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November 1992

Electronics NOW®

Vol. 63 No. 11

BUILD THIS

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TELEPHONE HOLD BUTTON

PAGE 45

BUILD A
POWER CONTROLLER
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PAGE 57

DEPARTMENTS

AND MORE

ON THE COVER

Point-and-shoot is fine for snapshots, but truly interesting photographs require some planning and some extra equipment. For instance, if you want to capture split-second action, such as a drop of milk splashing into a glass, you'll need either very fast shutter speeds or a good strobe light. Our Freeze Frame Super Strobe Trigger uses interchangeable sensors, so that anything that flashes, pops, snaps, or reflects or blocks light can be used to trigger your camera's flash or free-standing photographic lights. The inexpensive, easy-to-build Freeze Frame lets you capture stop-action shots for scientific purposes, or just because they're fascinating to look at. For all the details, turn to page 31.

COMING NEXT MONTH

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Protect your telephone equipment from electrical transients on the phone line.

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Still more uses for this versatile IC.

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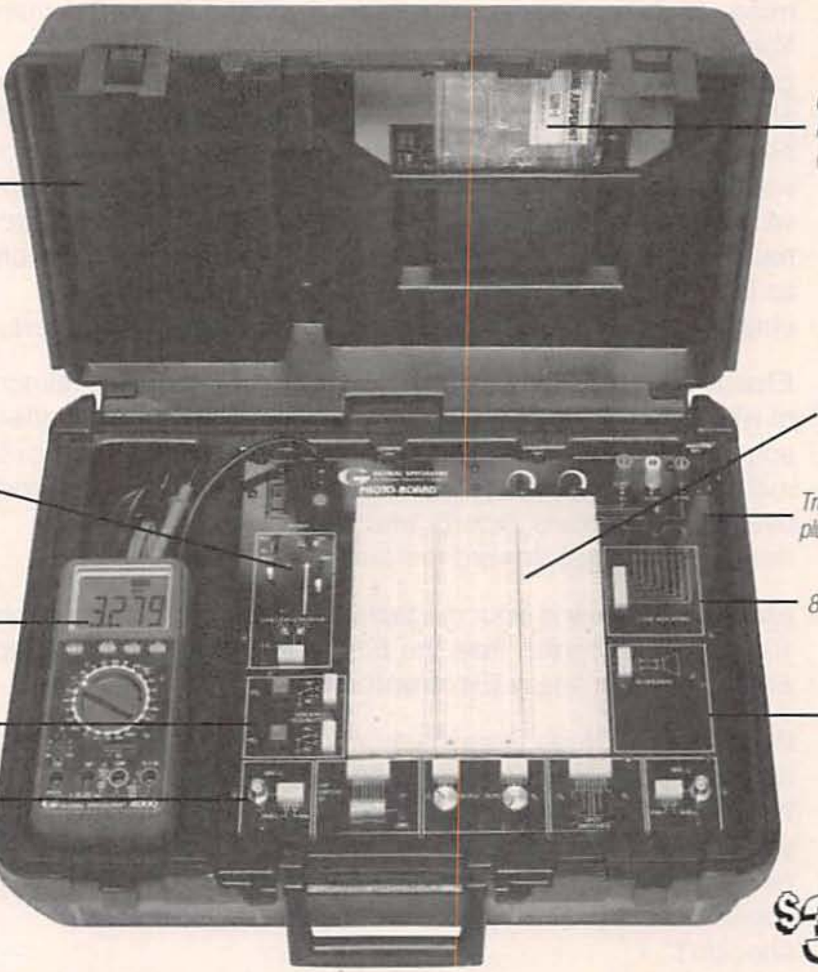

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EDITORIAL

IT'S NOW OR NEVER

Now. This moment, this instant—it lives but a microsecond. Then it moves on and changes and becomes something new and different and better.

That's exactly what our magazine—our magazine, yours and mine—is doing. I grew up on *Radio-Craft* and *Radio-Electronics*. You've probably grown up on *Radio-Electronics*. The next generation of electronics professionals may not even remember *Radio-Electronics*, but they will know **Electronics Now**. For this new, yet old, publication will be their introduction to electronics. It will be their primer, their teacher, their guide, their companion. It will travel with them through their career just as *Radio-Electronics* has through yours. As long as there are electronics professionals, as long as there are people who follow the wonderful ever-changing world of electronics, **Electronics Now** will be there.

Electronics Now is not a new magazine, it is simply a refinement of what has always been. It's an evolution to something better, something wiser, something stronger. A magazine more closely matched to electronics today. Carefully designed, tailored and directed by selected experts who can point you, our reader, through our pages, toward tomorrow.

Electronics Now is *your* magazine. It is the culmination of almost 100 years of progress from the *Electrical Experimenter* to *Radio-Electronics* and finally **Electronics Now.**

If our founder, Hugo Gernsback, were here today, he'd probably note that we should have acted sooner. Perhaps he would have been right. But no matter what, we know we are correct in taking you and us on this new adventure. Join us as we go. Revel in the excitement of today and the adventure of tomorrow. Tell us what you like, what you hate, what we should do, and what we shouldn't.

Write our editors, contact our bulletin board, send me your ideas, comments, and criticisms. Help us make **Electronics Now** exactly the kind of magazine you know it should be. And never forget we may now bear the name **Electronics Now**, but at heart we are *Radio-Electronics, Radio Craft, Shortwave Craft, Television*, and the *Electrical Experimenter*.

Larry Steckler

Larry Steckler, EHF/CET
Editor-in-Chief and Publisher

WHAT'S NEWS

A review of the latest happenings in electronics.

20 thousandth Associate Technician certified

Garry D. Streeter of Tacoma, WA has become the 20 thousandths Associate Technician certified by the International Society of Certified Electronics Technicians (ISCET). Mr. Streeter scored 96% on the ISCET examination given on June 10th at Bates Technical College in Tacoma.

An employee of Spectroscopy Specialties, Inc., a company that manufactures laboratory equipment for atomic research, Mr. Streeter is 26 years old. He served in the U.S. Navy for six years as a fire control technician.

The Associate Exam, which has now become the standard for judging the competence of electronics technicians by industry, commerce, and the U.S. Government, covers basic electronics theory and practice. Subject matter includes mathematics, physics, electronic fundamentals, semiconductors, circuit theory, troubleshooting, and network analysis. Journeyman CET options are available in the specialized sectors of audio, communications, computers, consumer electronics, industrial, video, medical, and radar.

Information on ISCET Associate and Journeyman CET exams is can be obtained from ISCET, 2708 West Berry Street, Fort Worth, TX 79109 (817-921-9101).

FCC approves video transmission by phone

Telephone-operating companies applauded but cable TV companies were miffed by the June 17th decision of the FCC to grant the telco's the right to transmit TV programs and video services over phone lines. The decision lifted previous restrictions that had kept the phone companies from competing with the cable TV industry.

The FCC ruling also set the ground rules for the operation of a class of wireless communication devices—pocket phones, wireless facsimile machines, handheld computers, and advanced pagers. It also decided that HDTV will share the UHF spectrum with conventional television. The ruling is intended to spur competition between telephone and cable companies.

The ruling by the Government is expected to encourage local telephone companies to accelerate the upgrade of their systems with new equipment to handle video services. According to FCC chairman Albert Sikes, the initiatives could produce billions of investment dollars and thousands of new jobs in the next year. It was recognized however, that it may take years before the phone companies master the technology needed to provide video programming over phone lines cost effectively.

That delay is attributed to both technical and political reasons. Although video compression technologies are now available, complete fiberoptic networks are seen as a necessary—and expensive–requirement. It is estimated that replacing the nation's existing copper wiring with fiberoptic cabling could cost more than $100 billion. Also impeding the phone companies entry in the cable TV arena is a federal law that prohibits them from owning cable programming equipment. The FCC ruling, however, allows a telephone company to own up to 5% of a cable company.

Centel commercializes dual-mode cellular phones

Centel Cellular Company ,Chicago, IL, became the first U.S. cellular carrier to offer dual-mode cellular phones incorporating Motorola's Narrow-Band Advanced Mobile Phone Service (NAMPS). Centel demonstrated its NAMPS capability recently in a successful trial in Las Vegas, NV. NAMPS is a digitally enhanced analog technology that is said to triple the capacity of existing analog systems. It is expected to smooth a service company's transition to a digital cellular network.

The NAMPS digital enhancements associated will allow Centel to offer its customers digital messaging services including alphanumeric paging and voice mail notification. It can also provide mobile reported interference (MRI) which reduces the incidence of static interference and lost phone calls by allowing a phone experiencing interference to request a hand-off to a clear channel automatically.

NAMPS' ability to allow frequencies to be cleared for other wireless applications will ease the transition to all-digital systems. The dual-mode mobile and portable phones look and feel the same as standard, analog units, but they can operate on either analog or digital cellular systems.

Blue-light laser promises higher CD data density

The blue-light solid-state laser could be a commercial reality in the near future. Both 3M and Sony have demonstrated their devices that could triple the amount of music or data be stored on CD's by the end of the decade.

The blue-light laser is expected to replace the red-light emitting lasers now widely used in CD players. Blue light has a shorter wavelength than red, so it can be focused on a smaller spot. That gives it the ability to store much more data in a smaller area and boost disk capacity.

