Whenever a solar panel will be used to charge a battery, a diode must be used to keep the batteries voltage from reverse-biasing the cells.

tentionally chopped. The latter technique is often used in instrumentation applications, while modulation is useful for communications applications. The transformer is an output transformer intended for audio-amplifier circuits. The 8-ohm winding is normally used as the secondary, but here it is the primary; the 1000-ohm winding is used as the secondary. The use of the transformer in this manner produces a step-up action that will increase the voltage fluctuations caused by a varying light source. The principal application of such a circuit is in communications where a light beam is modulated by an audio signal.

One application of such AC-coupled circuits is in burglar alarms. If a pulsed light or IR source is used for the source, then only signals from that source will be passed to the secondary; ambient light will not affect the circuit. If an intruder attempts to defeat the alarm by shining a flashlight onto the cell, then the alarm would sound anyway. One would not use a buzzer in that case, but rather a detector circuit that will indicate a break-in when the pulses disappear.

Figure 9A shows a typical circuit for instrumentation applications of the photovoltaic cell. The cell is connected across the input of a high impedance amplifier, such as the noninverting operational amplifier shown. The amplifier output voltage is found from:

$$V_o = V_{C1}(R2/R1 + 1)$$

The operational amplifier provides a high input impedance buffer between the cell and whatever circuit follows it as well as providing voltage gain. The operational amplifier can be almost any common type, depending on the application. For most applications, common forms such as the 741, LM301, CA3140 (or their dual derivatives such as 1458, CA3240), etc.

An alternate connection scheme is shown in Fig. 9B. In the circuit the cell is AC-coupled, so it will not pass the static DC level created by ambient light, but rather only changing voltages caused by modulation of the light, chopping, or natural variations. When the light beam is truly static, the alternate circuit will not produce a signal.

A practical light-beam communications receiver is shown in Fig. 10. This circuit uses the AC-coupled variant of Fig. 9 with a 741 operational amplifier.

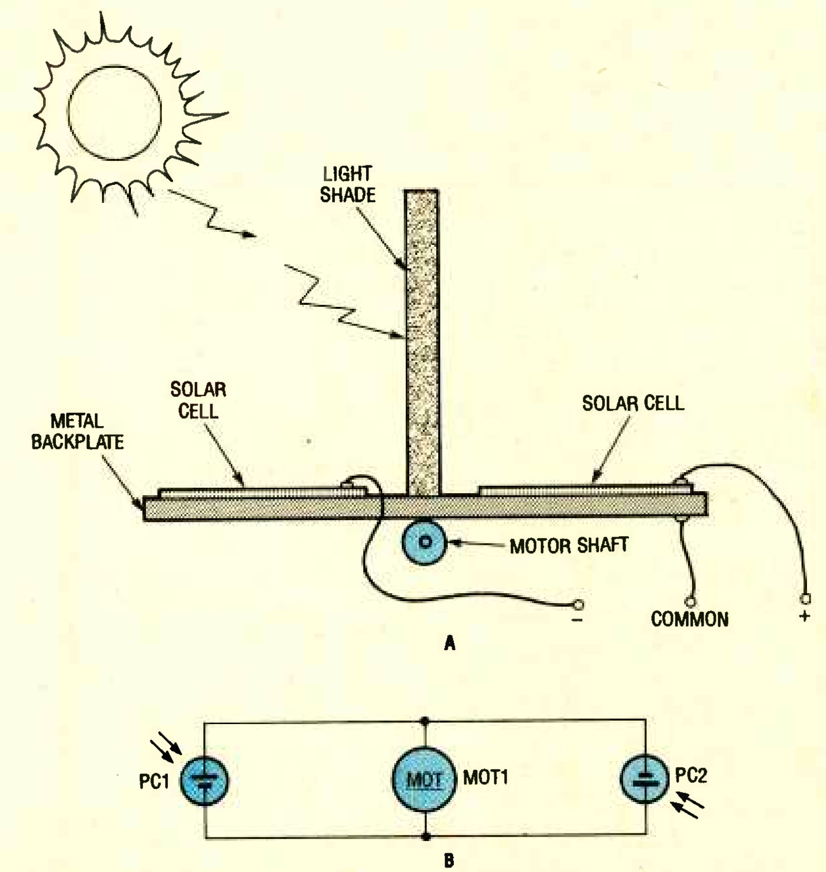


Fig. 12. Solar cells can be used to form a sun-tracking sensor array as shown in A. The cells must be connected to the positioning motor with opposing polarity as shown in B.

The circuit will operate from a any 9-volt DC power supply. The audio output stage is a single-chip audio amplifier that contains both preamplifier and power amplifier stages in one 8-pin DIP package. With the configuration shown, the LM386 will provide a gain of 20; if a higher gain (up to 200) is required, then connect a 10-µF capacitor between pins 1 and 8 on the LM386. Two controls are provided in the circuit: the gain control, which controls the circuit sensitivity by varying the gain of the operational amplifier, and the volume control, which can be adjusted to produce a comfortable sound level.

Other Applications. One of the needs that photovoltaic cells fill is in the generation of DC electrical power from sunlight. These cells are used in a variety of power applications, but virtually all involve charging batteries from sunlight. The batteries can then power electronic equipment at night or when the sunlight fails. Examples include radio equipment in the tropics or deserts, on boats, or in remote sites where servicing fuel-run generators or running electrical power lines is a bother and thus costly.

The photo at the beginning of this article shows some basic solar cells designed for power generation. The two smaller units (a penny is provided for size comparison) are 0.45-volt, 40-mA devices, while the larger is a 70-mA, 1.5-volt flexible solar cell.

Figure 11 shows such an array being used to charge nickel-cadmium (NiCd) cells. The diode (D1) in series with the photovoltaic cells is used to prevent the NiCd cells from discharging through the photovoltaic cells (which would otherwise happen, especially when the light level is reduced). The type of diode shown here is satisfactory for very low current levels, but for larger arrays a diode with a larger current rating is required. Note: some arrays contain built-in diodes, so they do not require an external isolation diode.

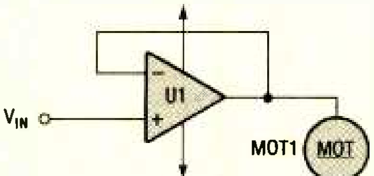


Fig. 13. A power op-amp can be used to drive a large solar panel's tracking motor. However, note that a dual supply is required.

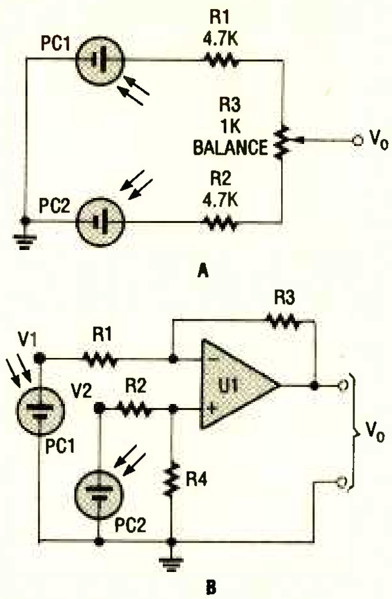


Fig. 14. Here are two solar cells in a summed-output circuit. The one in A is a passive circuit, while the one in B is an active version. The output voltage is proportional to the difference between cell output voltages.

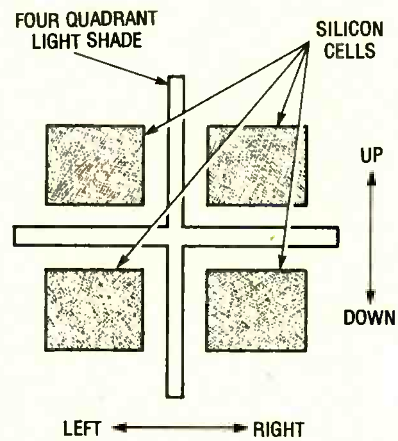


Fig. 15. Taking the two-cell tracker a step further results in this four-quadrant tracker. It is capable of following light by rotating along two axis.

One of the dangers of the circuit shown is the possibility of overcharging the battery during periods of prolonged sunlight. If that is a problem, then a voltage regulator can be inserted into the circuit in place of the isolation diode. The output voltage of the regulator is simply adjusted (with the battery disconnected) to the exact voltage that will be expected when the battery is fully charged.

Another problem with solar-powered devices is that the sun does not stand still over the course of a day, or even follow the same course as the seasons change. It is sometimes necessary to mount the solar-cell array on a movable platform that is connected to a motor/tracker circuit. Figure 12 shows a sun-position tracker designed by writer Forrest Mims III in *Science Probe!* magazine (November 1990, p. 75). Two matched solar cells are mounted on a metal backplate that can be made from printed-circuit board stock.

A light shade painted flat black is mounted vertically on the backplate so that the sun will fall unevenly on the two sensors except when the panel is pointed directly at the sun. The two solar cells are connected with opposite polarity across a low-voltage DC motor, that is mechanically linked to a bearing sleeve on the underside of the backplate.

A potential problem with the simple circuit is that it will not drive a motor powerful enough for a large array. The problem can be overcome by using an outboard power supply (which may require its own solar array and battery set) to drive the necessary motor.

To provide an appropriate drive signal one could use a power operational amplifier as shown in Fig. 13. The V_{in} signal is derived from a differential sensor circuit, two of which are shown in Fig. 14. In both cases, the mechanical arrangement, shown in Fig. 12A, is used for mounting the sensors. The passive version, shown in Fig. 14A, uses a pair of solar cells whose output voltages are opposing each other, and combined together in a resistive summer circuit. The output voltage, V_o, will be zero when the two cells are equally illuminated because the two cells' contributions cancel each other out, but V_o will take on the polarity of the most highly illuminated cell when the light level is uneven.

Figure 14B shows a pair of cells applied to the inputs of a DC differential amplifier made from an op-amp. The voltage gain (A_v) of the op-amp can be adjusted as needed by varying the ratios of the feedback and input resistors. The gain can be found from

(Continued on page 93)

ELECTRONICS TECHNICIANS DAY

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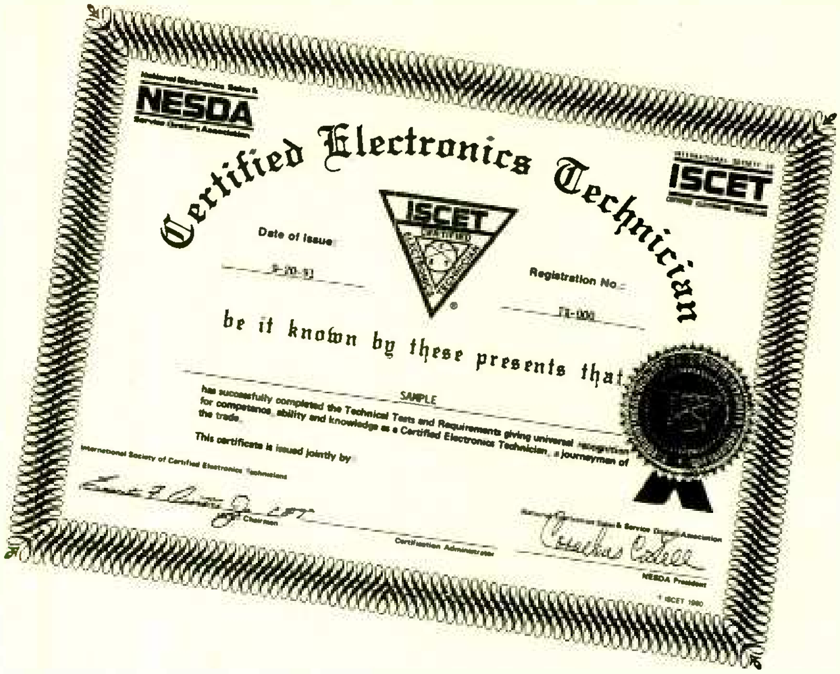

LARRY STECKLER, EHF/CET
EDITOR-IN-CHIEF

As electronic products have become increasingly sophisticated and microscopic, the number of individuals possessing the skills need to maintain and repair these products has decreased. The result is a "throw-away" society where non-functioning electronic products are simply discarded because "nobody knows how to fix it!"

That places a great premium on the skilled electronics technician with the ability to maintain, repair, or upgrade today's electronic equipment. Such a technician has the opportunity for advancement to more productive service and repair positions—assuming, of course, he or she has some way of demonstrating that skill. For many, that can be accomplished by attaining some suitable industry-accepted recognition. One of the best ways to get that recognition is to become a Certified Electronics Technician (CET).

One of the best times to become a CET is fast approaching. You are invited to join more than 35,000 Certified Electronics Technicians in a world-wide observance of "Electronics Technicians Day" on April 6, 1993. Ernie Curtis, CET, Chairman of the International Society of Certified Electronics Technicians stated, "More so than ever before, we must assist qualified electronics technicians in attaining positions commensurate with their training and experience. Through our qualified recognition program of certification, we can assist Certified Electronics Technicians in their efforts to gain responsible employment." ISCET recognizes that without this highly-skilled and specially-trained corps of Certified Electronics Technicians, breakdowns in modern complex electronics could quickly bring our society to an abrupt halt.

"ISCET's salient intention," Curtis continues, "is to focus international recognition on the high standards of performance and excellence maintained by professional electronics technicians."

Over 150 ISCET Certification Test Administrators, throughout the United States, have volunteered to give CET tests during the week of April 4 through 10 to honor Electronics Technicians Day. The complete list of all of these test sites, which includes this publication's offices, is included elsewhere in this article.

While the CET program is centered primarily in the U.S., technicians around the world seek CET certification, even in war-torn areas such as Slovenia, formally a part of Yugoslavia. In the summer of 1992, Drago Lumbar, CET, passed his Radar Option to become the first CET in that new nation. Lumbar, who studied electronics by correspondence from Cleveland Institute of Electronics, is employed at Lumbar & Co. in Ljubljana, Slovenia.

What is ISCET? As the proud electronics technicians division of the National Electronics Service Dealers Association (NESDA), ISCET was founded in 1970 by a committee of Certified Electronics Technicians whose main purpose was to foster respect and admiration for their profession. By maintaining rigorous standards in its certification program, ISCET is able to separate the highly skilled and knowledgeable technicians from those with less experience. ISCET's main functions include direction and administration of the CET program, the national apprentice and training program, technical information-training and upgrading programs, and the serviceability programs.

In addition, ISCET offers its members a continual source of technical material, including regular updates about new technology; training seminars; discounts on books, tapes, and software; newsletters; a magazine; an annual industry directory; and an annual convention with management and technical-training seminars, an instructor's conference, and a trade show.

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ISCET CERTIFIED ADMINISTRATORS FOR CET EXAM

Cindy Johnson
Herzing Institute
1218 South 20th St.
Birmingham, AL 35205
(205) 933-8536

Tony C Jetton, CET
Wallace State Collg
801 Main St NW
Hanceville, AL 35077-9080
(205) 352-6403

David L Bryan, CET
Al Aviation & Tech Collg
PO Box 1209
Ozark, AL 36360
(205) 774-5113, Ext. 252

R T Van Iderstine, CET
14563 South Blvd
Silverhill, AL 36576
(205) 947-4441

Russell Scarpelll, CET
10529 W Desert Forest Circle
Sun City, AZ 85351
(602) 972-5438

Dennis P Blum, CET
Phoenix Inst Of Tech
2555 E Univeristy Dr
Phoenix, AZ 85034
(602) 244-8111

H J Paine, CET
4631 E 8th St
Tucson, AZ 85711
(602) 881-6784

Parviz Shams
Southern CA Inst Of Tech
10600 Katella Ave
Anaheim, CA 92804
(714) 520-5552

Edward A Belsky, CET
881 Palo Verde Dr
Barstow, CA 92312
(619) 252-81940

Billy J Edmonds, CET
1311-16th St
Baywood, CA 93402
(805) 547-7900, Ext. 4671

Donald R Parker
Chuchawalla Vly State Prison
19025 Wiley's Well Rd
Blythe, CA 92226
(619) 922-5300

John V Craig, CET
531 W Hueneme Rd
Oxnard, CA 93033
(805) 982-5228

David Marson, CET
PO Box 1245
Paso De Robles, CA 93447-1245
(805) 238-4040, Ext. 428

Raymond L Unser, CET
The Audio Specialist
3806 Muirwood Dr
Pleasanton, CA 94588
(408) 944-4210

Jon R Sturtz, CET
10840 Alandale Way
Rancho Cordova, CA 95670
(916) 635-6000

Kevin J Price, CET
N.E.C.
825 E Hospitality Ln
San Bernardino, CA 92408
(714) 885-3896

Dr Kenneth L Wilson, CET
San Diego City College
1313-12th Ave
San Diego, CA 92101
(619) 230-2601

Fredrick J Smith, CET
Educ Dept/Ca Mens Clny
PO Box 8101
San Luis Obispo, CA 93409-0003
(805) 547-7900, Ext. 4671

Howard Bardach, CET
The Audio Specialist
4381 Tujunga Ave
Studio City, CA 91604
(818) 763-3009

Romualdo Malarayap, CET
ITT Tech Inst
1530 W Cameron Ave
W Covina, CA 91706
(818) 960-8681

John F Stackhouse, CET
2665 S Peona St
Aurora, CO 80014
(303) 695-1913

Marjorie Lona
Colorado Aero Tech
100 Technology Dr #100
Broomfield, CO 80021
(303) 466-1539

John F Mcmullen, CET
Denver Inst Of Tech Inc
7350 N Broadway
Denver, CO 80221
(303) 426-1808

Art Sorensen, CET
Arts Audio Video Svc
1416 N Lincoln Ave
Loveland, CO 80538
(303) 669-0883

Edward V Busch, CET
Porter & Chester Inst
124 Silas Deane Hwy
Hartford, CT 06109
(203) 529-2519

John E Depalma, CET
CT School Of Elect
586 Ella Grasso Blvd
New Haven, CT 06519
(203) 624-2121

Daniel J Shea, CET
CT School Of Elect
586 Ella Grasso Blvd
New Haven, CT 06519
(203) 624-2121

James Ewing, CET
Porter & Chester Inst
125 Silas Deane Hwy
Wetherfield, CT 06109
(203) 529-2570

Albert Moses, CET
PO Box 188
Cheswold, DE 19936
(302) 571-5402

James D Hite, CET
Pinellas Vo-Tech
6100 154th Ave N
Clearwater, FL 34620
(813) 531-3531, Ext. 226

Edward Guary Sr, CET
Eddy's Radio & TV Svce
1110 NE 4th Ave
Ft Lauderdale, FL 33304
(305) 763-2964

Karl A Hunter, CET
13850 Ketch Cove Dr
Jacksonville, FL 32224-1143
(904) 633-8143

John Steven Richards, CET
ITT Tech Inst
2600 Lake Lucien Dr #140
Maitland, FL 32751
(407) 660-2900

Noel Shevack
New England Inst Of Tech
1126 53rd Ct
Palm Beach, FL 33407
(305) 842-8324

Neil A Wertley, CET
U.E.I.
3924 Coconut Palm Dr
Tampa, FL 33619
(813) 626-2999

William S Brooks, CET
7112 N Habana Ave
Tampa, FL 33614-4365
(813) 933-1793

Dennis P Abell, CET
3433 Royal Oak Dr
Titusville, FL 32780
(305) 269-4208

Cal Reddick, CET
2413 Ave G NW
Winter Haven, FL 33880-2136
(813) 299-6514

Perry (Jim) Parks, CET/CA
1055 Hwy 434
Winter Sprgs, FL 32708
(407) 699-8811

W R Rooks, CET
176 Shiloh Rd
Americus, GA 31709
(912) 928-0283, Ext. 26

Daniel B Mundy, CET
Norman's Electronics
3653 Clairmont Rd Ne
Atlanta, GA 30341
(404) 451-5057

Roy Chastain, CET
N.G.T.I.
197 N
Clarkesville, GA 30523-0065
(404) 754-7751, Ext. 334

James P Van Sant, CET
Pickens Tech
100 Pickens Tech Drive
Jasper, GA 30143
(404) 692-3411

Mel Streeter
Lewis Clark St Collg
8th Ave 6th St
Lewiston, ID 83501
(208) 799-2301

Douglas E Minter, CET
Amer College Of Tech
1300 W Washington
Bloomington, IL 61701
(309) 828-5151

F A Schwarzkopf, CET/CA
3708 W 83 Place
Chicago, IL 60652
(312) 767-4126

Larry Didway, CET
Carl Sandburg Jr Collg
2232 S Lake Storey Rd
Galesburg, IL 61401
(309) 344-2518

Paul K Tan, CET
915 Augusta St
Oak Park, IL 60302-1678
(312) 848-6327

Frank Teskey, CET
F J Teskey Enterprises
3094 Lafayette Rd
Indianapolis, IN 46222
(317) 926-2639

Russel Lynd
Indiana Tech Collg
590 Ivy Tech Dr
Madison, IN 47031
(812) 265-2580

Arval W Donovon, CET
Donovon's Elect Servc
818 Dewolf St
Vincennes, IN 47591
(812) 886-4666

Leonard E Bowdre, CET
125 SE Thornton Ave
Des Moines IA 50315
(515) 964-6484

James E Boyer, CET
Western IA Tech Comm Collg
4647 Stone Ave
Sioux City, IA 51102
(712) 274-8733, Ext. 1393

Stanley Creitz, CET
Nck Area Vo Tech
PO Box 507-West Campus Dr
Beloit, KS 67420
(913) 738-2279

Michael L Baughman, CET
Ks City Area Vo Tech
2220 N 59th St
Kansas City, KS 66104
(913) 334-1000, Ext. 48

Keith E Knos, CET
Knos Electronics
1206 Elm Blvd
Liberal, KS 67901
(316) 624-5908

Pat Dunaway
Manhattan Area Tech Center
3136 Dickens Ave
Manhattan, KS 66502-2499
(913) 587-2800

Dr G W Ko, CET
550 N Fountain
Wichita, KS 67208
(316) 686-4664

Lamarr W Ritchie, CET
Hazard State Vo-Tech School
101 Vo-Tech
Hazard, KY 41701
(606) 436-3101

Edward J Kimmel, CET
Kimmel Electronics
2061 Eastern Parkway
Louisville, KY 40204
(502) 451-3457

Donald Johnson
Inst Of Elect Tech
509 S 30th St
Paducah, KY 42001
(502) 444-9679

Michael Dixon, CET
KY Tech-Somerset Campus
714 Airport Rd
Somerset, KY 42501
(606) 679-4303

Dr I F Creel, CET
Sullivan Tech Inst
1710 Sullivan Dr
Bogalusa, LA 70427
(504) 732-6640

Steven B Lumpkin, CET
164 Acadian Dr
Lafayette, LA 70503
(318) 233-6388

M G Mccann/Jr, CET
Mccann Electronics
100 Division St
Metairie, LA 70001
(504) 837-7272

James R Sorrels, CET/CSM
110 Oakridge Dr
Shreveport, LA 71106-7113
(318) 797-2952

W H Hartzfeldt, CET
Delta-Quachita Vo Tech
609 Vocational Pkwy
W Monroe, LA 71291
(318) 396-7431

Aurel J Daigle, CET
74 Mountainview
Madawaska, ME 04756
(207) 728-4304

Earl Tickler, CET
Rets Tech Trng Cntr
1520 S Caton Ave
Baltimore, MD 21227
(301) 644-6400

Frank Serra, CET
Serra's TV Video
1686 Mass Ave
Cambridge, MA 02138
(617) 492-2667

Bob Bellers, CET
Washtenaw Comm. College
4800 E. Huron River Dr.
Ann Arbor, MI 48106
(313) 973-3316

Willard Rush, CET
485 Amberwood St
Auburn Hills, MI 48326-1129
(313) 333-2531

Gerald H Heyn, CET
55 E Riling St., Lot 113
Gwinn, MI 49841
(906) 346-6396

Julius A Acs
Motech Educa Cntr
35155 Industrial
Livonia, MI 48150
(303) 522-9510

Dr Joel Goldberg, CET
Macomb Comm Collg
14500 12 Mile Rdn
Warren, MI 48093
(313) 445-7343

E Eugene Ranta, CET
Macomb Comm Collg
14500 Twelve Mile Rd
Warren, MI 48093
(313) 445-7343

Dr Irving W Larson, CET
Bemidji State University
Bridgeman Hall 232
Bemidji, MN 56601
(218) 755-2950

John Baldwin, CET
Faribault Campus
1225 SW 3rd St
Faribault, MN 55021
(507) 334-3965, Ext. 129

Jim Hunsucker
North Cntrl Area Vo Tech
Box 445
Bethany, MO 64424
(816) 425-2196

Annabel L Gooch
Davis Hart Mavts
905 N Wade St
Mexico, MO 65265
(314) 581-5684

James D Everett, CET
Northland Career Cntr
PO Box 1700
Platte City, MO 64079
(816) 464-2442

Marion B Denny/Jr, CET
Audio-Video Service
1405 Corinne St
Hattiesburg, MS 39401
(601) 545-7606

W Clem Small, CET
426 S 4th St
Hamilton, MT 59840-2737
(406) 363-1577

Earl Fosler, CET
SE Community College
Rt 2 Box D
Milford, NE 68405
(402) 761-2131, Ext. 266

James Belanger, CET
Beltronics Inc
19 Proctor Hill Rd Box 330
Hollis, NH 03049
(603) 465-2422

Joseph T Szumowski, CET
J T S Electronics
412 Pomona Rd
Cinnaminson, NJ 08077
(609) 829-9669

Mark A Ricciardi, CET
Plaza School Of Technology
Bergen Mall
Paramus, NJ 07652
(201) 843-0344

Dr Ronald P Hartman
Tech Training Inst
1320 S Solano
Las Cruces, NM 88001
(505) 522-6533

Ralph L Van Sickle, CET
Co-Op Electronics
4480 Gunnville Rd
Clarence, NY 14031
(716) 759-8198

Larry Steckler, EHF/CET
Gernsback Publications
500 B Bi-County Blvd
Farmingdale, NY 11735
(516) 293-3000

Hubert West, CET
20 Schuyler St
Lake George, NY 12845
(518) 668-9285

Gregory J Reiber, CET
13 Garnoch Ct
Liverpool, NY 13090
(315) 457-4917

Joseph A Passaretti, CET
Pyramid Electronics Ltd
353 E 76th St
New York, NY 10021
(212) 628-6500

Carl Meyer, CET
11 Hemlock Dr
West Seneca, NY 14224
(716) 674-7113

Wayne Smith, CET
224 St John St
Arden, NC 28704
(704) 255-7671

William H Mast, CET
Appalachian State Univ
Dept Of Tech
Boone, NC 28607
(704) 262-6352

Melvin E Talbert, CET
Heilig Meyer Service Co
PO Box 64189-2858 Owen Dr
Fayettevle, NC 28306-0189
(919) 483-0801

Bruce Ellington, CET
Electrical South
235 Burgess Rd-Drawer 49239
Greensboro, NC 27419-1239
(919) 668-4848

Linda Dickinson
Craven Community Collg
PO Box 952
Havelock, NC 28532
(919) 447-1141

Sammie C Thornton, CET
Wake Tech Comm Collg
9101 Fayetteville Rd
Raleigh, NC 27603
(919) 772-0553, Ext. 181

William D Barnette
Haywood Community Collg
10 Industrial Park Dr
Waynesville, NC 28786
(704) 452-1411, Ext. 23

Donald E Grinolds
GF AFB Education Center
310 Mssq/Mse
Grand Forks AFB, ND 58205
(701) 594-8192

Rod Schlingerman, CET
PVS Electronics Inc
3949 Cleveland Ave-Box 24400
Columbus, OH 43224
(614) 478-8200

Joseph Carney/Iii, CET
6365 Mills Creek Lane
N Ridgeville, OH 44039
(216) 871-8900, Ext. 241

John E Valerio, CET
Sencore
612 Lovers Lane
Steubenville, OH 43952
(614) 264-3001

David J Garwacki, CET
Sales & Service
4846 Oak Glen Dr
Toledo, OH 43613-3048
(419) 475-9221

Roy W Yonce
Tec-Ed Corporation
PO Box 1665
Broken Arrow, OK 74013
(918) 459-0200

J S Glosemeyer, CET
East OK Cnty Vo Tech
4601 N Choctaw Rd
Choctaw, OK 73020
(405) 390-9591

Curtis E Knight, CET
Central TV
203 East Idaho Ave
Ontario, OR 97914
(503) 889-2159

William H Manny, CET
Round-Up Elect Inc
2927 Riverside
Pendleton, OR 97801
(503) 276-3152

Larry Broschart, CET
14124, NE Knott St
Portland, OR 97230
(503) 255-6713

Vern Hartshorn, CET
2434 SE 158th St
Portland, OR 97233
(503) 667-7117

James C Shambow, CET
6035 NE 78th Ctr # 100
Portland, OR 97218
(503) 255-6500

Thomas V Gaudiello,CET
Rets Education Center
W Chester Pike & Malin Rd
Broomal, PA 19008
(215) 353-7630

Charles (Bill) Smith
Rets Education Center
West Chester Pike & Malin Rd
Broomal, PA 19008
1-800-336-7696

Gene Hedgepeth, CET/CA
2165 Alberdeen Rd
Mountaintop, PA 18707-9059
(717) 868-6566

Stanley A Salter, CET
Stan Salter Music Svc
826 Bat Blossom
Sumter, SC 29150
(803) 469-3022

Don Multerer,CET
Sencore Inc
3200 Sencore Dr
Sioux Falls, SD 57107
(605) 339-0100

William S Warren, CET/CSM
Warren's Audio-Video Svs
2540 Sutherland Ave
Knoxville, TN 37919
(615) 546-1121

Herman Patrick
3715 Lamar Ave
Memphis, TN 38118
(901) 362-8368

Jerry L Bunnell, CET
Techtronics
7801 N Lamar Unit B-156
Austin, TX 78752
(512) 832-0097

Henry W Corrie, CET
1460 C.R. 3413
Chandler, TX 75758
(903) 852-4140

F Gilbert Smith, CET
822 Creekridge Dr
Dallas, TX 75218
(214) 348-7734

Reiner Junge, CET
4710 Alabama
El Paso, TX 79930
(915) 566-9621

Robert M Griffin, CET
T.C.J.C.
5301 Campus Dr
Ft Worth, TX 76119
(817) 293-4327

Arthur J Ruppert, CET
30217 St Andrews
Georgetown, TX 78628
(512) 863-9157

Tom C Underwood, CET
Sony Service Company
3201 Premier #100
Irving, TX 75063
(214) 550-5270

Alden P Walther
Itt Technical Inst
9421 W Sam Houston Pkwy
Houston, TX 77099-1849
(713) 270-1634

James Harris, CET
3512 Chisholm Trail
Killeen, TX 76543-3172
(817) 288-2826

Elizabeth Sheets
American Commercial Collg
2007 34th St
Lubbock, TX 79411
(806) 747-4339

J W (Dub) Newson, CET
Advanced Electronics Inc
1310 19th St
Lubbock, TX 79401
(806) 763-8246

Loren R Hodge
3614-28th St
Lubbock, TX 79410
(806) 795-8617

Preston Wallace, CET
445 South Fuqua St
Rockport, TX 78382-4807
(512) 852-8022

Gerald Martin, CET
3347 Falcon Grove
San Antonio, TX 78247
(512) 496-1134

Joseph H Hudson/Jr, CET
Grayson County College
1500 Yarborough Dr
Sherman, TX 75090-5545
(903) 892-9356

Russell R Offhaus, CET
PO Box 1116
Chincoteague, VA 23336
(804) 336-5980

Leonard M Cowherd, CET
Piedmont Tech Ed Cntr
PO Box 999
Culpeper, VA 22701
(703) 825-0476

Edward F Reilly Jr, CET
9418 Starlit Ponds Dr
Fairfax, VA 22032
(703) 425-5468

Charles C Spiro, CET
Lord Fairfax Comm Collg
PO Box 47
Middletown, VA 22645
(703) 869-1120

Daniel C Bowling, CET
Southwest VA Comm Collg
PO Box SVCC
Richlands, VA 24641
(703) 964-2555

Cary D Thomas Jr., CET
2209 Eastover Dr
S Boston, VA 24592
(804) 572-6474

Jame Richerson, CET
Blue Ridge Comm College
Box 80
Weyers Cave, VA 24486
(703) 885-5960, Ext. 276

Michael Szymkewicz, CET
Olympic College
16th & Chester
Bremerton, WA 98310
(206) 478-4605

Ted Rodriquez, CET
Kagit Valley College
2405 College Way
Mt Vernon, WA 98273
(206) 428-1248

Arthur L Braden, CET
Phillips Jr College
N 1101 Fancher Rd
Spokane, WA 99212
(509) 535-7771

Carl E Mcdonald, CET
Sun Tech
417 S 6th
Sunnyside, WA 98944
(509) 837-8800

M B Hixenbaugh, CET
B N'H Service
3635 S Lawrence
Tacoma, WA 98409
(206) 475-8861

Harry A Sanders, CET
1819 S Woodlawn
Tacoma, WA 98465
(206) 564-1334

David E Nida
National Education Center
5514 Big Tylor Rd
Cross Lanes, WV 25313
(304) 776-6290, Ext. 24

Larry Lambert, CET
PO Box 46
Culloden, WV 25510
(304) 743-3719

Richard K Evans, CET
PO Box 217
Wilkenson, WV 25653
(304) 752-7267

Duane Busby, CET
B, C & D Ent.
2027 Sherman Ave
Madison, WI 53704-5934
(608) 244-0339

Larry Geissler, CET
Indianahead Tech Colleg
600 N 21st St
Superior, WI 54880
(715) 394-6677, Ext. 275

Jacob Klein, CET
Northcentral Tech Collg
1000 Campus Ave
Wausau, WI 54401
(715) 675-3331, Ext. 263

Thomas D Leitschuh, CET
Tdl Electronics
8014 W National Ave
West Allis, WI 53214-4554
(414) 774-2929

Robert Ing, CET
Atropos Telecom
1170 Bay St # 102
Toronto, Ontario, Can M5S 2B4
(416) 580-7508

Lew Thibeau, CET
Nova Scotia Comm Collg
Colchester Campus-60 Lorne St
Truro, Nova Scotia, Can B2N 3K3
(902) 895-7995, Ext. 142

Antonio M Avellanosa
Mt. Province Inst. of Technology
YMCA Bldg
Baguio City 2600, Philippines
442 6532

professional competence. Since its inception, the CET program has continued to gain acceptance by technicians, manufacturers, and consumers. Many organizations encourage, and often require, their technical employees to be certified by ISCET.

Technician Skills. Just keeping up with the changes that seem to occur daily in equipment is a full-time task. To be able to service the latest electronic equipment with its new circuitry, new components, and new principles is a difficult challenge. Today's electronics technicians must constantly learn, constantly acquire new skills, and constantly develop new techniques. They must become familiar with new kinds of test equipment and new servicing techniques to repair the latest electronics marvels.

Perhaps this was best summed up by Don Winchel, CET, ISCET's immediate past chairman, when he said, "Because of the dynamic changes that have occurred in electronics during the past decade, all corners of our modern world now look to electronics technicians to keep our civilization ticking. The new techniques, devices, and technology that have appeared just in one product, the camcorder, in the past few years alone are mind-boggling. With what today's electronics technicians must know and be able to instantly analyze, places them in a select group in the world's work force that will see unprecedented rewards of a grateful industry in the 21st century."

The CET Exam. To become certified by ISCET, the electronics technician must pass both a 75-question Associate-level CET test, and a 75-question Journeyman-level test. To pass, the candidate must score a grade of 75 percent or better. An electronics technician or student with less than four years of experience may apply for the Associate-level exam only, which covers the following subjects: Basic Mathematics, DC Circuits, AC Circuits, Transistors and Semiconductors, Electronic Components, Instruments, Tests and Measurements, Troubleshooting, and Network Analysis.

Keeping up with current equipment and technology is an important part of being a professional technician. Shown here is an ISCET seminar on Sencore servicing techniques.

A fully certified technician must have four or more years of education or experience in electronics and must pass, in addition to the Associate-level test, one or more of the Journeyman options available in specialized fields of electronics. The Journeyman options that are available are:

- Consumer—Subjects covered include antennas and transmission lines, digital and linear circuits in consumer products, TV and VCR servicing problems, and the use of test equipment.

(Continued on page 92)

ANTIQUE RADIO

By Marc Ellis

The Sky Buddy Speaks Up!

The first order of business for this month's column is to report the progress to date on the *Sky Buddy* restoration. For those who just joined us, the set was Hallicrafter's low-end shortwave receiver during the years just prior to the onset of World War II.

The Sky Buddy's attractive appearance, feature-packed design, and hefty construction made it a popular starter set for budding radio hams and shortwave listeners. Although its $29.50 price tag wasn't exactly cheap by the standards of the day, the receiver was still within reach of a teen or pre-teen with an enterprising spirit and a regular part-time job.