Last year 3M demonstrated a laser based on doped zinc selenide that emits in the blue-green 490 to 530-nanometer range. The active layer of zinc cadmium selenide is surrounded by zinc selenide. Sony Corp. showed off its true blue-emitting laser last July.

VIDEO NEWS

What's new in the fast-changing video industry.

DAVID LACHENBRUCH

• **Photo CD arrives.** With the fanfare of a national advertising campaign, Eastman Kodak has launched the newest video medium, Photo CD—combining the high resolution of film photography with the convenience of electronic display. Photo processors from coast to coast are now equipped with the work stations to transfer negatives and slides in digital form to compact discs that can be played through any TV set, regardless of standards—including future high-definition sets. The transfer of 20 negatives to a digital disc costs about $20, including the disc, and additional pictures can be added to the disc at a later time, up to a total of 100 per disc.

Kodak-brand Photo CD players (which also can play audio CD's) sell for about $379 to $499, depending on features, with a carousel changer due in time for the Christmas season. The players are being made in Belgium by Philips, but Kodak says that it plans to license other manufacturers to make players as well.

Philips CD-I players are also capable of playing Photo CD's, and an increasing number of computers will be equipped to display the digital photos. Photo CD players can play some specially recorded multimedia picture-and-sound discs (including the audio-visual instruction manual for the Photo CD player). A remote control for the higher priced Photo CD player permits the viewer to zoom in on any part of the picture and to crop the photo electronically. Kodak will introduce thermal transfer equipment to make high-quality color prints and enlargements from Photo CD's. Kodak also promises to add equipment to put soundtracks and captions on the digital photo discs.

• **New interactive system.** The two largest American-owned consumer-electronic companies at our press time were scheduled to introduce a new CD-ROM-based system designed for attachment to home TV's that is competitive—and incompatible—with Philips' CD-I. Hardware for the new Video Information System (VIS) will be made by Tandy Corporation in Fort Worth, Texas, for sale by Radio Shack stores under Tandy's Memorex brand name and it will be offered by other dealers under the Zenith brand.

VIS differs from CD-I in that it can accommodate much of the existing CD-ROM software (designed for MPC and Macintosh standards) with only slight modifications, providing VIS with a large, virtually ready-made library. The companies have worked with Microsoft to achieve that semi-compatibility. VIS will come with a large library of entertainment, educational, and information software, and will be priced competitively with the CD-I player (which now carries a suggested list price of $699). According to its developers, VIS is designed so that eventually it will accommodate such add-ons as a modem and a keyboard. They see "VIS" as an overall product identification standard—like "VHS"—and they are inviting other manufacturers to join them with their own players.

• **U.K.'s massive recall.** Prospective applicants for a new commercial television network in the U.K. have been asked to outline their plans to retune, modify, or exchange virtually every VCR, video game, and home satellite receiver in the U.K. As a result of that intimidating prospect, only one applicant remained at the deadline for filing.

The dilemma resulted from what one journal called a "classic booboo" by the Independent TV Commission, which assigned UHF channels for the new nationwide network close enough to interfere with those used for connecting attachments to home TV-set antenna terminals. The ITC decreed that the winning applicant must modify any and all such devices to prevent interference. The winner, a consortium led by Thames TV, says that it will unleash an army of 2000 technicians, who will literally go to door-to-door to do the modifications, at a cost of about $135 million, although some skeptics think that the final price tag will be much higher.

• **Widescreen TV sets.** Despite controversies over national HDTV systems, there is a worldwide movement toward widescreen TV sets that will work with present transmissions. TV sets with a 16:9 aspect ratio are now being sold in Europe by the top three manufacturers there (Philips, Thomson, and Nokia) and by almost all manufacturers in Japan. The introduction in the U.S. of those sets was imminent as this was being written.

In Japan, Sharp introduced the lowest priced widescreen set to date (with a tube measuring 26 inches in viewable diagonal) for the equivalent of about $2000. That company was the first to announce a changeover to widescreen for all large-tube receivers, with the 26-inch (4:3 ratio) in its product line. Sharp officials are forecasting the sale of 300,000 widescreen sets on the Japanese market by all manufacturers in the present fiscal year (ending in March 1993), rising to 800,000 in the following year.

In the U.S., both Thomson (RCA, GE) and Philips (Magnavox, Sylvania, Philips) are beginning to import widescreen tubes from their European factories. Thomson is importing 34-inch tubes and Philips is importing 34- and 26-inch versions. Both companies reportedly plan to introduce larger sets here in projection versions, and say that if the new picture proportions catch on with buyers they'll build the wide tubes domestically. Neither company had announced a specific price at press time, but at their introduction the wider sets are expected to cost considerably more than comparably sized conventional models. **R-E**

Q & A

Write to Q & A, Electronics Now, 500-B Bi-County Blvd., Farmingdale, NY 11735

ALL LOCKED UP

I've been having intermittent problems with my computer where the whole system locks up to the point where even a warm boot from the keyboard won't get it started again. After a lot of trouble, I discovered that one of the IC's on the motherboard is bad. Just about the only good thing about this is that it's a simple gate. The bad news is that it's soldered directly to the board. Do you know of any method for getting it off the board without damaging anything?—B. Sherif, Engale, NY

I've never found an *absolutely* safe way to desolder an IC. There's always some risk of damaging a PC board when removing a part, and the amount of damage is usually proportional to your desoldering skills and the number of pins on the part being removed. Consider whether the whole operation is worth the time and trouble it's going to take before starting.

If you're determined to do the repair, I'll tell you that the amount of success you're going to have will depend on the type of motherboard. If you have a simple double-sided board, what you do is fairly easy, but if your board is a multilayer one, the job is somewhat harder.

The easiest—and crudest—way I know to get an IC off the board is to cut off the pins close to the body of the chip and solder the new chip right onto the old pin stubs. Another method is to use a "solder sucker" that will remove solder after your iron has melted it—but you have to act quickly. The easiest non-professional method for chip removal is to use desoldering braid. (Professionals might use an electric "solder sucker," which can be quite expensive.) Desoldering braid is basically just braided copper wire that is pressed onto the solder joint with the tip of a hot iron. When the solder melts, it is "wicked" up by the braid. After the solder is removed from all of the pins, wiggle each pin back and forth with long-nosed pliers before pulling the dip off the board.

Whatever method you decide to use, try to practice removing parts from a junk PC board to gain a little experience before attempting the job on a more valuable board.

LOTS OF SWITCHING

I have a problem that revolves around the need to switch 12 bundles of wire, with each bundle containing 24 wires that carry a variety of both AC and DC signals ranging from 1 to 3 amps. I initially used a Stackpole rotary switch driven by a computer-controlled motor to position the switch as commanded by input position logic. Everything worked well for a while, but the Stackpole switch would misalign every few hours or so. My specialty is software and I could use a little help with the hardware. Any suggestions?—D. Price, Coronado, CA

You really haven't given me the details needed to give you a complete answer, but there's certainly enough here to be able to point you in the right direction. And while your solution is feasible, you're having a problem simply because you haven't thought the problem through logically.

The easiest way for you to understand what's going wrong is to imagine that you are rotating the shafts by hand. If that were the case, you'd know when you reached the right position because you'd be doing something such as aligning marks on a dial. Well, now you have to do the same thing electronically.

What's missing in your system is some form of feedback from the switch that tells the controlling hardware exactly what the position of the switch is. The feedback mechanism can be something as simple as a potentiometer positioned on the shaft so that it reports a voltage back to the controller.

Another way to go about this is to use a stepper motor—the kind of motor used in a disk drive to position the head at a particular track on the disk. This might be the best way to go because stepper motor controllers designed for use in PC-compatible computers are readily available.

DIGITAL TACHOMETER TROUBLE

I'm building a digital tachometer for my car, and I'm having problems getting reliable readings. The counting circuit is OK, but the engine is a diesel, and I need a way to pick off an electrical signal. I've put a disk with holes around the circumference of the alternator and I am using an optical pickup and emitted infrared to read the holes. Do you know of a simple circuit that will amplify the pulses from the receiver so they can be read reliably by the counting circuit? I'm using CMOS logic.—J. Hewit, Florida, NY

I'm not sure what kind of car

you're talking about so I can't suggest a better way to get the pulses from the engine. Optical stuff is okay but it seems like a bad choice for an engine compartment since there's always an oil mist and other grunge that can interfere with the operation of the pickup. Magnetic pickups or a Hall-effect switch would seem like a better way to go.

If you have solved the problems of dirt and alignment, I'm surprised you're having a problem with the level of the pickup output. It's an easy one for you to solve if you're using CMOS.

The circuit shown in Fig. 1 is a simple amplifier that will work well with just about any phototransistor. The layout isn't at all critical, and you can put the whole thing (minus the phototransistor, of course) inside a sealed plastic box anywhere in the car. The 741 is a readily available op-

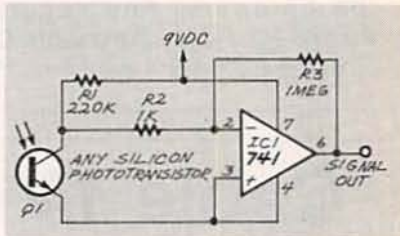

FIG. 1—THIS SIMPLE AMPLIFIER will work well with just about any phototransistor. The 741, although designed to operate with a split supply, will work with a single-sided supply as well.

amp that was designed to operate with a split supply. But since you're only dealing with ons and offs, it will work well with a single-ended power supply.