The front cover of the Sky Buddy's instruction booklet. Quaint, isn't it?

If you'd like to learn more about the history of the set and follow the work that's been done on the restoration so far, check the following back issues of this column: May, June, September, October and December, 1992; January and March, 1993.

HANDSOME BUT INSENSITIVE

Now that the Sky Buddy's cleanup and physical restoration are complete, it is an impressive receiver. With its black-crackle finish and white silk-screened lettering free of grime, and its German-silver dial and Bakelite knobs shining, the set is ready to grace a display shelf. The Sky Buddy's performance, however, was still a problem.

The audio was quite weak—scarcely above a murmur—and would occasionally fade out entirely. Although the level could be adjusted with the volume control, audio could still be heard with the control in its full counterclockwise position.

Broadcast-band reception was a disaster. Even when connected to a good antenna, the set would pick up only a few local stations. Reception on the shortwave bands was difficult to judge because of the vagaries of propagation, but (apart from the volume problem) seemed fairly normal. Band 3, especially, (5.5–17 MHz) seemed alive with signals.

The few tests performed to date had turned up no clues. All tubes had checked good, and voltages measured at the tube sockets seemed in line with the operating parameters given in the RCA tube manual.

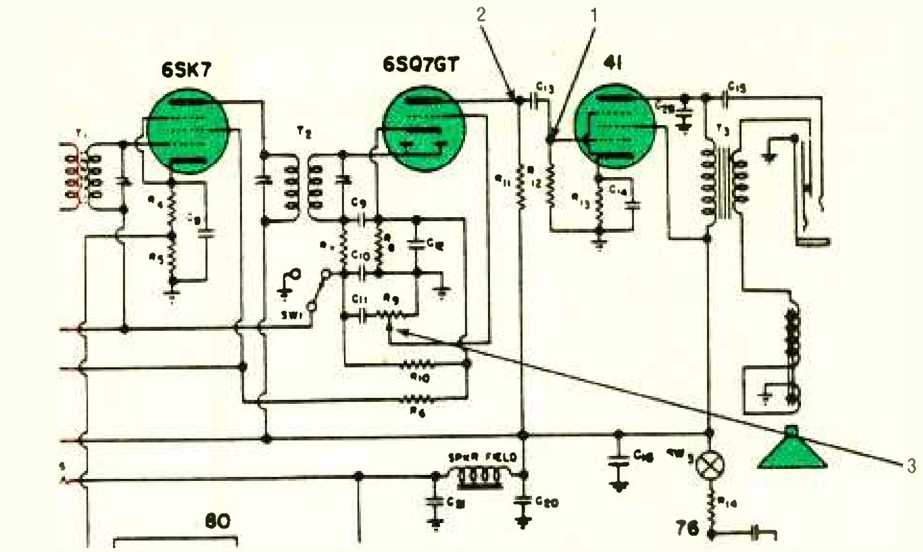
LOCALIZING THE TROUBLE

I decided to start with the audio problem. Since I had spares for the 6SQ7 (detector-first audio) and 41 (audio-output) tubes, I began by substituting them for the ones in the radio. Tube checkers have been known to be wrong, or to miss an intermittent condition. No such luck, though. The audio remained as weak as ever.

Still looking for an easy way out, I decided to try some tests using the time-honored index-finger method. Placing that digit on the grid terminal of the type-41 audio-output tube, I was able to induce what seemed to be a normal hum level in the speaker. For the time being, then, I was prepared to assume that the audio-output stage was okay.

Moving my finger to the other side of the grid-coupling capacitor (see schematic), I heard about the same amount of hum. Since that capacitor was capable of passing audio, I could probably assume that it wasn't open-circuited.

By the way, don't try this method of diagnosis at home unless you're quite aware of the safety hazards involved. When doing index finger tests, always keep your other hand in your pocket (or at least well away from the radio). Also



This schematic shows the Sky Buddy's audio circuitry. The connections labeled "1," "2," and "3" are those that were checked by the "finger probe" method (see text).

make sure that the finger used as a probe touches *only* the connection in question and that no other part of your "test hand" comes in contact with any part of the radio.

Dangerous, even lethal, high voltages are present in all tube sets. For instance, when I moved my finger to the other side of the grid-coupling capacitor, it was in contact with the 6SQ7's plate-voltage supply. If any other part of me had touched the Sky Buddy's chassis at that time, I definitely would have received a nasty jolt.

Actually, if the coupling capacitor had been leaky (a definite possibility), I might have been in contact with the 6SQ7's plate voltage even on the *grid* side of the capacitor. Moral: When a radio's in need of repair, dangerous voltages can appear in very unlikely places!

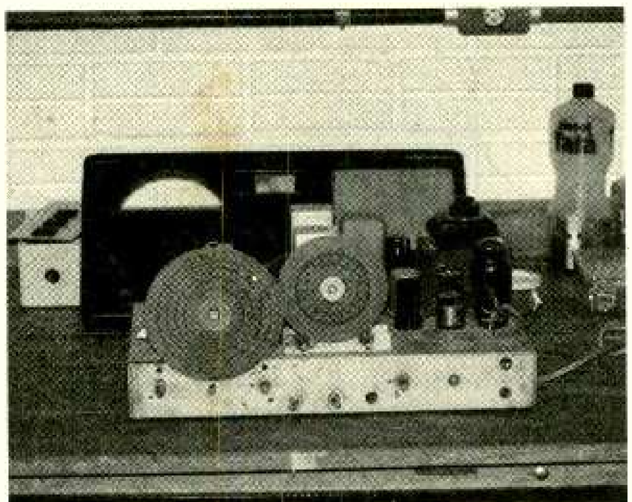
Just one more point before I finish my safety speech. Don't touch *any* metal part on an AC-DC (transformerless) set while it is plugged in. Many of those have the chassis directly connected to the AC line, which is a dangerous situation indeed. Hands-on contact is okay *only* if you are powering the set through an isolation transformer—which is a must when working with those radios.

Getting back to the troubleshooting, I next moved my "test probe" back one stage, to the center connection of the volume control, which is wired (see schematic) to the grid of the 6SQ7's triode section (otherwise known as the first audio amplifier). Because it should now be undergoing amplification by an additional tube, the hum being picked up from my finger should now have sounded much louder in the speaker. However, just the opposite turned out to be the case. The hum was actually a little weaker! I had now located the trouble somewhere in the first audio stage.

WE HAVE AUDIO!

Continuing to move backward though the Sky Buddy's stages in methodical fashion, I decided to isolate the first audio amplifier from the detector stage preceding it. Both of these stages utilize the 6SQ7 tube—but they could be separated by disconnecting the grid of the triode (or amplifier) section of the tube from the diode (or detector) section. That was handled simply by removing the wire connected to the center contact of the volume control.

Touching the free end of that wire (the other end being still connected to the grid) resulted in a loud, hum! So, with its grid removed from the network of components associated with the volume control, the first audio stage was now operating as it should. Something in the network was causing the trouble.



Joel Robinson's S-40A disassembled on the bench and awaiting restoration. Can someone help him with the schematic? (See text.)

I started my investigation with the detector-to-first-audio coupling capacitor, a 0.01-µF unit connected to one end of the volume control. Disconnecting one of its leads so that I could check continuity independently of the rest of the circuit, I put an ohmmeter across the capacitor. Sure enough, it was leaky—showing a resistance of less than a thousand ohms. A capacitor of this kind should read as virtually an open circuit; its resistance should be somewhere in the 10-megohm range.

Replacing the coupling capacitor with a good unit solved the audio problem. Signals now come it at normal volume, except on the broadcast band—where reception continues weak to nonexistent. That is a separate problem, probably in the RF circuitry at the front end of the receiver. We'll look into it on another occasion.

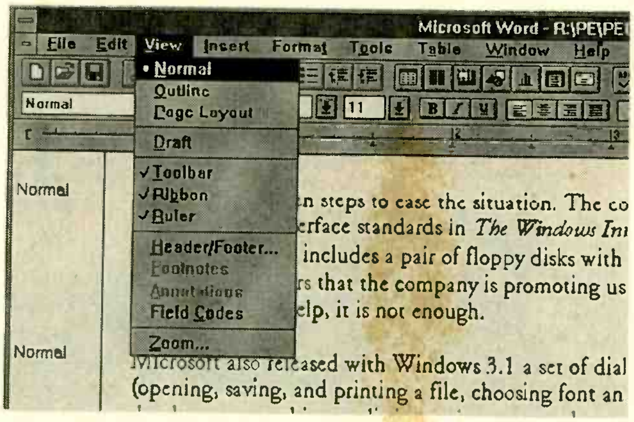
I've already made one front-end check, however. As I was putting away my tools after the audio-fixing session, I was struck with the

(Continued on page 94)

By Jeff Holtzman

A GUI STANDARD?

PC magazine recently presented a cover story on 20 alternate "shells" for Windows. Now that's odd—isn't Windows is supposed to be Mac-like, easy-to-use, and user-friendly? If so, then why is there a huge subsidiary industry dedicated to improving Windows' Task Manager and Program Manager, not to mention



The View menu in Microsoft Word for Windows 2.0 is a model of user-interface complexity. It indicates states, changes states, initiates actions, and brings up subsidiary dialog boxes. For all that, you still have to go to other menus to change some display items.

background wallpaper, color schemes, cursors, sound effects, and even the basic look of its dialog boxes? And why do different applications use different menu commands and toolbar icons? And why do some applications dispense with most or all of what little there is in the way of user-interface standardization?

Maybe Windows isn't so easy to use after all. I've been using Windows since version 1.0, so I'm very familiar with all its operational quirks. However, recently I participated in helping a 100-person organization move *en masse* to the Windows environment. They had been using OS/2 1.3, but mostly to switch among DOS-based applications, *e.g.*, Word Perfect and CC:Mail. The graphical shell was really incidental to what they were doing. Anyway, seeing things through the eyes of those new Windows users taught me a few things, mostly about how far the industry still has to go before the decade-old phrase "user-friendly" really means anything.

FILE WHAT?

For example, take a look at some menu items in three Microsoft word processors: Notepad and Write (which come with Windows), and Word for Windows (a stand alone product). All three place the File menu near the left edge of the screen. Some commands across the three are consistent (New, Open, Save, Save As, Print); others are not.

For example, Notepad has an item called Page Setup that allows you to specify headers, footers, and margins. To perform those functions in Write, you go to an item called Page Layout—but on a totally different menu (Document). In Word, you must go to Page Setup on the Format menu to set margins, and to Header/Footer on the View menu to set headers and footers.

In yet another Microsoft product, Excel, Page Setup appears back on the File menu. Word has a Repaginate command on the Tools menu; Write puts it on the File menu. User-interface conventions from other vendors diverge even more. Keyboard and mouse conventions are just as bad. For example, F3 in Notepad initiates a search or finds the next instance of a search target. In Word, F3 inserts a glossary item (boilerplate text or graphics). The key appears to have no function at all in Write. The right mouse button is unused in most applications, but how it is used in those that do is wildly inconsistent.

In Word, a right-click can select a whole column of a table or can initiate a columnar select mode in regular text. The right button has no function in Notepad and Write. In Excel, a right click typically brings up a menu of actions that can be performed on the currently selected cell(s) or object(s). Recent Borland products push the object-oriented behavior even farther.

Take clicking. When do you single-click? When do you double-click? When do you triple-click? Even experienced users typically have to think carefully before answering that question, and I've seen beginner after beginner become completely befuddled.

Generally speaking, menu items are used for multiple purposes. They can initiate immediate execution of some action, they can bring up a dialog box that in turn initiates some action, and they can indicate (and change) program status. The View menu in Word for Windows is a great example. (I only pick on Word because I love that software so much.)

That menu has one group of items that selects one of three document views (normal, page layout, outline); a bullet appears on the menu in front the current view. The menu has a single item that turns draft mode on or off, indicated by the presence or absence of a check mark. The menu has another group of items that turn some (but by no means all) screen items (toolbar, ribbon, and ruler) on and off, also indicated by check marks. And there's more! All-in-all, it's a total mess!

STYLE GUIDELINES

Microsoft has taken steps to ease the situation. The company recently published a set of Windows user-interface standards in "The Windows Interface, An Application Design Guide," which also includes a pair of floppy disks with demo programs and standard buttons and cursors that the company is promoting use of as standards. However, although it may help independent software developers get on the same page, a mere style guide is not nearly enough.

Microsoft also released a set of dialog boxes for common functions (opening, saving, and printing a file; choosing font and color; and more) with Windows 3.1. applications developers can achieve user-interface consistency—and save a fair amount of time over writing their own—by using those dialog boxes. But many developers immediately criticized both the look and the functionality of those common dialog boxes. As a result, most developers simply went on creating their own.

Is it mere egotism on the part of developers who want to do it their way? Or is there something deeper going on here? I think the latter. I think that all those shareware and commercial authors of alternate Windows shells, every developer who has ever implemented a "standard" function in a "nonstandard" way, every promoter of user-interface standards, however premature—every one is responding to our collective lack of understanding of the most efficient ways of interacting with a computer. They sense that something is wrong, and want to improve it. But in the vast majority of cases, those efforts are misdirected, like perfecting the design of the buggy whip, when what people really want are self-propelled autonomous locomotive units (you know, cars).

The graphical user interface takes us part of the way there, but not all the way. What we really need is less metaphor and more direct representation of the objects we deal with. For example, typical print preview modes should allow active editing. In truth, we even need to go much farther than that. The entire interaction needs to take place at a higher level.

Leading user-interface *gurus* have begun promoting the idea of what might be called a CUI, or collaborative user interface, one in which the user does not do things to data stored inside a computer by way of some more or less "friendly" (*ugh!*) interface, but one in which human and electronic agents collaborate on performing useful tasks. That type of interface—whoops, interaction—in the past required unreasonable (*i.e.* expensive) amounts of computer power. But in the age of $2000 486 boxes, cost is no longer a concern. ■

CIRCUIT CIRCUS

By Charles D. Rakes

More Stepper-Motor Driver Circuits

On our last visit, we were deep into stepper-motor circuits and before we could wrap up the loose ends, we ran out of time and space. So this month we'll just continue along the same path with more stepper-motor circuits.

Since most of us have slept since then, a brief look at what we covered in last month's column might be a good move. We started things off with a schematic diagram of a typical six-wire stepper motor and a chart showing how to make the motor step in either direction. Then we took a look at two methods of switching current to the motor's windings; one using transistors and the other using power hexFET's. A digitally-controlled, dual-oscillator driver circuit and a rotation reversal circuit brought the visit to a close. Now go dig out last month's issue of **Popular Electronics** and get things moving.

With a single or 4-step driver circuit (that's what we've been using), the stepper motor takes 200 steps per 360° of rotation. That's not too shabby for a number of applications, but for some, a greater number of steps are need. Table 1 shows an eight step sequence that doubles the number of steps from 200 to 400 per complete revolution, giving twice the resolution of that obtained by the 4-step driver circuit. To follow each step position given in Table 1, refer back to the motor schematic, in Fig. 1 of last month's Circus, and run through the eight switch positions. If you have a similar 6-lead stepper motor and four switches you can step the motor through each of the eight steps by operating the four switches in the sequence shown in Table 1.

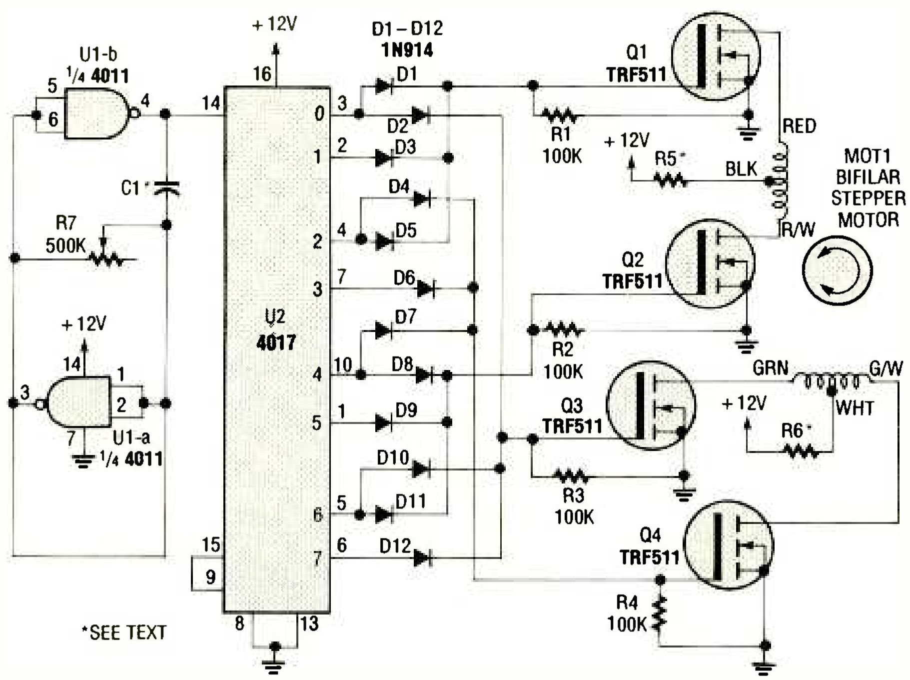


Fig. 1. The half-step driver circuit shown here requires that the stepper motor go through 400 steps to complete one revolution, doubling the number of steps (200) that is normally required.

HALF-STEP DRIVER CIRCUIT

The stepper motor can make the 400 steps per complete revolution at a much faster rate by using the half-step driver circuit shown in Fig. 1. Two gates of a 4011 quad 2-input NAND gate are configured as an astable oscillator, with C1 setting the oscillator's output frequency. (Capacitor C1 can be a 0.01-µF, 50-volt unit for high-speed operation or a .047-µF, 50-volt unit for low-speed operation.) The square-wave output of the circuit at pin 4 of U1-b supplies the clock pulses for U2 (a 4017 divide-by-ten counter). The 4017 produces a sequential eight step output that is repeated over and over as long as clock pulses are applied to pin 14 of U2. The 500k potentiometer sets the motor's stepping speed.

Here's how the 4017's eight-step output matches up with Table 1 to turn on the correct hexFET's in the proper sequence to make the motor turn in the half-step mode: Table 1 shows that in step 1, switches (hexFET's) Q1 and Q3 must be on and Q2 and Q4 off.

Refering to the circuit diagram in Fig. 1, there's a diode from pin 3 of the 4017 that goes to the input of Q1 and another diode from the same pin to the

TABLE 1—HALF-STEP INPUT SEQUENCE

Step	Switch 1	2	3	4
1	On	Off	On	Off
2	On	Off	Off	Off
3	On	Off	Off	On
4	Off	Off	Off	On
5	Off	On	Off	On
6	Off	On	Off	Off
7	Off	On	On	Off
8	Off	Off	On	Off

input of Q3. In that output sequence, the 4017 supplies a positive output to both FET's. The remaining seven outputs follow suit, turning the correct hexFET's on and off.

Resistors R5 and R6 are selected to limit the motor's current to its maximum or a lesser level. The following example may be used as a simple guide in selecting current-limiting resistor values for any stepper motor, power source, and driver circuit. If our stepper has a maximum current rating of 2 amps with a winding resistance of 1.5 ohms and we're using a 12-volt power source, then the total-circuit series-resistance value may be found by dividing the source voltage (12) by the maximum current (2), or R = E/I.

The total circuit resistance for the above example is 6 ohms. The resistance of the motor winding and the hexFET's on-resistance (R_{ds}) values must then be added together and subtracted from the total resistance value to obtain the needed values for R5 and R6. That's 1.5 ohms added to .5 ohms or 2.0-ohms total, subtracted from 6 ohms, which leaves 4 ohms as the value of the two current-limiting resistors. The resistor's maximum power dissipation may be determined by using the power formula of $P = I^2 \times R$, or in this case $P = 2 \times 2 \times 4$, or 16 watts. A 4-ohm, 25-watt resistor would be a good choice for R5 and R6.

There are several high-priced, commercial stepper-motor drivers available that completely eliminate the need for the high-wattage, current-limiting resistors. Instead of turning the excess voltage into heat with power resistors, the driver circuits use a built-in high-frequency chopper circuit that controls the stepper motor's input power. The circuit's operation is similar to that of a switching-mode, power-supply circuit. The chopper supplies a variable pulse-width output that can be adjusted to supply the recommended motor current.

HIGH-FREQUENCY CHOPPER CIRCUIT

Our next entry is an experimental high-frequency chopper circuit. The chopper circuit shown in Fig. 2 connects directly to the hexFET's gates to control the motor driver's on/off time. Three gates of a 4011 quad 2-input NAND gate make up a variable pulse-width generator that operates at about 15 kHz; R4 sets the on/off time. The output, at pin 10 of U1, drives a 2N3904 transistor. The transistor's collector switches the four connected diodes from ground to the positive supply rail.

To use the chopper circuit in conjunction with our half-step driver, connect the anodes of the four diodes in Fig. 2 to the appropriate hexFET gates in Fig. 1. Set R4, in Fig. 2, to mid position and

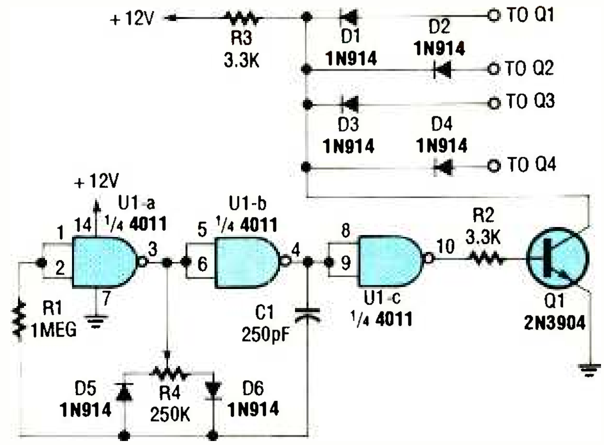


Fig. 2. This high-frequency chopper circuit can be connected directly to the hexFET gates to control the motor driver's on/off time.

PARTS LIST FOR THE HIGH-FREQUENCY CHOPPER CIRCUIT

SEMICONDUCTORS
U1—4011 quad 2-input NAND gate, integrated circuit
Q1—2N3904 general-purpose NPN silicon transistor
D1–D6—1N914 general-purpose silicon diode

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1—1-megohm
R2, R3—3300-ohm
R4—250,000-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS
C1—250-pF, 100-WVDC, ceramic-disc capacitor
Perfboard materials, 12-volt power source, IC socket, wire, solder, hardware, etc.

PARTS LIST FOR THE HALF-STEP DRIVER CIRCUIT

SEMICONDUCTORS
U1—4011 quad 2-input NAND gate, integrated circuit
U2—4017 decade counter/divider, integrated circuit
Q1–Q4—IRF511 hexFET
D1–D12—1N914 general-purpose silicon diode

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1–R4—100,000-ohm
R5, R6—See text
R7—500,000-ohm potentiometer

ADDITIONAL PARTS AND MATERIALS
MOT1—12-volt stepper motor
C1—0.01-µF or .047-µF, 50-WVDC, ceramic-disc capacitor (see text)
Perfboard materials, 12-volt power source, IC sockets, wire, solder, hardware, etc.

leave the power to the chopper circuit off. Now set the half-step oscillator to 10 Hz and the stepper will rotate at about 1.5 rpm. Connect a DC ammeter in series with junction of R5 and R6 (in Fig. 1) and the positive supply rail, and note the motor's operating current. Apply power to the chopper circuit and the ammeter reading should drop to about half of its previous value. Here's why that happens: The chopper circuit takes each of the hexFET's gates to near ground level at a 15-kHz rate for about 50 percent of the time. That reduces the power that is applied to the stepper motor's windings by about the same percentage.

Adjust R4 (Fig. 2) while observing the current meter to increase the motor's current to the desired level. While the current meter is in place, connect a temporary jumper from pins 1 of U1 (Fig. 2) to ground to stop the motor's rate of rotation. If necessary re-adjust R4 for a current reading that's less than the motor's maximum rating. Repeat the procedure several times to make sure that the motor's maximum current is at or below its rated value.

In the eight-step circuit, the motor may be stopped with either one or two motor windings turned on; to properly set the maximum current, two windings must be on.

The 4017 counter has a built-in output-current-limiting circuit that protects the IC from output overloading. That feature allows the shunt-chopper circuit to be tied to the driver circuit without causing damage to the IC.

COUNT-DOWN CIRCUIT

Our last entry this time around, see Fig. 3, is a count-down circuit that counts each step that the motor takes and stops the armature at a pre-set point. The circuit as shown will count up to 99 steps and can be programmed to stop anywhere in between.

Here's how the circuit counts. Counter U1's clock input (pin 14) is tied to pin 14 of the 4017 in the motor-driver circuit (Fig. 1). That keeps the two counter circuits in sync. Counter U1 counts from 0 to 9 and U2 from 10 to 90. The counter circuit is reset by momentarily closing S1 (Fig. 3). Switches S2 and S3 select the desired stopping position.

With S2 and S3 positioned as shown in Fig. 3, the circuit is set to count 22 steps and stop. On the 20th step pin 2 of U3 goes high and on the 22nd step pin 1 goes high, causing the output to go low, stopping the oscillator in the driver circuit. Pin 3 of U3 can be tied to the override input or the on/off input of the driver-oscillator circuit in Fig. 5 of last month's Circus.

The count-down circuit may be connected to the half-step circuit in Fig. 1 by removing the jumper between pins 1 and 2 of U1 (Fig. 1) and connecting pin 3 of U3 (Fig. 3) to pin 1 of U1 (Fig. 1). Leave pin 2 of U1 (Fig. 1) connected to C1 and R7.

Additional 4017 counters may be added to increase the count. Adding one IC will increase the count to 999, and the 2-input NAND gate (U3) will need to be changed to a 3-input NAND gate to accept the three-digit input.

It's time to close again, so until we meet again next time, good circuitry. ■

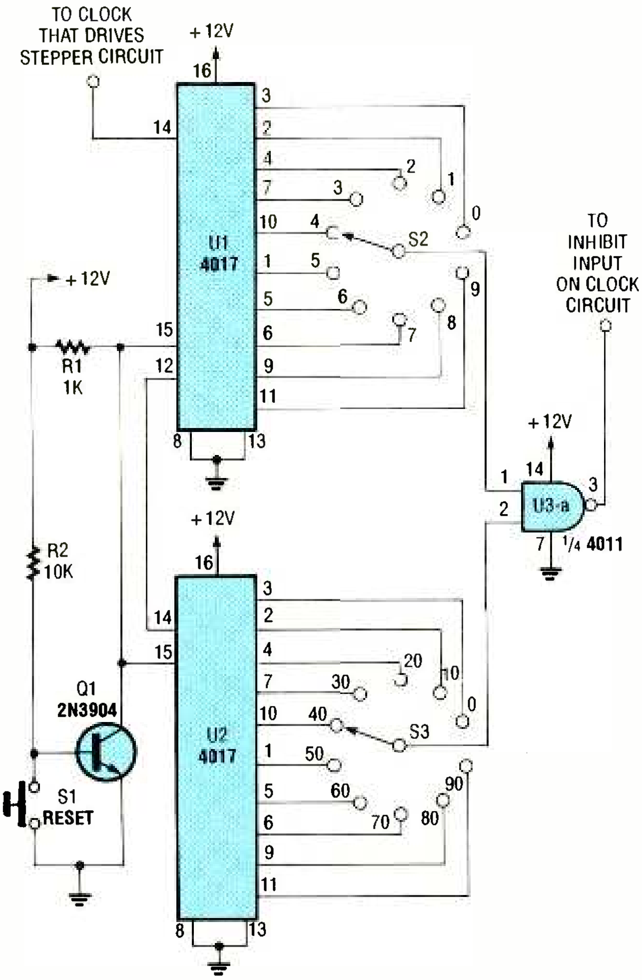


Fig. 3. The count-down circuit counts each step that the motor takes and stops the armature at a pre-set point. In this configuration, the circuit counts up to 99 steps, but can be programed to stop anywhere in between.

PARTS LIST FOR THE COUNT-DOWN CIRCUIT

SEMICONDUCTORS

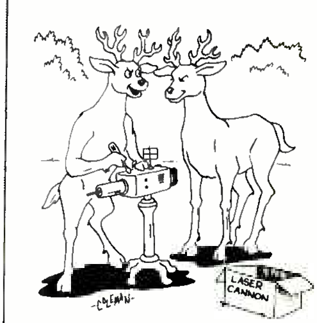
U1, U2—4017 decade counter/divider, integrated circuit
U3—4011 quad 2-input NAND gate, integrated circuit
Q1—2N3904 general-purpose NPN silicon transistor

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1—1000-ohm
R2—10,000-ohm

ADDITIONAL PARTS AND MATERIALS

S1—Normally open pushbutton switch
S2, S3—SP10T rotary switch
Perfboard materials, enclosure, 12-volt power source, IC sockets, wire, solder, hardware, etc.



"This year, when hunting season opens, we'll be ready!"

THINK TANK

By John J. Yacono

Logic Levels And More

If you read last month's column, you know we were right in the middle of discussing how logic levels are represented by voltages and then we switched over to some letters. This month, I'll continue the discussion where we left off, and follow-up with a few audio/video projects contributed by readers.

As we mentioned last time, in positive-logic circuits, lows (or logical zeros) are represented by a voltage near ground. Highs (or logical ones), on the other hand, are indicated by a voltage near the power-supply voltage.

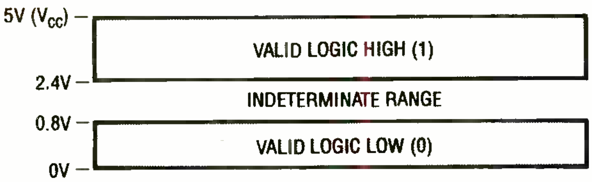


Fig. 1. The voltages used to define highs and lows in bipolar-transistor logic circuits are stratified by the fact that the chips must be operated at a particular power-supply voltage.

That rule is simple in theory, but is a little difficult to put into practice because the two major logic families—complementary metal-oxide semiconductor (or CMOS) and bipolar-transistor logic—define their logical voltage levels differently.

By the way, bipolar-transistor logic is sometimes referred to as TTL (transitor-transistor logic). However, TTL is actually just a subset of the bipolar-transistor logic family. For example, the TTL family does not include a group of chips known as RTL (resistor/transistor logic), which is part of the bipolar-transistor logic family.

To show why CMOS and bipolar chips must define their logic levels differently, we'll have to discuss the key differences between the two families.

CMOS AND BIPOLAR LOGIC

The fundamental difference between CMOS and bipolar logic are the transistors they contain. The transistors are so different, the two families are typically manufactured using two distinct processes. So as not to get bogged down in detail, suffice it to say that bipolar-logic circuits contain tiny versions of ordinary bipolar transistors, whereas CMOS chips are made from MOS transistors.

As you may know from dealing with them, bipolar transistors require at least a few of milliamps of current to saturate them fully on or fully off. By contrast, MOS transistors respond to voltages and require very little bias current to turn them fully off and fully on. To summarize, it could be said that bipolar logic circuits are current-based devices, while CMOS IC's are voltage-sensitive units.

Of course, the more current flowing through a transistor (or any component for that matter), the more it heats up according to Joule's Law. Since raising the supply voltage of a device will increase current flow through it, and thus the heat produced by it, bipolar IC's (with their current-hungry ways) must be designed with a particular maximum supply voltage in mind. Typically that maximum is 5 volts.

That restriction essentially stratifies the voltages that can be used to define bipolar-logic highs and lows. The convention is that any signal below 0.8 volts is interpreted as low, a signal above 2.4 volts is considered high (see Fig. 1). Note that there is a 1.6-volt gap between the defined logic levels. That gap provides a certain amount of noise immunity by preventing noisy high signals from migrating down into the low-level territory, and preventing noisy lows from reaching logic-high voltage levels.

Since little current flows through any CMOS circuit, heat production is not as much of a concern. So CMOS chips are designed to operate over a wide range of voltages (3 to 18 volts is typical). Of course, that means that the logic levels of CMOS devices are less rigorously defined, too. Their logic levels are defined as percentages of the power-supply voltage—anything below 30% is a low, and a signal must be over 70% of the supply voltage to be considered a high (see Fig. 2). That system of logic interpretation has a gap in the middle to heal over noise problems just as the bipolar-logic system does.

Next month we'll explore the other differences between those two logic families. For now lets open the mail bag and dig-in.

NO MORE THUMP

We have a tape deck and amplifier that are used for background music that is turned on and off three times a day by a timer. It's a

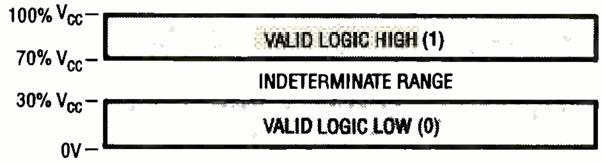


Fig. 2. Since CMOS chips can be operated over a wide range of possible power-supply voltages, the voltages that distinguish highs, lows, and noise are stated in percentages of the supply voltage.

simple arrangement that works fine, except that when the timer turns off, the filter capacitors in the amplifier's power supply hold enough charge to keep it operating for 2 or 3 seconds, and you can hear the tape deck slowing down. The ideal arrangement would be a circuit that shuts off only at the end of a song on the tape, but I haven't gotten that done yet.

Until I do, I devised the enclosed circuits (see Fig. 3) for a delayed turn-off of AC power to the tape deck, allowing the amplifier's capacitors to discharge before the tape deck stops. I got the idea from the article "Solid-State Relay" in *Radio-Electronics*, May 1992, with additional information from the MOC3010 spec sheet in Radio Shack's Semiconductor Reference Guide, and from the circuits on Radio Shack's package for the MOC3010.

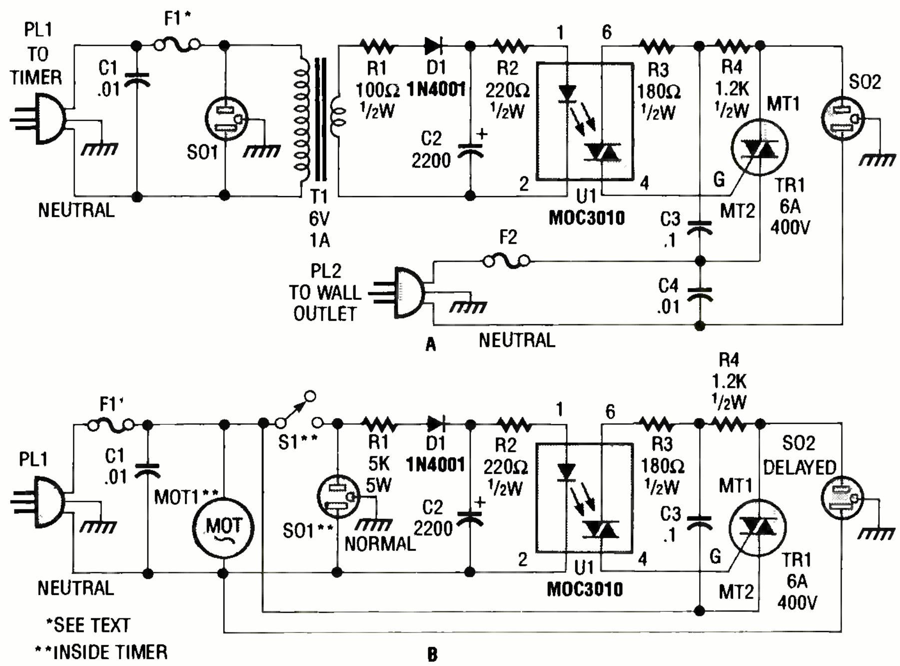


Fig. 3. Here are two versions of a turn-off delay circuit. The first one (A) requires a power transformer, while the one in B does not.

My first version of the circuit (see Fig. 3A) had a small 6-volt power transformer (any current rating proved adequate), and worked very well. After looking at it, I decided that the transformer could be eliminated by increasing the size of R1 (see Fig. 3B), and being very careful about the wiring polarity of the AC circuit. In both circuits, the length of the delay in both turn on and turn off is controlled by value of C2. The value shown gives a delay of about 1½ seconds; making C2 a 4700-µF unit gives a delay of about 3 seconds. In the revised circuit, I used a value of 500 ohms, 5 watts for R1. I also tried it with a 4700-ohm, 2-watt resistor, and it did not seem to overheat. Capacitors C1 and C3 (and C4 in the original circuit), should have a minimum rating of 150-volts AC or 400-volts DC.

For either circuit, it is desirable to use polarized AC plugs, cords, and sockets (neutral is the wide prong, the white wire for color-coded cords, and the wire with the ribbed outer surface in flat cords). Also, the circuit should be built in an all-plastic case for safety. I used an 8-pin IC socket for U1, and built the circuit on a pre-drilled IC board except for TR1, which I mounted on a terminal strip.