I've shown the input voltage as 9 volts, but if you've got regulated 12 volts available for the CMOS circuitry, that will do just as well. I suggest that you look at the 741 output on a scope and make sure the pulses are well-shaped and low in noise. CMOS is noise tolerant, but there are limits. If you see lots of glitches, run the 741 output through a CMOS gate before sending it to your tachometer. If you have some extra gates available, you can use one of them. If you're going to add a gate, use a Schmitt trigger such as a 4093 NAND gate or a 4584 inverter. The inherent hysteresis in a Schmitt trigger will to clean up messy pulses and odd circuit line noise. **R-E**

Write to Letters, Electronics Now, 500-B Bi-County Blvd., Farmingdale, NY 11735

AUDIO BUYING TIPS

I have enjoyed Larry Klein's *Audio Update* column very much over the years. He provides a breath of fresh air in a field often fogged by the strong odor of addled logic. Larry's coverage of the 1991 AES Convention was also enlighteninging because he drew attention to the significant psychophysical research concerning what we really can or cannot hear.

I'd like to add a few buying tips for consumers from my article "Can You Trust Your Ears?" *AES Preprint 3177*. Because humans have such a strong tendency to hear sounds that might never have occurred, audio equipment customers should be aware that even the best receivers, preamplifiers, CD players and amplifiers cannot be reliably evaluated under controlled conditions. (I am assuming that this equipment is being operated at its specified power limit and all cabling meets the manufacturers' requirements.)

Second, it is practically impossible to conduct a fair listening evaluation even in a studio-equipped retail store with all components matched and compensated. Finally, you are not stupid if you don't understand everything the salesman tells you. When you are tempted to buy a product but still unsure of yourself, wait until the next day to make a decision. There's a good chance that you'll decide you don't need whatever it was that was being pitched. *Caveat emptor.*

TOM NOUSAINE
Cary, IL

NETWORKING CORRECTION

As a long-time reader of **Radio-Electronics** and a data-communications professional, I was pleased to read the first part of Gary McClellan's series entitled "From Not Working to Networking." in your August issue. Unfortunately, the section entitled "Connecting networks" positions bridges, routers, and repeaters in the incorrect layers of the ISO/OSI model.

It is generally accepted in LAN networking that a repeater operates at layer one, a bridge operates at layer two, and a router operates at layer three of the ISO/OSI model.

I trust that statement clarifies Mr. McClellan's information, and I look forward to reading the remainder of the articles in his series.

SHELDON H. DEAN, CET
Calgary, Alberta, Canada

THE BOTTOM LINE

As panelists in a seminar entitled "Strategies to Guard Against Productivity Loss" during PC Expo on June 25, we were astonished to find that of the thousands of industry professionals at the show, only one decided that a session on productivity enhancement was important enough to attend.

The show's management found the topic compelling enough to sponsor the seminar, and experts on the subject were ready to talk. But it seems that the individuals in the industry—vendors, customers, and managers of corporate computing resources—did not find it important enough to learn more about the link between technology and productivity.

Members of the industry do seem to find glitz, power, and speed interesting. They seem to fixate on the question: "Can we make it bigger, faster, or better than our competitors?" The name of the game seems to be "hardware for the sake of hardware" and "software for the sake of software."

We forget that senior management, which controls the purse strings, cares about return on investment, productivity and profit. They don't care about chip speed or power. Who in our industry is thinking about vital productivity issues such as education, training, and support? Is anyone thinking about the need to re-engineer products to take advantage of developing technology? Is management afraid to find out if there really is a positive return on investment in computer technology?

Until the computer industry stops to takes stock of where it has been and where it is going—particularly the relationship between computer technology and the bottom line—the promise of technology will *not* happen. We should be concerned with how the technology can change the workplace, improve corporate competitiveness, and help us to meet our national economic goals.

None of this is glamorous stuff. Making technology deliver on its promise is tough, tedious work. It certainly does not offer the fun of playing with the latest and greatest graphics user interface. But it is where to find productivity increases. Productivity is the responsibility of people, not just machines. It seems that those attending PC Expo were looking for something other than strategies to prevent losses in productivity.

KAREN KARTEN
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de Jager & Co.
DAVE WHITTLE
IBM
SUSAN RASKIN
Rastec
RALPH E. GANGER
Sterling Resources

I'd like to respond to the letter by Stephen Schleick, "Seeing the Light," (June **Radio-Electronics**.) In my opinion, as a technically trained person Mr. Schleik should have been better able to understand the point made by his "rocket scientist" friend. Mr. Schleik's anger at his friend is unwarranted, but he is correct in what he said about the average power usage of a light bulb.

However Mr. Schleik missed by a mile the point being made by his friend. The problem is not average power consumed by the bulb, but the power surges that damage the bulb and cause its premature failure—the reason why we are always purchasing new bulbs.

The three reasons for filament lamp failure are operating time, frequency of turn-on, and supply voltage. A standard commercial bulb can be expected to fail after it has operated at its rated voltage for about 750 hours. (This is an average life for household incandescent bulbs). The lamp manufacturer is in business to sell lamps at a profit. If bulbs last ten years, replacement sales will be low.

The more frequently the bulb is turned on and off, the shorter its life. The 750 hour-life is an average determined from specified test procedures. Consumers usually don't get that kind of life from lamps for the same reason they don't get the gas mileage shown on new car stickers. People don't use light bulbs or cars the same way they are tested!

When I lived in an apartment in New York City, I never turned off certain lights because the electric bill was included in my rent. I just turned down the light, with a dimmer. The pont is, I never replaced light bulbs in the eight years I lived there.

When I bought a house and had to pay the electric bill, I turned off all my lights at night. I had to replace my eight-year-old bulbs in a few days. Coincidence? Maybe, but I don't think so. In my own house we had to replace bulbs every few months. We operated the bulbs at full brightness only in the evenings and on weekends.

Which is cheaper, a $1.00 bulb that lasts eight years with a dimmer (10 cents a year without being turned off) or replacing bulbs costing a buck two to three times a year?

I measured the idle current of a lamp with a dimmer having a 4.3-ohm resistor in series. The voltage across the lamp was 8 millivolts. With Ohm's Law, $0.008/4.3 = 0.00186$ amperes or 1.86 milliamperes. I multiplied 120 volts × 1.86 milliamperes to get 223 milliwatts (from the line). Then 223 milliwatts × 8760 hours/year equals 1953 watt-hours. This is a 1.953 kWh power consumption with a dimmer.

For practical purposes 1.953 equals 2 kWh at 5 cents (average U.S. power cost) per kWh for a cost of 10 cents. (In New York City with power costing three times the U.S. average, the result is 30 cents.) I ignored the time the bulb was at full brightness because I assumed that time and cost would be the same in both cases. And I haven't included the lost time and trouble of buying new bulbs and spares.

Based on the standard of 120 volts rms in the U.S., a good rule of thumb is that a 10% voltage increase shortens bulb life by half, but a 10% decrease doubles bulb life.

Are there ways to get around this? First, don't buy standard long-life or guaranteed bulbs; all you get is one designed for 130 volts, usually poorly made.

Consider traffic-light bulbs. They are made for long life and reliability.

The tungsten filament must be longer and thicker to obtain the same level of illumination but have a longer life. That makes the bulb more expensive to manufacture. Higher price means fewer will be sold which, in turn, forces up the retail price even further. Most people buy the cheapest bulbs they can find because they don't remember how long its predecessor lasted!

PAUL CHRISTIE
Bayside, NY

DISTORTION STOPPER

The distortion problem presented under the heading "Pocket-Stereo Amp" in *Ask R-E* (**Radio-Electronics**, August 1992) might not be caused by the LM386 circuit; it could be caused by insufficient load on the source amplifier from the pocket stereo—particularly if the output amplifier is made from discrete components. The key to my conclusion was the report of distortion at all listening levels.

I recommend loading the pocket stereo with a 20- to 50-ohm resistor, as shown in Fig. 1.

JIM HATHAWAY II
North Highlands, CA

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NRI's practical combination of "reason-why" theory and hands-on building skills starts you with the fundamentals of electronics, then guides you through more sophisticated circuitry all the way up to the latest advances in computer technology.

Train with and keep a powerful 386sx/20 MHz computer system plus popular Microsoft® Works software!