While my original application might not have widespread use, I think there are other uses for a delayed AC turn-off.

—William Stiles, Hillsboro, MO

An interesting pair of circuits. Your warning about wiring and insulating the revised unit properly is very important. All transformerless AC circuits are dangerous unless the utmost precautions are taken during construction. Insulate everything, watch the polarity of your wiring, and be extra careful while testing the unit.

HEADPHONE JACK CONVERTER

Several weeks ago, the pre-amp unit in my stereo system developed faults

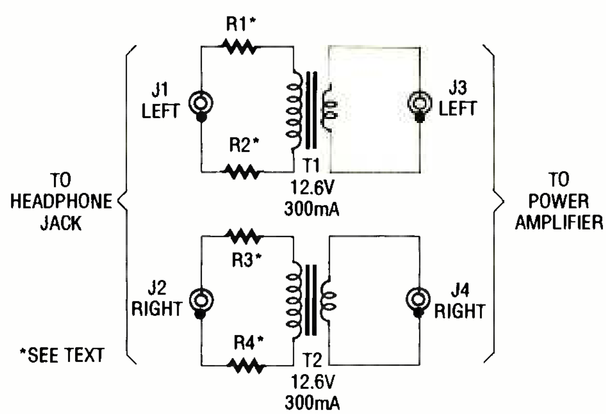


Fig. 4. This straightforward circuit can turn moderately amplified audio signals into line-level equivalents for recording or amplification by a different amplifier.

that required it to be serviced at the factory. I was saddened by the fact that I would be without music for 2 or 3 months. After I mailed

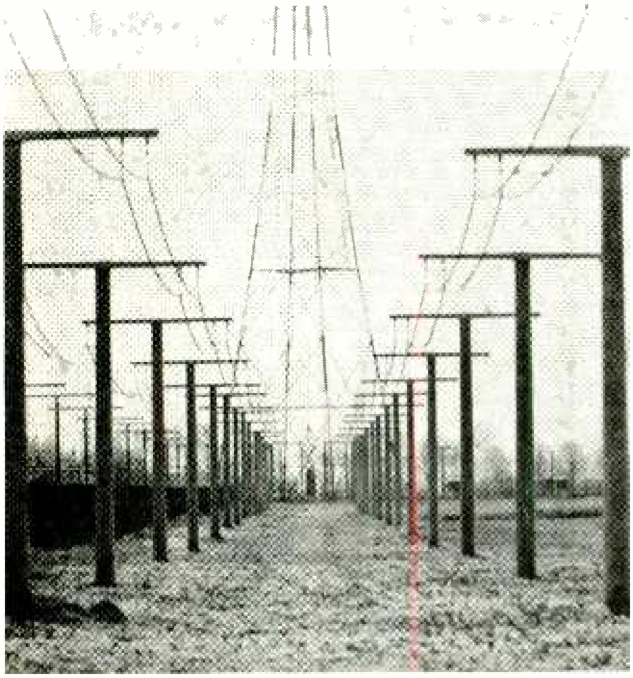
(Continued on page 90)

DX LISTENING

By Don Jensen

Who's Tuning World-Band Radio?

Shortwave listeners, world-band monitors, DX'ers . . . who are we? By its very nature, SWL'ing tends to be a one-on-one activity, one listener, one receiver. As a result, we tend to operate in a vacuum. We tune in regularly, but are unaware of the many others out there—one study says more than 11-million of them are American—who also are listening to the world bands.



A part of the shortwave transmitting antenna system of Germany's Deutsche Welle.

There are, of course, many reasons for listening-in on the world. For some of us, it is a cheap and easy way to travel to exotic places, if only in our imaginations. For others, shortwave radio offers the chance to learn about other peoples and cultures.

Many people, particularly since the Gulf War, turn to SW radio as a way of getting firsthand news from around the world. Some love the music they hear on shortwave, everything from the African high-life beat to Latin *salsa* rhythms, and with off-the-air recording, build extensive taped libraries. Others find SW a good way to learn, or brush up on foreign languages.

Some of us do it as a hobby. Some of us have never thought of it in that way, but still enjoy tuning-in at any opportunity.

But that still does not answer the question of who listens. The answer is everyone, from A to Z! Confused? Allow me to wax poetic and explain!

Architects and Ayatollahs . . . Khomeini was a shortwave-news junkie according to reports. There are barbers and bartenders and convicted murderers—at least three that I know of, including one who continued to tune shortwave from his prison cell.

SWL's include doctors, both physicians and PhD's, and editors, including at least one at the CNN news headquarters in Atlanta who long ago realized shortwave's value as a news source. Entertainers? The late Jackie Gleason had an extensive listening set up in his Florida mansion and found SWL'ing fascinating. Singer-author Jimmy Buffett is reportedly a shortwave listener.

The ranks of shortwave enthusiasts include farmers and framers, of pictures that is. Our listening fraternity has more than its share of grandpa's—I'm one of those—and green grocers, hairdressers and haberdashers, iron workers and ice cream vendors. There are jockeys, the disc jockey variety, at least. Several very active DX'ers are, themselves, radio professionals, familiar with broadcasting from both sides of the microphone.

Kings? At least several monarchs have been shortwave listeners, according to palace gossip. Jordan's King Hussein, while primarily an amateur-radio operator, has more than a passing interest in shortwave programming. Lawyers, yes, more than a few, and loafers too. You don't have to be employed to be a shortwave listener. Reportedly, British-born film star Michael Caine is a shortwave-newscast fan.

SWL's include nannies and ninnies and neighbors, yours and mine. Post a note on your local supermarket bulletin board and I'll bet you get at least a few calls from others in your hometown who also listen to shortwave radio. Birds of a feather can flock together . . . And speaking of birds, how about the SWL owl? Members of one international SWL club probably do not know that one of their group—for reasons unknown—reports his loggings to the monthly bulletin under an assumed name, that of his stuffed owl.

There are listeners who are priests and professors and pirate broadcasters, as well as quiet, everyday folks for whom buccaneer means only a steep price for corn. Shortwave-radio personalities tune in on the competition, and radar technicians SWL til it really

Hertz . . . as in kilohertz. We have students, and more students, and former Senator (and presidential candidate) Barry Goldwater, who has said young people can learn a lot from shortwave. And UFO experts. Perhaps the foremost scientist probing those unexplained mysteries was an avid SWL as well.

SWL's include veterinarians, whiskey salesmen, and X-ray technicians. I suppose, out there somewhere, there is an SWL zoo keeper or zebra trainer. If so, that completes our alphabetical roster of listeners, our world of listeners.

Where do you fit in? Why don't you drop us a line and let us know? Address your letter to me, Don Jensen, *DX Listening*, **Popular Electronics**, 500-B Bi-County Blvd., Farmingdale, NY 11735. Tell us about yourself, how you got started SWL'ing, and what you most enjoy tuning on shortwave.

And while you're at it, why not include a picture of yourself too. So, do we have any archbishops, balloon sellers, cookie bakers....xylophonists, yak herders or, yes, zoo keepers among our SWL readership?

COMING-UP DOWN UNDER

Long the 98-pound weakling of Pacific-Rim shortwave broadcasting, *Radio New Zealand*'s 100-kilowatt transmitter has moved this island broadcaster into the ranks of the bigger boys. The new transmitter, manufactured by the French electronics firm, Thompson CSF, is located at Rangikaiki, in the center of New Zealand's North Island. RNZI's studios remain at Wellington, some 220 miles to the south. Programs are fed to the remotely-operated, unmanned, transmitter center by microwave link.

A pair of antennas, covering the frequencies from 9,000 to 18,000 kHz, aimed to cover the Pacific area, at headings of 325 degrees and 35 degrees, have been installed. Additional shortwave antennas are to be built in the two-stage project, but the existing pair are expected to satisfy the needs of the station for about the next four or five years. At some time down the road, RNZI expects to add an antenna system covering 6,000 to 12,000 kHz.

Radio New Zealand International, which is broadcasting 18 hours daily, at this writing, was using these frequencies: 9,510, 9,675, 9,700, 15,120 and 17,770 kHz. Try 17,770 kHz during the evening until almost 0700 UTC; 9,700 kHz from then until shortly after 1200 UTC.

*Credits: Mark Anderson, MI; Jim Clar, NY; Rich D'Angelo, PA; Richard Hankison, KS; Tony Orr, VA; Dave Valko, PA; Andrew Yoder, PA; North American SW Association, 45 Wildflower Road, Levittown, PA 19057; Ontario DX Association, P.O. Box 161, Station A, Willowdale, ONT M2N 5S8, Canada.

IN THE MAILBOX

This month, Em Fawcett, Wichita, KS, writes to ask about a station that I've always considered one of the more exotic catches on SW, not so much for its programming, but because Mongolia conjures up, at least for me, wondrous images of the court of Kubla Khan.

"How about a tip on tuning Mongolia's *Radio Ulan Bator*, Em asks? Canadian listener Harry Riddell, reporting in "DX Ontario," the monthly publication of the Ontario DX Association, says that Radio Ulan Bator, logged at 1200 UTC on 12,015 kHz, announced this schedule of English-language programs:

7,260 kHz, 1445–1515 UTC daily; 11,790 kHz, 1940–2010 UTC daily; 11,580 kHz, 0910–0940 and 1940–2010 UTC daily and 1200–1230 UTC Monday, Thursday, and Saturday; 12,015 kHz, 1200–1230 UTC Monday, Thursday, and Saturday.

"I'm a rank beginner at shortwave listening," writes one of our new readers, who lives in California but has asked me not to use his name or city. "I don't want to get involved in a lot of technical stuff that I won't understand and, frankly, don't care if I ever do. But I need to know where I should be tuning to hear shortwave broadcasters. Help!"

Okay, Mr. X, fair question. I think, eventually, you'll find it useful to pick up at least a smattering of information on things such as propagation . . . when you should be tuning at various times of the day and night to maximize your chances of hearing SW broadcasters. But, let's leave that for some future time.

Right now, you ask about frequencies to tune. There are 12 ranges of frequencies established for shortwave-program broadcasting. They are: 2,300–2,495 kHz (120-meter band); 3,200–3,400 kHz (90-meter band); 3,900–4,000 kHz (75-meter band); 4,750–5,060 kHz (60-meter band); 5,950–6,200 kHz (49-meter band); 7,100–7,300 kHz (41 meter band); 9,500–9,900 kHz (31-meter band); 11,650–12,050 kHz (25-meter band); 13,600–13,800 kHz (22-meter band); 15,100–15,600 kHz (19-meter band); 17,550–17,900 kHz (16-meter band); 21,450–21,850 kHz (13-meter band); and 25,600–26,100 kHz (11-meter band).

You'll have the best luck tuning the lower bands during your local nighttime hours and the higher frequencies during daylight. That's about as barebones as I can make it. I hope that helps enough to at least get you started in this wonderful hobby.

DOWN THE DIAL

Here are some stations to try. Remember that all times are given in UTC (Coordinated Universal Time; sometimes called Greenwich Mean Time), which is equal to EST + 5 hours, or CST + 6 hours, MST + 7 hours, and PST + 8 hours.

COLOMBIA—5,075 kHz. *CARACOL*, a network SW outlet from this South American country, is not a difficult catch most evenings, say around 0300 UTC, although the programming is all in Spanish. But you should be able to make out the frequent identification—*car-ah-coal*—amidst the jingles and ads.

KENYA—4,934 kHz. With some luck you may hear the *Kenya Broadcasting Corp.* station at Nairobi from 0300 UTC with English news, sports, commentary, and music.

UGANDA—4,934 kHz. *Radio Uganda*, located at Kampala, is noted on this frequency during the 0357 to 0419 UTC time slot, with the announcement: "This news comes to you from Radio Uganda."

URUGUAY—11,835 kHz. *Radio El Espectador* in Montevideo, the Uruguayan capital, has been reported here at around 0200 UTC, all in Spanish, and suffering from some interference.

VIETNAM—15,009 kHz. *Hanoi's Voice of Vietnam* is heard at 1230 UTC in English, with news, identification, commentary, and music. ■

HAM RADIO

By Joseph J. Carr, K4IPV

More On Direct Conversion Receivers

Last month we introduced the direct-conversion receiver (DCR). Those simple high-frequency receivers work well from 75/80 meters up to 20-meters, although performance deteriorates a bit above 40-meters. In the DCR, a local-oscillator (LO) signal is mixed with the RF signal of the same or a nearby frequency to produce direct conversion of the modulation to audio. Direct-conversion receivers work best with CW and SSB signals, but can also be used for AM signals when the LO and RF are on exactly the same frequency, *i.e.*, it is zero beat with the AM signal's carrier. When that condition is met, the difference (IF) frequency will be the audio modulation in the sidebands of the AM signal. Neat, huh?

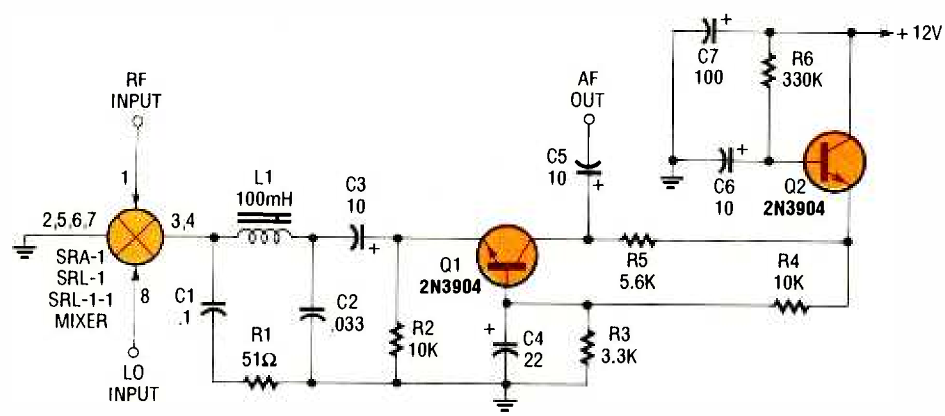


Fig. 1. Here is a partial schematic for a basic DCR circuit based on a passive, double-balanced mixer (DBM) such as the Mini-Circuits (P.O. Box 166, Brooklyn, NY 11235; 718-934-4500) SRA-1, SRL-1, and SRL-1-1.

Last month, we learned that there were several necessary stages to a DCR: mixer, local oscillator, an audio low-pass filter, and a very high-gain, audio-amplifier section. The mixer should be a double-balanced type, so that the LO- and RF-signal residuals do not appear in the output of the mixer. The LO can be nearly any stable variable-frequency oscillator (VFO); many such VFO designs are given in sources such as the *ARRL's Radio Amateur's Handbook* (ARRL, 225 Main Street, Newington, CT 06111).

The low-pass filter can be a simple LC or RC filter, or a complex multi-section or diplexer filter. If SSB and AM signals are desired, then the upper −3 dB cut-off frequency should be 3,000 Hz for reasonable fidelity, or about 2,500 Hz if you are willing to trade off a bit of fidelity for better rejection of adjacent-signal crud. If you are going to do CW only, then set the filter cut-off frequency to 1,000 Hz, or a bit above whatever frequency tone you like to hear.

Of course, if you are only interested in CW, then select a note for the tone that is comfortable for you, and then build an op-amp bandpass filter centered on that frequency. It will add a lot of selectivity at low cost. In fact, many DCR designs include a bandpass filter for both CW and SSB/AM versions, although for the different modes, the bandwidth and center frequencies will be different.

PASSIVE DBM-BASED DCR

Figure 1 shows a partial schematic of a DCR based on a passive, double-balanced mixer (DBM) such as the Mini-Circuits (P.O. Box 166, Brooklyn, NY 11235; 718-934-4500) SRA-1, SRL-1, and SRL-1-1. The RF signal, up to +1 dBm, is applied to pin 1 of the mixer, while the LO signal (up to +7 dBm) is applied to pin 8. Pins 2, 5, 6, and 7 are grounded. The IF output, which in this case is audio, is taken from pins 3 and 4, which must be connected together for the device to work.

The output circuit of the mixer consists of two circuits. First, there is an RC-terminating network (consisting of R1 and C1) and an audio low-pass filter, consisting of L1 and C2. The terminating network consists of a 0.1-µF capacitor (for high frequencies) and a 51-ohm resistor. The idea of the resistor is to exactly match the output impedance of the mixer, so that unwanted high frequencies will be absorbed in a matched impedance rather than being reflected back into the mixer. The audio frequencies are excluded by the use of the 0.1-µF capacitor.

The audio frequencies are stripped off by the low-pass filter, consisting of L1 (a 100-mH series RF choke)

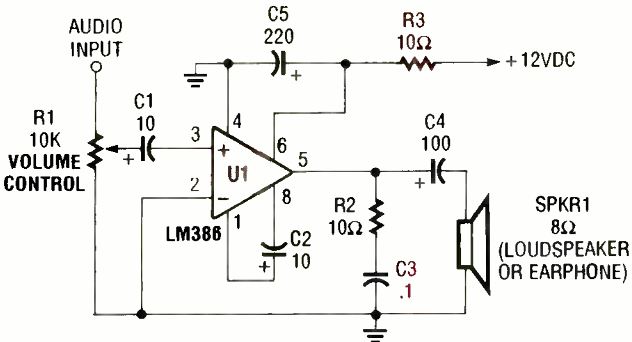


Fig. 2. Shown here is a simple LM386-based audio amplifier that can be used with the passive DBM circuit shown in Fig. 1.

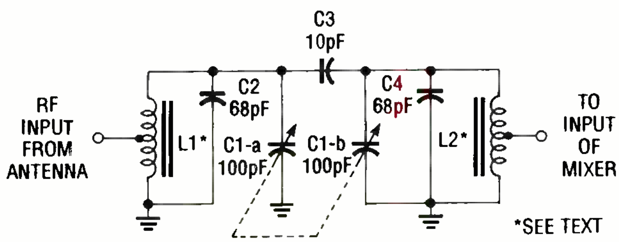


Fig. 3. The tunable bandpass filter shown here can be used in the 40-meter band. The tuning is handled via a dual 100-pF variable capacitor that is connected in parallel with 68-pF fixed capacitors.