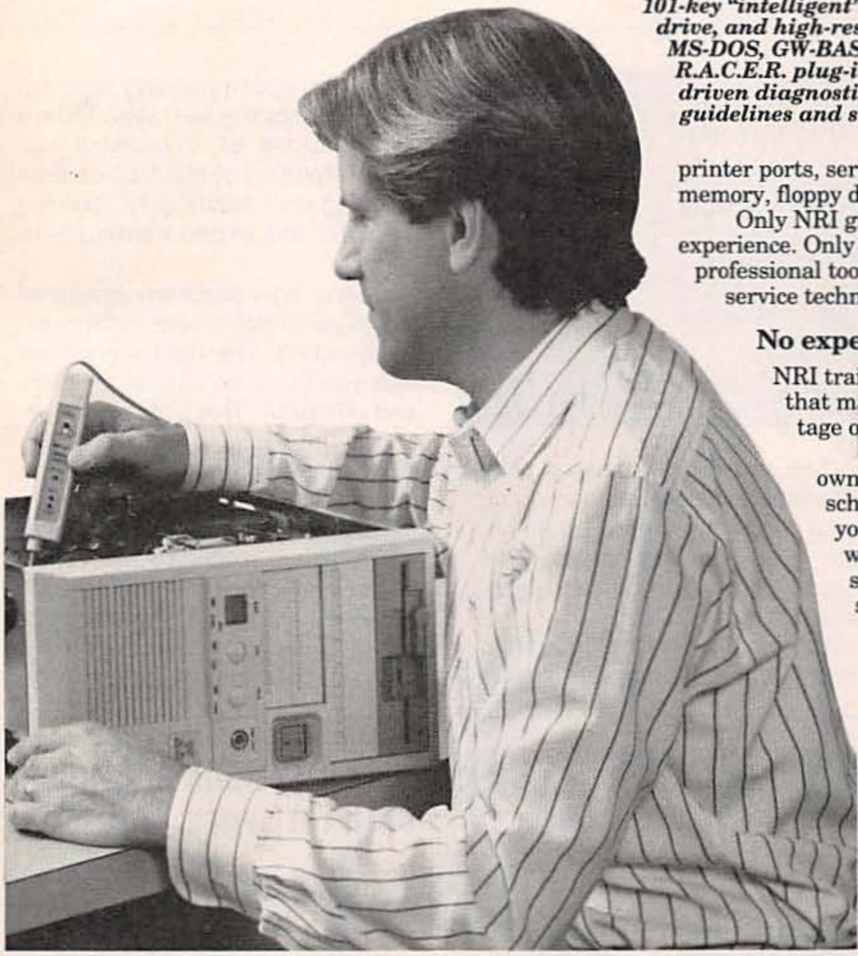
Only NRI gives you hands-on training with the finest example of state-of-the-art technology: the powerful new West Coast 386sx/20 MHz mini tower computer. As you assemble this 1 meg RAM, 32-bit CPU computer from the keyboard up, you actually see for yourself how each section of your computer works.

You assemble and test your computer's "intelligent" keyboard, install the power supply and 1.2 meg, high-density floppy disk drive, then interface the high-resolution monitor.

Your hands-on training continues as you install a powerful new 40 meg IDE hard disk drive—now included in your course to dramatically increase the data storage capacity of your computer while giving you lightning-quick data access.

Plus you now go on to work with today's most popular integrated software package, Microsoft Works, learning to use its word processing, spreadsheet, database, and communications utilities for your own personal and professional applications. But that's not all.

Only NRI gives you hands-on training with the remarkable R.A.C.E.R. plug-in diagnostic card and QuickTech diagnostic software from Ultra-X—professional, state-of-the-art diagnostic tools that make computer troubleshooting fast and accurate.

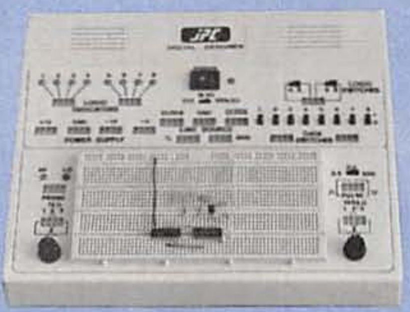



NEW!
386sx

EQUIPMENT REPORTS

JPC International TD107 Digital Designer

Breadboarding circuits is the only way to learn electronics design!



CIRCLE 10 ON FREE INFORMATION CARD

From the mail that we receive at Electronics Now, we know that many of our readers enjoy our concentration—in both feature articles and columns—on circuit theory and design. In this issue, for example, we present almost two dozen circuits based on the 555 timer in a feature article, and a simple video scrambler circuit in our "Drawing Board" column. And, of course, our construction projects provide new circuits every issue.

Although it's possible to learn a great deal by studying the circuits and their accompanying descriptions, it's not the best way. There's just no better way to increase your understanding of electronics than "getting your hands dirty" building circuits and experimenting with them.

Having an adequately equipped lab is essential to electronics experimenting. The right equipment lets you build circuits more easily and efficiently. That's important because the easier it is to build circuits, the more you will experiment, and, thus, the more you will learn.

Such thoughts kept crossing our minds as we examined the *TD107* Digital Designer from JPC International (P.O. Box 55, Agoura Hills, CA 91301). The *TD107* makes it easy to build circuits and change their configurations, and examine how they operate. The designer, which is housed in a sturdy cream-colored plastic case that measures about $10\frac{3}{4} \times 8\frac{3}{4} \times 2$ inches, features a large solderless breadboard on its front panel. The breadboard provides a total of 1380 tie points, which can accommodate up to sixteen 14-pin DIP's. Because the *TD107* offers built-in power supplies, pulse generators, clock generators, and more, it's possible to build circuits that are quite complex.

Eight LED logic indicators are located at the top left side of the designer's sloping front panel. A logic probe, which indicates high, low, and pulsing logic levels is also available. Two momentary logic switches let you manually generate pulses. Pulses of 0.5 Hz and 500 Hz can be obtained from front panel terminals in either high-to-low or low-to-high transitions.

Clock signals are also provided by the designer. Complementary clock signals with frequencies of 1 Hz, 1 kHz and 100 kHz can be switch-selected. A line frequency (60 Hz) clock is also available. Eight slide switches provide switchable high or low data lines that can serve as inputs.

Two potentiometers, 1K and 100K units, are conveniently located at the bottom of the panel. Among other things, they can be used to adjust the levels of the +5 and ±12 volt power supplies.

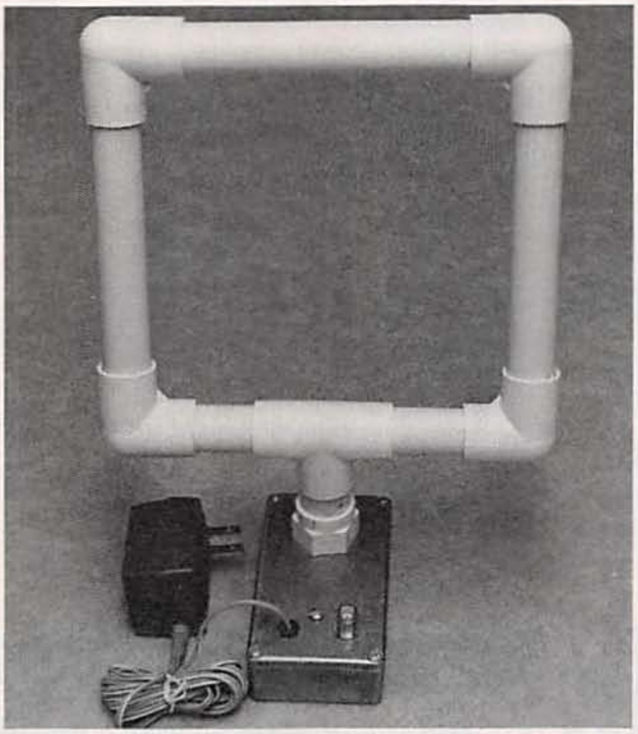
Having such building blocks as power supplies, pulse generators, and clock generators around the breadboard means that you can concentrate on accomplishing a task without worrying about basic, mundane circuitry. That makes the TD107 designer ideal for formal laboratory courses because it lets students use their class time more efficiently. The designer would also be appropriate for home use by any electronics hobbyist or enthusiast. For those users who need to build large circuits, the designer can be expanded with additional breadboard space that can hold up to eight additional 14-pin DIP's.

The *TD107* digital designer carries a suggested retail price of $159.95, which is competitive for this type of device. JPC also offers an analog designer, the TA102, which is priced at $149.95. The analog designer provides the user with variable regulated power supplies, a center-tapped 30-volt AC supply, sine-, square-, and triangle-wave generators instead of the digital pulse and clock generators, and logic indicators. **R-E**

NEW PRODUCTS

Use the Free Information Card for more details on these products.

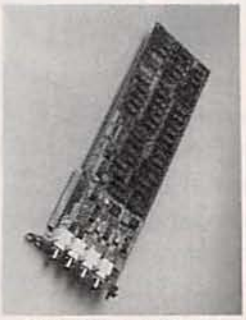
AM BROADCAST LOOP ANTENNA. The *BCL-1* receiving antenna from *Electron Processing*, a compact 8 × 8-inch square unshielded loop, is said to receive AM broadcast stations while rejecting excessive noise. A 30-dB preamplifier assures strong signals, and interference is reduced or eliminated by the loop's directional characteristics. Noise reduction permits the reception of stations that otherwise could not be received. With a reception range of 530 to 2000 kHz, the antenna is powered by line 120-volt AC. It is equipped with a jumper cable to connect the receiver and a selection of connectors is available.


CIRCLE 16 ON FREE INFORMATION CARD

The price of the *BCL-1* AM loop antenna is $125 plus $5 for shipping and handling.—**Electron Processing, Inc.**, P.O. Box 68, Cedar, MI 49621; Phone: 616-228-7020.

DATA-ACQUISITION CARD. *Gage's CompuScope LITE-64K* data-acquisition card provides 40-MHz sampling with 64K of memory. According to the company, its card permits personal computers to match the performance of stand-alone digital oscilloscopes.

The card, in an IBM PC/XT/AT format, performs 40-msps digitization on one channel or simultaneous 20-msps digitization on two channels. It also offers 8-bit resolution, 32 kilobytes of memory per channel, external trigger capability, software drivers, and a user-friendly interface. Up to eight of the cards can be installed in the same PC making it equivalent to an eight-channel, 40-MHz or a 16-channel, 20-MHz digital oscilloscope.


CIRCLE 17 ON FREE INFORMATION CARD

The *CompuScope LITE* card purchase includes digital-oscilloscope software permitting users to store, analyze, print, and transmit their data. GageCalc software also permits users to carry out math functions such as FFT and frequency counting. Gage offers software drivers compatible with all popular compliers: Turbo Pascal, Turbo C, Microsoft C, and Turbo Basic. Those drivers can control the board in OEM applications. The software, which runs under MS-DOS, has an installation utility and an AutoDetect feature that is said to be simple to use.

CompuScope LITE–64K costs $995.—**Gage Applied Sciences Inc.**, 5465 Vanden Abeele, Montreal, Quebec, Canada H4S 1S1; Phone: 514-337-6893; Fax: 514-337-8411.

PULSE GENERATOR. Protek's Model B-1010 1 Hz to 10 MHz pulse generator includes includes variable delay and seven pulse widths, 0 to 5 volts into 50 ohms. Delay time is 0 to 50 and 500 nanoseconds, 5, 50 and 500 microseconds and 5 milliseconds, variable in each step.


CIRCLE 18 ON FREE INFORMATION CARD

Seven pulse widths range from 50 nanoseconds to 50 microseconds with each step variable. Four operational modes are offered: internal, external, manual, and external up and down. The pulse generator measures $10\frac{3}{8} \times 9 \times 3\frac{3}{8}$ inches and weighs $5\frac{1}{4}$ pounds.

The *B-1010* pulse generator price is $499.—**HC Protek**, P.O. Box 59, Norwood, NJ 07648; Phone: 201-767-7242; Fax: 201-767-7343.

PORTABLE PROTOTYPING STATION. How about a portable electronics laboratory to take to school, the job—or even on vacation?

CIRCLE 19 ON FREE INFORMATION CARD

Global Specialties' PB-503-C is a complete electronics prototyping station housed in a carrying case. It can be used for prototyping analog, digital, and microprocessor circuits and performing many kinds of experiments.

The breadboard has an area large enough to hold circuits with as many as 24 DIP-packaged devices. The portable lab contains a function generator, a power supply with three output voltages, an 8-channel logic probe, and two digital pulsers.

The power supply has a +5-volt, 1 ampere, and two variable 5–15-volt, 0.5-ampere terminals. The function generator produces frequencies from 0.1 Hz to 100 kHz with a choice of sine, square, and triangular waveforms or TTL clock output. The briefcase-sized, fold-down carrying case is roomy enough to store an optional *Proto-Meter 4000* multimeter and *WK-1* wire-jumper kit.

The *PB-503-C* portable prototyping station is priced at $349.95; the *Proto-Meter 4000* price is $139.95, and the WK-1 wire-jumper kit price is $13.95.—**Global Specialties**, 70 Fulton Terrace, New Haven, CT 05412; Phone: 800-572-1028.

486-CLASS SINGLE-BOARD COMPUTER. This PC-compatible, single-board computer from *Computer Dynamics* is intended for embedded OEM applications. It includes an Intel 486-compatible MPU, flash memory, and an advanced video controller.

The board measures 5-3/5×7-3/4 inches, taking up only about 10% of the space required by a desktop PC. The board's 25-MHz Cx486SLC MPU executes the 486SX instruction set and all 486SX operating systems, including DOS and Windows.

An on-chip, one-kilobyte cache gives the processor more than twice the speed of a 386SX at the same clock frequency. In addition to the full complement of standard PC functions, the board provides for up to 786 K of flash ROM.

CIRCLE 20 ON FREE INFORMATION CARD

For fixed-program storage, the *SBC-486* has up to 1.5 megabytes of on-board ROM/RAM disk, ensuring quick boot-up and reliable operation. The on-board video controller drives CRT's and flat-panel displays directly. Other features include hard- and floppy-disk controllers, a battery-backed real-time clock, a math co-processor socket, and an SBX interface that lets the user add "non-IBM" expansion boards.

The *SBC-486* board is priced from $936 in OEM quantities.—**Computer Dynamics**, 107 South Main Street, Greer, SC 29650; Phone: 803-877-8700; Fax: 803-879-2030.

GRAPHICS CALCULATOR. Here is a calculator that plots graphs to speed-up problem-solving. *Texas Instruments' TI-85 Graphics Calculator* combines an advanced scientific calculator with graphics plotter in a handheld package.

CIRCLE 21 ON FREE INFORMATION CARD

The *TI-85* is intended for use in the office, when traveling, and in the field. According to H-P, engineering and science students can purchase this calculator for class work and be assured that it will still be useful in their professional careers after graduation.

The calculator's built-in software allows users to run trial solutions and test a range of strategies. The calculator displays graphs of functions as well as parametric, polar, and differential equations. It can determine any variable in an equation, solve 30 equations simultaneously, and extract the roots of a polynomial up to the 30th order. The calculator can handle complex numbers, matrixes, vectors, lists, and strings.

The TI-85 has 32 kilobytes of RAM. A built-in I/O port can link the calculator to a PC or another *TI-85*. Optional *LINK-85* software makes it possible to edit, store, and print programs, graphs, and math notations in IBM-compatible compatibles and Macintosh computers. The display provides eight lines of information with up to 21 characters each or 64 × 128-pixel graphs.

The *TI-85* graphics calculator has a list price of $130.—**Texas Instruments**, Consumer Relations, P.O. Box 53, Lubbock, TX 79408-0053; Phone: 800-TI-CARES; Fax: 800-741-2146.

CONVERTER-MOUNTING KIT. The *MS 15* mounting kit allows *Calex* 1 × 2-inch and 2 × 2-inch DC/DC converters to be used in many different non-AC powered systems. The kit consists of a 2½ × 3-inch card attached to a 15-pin connector, which makes it convenient to rack mount many DC/DC converters in any system.

CIRCLE 22 ON FREE INFORMATION CARD

Each connector has two No.4 screw holes on either side for mounting the *MS-15*. The kit will accommodate all *Calex* single- and dual-output converters rated from 1.8 through 7.5 watts. The *MS 15*, when coupled to those converters, is suitable for use in field-portable, battery-operated systems.

The unit price for the *MS 15* mounting kit is $32—**Calex Mfg. Co., Inc.**, 2401 Stanwell Drive, Concord, CA 94520-4841; Phone: 510-687-4411 or 800-542-3355; Fax: 510-687-3333.

DMM TEMPERATURE HEAD ACCESSORY. The *Fieldpiece* "Stick" series digital multimeter can be converted to a one-piece temperature meter with the addition of the *ATH3 dual temperature head.*

The *ATH3* with the optional *ADL2* test leads can be used with any DMM having "Fluke-style" jacks. The accessory can field-calibrated to an accuracy of ±1°F. The converter accepts inputs from two K-type thermocouples to display them as temperature on a DMM.

CIRCLE 23 ON FREE INFORMATION CARD

A DMM with resolution to 0.1 mV displays resolution to 0.1°F. A DMM with resolution to 0.1°F displays resolution to 1.0°F. Input impedance must be 9 or 10 megohms.

The dual-temperature head has a green LED to indicate "on" and a red LED to indicate low battery. The unit, which is internally powered by a standard 9-volt battery, automatically shuts off after 45 minutes. Two bead-type K-thermocouples are included.

The *ATH3* DMM dual-temperature head is priced at $89.—**Fieldpiece Instruments, Inc.**, 8322B Artesia Blvd., Buena Park, CA 90621; Phone: 714-922-1239; Fax: 714-992-1239.

COMPACT MULTIMETERS. *B+K-Precision* has extended its line of low-cost, digital multimeters. Each of the four models in the "Tool Kit" series measure current to 10 amperes, DC voltage to an accuracy of 0.5%, and resistance, as well as test diodes. All of the DMM's have 3½-digit LCD's, audible continuity checking, and overload protection.

The basic *Model 2703* measures voltage , resistance , and DC current. The other models have additional features.

CIRCLE 24 ON FREE INFORMATION CARD

- *Model 2704A* also measures AC current and capacitance, and it makes transistor tests.
- *Model 2706* adds temperature measurement.
- *Model 2707* has a built-in frequency counter and logic-probe.

The DMM prices are: Model 2703A—$39, 2704A—$59, 2706—$79 and 2707—$89.—**B+K-Precision**, 6470 West Cortland Street, Chicago, IL 60635; Phone: 312-889-1448; Fax: 312-794-9740. **R-E**

NEW LIT

Use The Free Information Card for fast response.

ANALOG DIALOGUE; from Analog Devices, Literature Center, 70 Shawmut Road, Canton, MA 02021; Fax: 617-821-4273; free.