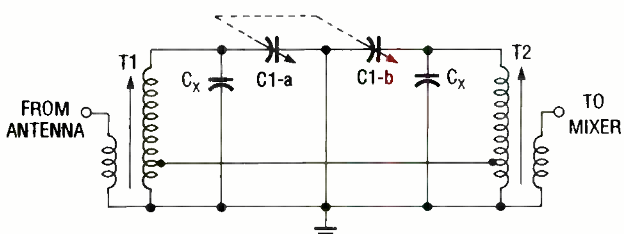


Fig. 4. An alternative scheme to using the circuit in Fig. 3 is to use a pair of 10.7-MHz IF transformers with low-impedance taps. The low impedance taps are connected together, while the input signal is applied to the link coil on T1, and the output signal is taken from the link from T2.

and C2 (a 0.033-µF shunt capacitor). The audio output of the filter is passed to a common-base (*i.e.*, emitter input) transistor amplifier, Q1. That particular configuration is selected because it will match the input of the filter circuit. The amplifier is based on a 2N3904 general-purpose unit but any equivalent part will do.

The other transistor (Q2) is used as an active decoupler, whose purpose is to stablize the circuit. Like the audio preamplifier, it is built around 2N3904 general-purpose transistor, although, again, something similar will do.

The output signal is coupled from the collector of the transistor amplifier to an audio amplifier with a high gain. A circuit built around the LM386 audio amplifier will be sufficient for most applications.

AUDIO AMPLIFIER

A typical LM386 amplifier circuit is shown in Fig. 2. That IC is available from Digi-Key (P.O. Box 677, Thief River Falls, MN, 56701-0677; 1-800-344-4539), from local Radio Shack stores, and a host of other sources.

The input of the mixer does not have to be tuned, in theory, but in practice its a good idea to provide some selectivity "up front." The problem is the dynamic range of input signals overloading the front-end of mixer. Consider the 40-meter band in the evening for an indication of how bad it can get. There are flea-powered QRP stations, ordinary stations that are weak because of distance and propagation conditions, along with "bone-crushing blow torches."

BANDPASS FILTER

Figure 3 shows a tunable bandpass filter for use in the 40-meter band. The tuning is handled via a dual 100-pF variable capacitor, in parallel with two 68-pF fixed capacitors. You can theoretically set this circuit to mid-band, and then leave it. It has sufficient bandpass for all the band. However, you can "twiggle" the center frequency by adjusting C1-a/C1-b. I've found that it's possible to dump some powerful stations down in the mud using that process.

The inductors are made from Amidon Associates (P.O. Box 956, Torrance, CA, 90508) type T-50-6 core toroidal forms wound with 32-turns of #26 AWG enameled wire, tapped for input or output at five turns.

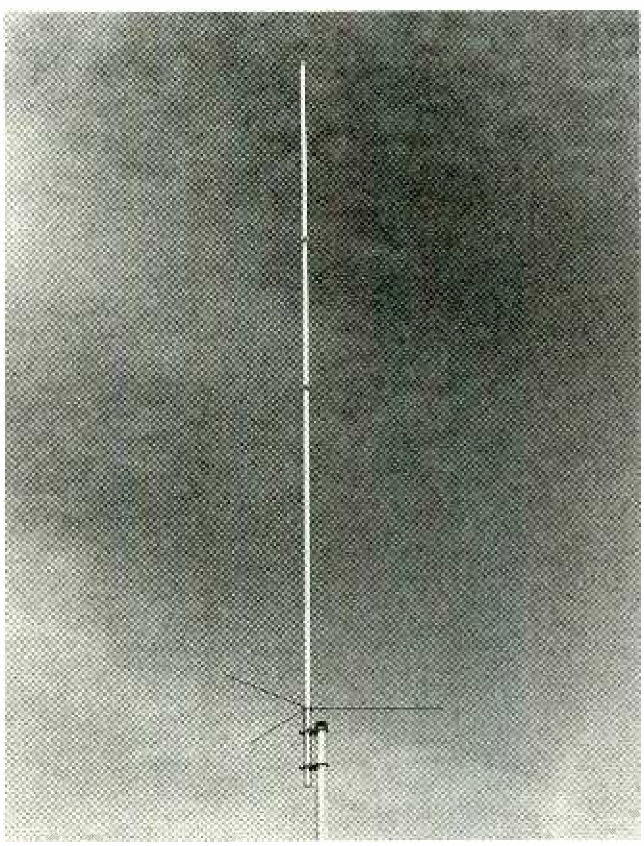
An alternative scheme (see Fig. 4) is to use a 10.7-MHz IF transformer with a low-impedance tap. In the circuit, two such transformers are used, with their low impedance taps connected together. The input signal is applied to the link coil on T1, while the output signal is taken from from T2. A dual-section 365-pF variable capacitor (C1) is used to tune the circuit down to 40-meters or lower. ■

SCANNER SCENE

By Marc Saxon

Antenna Roundup

Look, up in the sky! It's a bird, it's a plane, no, it's an antenna! It certainly can't be *Superman*—the Man of Steel got whupped good and proper by a super-villain. We'll settle for the antenna, though, because it's an important part of any monitoring installation.



The Cushcraft ARX-270, an omnidirectional antenna designed for ham use, also makes a good receiving antenna for scanners.

We wanted to pass along some thoughts and information on antennas for your home scanner. Ideally, you'll want an antenna mounted outside, as high as possible. As a rule, the on-board telescoping whip that was supplied with your desktop scanner doesn't do very much.

One frequently overlooked aspect of getting a scanner antenna is the option of using an omnidirectional ham antenna. For receiving purposes only, these antennas do just fine quite far outside the edges of the ham bands for which they were designed. That wouldn't be true if they were being used for transmitting, where they were designed for proper operation only within specific ham bands. However, ham antennas usually are rugged, easy to install, reliable, and inexpensive. In addition, there are a lot of different models from which to chose.

For instance, a ham antenna that is well suited to scanner use is the *Cushcraft ARX-270*. This antenna was designed for operation in both the 144–148-MHz and the 420–450-MHz ham bands. It offers 9-dB gain on the VHF band and 12-dB gain on the UHF band. It stands 16½ feet tall but, since it is made of fiberglass, it weighs only five pounds. It will survive a 90-mph wind! The ARX-270 is quite a good VHF/UHF scanner antenna.

The antenna is available from ham-radio dealers that handle Cushcraft products. For more information, check with Cushcraft Corporation, P.O. Box 4680, Manchester, NH 03108. Their phone number is 603-627-7877.

A unit called the *Super Dana* is a base-station scanner antenna designed solely for receiving 800–950-MHz band signals. It uses a multi-section colinear design encased in a rugged PVC tube and contains an internal 15-dB gain amplifier to boost even the weakest signals. The antenna stands about three feet high, comes fully assembled, and includes all mounting hardware. Installation is easy (it clamps to masts up to 1½ inches in diameter).

The Super Dana costs $80 plus $5 shipping ($8 to Canada, Alaska, and Hawaii) from Electron Processing, Inc., P.O. Box 68, Cedar, MI 49621. Call 616-228-7020 for phone orders.

For the many scanner owners who tell us that they don't want to install an outside antenna, or can't because of landlord restrictions, there is the popular *AE-12* antenna eliminator. The UL-listed AE-12 plugs into any AC outlet to serve as an interface, allowing safe access to a building's electrical wiring, providing an effective local receiving antenna for your scanner, VHF/UHF color TV, FM stereo, or AM radio. Tunable to peak your reception from 100 kHz to 900 MHz, the device comes with six feet of coaxial cable, F-type connectors, a 75–300-ohm VHF/UHF splitter, instructions, and a one-year manufacturer's limited warranty for defects or malfunction. If your scanner has a BNC-type antenna connector, you'll need a Radio Shack 278-251 ($1.99) adapter to hook the AE-12 to your scanner. The AE-12 isn't intended to work inside metal buildings, or near AC lines surrounded by metal conduit.

The AE-12 is available for $37.50, plus $3.50 shipping ($4.50 to Canada), from CRB Research, P.O. Box 56, Commack, NY 11725. (New York State residents please add $3.49 sales tax.) Phone orders (Visa or MasterCard) are accepted on Mondays, Tuesdays, Thursdays, and Fridays from 10:00 to 2:00 EST, at 516-543-9169.

FLYING HIGH

The airlines are quite a mess. Practically every time you turn on the TV news, or read a newspaper, you learn about mechanical work that didn't get done, or passengers who were supposed to fly to Anchorage, but were put on a flight to Ankara because of employee error. If you have ever flown, you have seen the problems with baggage gone astray, in-flight meals that didn't get cooked, seats that don't recline (or that do recline, but then balk at returning to the upright position.)

It's more interesting—and certainly much less stressful—to experience those little disasters via your scanner than while actually traveling. Did you know it was possible to do just that?

As you know, most better scanners have a VHF aeronautical band that runs from 118 to 137 MHz. Tucked away in the midst of that band is a sub-band that extends from 128.825 to 132.00 MHz. This band, contains "company frequencies," which are set aside for exclusive communications between airplanes and ground stations wherein company matters are discussed.

Some company frequencies are used for routing (read "dull") things like gate assignments at larger airports or other similar logistical matters. However, some of the company frequencies buzz away with annoyed pilots radioing down complaints about their aircraft, often noting that it's something that has been reported several times but never fixed—"little" things like navigational equipment that isn't working properly, cracked or filthy windshields, broken cockpit headsets, etc.

There are passengers who are described as being drunk, nasty, ill, emotional, nervous, or upset about one thing or another. And there are those who demand that some other airline be notified that they are going to be late making a connecting flight. Others are absolutely panicked when they realize that they left an attache case, suitcase, or camera at the last airport.

That is what you can hear on some of the frequencies between 128.825 and 132.00 MHz. Put your scanner into search/scan mode. The frequencies here are in 25-kHz steps in the AM mode. After you listen for a while, you will find that in your monitoring area there are certain specific frequencies where the best action and the most complaints are being passed. Once you learn the best frequencies, program them into your scanner's memory.

Write to us with your frequencies, questions, etc., at *Scanner Scene*, **Popular Electronics**, 500-B Bi-County Blvd., Farmingdale, NY 11735. ■

ELECTRONICS LIBRARY

Tune In On Telephone Calls

by Tom Kneitel, K2AES

Most people, operating under the false assumption that they have total privacy on the telephone, exchange personal and business secrets, wheel and deal, argue, make up, whisper sweet little nothings, conduct legal and illicit business, gossip—in other words, gab unconcernedly about all sorts of

personal affairs. Yet calls made over cellular and cordless phones and other modern telecommunications devices are being broadcast over the airwaves, where they can easily be intercepted by anybody with a shortwave receiver or scanner. No technical expertise is required for such eavesdropping, but a bit of know-how helps. The second edition of this book provides more than a little bit of know-how. Completely revised and updated to include hundreds of new frequencies, the book now has information on the 900-MHz cordless telephones and the new frequencies available for 46/49-MHz cordless phones. All of the hundreds of HF frequencies and bands for high-seas telephone service, originally shown in the first edition, have changed, and the new frequencies are listed in this edition. Also included is information on frequencies used for radio paging, and upgraded data on airline air/ground service and ham-radio VHF/UHF autopatch bands. Two areas covered for the first time are the frequencies set aside for calls from off-shore drilling rigs and the radio service set up to provide radio telephones in rural and wilderness areas. In addition, the book covers the legalities of monitoring phone calls, and the hardware required.

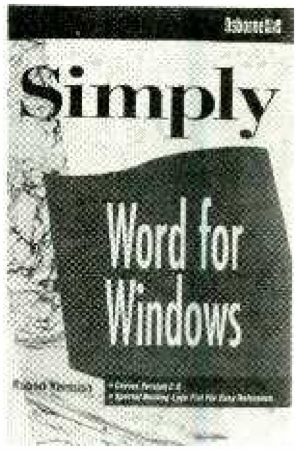
Tune in on Telephone Calls is available for $12.95 plus $3.50 shipping ($4.50 to Canada) from CRB Research Books, Inc., P.O. Box 56, Commack, NY 11725; Tel: 516-543-9196 (10:00–2:00 EST, Monday, Tuesday, Thursday, and Friday only). NY State residents must add $1.40 sales tax.

CIRCLE 91 ON FREE INFORMATION CARD

SIMPLY WORD FOR WINDOWS

by Robert Kermish

Providing an easy introduction to Microsoft's Word for Windows, this book explains the popular word-processing program in easy-to-understand language. It offers clear definitions of key words and concepts, and includes dozens of helpful illustrations. No prior word-processing experience is required. Through simple illustrated instructions, the book demonstrates how to start the program and how to use menus



for fast and easy access to commands. It goes on to explain how to create, save, and print a document, and then how to exit from the program. Readers are shown various options for changing the format and appearance of paragraphs and characters and importing graphics to make eye-catching documents. The book also explains how to perform quick proofing using the spelling and thesaurus features and how to store phrases, names, and addresses with the glossary feature.

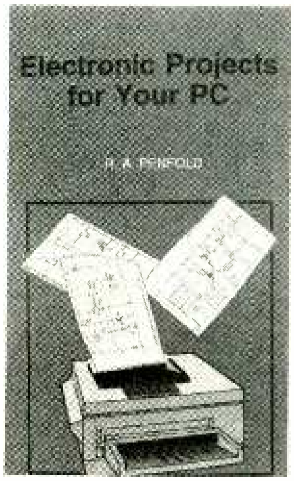
Simply Word for Windows costs $14.95 and is published by Osborne McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710; Tel: 510-549-6600; Fax: 510-549-6603.

CIRCLE 92 ON FREE INFORMATION CARD

ELECTRONIC PROJECTS FOR YOUR PC

by R.A. Penfold

The internal expansion slots in IBM-PC's and compatibles provide full access to the computer's buses and allow a number of add-ons to be easily installed. The computers' sophistication enables them to handle almost any interfacing task that you can conceive. This



book details several useful PC add-on circuits that hobbyists can build. Included are digital I/O ports, A/D and D/A converters, voltage- and current-measurement circuits, a resistance meter, a capacitance meter, constant- and pulsed-voltage model-train controllers, position sensors, a stepper-motor interface, relay and LED drivers, and a Triac-based mains-switching interface. Each of the projects uses a basic 8-bit slot, making them suitable for use with any PC or compatible with the standard ISA or EISA expansion bus.

Electronic Products for your PC (order number BP320) is available for $5.95 plus $2.50 shipping and handling from Electronics Technology Today Inc., P.O. Box 240, Massapequa Park, NY 11762-0240.

CIRCLE 97 ON FREE INFORMATION CARD

1993 TEST & MEASUREMENT CATALOG

from Extech Instruments

This 43-page, full-color catalog includes detailed specifications and descriptions of portable and benchtop instruments for use in test and measurement, plant maintenance, water-quality testing, and monitoring- and-control fields. New products highlighted in this year's catalog include DC/AC current clamp meters ranging from 1 mA to 2000 amps, a thermo-hygrometer/recorder with built-in printer for temperature and humidity, a data-acquisition system with a multimeter that has a built-in RS-232 interface, and a pH/ORP controller with alarms. Other new products include an ACA leakage tester, a DC power supply, a 4½-digit true-RMS multimeter, and a viscosity meter. Standard product lines feature multi-function multimeters, sound and light meters, timed controllers, temperature and humidity meters, pH and conductivity meters, and instruments for controlling and monitoring.

The 1993 Test & Measurement Catalog is free upon request from Extech Instruments Corporation, 335 Bear Hill Road, Waltham, MA 02154; Tel: 617-890-7440; Fax: 617-890-7864.

CIRCLE 93 ON FREE INFORMATION CARD

ELECTRONIC COMPONENTS/ COMPUTER PRODUCTS CATALOG

from Jameco

Products and services for computer buffs, electronic hobbyists, and professionals in both fields are offered in this catalog. New for 1993 are an additional 900 components, special MIS network products, and a kit contest in which you can win $300 for your idea for a particularly exciting or creative kit. Also highlighted in this issue are full pages of new test leads, hardware, and enclosures; a phone/fax switcher; and the Kidz Mouse for IBM PC's and compatibles, designed to fit smaller hands. Interspersed among the product listings are "InfoBytes," short technical articles containing tips to make you a better informed customer.

The Electronic Components/ Computer Products Catalog is free upon request from Jameco, 1355 Shoreway Road, Belmont, CA 94002; Tel: 1-800-831-4242; Fax: 1-800-237-6948. ■

CIRCLE 100 ON FREE INFORMATION CARD

NEW PRODUCTS

40-Inch Direct-View TV

The world's first consumer 40-inch direct-view television is *Mitsubishi's CS-40FX1*. It provides 768 inches of screen surface, which is 66% more picture than 31-inch sets, 119% more than 27-inch models, and 300% larger than a 20-inch TV.

As a stand-alone unit, the CS-40FX1 provides outstanding audio performance with built-in twin speakers, an MTS stereo system, and a remote-driven graphic equalizer. An optional base (model *MB-40FX*) features four built-in speakers and a VCR compartment. It is compatible with all other Mitsubishi home-theater components, including A/V receivers, multiple VCR's, external loudspeakers, and subwoofer systems.

The 40-inch set is just over 27 inches deep, making it easy to fit in an average-sized living room. It comes with an illuminated programmable remote control, and features an on-screen operating system called ViewPoint, which uses complete sentences in straightforward English to guide owners through set-up and operation.

The CS-40FX1 has a suggested retail price of $4999. For additional information, contact Mitsubishi Electronics America Inc., 5665 Plaza Drive, Cypress, CA 90630; Tel: 800-828-6372; Fax: 714-229-3854.

CIRCLE 101 ON FREE INFORMATION CARD

HAND-HELD TEST BENCH METERS

Two additions to *B+K Precision's* popular *Test Bench* line of multi-function DMM's offer the capabilities of a voltmeter, an ammeter, an ohmmeter, a frequency counter, a transistor tester, a capacitance meter, a logic tester, and a continuity tester in one rugged, handheld unit. Each meter is housed in a drop-resistant case with an impact-absorbing rubber boot that also provides test-lead storage. Internal circuitry is protected by overload protection and high-energy fusing on both μA/mA and 20-amp current ranges.

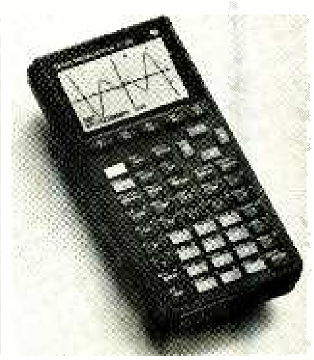
Readings are displayed to 3¾ digits (4000 count). The *Model 388A* has DC accuracy within 0.5% and AC accuracy within 1.2% from 50 Hz to 500 kHz. The *Model 389* has 0.25% DC accuracy and 0.8% AC accuracy. DC and AC current measurement capabilities extend to 20 amps, with resistance measurement to 40 megohms. Five capacitance ranges extend to 40 μF. The frequency-counter capability reaches to 4 MHz with resolution of up to 1 Hz on the Model 388A, and to 500 kHz with resolution of up to 0.1 Hz on the Model 389. Both models test diode junctions with a maximum test current of 1 mA and a maximum open circuit of 3.45 volts. Both units also have an audible continuity test beeper. The Model 388A also tests bipolar transistors for hFE gain and indicates a logic state (1 or 0) in TTL level digital circuits. The Model 389 features a 42-segment analog bar graph to simplify peak, null, or level adjustments. Other added features include relative mode, min/max recording, data hold, memory, and auto or manual ranging.