Analog Dialogue is Analog Device's house organ for the dissemination of information about its products and related technology. The company terms it "a forum for the exchange of circuits, systems, and software for real-world signal processing."

CIRCLE 25 ON FREE INFORMATION CARD

This edition (Volume 26, Number 100) features highlight the subject of mixed-signal chips for driving digital radio. It discusses a pair of monolithic I/O chips that provide critical functions for digital mobile-radio communications. The AD7001 and AD7002 are described in a tutorial titled "IF Stages Are Going Digital for Both Analog and Digital Signals."

The journal also carries an article on monolithic sigma-delta converters with 21-bit resolution backed up by a tutorial on sigma-delta architectures. Another article covers a SPICE macro-model of an analog multiplier. Other sections include a new product overview, an advice column on voltage references, and a review of new literature from Analog Devices.

MINIATURE SWITCH CATALOG; from Eaton Corporation, Aerospace & Commercial Controls Division, 4201 North 27th Street, Milwaukee, WI 43216; Phone: 414-449-7483; free.

CIRCLE 26 ON FREE INFORMATION CARD

This catalog (publication number NC-169) contains a technical specification information and illustrations on Eaton's line of miniature switches for electrical and electronic applications. To simplify the search for the switch that will meet your requirement, each product section includes a brief product description and a selection table.

DESKTOP PUBLISHING WITH WORD FOR WINDOWS VERSION 2.0; by Tom Lichty. Ventana Press, P.O. Box 2468, Chapel Hill, NC 27515; Phone: 929-942-0220; Fax: 919-942-1440; $$21.95.

The software Word for Windows, version 2.0 is intended for word processing and desktop publishing. This book offers advice and examples to help users take full advantage of that software. Mr. Lichty's book, which assumes that readers have a working knowledge of Word, explains how to create attractive, well-designed documents on a computer.

CIRCLE 27 ON FREE INFORMATION CARD

It addresses framing and text placement in desktop-publishing. Also covered are the fundamental principles of page design such as proportion, balance, and unity. The book tells the reader how to apply those principles to setting margins, white space, rules, and borders. Other topics include typography, style sheets, multiple columns, and graphics placements. The final chapter contains specifications for recommended printers and printing methods.

KNOB CATALOG; from Rogan Corporation, 3455 Woodhead Drive, Northbrook, IL 60062; Phone: 800-423-1543; free.

You'll be amazed at the variety of sizes, shapes, colors and styles in which a simple product like a knob can be produced. Rogan's catalog proves that push-buttons have yet to usurp the role of rotating controls in electronics. The right selection of knob can make or break the appearance of your product.

CIRCLE 28 ON FREE INFORMATION CARD

This catalog illustrates Rogan's broad range of products, spelling out its options in material, size, style, markings, color, decorative options, mountings and dimensions. There are, for example, ergonomic clamping knobs, digital turns-counting knobs, instrument knobs, and military spec knobs.

TECHNI-TOOL CATALOG 42; from Techni-Tool, 5 Apollo Road, P.O. Box 368, Plymouth Meeting, PA 19462; Phone: 215-941-2400; free.

CIRCLE 29 ON FREE INFORMATION CARD

Techni-Tool's 1992 catalog gives information on the company's tools, tool kits, test equipment, and supplies for factory production and professional trouble-shooting as well as field service on all kinds of electrical and electronic equipment.

1992 CATALOG; from MCM Electronics, 650 Congress Park Drive, Centerville, OH 45459-4072; Phone: 1-800-543-4330; free.

MCM's latest catalog contains specifications information on more than 17,000 electronics parts and components. This 212-page edition includes reference to 1500 more items than the 1991 edition. Product categories include semiconductors, television and VCR parts, power supplies and regulators, telephone components and accessories, batteries, speakers, and tools.

CIRCLE 30 ON FREE INFORMATION CARD

YOUR VHF COMPANION; edited by Steve Ford, WB8IMY. The American Radio Relay League, 225 Main Street, Newington, CT 06111; $8.00.

CIRCLE 31 ON FREE INFORMATION CARD

This book will be welcomed by veteran VHF operators as well as novices because it contains plenty of useful information in an entertaining, easy-to-read format. For example you'll find out how to participate in all the activities on the VHF bands—FM and repeaters, packet radio, CW and SSB, satellites, and amateur television.

UNDERSTANDING HARMONICS IN POWER DISTRIBUTION SYSTEMS; from John Fluke Mfg. Co., Inc., Service Equipment Group, P.O. Box 9090, M/S 250-E, Everett, WA 98206-9090; Phone: 800-526-4731; $19.95.

Power line harmonics can be a source of unwanted interference in factories and offices that depend on the reliability of line-powered electronic equipment from PC's to copying machines. Harmonics can cause transformers and neutral conductors to overheat and circuit breakers to trip for no apparent reason.

CIRCLE 32 ON FREE INFORMATION CARD

This 17-minute educational video will help you to understand and solve harmonics problems. It covers such subjects as the definition and classification of harmonics, electrical loads, equivalent circuits, and the detection of harmonics. It suggests methods for solving harmonics problems in new and existing buildings. **R-E**

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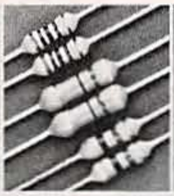

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CIRCLE 78 ON FREE INFORMATION CARD

BUILD THIS SUPER STROBE

Create breathtaking stop-action photos with the Freeze Frame.

JOHN SIMONTON and TREY SIMONTON

SO MUCH OF LIFE IS A BLUR. WHEN you can slow it down and savor it, you discover the most interesting things.

Take, for example, the pictures showing a water-filled balloon being popped by a dart. You might anticipate that the burst balloon would leave a ball of water hanging in the air for a fraction of a second, but would you have guessed that the surface of the water ball would froth the way it does? What a beautiful surprise.

Our Freeze Frame strobe trigger lets you use photographic techniques that substitute a strobe flash for high shutter speeds. You can reproduce these and other stop-action shots either for serious scientific purposes or just because they make such interesting pictures. The inexpensive, easily built unit has been designed to use interchangeable sensors, so that anything that pops, snaps, flashes, or reflects or blocks light can trigger your camera's strobe.

How it works

The complete schematic for the Freeze Frame is shown in Fig. 1. Either of the sensors (phototransistor Q2 or electret microphone MIC1) acts like a variable current sink in series with R1. As light or sound levels change and more or less current sinks into the sensor, a voltage develops across R1.

The processing amplifier for the sensors is built around two stages of an LM324 quad operational amplifier (IC1-a and IC1-b). The amplifier is AC-coupled so that only changes in the triggering signal are detected. The values of the coupling capacitor between stages are intentionally small so that only changes with higher-frequency components (above about 5 kHz) pass through the amplifier. When using the microphone, that means that snaps and pops will be more likely to trigger the unit than other ambient noise, including speech.

Capacitor C2 couples the output of the processing amplifier to the rectifier- and peak-detector section consisting of D1, D5, R9, R10, and C4. The DC voltage that appears across R9 is approximately the same as the peak-to-peak voltage at the output of the amplifier.

The voltage is applied to a threshold detector, which is a

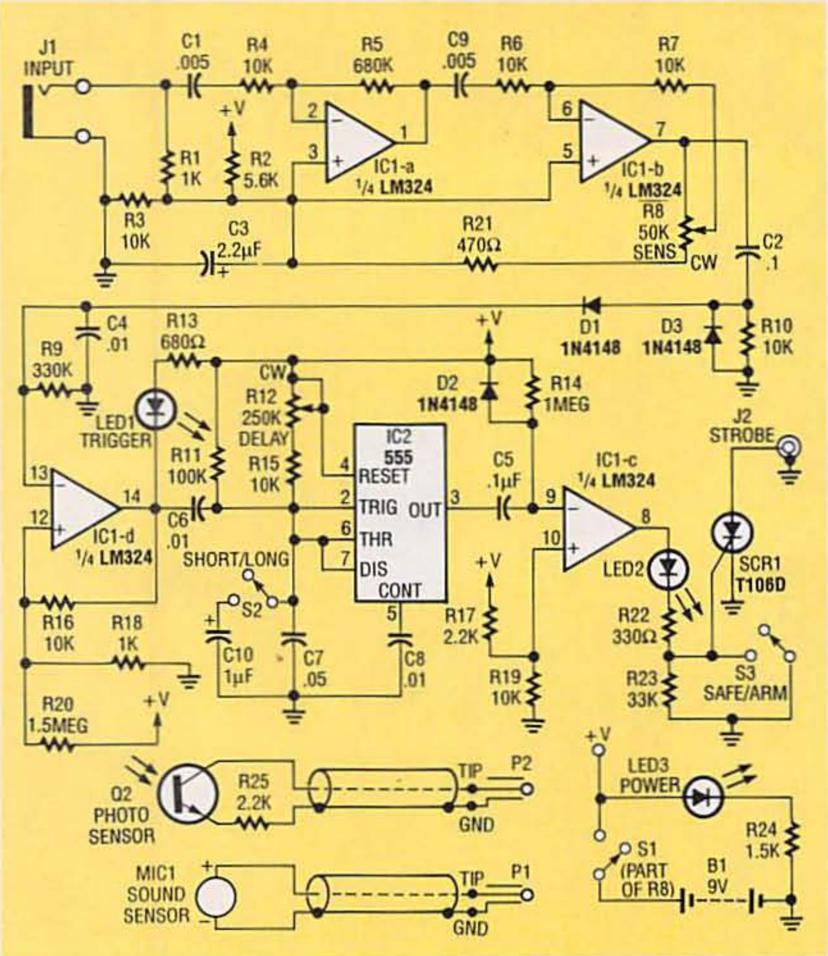


FIG. 1—SCHEMATIC FOR THE FREEZE FRAME. The sensors act like a variable current sink in series with R1. As light or sound levels change and more or less current sinks into the sensor, a voltage develops across R1.

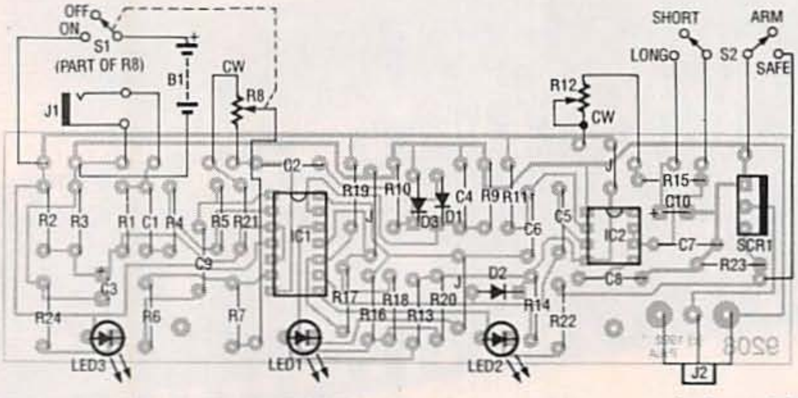
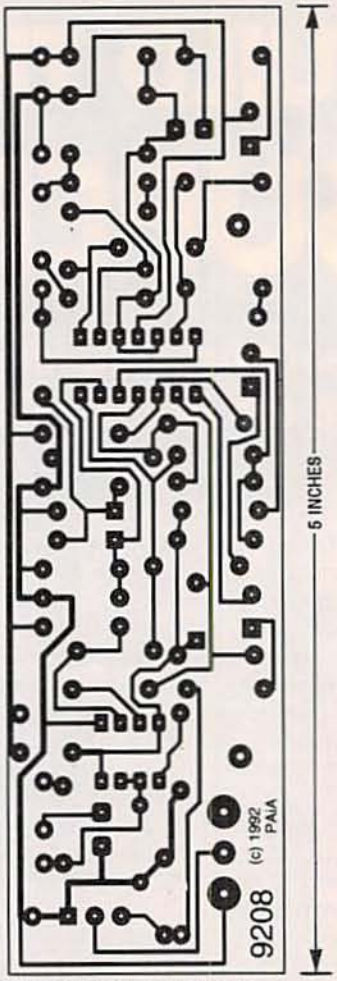


FIG. 2—PARTS-PLACEMENT DIAGRAM. The three wire jumpers can be formed from excess component lead.

Schmitt trigger built around IC1-d. The trigger level is set to a couple of volts and hysteresis is set to about one volt by R16, R18, and R20. At the output of the amplifier, LED1 indicates when a stimulus has exceeded the threshold.

When the output of the threshold detector goes low, C6 couples the transition to the input of the 555-based timer section and triggers it. The amount of delay produced by the timer is set by the DELAY CONTROL R12 and capacitor C7. Capacitor C10 is switched in by S2 when longer delays are needed.

The output of the timer is coupled by C5 to the final ampli-



FREEZE FRAME foil pattern.

fier stage in IC1, which is wired as a comparator. At the end of the time-out, IC2's output goes low and is inverted by IC1-c to a positive transition that turns on SCR1. The current path to SCR1's gate is provided by LED2, which also indicates that the triggering signal has happened. As a convenience when setting up to take photos, switch S3 can be closed to ground the gate of SCR1 and prevent it from firing.

Building the Freeze Frame

You can build the Freeze Frame with just about any construction technique you like. A circuit board is always the neatest, quickest, and easiest way though, so we've provided a foil pattern. You can buy an etched and drilled board from the source given in the Parts List. If you use a PC board, mount and solder all of the components following the parts-placement diagram in Fig. 2. There are three

PARTS LIST

All resistors are ¼-watt, 5%.
R1, R18—1000 ohms
R2—5600 ohms
R3, R4, R6, R7, R10, R15, R16, R19—10,000 ohms
R5—680,000 ohms
R8—50,000 ohms, audio-taper potentiometer with switch (S1)
R9—330,000 ohms
R11—100,000 ohms
R12—250,000 ohms, linear-taper potentiometer
R13—680 ohms
R14—1 megohm
R17, R25—2200 ohms
R20—1.5 megohms
R21—470 ohms
R22—330 ohms
R23—33,000 ohms
R24—1500 ohms
Capacitors
C1, C9—0.005 µF, ceramic disk
C2, C5—0.1 µF, Mylar
C3—2.2 µF, 10 volts, electrolytic
C4, C6, C8—0.01 µF, ceramic disk
C7—0.05 µF, ceramic disk
C10—1 µF, 10 volts, electrolytic
Semiconductors
IC1—LM324 quad op-amp
IC2—555 timer
D1–D3—1N4148 diode
LED1–LED3—red light-emitting diode
Q1—IR phototransistor
SCR1—T106D silicon-controlled rectifier
Other components
B1—9-volt battery
J1—Miniature phone jack
J2—RCA jack
MIC1—Electret microphone
PL1, PL2—Miniature phone plugs
S1—SPST switch (part of R8)
S2, S3—SPST slide switches
Miscellaneous: case with top panel, knobs, wire, hardware, battery snap, heat-shrink tubing, coaxial cable, circuit board, etc.

Note: The following items are available from PAIA Electronics, Inc., 3200 Teakwood Lane, Edmond, OK 73013 (405) 340-6300:

• Etched, drilled, and silkscreened PC board (#9208pc)—$12.75

• Complete Freeze Frame kit including PC board, case, and all components (#9208k)—$39.75

Please add $3.50 shipping and handling to each order.

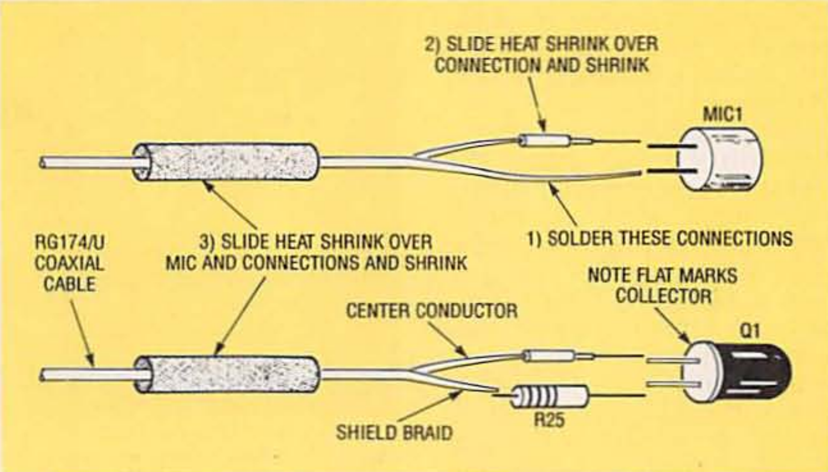


FIG. 3—MAKE THE SENSOR ASSEMBLIES with heat-shrink tubing and small diameter coaxial cable such as RG-174/U. The space between the coaxial cable and the outer heat-shrink tubing is filled with a little silicone rubber.

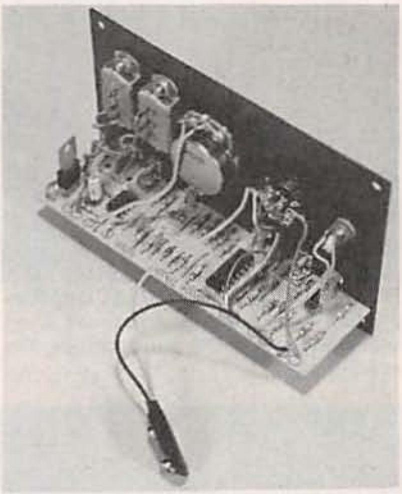


FIG. 4—THE COMPLETED FREEZE FRAME. This is one of the most attractive boards you'll ever see.

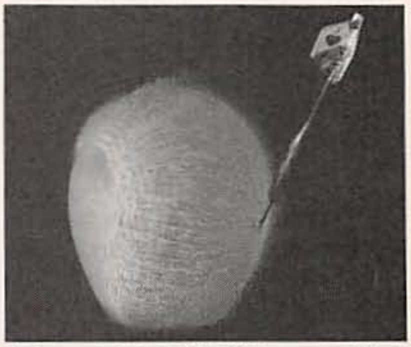


FIG. 5—A DART HITTING a water-filled balloon from an angle. The microphone sensor picked up the sound of the balloon bursting.