The Models 388A and 389 Test Bench meters have suggested retail prices of $119 and $139, respectively. For more information, contact B+K Precision, 6470 West Cortland Street, Chicago, IL 60635; Tel: 312-889-1448; Fax: 312-794-9740.

CIRCLE 102 ON FREE INFORMATION CARD

GRAPHICS CALCULATOR

Combining the engineering functionality of an advanced scientific calculator with the visual problem-solving approach of a graphics calculator, *Texas Instruments' TI-85 Graphics Calculator* is designed to help technical students and professionals evaluate problem-solving strategies quickly and efficiently. The programmable handheld unit has built-in software that makes it possible to perform graphic investigations of almost any type of problem. It displays graphs of functions (up to 64 × 128-pixels) as well as parametric, polar, and differential equations (on eight 21-



cnaracter lines) on its supertwist LCD readout. The TI-85 can solve for any variable in an equation, simultaneously solve 30 equations, and find the roots of a polynomial up to the 30th order. It handles complex numbers, matrices, vectors, lists, and strings. Matrix dimensions can range up to 30 × 30, and the number of matrices and vectors that can be handled is limited only by the calculator's memory.

The TI-85 has 32K bytes of RAM for storing any combination of equations, matrices, vectors, programs, pictures, and graph databases. Programming capabilities of the unit include extensive control features and I/O instructions. A built-in I/O port can be used to link the calculator to a personal computer or to another TI-85. Optional LINK-85 software utilities make it possible to edit and store programs and to print programs, graphs, matrices, vectors, and lists using an IBM or compatible PC or an Apple Macintosh computer.

The TI-85 Graphics Calculator has a suggested retail price of $130. For further information, contact Texas Instruments, Consumer Relations, P.O. Box 53, Lubbock, TX 79408-0053; Tel: 800-TI-CARES; Fax: 806-741-2146.

CIRCLE 103 ON FREE INFORMATION CARD

TEMPERATURE-CONTROL SOLDERING STATION

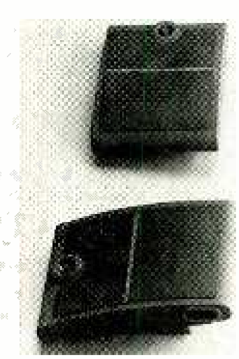
Designed for use with sensitive electronic components, the *Antex TCSU-D2 Temperature Control Soldering Station* from *M.M. Newman* provides positive tip-temperature feedback and zero-voltage switching. Its dial can be used to select temperatures from ambient to 450 °C with ±5 °C accuracy and 1 °C display resolution. Featuring a 50-watt soldering iron with a positively grounded tip and thermocouple that constantly monitors temperature, the station provides zero-crossing electronic switching to eliminate RF interference and magnetic fields. Among the soldering iron's other features are a built-in coil spring holder, a removable sponge tray, and a four-foot, burn-proof cord with a 5-pin DIN connector.

The Antex TCSU-D2 Temperature Control Soldering Station has a list price of $308.16. For further information, contact M.M. Newman Corporation, 24 Tioga Way, P.O. Box 615, Marblehead, MA 01945; Tel: 617-631-7100; Fax: 617-631-8887.

CIRCLE 104 ON FREE INFORMATION CARD

WALL-MOUNTED SPEAKERS

Designed specifically for use in home-theater set-ups, *Jasco's Wall Sounds Stereo Speakers (Model 415)* mount unobtrusively to the walls. They feature a high-tech, thin-profile design with a gray velvet-textured finish. They come with flat and angled wall-mount brackets, and also include stand-up brackets. The 30-watt speakers have a 5¼-inch high-compliance woofer and a one-inch dome tweeter.



The Wall Sounds speakers have a suggested retail price of $159.95. For further information, contact Jasco Products Company, Inc., P.O. Box 466, Oklahoma City, OK 73101; Tel: 405-752-0710. ■

CIRCLE 105 ON FREE INFORMATION CARD

SOLAR POWER SUPPLIES

(Continued from page 40)

A solar cell will deliver about ½ volt into its rated load when exposed to full sunlight; a set of eight connected in series will deliver 4 volts for use with this project. The current capability of a cell may be estimated by noting its area. A rule of thumb for solar-cell current rating is 40 mA for each square centimeter of cell area, when exposed to full sunlight.

Refer to Fig. 8, illustrating the proper way to connect solar cells in series. The connections are made to the back of the cell (positive terminal), and the silver colored band on the front of the cell (negative terminal). One must be extremely careful when soldering wires to the cells, which are extremely fragile and will break if subjected to excessive force. Use a low-power soldering iron and very fine flexible wire to make the connections.

The assembly of cells should be placed into a frame that's made of wood or some other suitable insulating material. The cells can be held in place by sandwiching them between a piece of glass or clear rigid plastic and the frame. A ⅛ or ¼-inch thick piece of flat foam rubber makes a good cushion to prevent excessive force on the fragile parts.

The regulator circuit itself may be placed into the frame, or a pair of flexible wires can be brought out of the solar panel to allow connection to the circuit.

Checkout. The regulator circuits can be checked out using either the solar-cell array placed in full sunlight as the power source or using a well-filtered adjustable DC supply that can provide 3 to 4 volts at 250 mA. Using a power supply is the preferred method as it will demonstrate that the regulator circuit will operate properly with the minimum specified input voltage.

The radio or cassette player that you intend to power from the circuit can be used as the load, but it would be more convenient to calculate its representative load resistance and use a fixed resistor instead. The load resistance (R_l) is equal to the regulated output voltage ($V_{reg\ out}$) of the supply divided by the required load current (I_{load}) in amperes. Be sure to use a resistor with a sufficient power rating; about 1 watt should do.

Testing the circuit will require a DC voltmeter with an input resistance of 1 megohm or more. A typical DVM or VOM is satisfactory. Before applying power to the circuit, check the polarity of the input and output connections to be sure they are correct. If a current-limited power supply is used for power, set it to limit the current to slightly more than the circuit requirement.

Apply about 3.5 volts to the regulator circuit while measuring the regulated output voltage. It should be within 0.1 volt of the nominal rating, 2.4 (for the linear circuit), 4.8, or 7.2 volts (for the switching circuits). Vary the input voltage to the circuit by partially shielding the solar cells from the Sun or adjusting the DC power source. Note that the output voltage of the regulator circuit remains relatively constant as the input voltage varies from about 3 to 4½ volts.

If the supply is operating as described, remove the load resistor and connect the radio or tape player to the output of the regulator. Verify that the circuit will properly drive the unit, delivering a minimum of 2.4, 4.8, or 7.2 volts DC (depending of the type and regulator configuration you've chosen to build. Replace the power supply (if one was used) with the solar-cell array; place solar cell in full sunlight, and verify radio or cassette operation. That completes the checkout.

If the circuit does not work as described, examine it very carefully for proper component values, and correct orientation of the IC, electrolytic capacitors, and diodes. Inspect the wiring for inadvertent short circuits, open circuits, and bad solder joints. Check the input and output connections of the supply to be sure the polarity is correct.

Check the output voltage of the solar-cell array to be sure it is delivering 4 volts in full sunlight. If the output voltage of the regulator is not within 0.1 volt of nominal, check the values of R1/R2, or R3/R4 to be sure they are correct.

Using the Solar Power Supply. When using the Solar Power Supply, the batteries should be removed from the radio or tape player. The easiest way to connect the power supply to the unit to be powered is via that unit's external power supply (AC-adapter) jack. Units that do not have an external power jack can easily be modified by connecting a pair of wires to the positive and negative contacts in the battery compartment and bringing the wires out to the output terminals of the Solar Power Supply.

The solar panel should be exposed to direct sunlight for best performance. If the sun is very bright, the panel may simply be placed in a horizontal position during most of daylight hours. On hazy or cloudy days, it may be necessary to position the panel so that it is perpendicular to the rays of the Sun to achieve maximum performance.

If the switching Solar Power Supply is to be used for AM radio reception, some interference from the radiated switching-frequency harmonics may be experienced. That may be counteracted by placing the supply some distance from the radio, and using additional filtering and/or shielding to minimize interference. ■

THE EV REVOLUTION

(Continued from page 36)

in Boston, Los Angeles, and Houston revealed that 40% drive less than five miles a day, and 84% less than 75 miles a day—well within the range of any EV. The public must be convinced that EV's are safe to drive and to recharge, and that when they need a quick charge, a recharging station will be within range. There's no reason that an EV couldn't make a perfect "second" car.

Once consumers feel comfortable with the idea of EV's, Madison Avenue can start the big sell. With innovative ad campaigns, they must convince people that in buying an EV, they are proving themselves to be forward-thinking, environmentally correct, automotive pioneers. We can see the commercial now: A sporty, tear-shaped EV zooms along a pristine mountain road, next to a stream of sparkling clean water . . . you get the idea, we're sure. The big question is: Will the general public get it—and buy it? ■

TELEPHONE INTERCOM
(Continued from page 46)

clock period. If you want to simulate the Australian ring standard, simply adjust R17 so that each complete ring cycle lasts three seconds (*i.e.*, 400 ms on, 200 ms off, 400 ms on, 2 s off). Alternatively, you can connect the two telephones to the circuit, take one of them off-hook, and adjust R17 until you get the correct sound.

Installation. The values of the current-limiting resistors (R1 and R4, which are in series with D12 and D13) may have to be adjusted according to the lengths of the individual lines. Generally, a loop current of 30 mA should be considered the maximum. For most in-house or house-to-garage uses, R1 and R4 should be 1.2k, 1-watt resistors (as shown on Fig. 2). However, lines of considerable length require lower-value resistors because of the resistance of the cabling itself.

If the circuit is built solely for use as an intercom, the loop current can possibly be reduced to as low as 10 mA. The benefits of lower loop current include longer operating distances and extended life for carbon granule type transmitters. The level of sidetone (*i.e.*, the level at which you hear your own voice) can also be reduced.

Troubleshooting. If you encounter problems, first check that all IC's are receiving +12 volts at their supply pins. You should also check the boards for poor solder joints and for solder shorts between adjacent IC pins (make sure that the power is off).

Next, trace through the gates with a logic probe or a digital voltmeter to check that the input logic is operating correctly. Check that pin 12 of U1-b, pin 10 of U1-d and pin 4 of U2 are all high when both phones are on-hook. Pin 4 of U2-a should go low when one phone is taken off-hook. If you do not get the correct readings, check the optoisolators and the input buffering circuitry (U1-a–d).

If there is no sidetone in either phone, check to see if LED1 (the green "power-on" LED) is lit. Check all voltages. If either the 12- or 46-volt rail is missing, switch the circuit off and disconnect the logic board from the supply. Power up and check the supply rails again. If the proper supply rail(s) is still missing, check the power supply board; if the supply rails are now correct, check for a short on the logic board.

If there is no sidetone in one phone only, check that the associated 220-ohm protection resistor (R2 or R3) in the loop circuit has not burnt out (opened). Do the cabling and telephone test okay? Check by swapping the phone lines on the back of the interface. If the same phone still has no sidetone, then the fault is either in the phone itself or in the cable.

If neither phone rings, check that the 220-ohm ring protection resistor (R20) connected to T2 has not burnt out due to excessive current. Check the loop circuitry carefully before replacing that resistor. Are the interrupted ring counter (U4) and transistor Q3 operating? Test them by grounding the collector of Q3. Check that LED2 (the orange LED) is off when both phones are on-hook. If LED2 is on and the logic circuitry is okay, then one phone is faulty or there is a cabling fault. Test that by removing the wires to the telephones from the interface one set at a time.

If one phone does not ring, check the ring supply voltage from T2. Is the associated ring relay (K1 or K2) operating? If phone 1 does not ring, check for a high on pin 11 of U2-c. If pin 11 is high, suspect Q1 and K1. If phone 2 does not ring, check for high on pin 10 of U2-d. If pin 10 is high, suspect Q2 and K2. ■

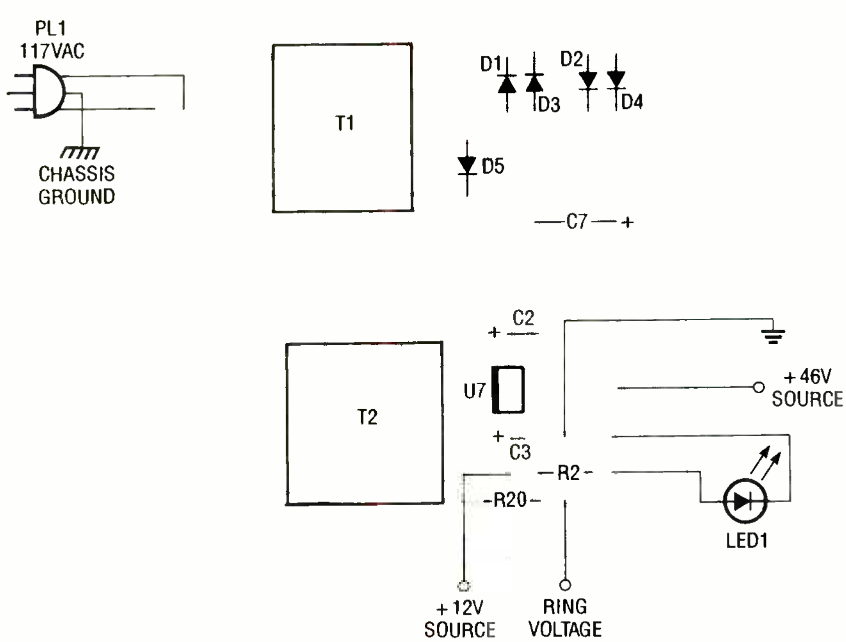


Fig. 6. Here's the parts-placement diagram for the Intercom's power-supply board. This board and the logic board are connected together using 4-conductor telephone cable.

THINK TANK

(Continued from page 74)

the unit off for repairs, I dug out an integrated amplifier/receiver in the hopes that it had a preamplifier-output jack that would allow me to patch it into the main amp. It did not. It did however, have a stereo-headphone jack that kicked out 30 volts AC at the middle mark on the volume dial. The problem is that the main amp can only handle a maximum input of 8 volts.

My solution was the circuit shown in Fig. 4. It allows the high-level headphone output to be used with the low level input of a power amplifier. The 10:1 step-down transformers ensure that the main amplifier's input-signal level is held low and stops DC from passing through ground. The matching low-ohm resistors (10–100 ohms) also prevent the primaries from shorting the output circuits in the integrated amp.

All parts are available from Radio Shack and construction is simple enough so that the device can be built on perfboard and put in a small box outfitted with RCA jacks. Signal loss is negligible and there's little or no noise. It's not as flashy as a pre-amp, but it will get you through some "dry times."

—Robert McLean, San Diego, CA

I like the fact you maintained a balanced load to the headphone jack by using matching resistors. I think a lot more people are going to fiddle with the circuit than you may believe.

TV-STEREO CONTROLLER

I built this simple circuit (see Fig. 5) so that when I had my stereo system turned on and turned on the TV by remote control, the circuit would automatically turn off the stereo. The stereo would also automatically come back on when the TV was turned off.

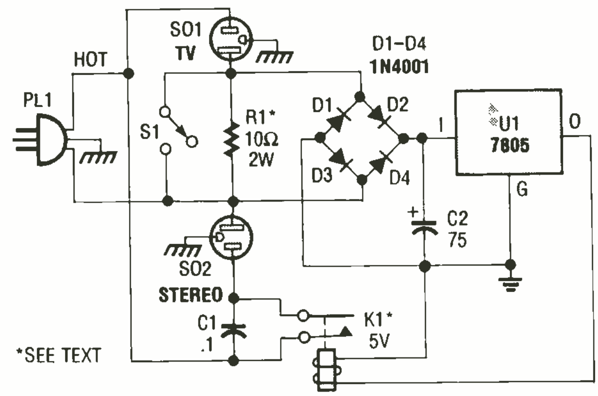


Fig. 5. Need to tie the operation of two AC-powered devices together so when one goes on so does the other? Try this simple circuit.

The current flowing through the appliance plugged into SO1 causes a voltage drop across R1. That AC voltage is converted to DC by the bridge rectifier (formed by diodes D1–D4), filtered by C2, and then clamped to a 5-volt maximum by voltage regulator U1. When the current through R1 exceeds several-hundred milliamps, there is sufficient voltage to open normally closed relay K1. When relay K1 opens, the power supplied to SO1 is disrupted. Capacitor C1 increases the life of the relay contacts by reducing arcing when the relay opens. Switch S1 can be closed to disable the circuit and use the appliances in the normal way.

Resistor R1 should be chosen so that the current through it will not generate sufficient voltage to enable the relay when the appliance connected to SO1 draws quiescent current (to power memory, a remote-control receiver, etc.), but does generate sufficient voltage to turn on the relay when the appliance connected to SO1 is on. Also insure that the maximum power rating of R1 is not exceeded when SO1 draws maximum current. The current rating of K1 should be sufficient for the load plugged into SO2.

Of course, this circuit could be used for other applications, where it might be desirable to turn off appliance "A" when appliance "B" is turned on.

—Edward Suder, Mesquite, TX

It should be mentioned that if you live in an area where fluctuations in the AC line voltage are significant (especially in hot weather), the circuit may not behave well. During heavy-demand times (like midday in the summer when air conditioners are cranking), the line voltage may sag enough to release K1. If you set the value of R1 during one of those heavy-demand times, the relay may latch when the line voltage floats back up later.

If you would like to contribute to these pages, be sure to write in to me at *Think Tank*, **Popular Electronics**, 500-B Bi-County Blvd., Farmingdale, NY 11735.

555 ASTABLE CIRCUITS
(Continued from page 56)

the circuit is that its duty cycle is fully variable from 1% to 99% via R3. In the circuit, C1 alternately charges via R1, D1, and the upper half of R3, and discharges via D2, R2, and the lower half of R3 With the component values shown, the circuit operates at about 1.2 kHz.

Astable Gating. A 555-based oscillator can be gated on and off, via either a switch or an electronic signal, in several different ways. One way is by using the reset (pin 4) terminal as shown in Fig. 4. To enable a 555, its reset pin (pin 4) must be biased above 0.7 volts, but is disabled (with its output low) if pin 4 is pulled below 0.7 volts by a current greater than 0.1 mA (*i.e.*, by grounding pin 4 via a path with a resistance of 7k or less). Thus, the circuit in Fig. 4 is normally gated off by R3 but can be turned on by closing S1.

As mentioned, such an oscillator can also be gated by a circuit attached to pin 4 instead of the simple pushbutton. For example, in Fig. 5 Q1 is normally biased on via R1 and thus acts like a closed switch that (via R2) pulls the C1/R4 junction low and keeps the astable from operating; but when S1 is closed, Q1 is turned off and the astable operates in the normal way. Note that the output terminal is high when the astable is off.

FM and PPM. All the 555 astable circuits shown so far can be subjected to frequency modulation (FM) or to pulse-position modulation (PPM) by simply feeding a modulating signal to pin 5, which is connected to the IC's internal voltage-divider network. The modulating signal may be any AC or DC signal. The voltage at pin 5 influences the oscillator's high time but not the low part of each cycle, and thus provides both PPM and FM actions. These types of modulation are useful in special waveform-generator applications, as in various electronic siren and alarm-call generator circuits.

555 Sirens and Alarms. One very popular application of the 555 chip is as a speaker-driving siren or alarm-call generator. Figure 6 shows two circuits that generate pulsed-tone or warble-tone sounds, each using a pair of 555's. Both circuits have a power-boosting output stage (Q1) that provides several watts to the external speaker; clamping diodes are used to limit the speaker's inductive kickback to a safe level. To prevent the output signal from feeding back into the 555's via the supply line, the supply lines are filtered by a capacitor and an isolating diode (C5 and D2 in Fig. 6A).

The circuit acts as a pulsed-tone alarm-call generator. Integrated circuit U1 acts as an 800-Hz tone generator, and is gated on and off once per second by U2 via D1.

The Fig. 6B circuit acts as a warbling alarm-call generator that simulates the "dee-dah-dee-dah" sound of an old-style British police siren. In the circuit, U1 is again wired as a tone generator and U2 as a 1-Hz astable multivibrator, but in this case U2's output is used to frequency-modulate U1 via R5, the action being such that U1's frequency alternates between 440 and 550 Hz at a 1-Hz rate. ■

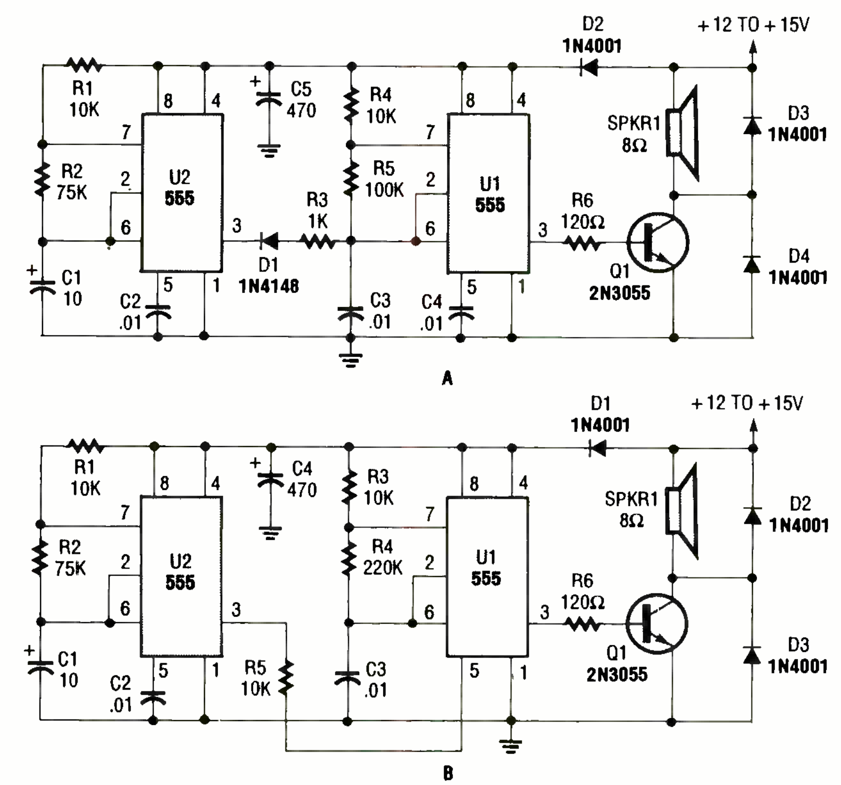
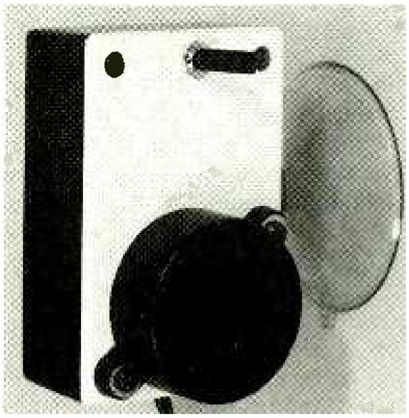


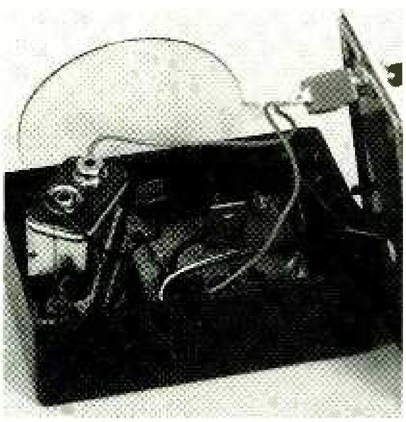
Fig. 6. The pulsed-tone alarm-call generator in A is much more intrusive than a continuous-tone unit. The sound of the warble-tone alarm-call generator in B is even more noticeable as it simulates a British police-car siren.

WATER ALERT

(Continued from page 54)



Everything fits inside a small project case, and a suction cup is attached to the bottom to secure it to the tub. We included both transistors in the prototype, and tested the unit to determine the input that worked with the water in our area.



To give us a little bit of extra room for the battery, we removed the two metal connectors from the battery clip, and soldered leads directly to them.

have the unit turn on a sump pump when water reaches a certain level.

Operation. The way we've got the prototype set up, the water probe can be stuck to the side of a tub at the level that you want the water filled to. When the unit is turned on, the instant that water completes the path between the two probe ends, the buzzer will turn on and stay on until the power is turned off, even if the probe is removed from the water. As mentioned before, you can leave R6 out of the circuit, or put a switch in series with it, so that the buzzer turns on when water touches the probe, and shuts off when it is removed. ■

ELEC. TECH DAY

(Continued from page 65)

- Industrial—Subjects include transducers, switches, power factor, differential amplifiers, closed-loop feedback, basic logic circuits and functions, elements of numeric control, thyratrons, and SCR controls.
- Communications—This test covers two-way radio transceiver theory and servicing, receivers, transmitters, basic communications theory, deviation sensitivity, quieting, and troubleshooting.
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- Audio—Products covered in this option include turntables, tape decks, compact discs, and radios. The exam consists of both digital and analog sections, amplifiers and sound quality, system set-up, speaker installation, and troubleshooting audio systems.
- Medical—The priorities of this option are electrical safety and accuracy of calibration for electromedical instruments. The technician must be familiar with the basic vocabulary of medical instrumentation, telemetry, measurements, and differential and operational amplifier applications.
- Radar—A general knowledge of both pulsed and continuous-wave radar is necessary to take this Journeyman option. The test covers transmitters and receivers; CRT display systems and their power supplies; and antennas, transmission lines, and their characteristics.
- Video—The rapidly growing field of video is covered by this exam. The technician needs to know NTSC standards, video basics, test signals, and the operation of both the electronic and mechanical systems in VCR's. Also covered are 8mm video, camcorders, cameras and monitors, and the microprocessors used in video products.

In addition, there is the new Certified Appliance Technician (CAT) exam, which is independent of the CET Associate or Journeyman certificate. The experience requirement is the same four years as for a Journeyman CET options, and the successful CAT receives a permanent wall certificate. CAT's are eligible to join ISCET. The exam consists of 100 multiple-choice questions covering electrical circuits and components, refrigerator systems, laundry equipment, cooking equipment, and dishwashers and trash compactors.

Fees and Difficulty. The fee for the CET exam is $25.00, which includes both the Associate exam and any one Journeyman option if taken in one sitting. If the Journeyman option is taken separately from the Associate exam, each test is $25.00. Each additional Journeyman option is $25.00. If you fail any portion, the first re-take is free, after a 60-day waiting period. The fee for any additional re-take is $12.50. Don't underestimate the difficulty of the CET exam. Every year only 30 percent of those who take a CET test pass-it! It is not an easy test!

The best way to prepare for this exam is to study diligently. Tab Books publishes *The CET Study Guide* by Sam Wilson, which will help you prepare for some tests. ISCET also has additional study guides available for a nominal fee.

If after reading this article you're interested in taking the CET exam and joining the growing ranks of Certified Electronics Technicians, contact any one of ISCET's volunteer test administrators listed in this article for details. The exams are scheduled to be given during the week of April 4 through 10, 1993. For any additional information or an order form listing all materials, contact ISCET directly at 2708 West Berry St., Fort Worth, TX 76109; Tel. 1-817-921-9101.

Why not join the professionals. Take the CET challenge—it's worth the effort! ■

"That is the keyboard—I play piano, too"

NON-SERIOUS CIRCUIT
(Continued from page 48)

tact and make sure that no solder is blocking the small hole in it.

Apply a liberal coating of epoxy to the inside of the shell and install it on the base. The uncut lead from the diode goes through the hole in the end contact and the short length of hookup wire through the small notch in the shell. Clamp the assembly together and allow the epoxy to set with the bulb in a base-up position.

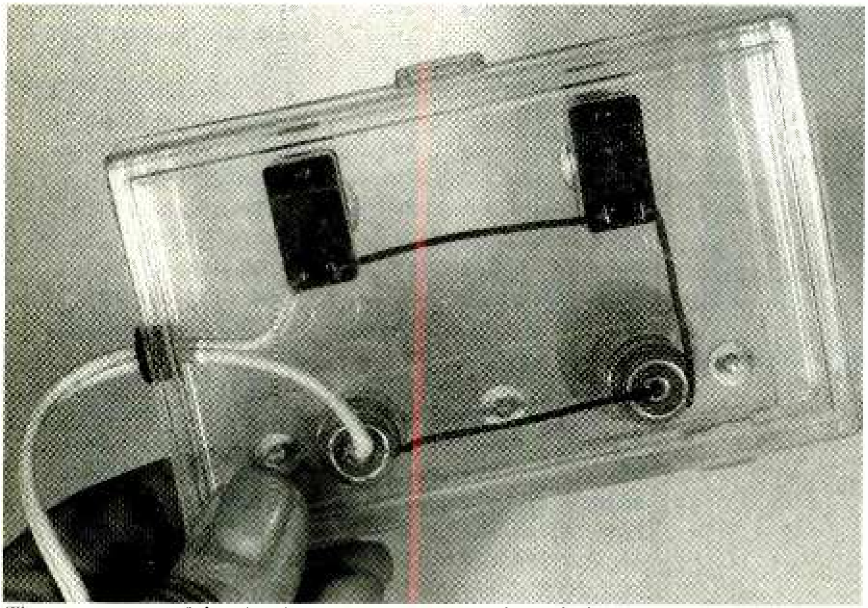
When the adhesive has cured, solder the diode lead to the end contact and cut it off flush. With your goggles on, clip off the other lead so that about 1/16 of an inch is exposed, bend it over, and solder it to the shell. Repeat the operation with the other lamp, but this time the cathode end of the diode should be left long for connection to the end contact.

Open up the toggle switches and, by pushing them out from the back, remove the contacts. If you use the same switches the author did, drill a small hole in the left-hand contact for one lead of the diode, and tin the area of the right-hand contact where the other lead will go. Reassemble the contacts into the switch housing and, with its leads cut short, solder the diode to the contacts. In one switch, the cathode should face to the left, in the other, to the right.

If you are using a different type of switch or you cannot locate any diodes small enough to fit, you can probably find some space for the diode somewhere else in the switch housing. A motor tool with a small burr bit can be used to rout out space at the end of the housing opposite the contacts. Small wires can be used to connect the diode to the contacts.

Reassemble the switches, making sure that the slot in the mounting bushing is on the side opposite the contacts. This assures that the on-off nameplates will read correctly.

Mount the components in the box and make the connections as shown back in Fig. 2. Be careful to wire the unit properly with respect to the diodes. If, for example, you were to wire from the shell of one socket to the shell of the other socket, the DC would be routed through the diode in the wrong direction, resulting in its destruction when both switches were closed. Install the lamps and paint the switch handles to correspond to the colors of the bulbs.



The components of the circuit can be clearly seen through the transparent enclosure. Note the clear-plastic strip holding the socket shells in place beneath the box's cover.

Using the Unit. The best way to present the Non-Serious Circuit to a friend is to pretend to be confused. Explain that you'd like his help—it seems that you wired up this circuit and it is operating in a very strange manner. You can probably build the unit in one evening with parts already on hand, so I hope you'll give it a try. ■

PHOTOVOLTAIC CELLS
(Continued from page 62)

the following equation:

$$A_v = R3/R1$$

if R1 = R2 and R3 = R4. The output voltage from the operational diff-amp is:

$$V_o = (V2 - V1)R3/R1$$

The output of the differential amplifier is connected to the input of the circuit of Fig. 13. Note in Fig. 14B that the two cells are connected with the same polarity, but that the inputs of the differential amplifier have opposite polarities. When the two cells are equally illuminated, then the two voltages (V1 and V2) are equal, so by the last equation the output voltage is zero. Thus, the motor will not turn in either direction. But when the illumination is unequal, V1 and V2 are unequal, and the output voltage is proportional to the difference between V1 and V2.

A crude four-quadrant light sensor is shown in Fig. 15. This sensor will detect a light's orientation along two axis. I've seen similar circuits used in toy cars and robots that will follow a light source. This sensor is used with two circuits like the one in Fig. 14B; one for the up/down motor and one for the left/right motor.

Photovoltaic sensors are readily available from sources such as Radio Shack, Edmund Scientific Co. (C918 Edscorp Building, Barrington, N.J., 08007; Tel. 609-547-8880) and Digi-Key (P.O. Box 677, Thief River Falls, MN, 56701; Tel. 800-344-4539). They are easy to use, and a lot of fun to experiment with. ■

"It's a flight simulator . . . or in my case, a crash simulator"

ANTIQUE RADIO

(Continued from page 67)

horrible thought that the broadcast-band antenna coil might have burned out.

That could easily have happened if the radio had been left connected to the antenna, with the band-switch set to the broadcast position, during a thunderstorm. A static discharge from a nearby lightning strike could then have wasted the broadcast antenna coil.

I quickly connected an ohmmeter across the Sky Buddy's antenna terminals with the bandswitch set to band 1 (broadcast). And I was relieved to see that the coil was not open, but showing a resistance of about 30 ohms. That is about 10 times the resistance of the shortwave coils for bands 3 and 4, which check out at just a few ohms. Though the broadcast coil's resistance seems a bit excessive, a higher reading is to be expected because the broadcast coil would have many more turns than the shortwave coils. Band 2 doesn't have a separate antenna coil, but uses the band 1 coil.

SOME HALLICRAFTERS MAIL

Since I have a little extra room in the column this month, I thought I'd run some letters from readers who recently wrote about *their* Hallicrafters sets. For instance, *Edward Vanduyne* (Potomac, MD) is also working on a Sky Buddy restoration. He sent me photocopies of some of the pages from the original instruction manual, and I'm running a picture of the quaint-looking cover.

Ed answered some of the questions I posed about the set during earlier installments of this restoration series. For instance, he reports that the main tuning/bandspread subchassis on his model has a plated finish with no trace of paint. I'm glad to hear that because I exposed a plated surface after cleaning up mine. But I wasn't sure if I had removed an original finish along with the dirt.

Fred A. Kumpf (Dallas, TX) is also restoring a Sky Buddy, and *M.R. Stephens* (Whitefish, MT) still enjoys listening to the one he purchased in 1939.

Rick Czek (207-B McClure Dr., Gulf Breeze, FL 32561) needs a bandswitch for a Hallicrafters S-38 he is restoring (unfortunately he didn't mention which letter model). If anyone has a junker set from which that part might be salvaged, get in touch!

Rick was also baffled by the earphone connections behind the set, never having seen pin jacks before. Rick, next time you're at a hamfest or other electronic flea market, check the old earphones. You'll find that, instead of a single plug, many have a pair of leads fitted with metal pins. That's the type of connection you need for your set.

Finally, *Joel J. Robinson* (Av. Pedro Adams Filho 4453, 93320-005 Novo Hamburgo RS-BRASIL) sent along some shots of a Hallicrafters S-40A he's working on. He has a schematic for an S-40, but would like to acquire the S-40A version. As a matter of fact, the back of his set bears a paper tag further identifying it as an S-40AU. Can anyone help Joel?

I'd like to hear from you, too. Please write me c/o *Antique Radio*, **Popular Electronics** 500-B Bi-County Blvd., Farmingdale, NY 11735. ■

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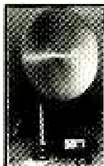

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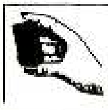

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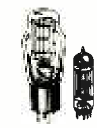

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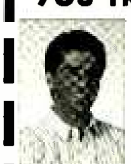

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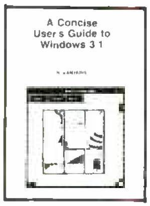

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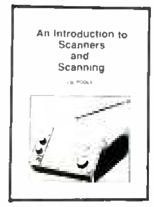

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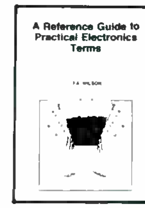

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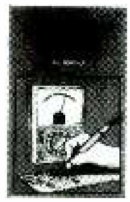

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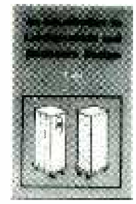

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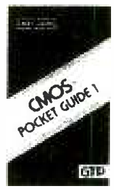

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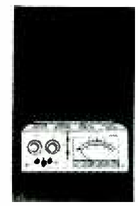

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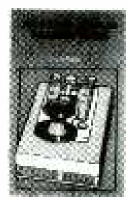

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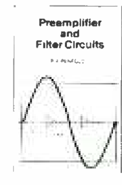

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