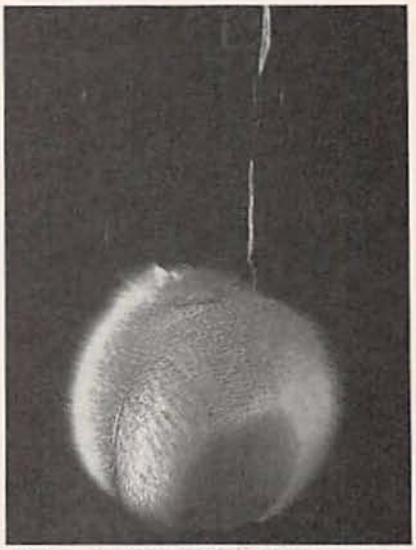


FIG. 6—ANOTHER DART hitting another water balloon, but from directly above.

wire jumpers on the board that can be formed from the excess leads clipped from other components.

A fairly light gauge wire such as AWG 26 is appropriate for making connections between the circuit board and front-panel controls. With any electronic circuit, keeping the wiring between the circuit board and front panel as short and direct as possible is good practice, and with the Freeze Frame it is important because the high signal gains in the sensor-processing amplifier at maximum sensitivity could cause the pickup of stray signals.

The circuit board is laid out so that the LED's and the STROBE-TRIGGER output jack J2 are on an edge of the board where they can look out through holes in the front panel when the board is mounted at a right angle to the panel with "L" brackets.

Providing a miniature phone jack (J1) will allow interchangeable sensors. Using different style jacks for the trigger input and strobe output prevents the possibility of damaging the Freeze Frame's circuitry if a high voltage on the flash unit were suddenly connected to the input of the amplifier circuitry. Even if you're going to be using only one sensor, having it remote from the rest of the circuitry is an advantage because it makes it much easier to set up photos and to protect the trigger parts from splashes and other abuse.

Make the sensor assemblies with heat-shrink tubing and small diameter coaxial cable such as RG-174/U (see Fig. 3). Both the phototransistor and microphone are polarized components, so make sure their positive sides (the collector in the case of Q2) connects to the center conductor of the coaxial cable, which, in turn, connects to the tip of the phone jack. Note the resistor in series with the phototransistor; we mounted it at the detector end of the coaxial cable and made the heat-shrink tubing long enough to cover both it and most of the case of Q2. The space between the coaxial cable and the outer heat-shrink tubing was filled with a little silicone rubber.

An infrared photodetector is recommended because it allows a setup under limited fluorescent lighting, which is low in IR. At the same time, many of the events that will be triggering events (such as things blowing up, for instance) are high in IR.

You will need to modify a flash extension cord by replacing its normal camera-end connector with an RCA plug. There are a couple of things to be aware of here. First check the polarity of the voltage on the flash cord; the positive side must go to the anode of SCR1 (the center of the RCA jack) and the negative side to ground. Also, the voltage on those leads varies widely; on some strobes it might be only a couple of volts, while others might be over 200 volts. There is fairly low energy here in either case, so we're not talking about a lethal situation. But you'll definitely feel the higher voltage if you touch it. If you don't want to purchase an extension cord to be dedicated to the Freeze Frame, you might be able to cut your existing cord and patch the two ends together with an in-line plug and jack pair. Make sure the male connector on the end of the cord is connected to the flash. Figure 4 shows the completed unit.

FIG. 7—AIR-FILLED BALLOON hit by a pellet. The streak on the right side is the pellet.

FIG. 8—WATER-FILLED BALLOON hit by a pellet. The sound sensor was used with the report of the gun providing the event trigger.

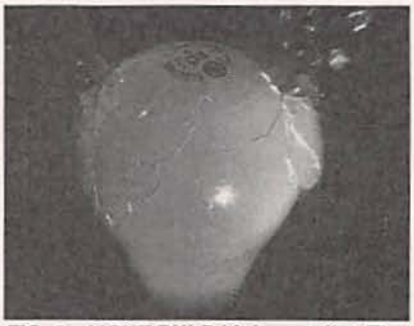


FIG. 9—LIGHT BULB hit by a pellet. The delay was set at its minimum value for this shot.

FIG. 10—THE LIGHT BULB is almost totally gone in this picture. Don't forget to wear goggles when shattering light bulbs.

Testing

Any testing procedure should start with a close visual inspection of your work. Make sure component polarities have been observed, that all solder joints look good, and that there are no solder bridges on the circuit board.

Don't plug in a sensor yet—our initial tests won't need one. Snap in a fresh 9-volt battery and turn the unit on by rotating the sensitivity control clockwise beyond the detent; the power indicator (LED3) should light. If not, check for a dead battery, short circuits, etc.

Set the SENSITIVITY (R8) and DELAY (R12) controls to about the mid-point of their rotation, and set the SHORT/LONG switch (S2) to "short." With a wire jumper or clip lead, short the tip and ground lugs of the input jack J1 together. If everything's working properly you should see both the TRIGGER and FIRE LED's flash briefly and apparently simultaneously. If neither LED flashes, it could indicate problems in the sensor-processing amplifier, so check the circuitry associated with IC1-a and -b, the polarity and assembly integrity around diodes D1 and D3, and the circuitry associated with IC1-d. If only the TRIGGER LED lights, it could indicate problems in the timer circuitry associated with IC2 or the final comparator IC1-c.

Switch S2 to "long," and once again short the input. Now you should be able to see a discernible time delay between the flash from the TRIGGER and FIRE LED's. If you don't see an obvious delay it could mean problems with the timer or with S2 and C10.

Now plug in the microphone sensor. With the SENSITIVITY control set to about mid-range, a finger snap from within a foot of the microphone should cause both the TRIGGER and FIRE LED's to light. At maximum sensitivity, a finger snap within several yards should trigger the unit, and at minimum sensitivity you will have to be within a inch or so from the microphone. If there are no obvious differences in the sensitivity of the unit as the SENSITIVITY control is rotated over its range, check the wiring around potentiometer R8. If there is no response from the microphone as an input, check the wiring of the phone plug and coaxial cable of the microphone, as well as the polarity of the microphone.

Plug in the IR sensor and point it at an incandescent lamp (fluorescent or Krypton lights might not have sufficient infrared energy to be detected by the phototransistor), and set the SENSITIVITY control to mid-range. Passing your finger in front of the phototransistor should cause the TRIGGER and FIRE LED's to flash briefly. Striking a match or lighting a cigarette lighter in front of the sensor should trigger the unit. If there are problems here, check the wiring of the sensor, in particular the polarity of the phototransistor.

Finally, mate the RCA plug on the end of your modified flash extension cord with the STROBE jack and turn the strobe on. Set the ARM/SAFE switch (S3) to "arm" and trigger the Freeze Frame. The strobe should flash when the FIRE LED flashes. If not, check the strobe first, making sure its battery is good by firing it with its own test switch. Then check the modifications you've made to the flash's extension cord; make sure that the positive voltage from the strobe connects to the tip of the RCA plug. If there are still no results, check the SCR.

Using the Freeze Frame

The Freeze Frame helps you to get shots that would be difficult to obtain otherwise. But that doesn't mean that they're necessarily going to be easy. The quality of the pictures you get will depend to a large extent on how carefully you set up the shot.

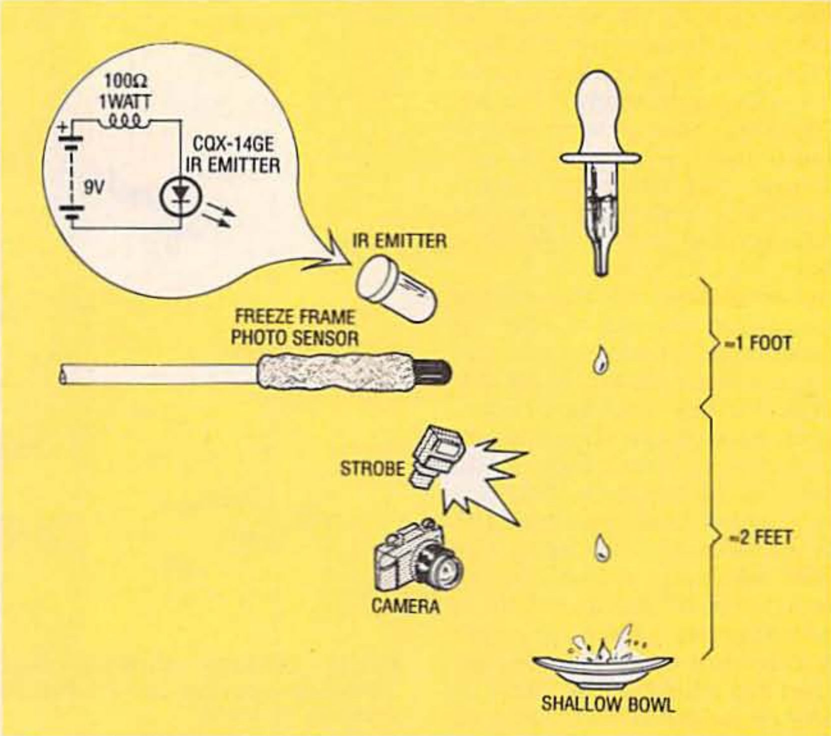


FIG. 11—YOU CAN TRIGGER A MILK DROP by pointing an IR emitter and the sensor in the same direction toward the space through which the drop will fall through.

FIG. 12—THIS MILK CROWN is formed after the drop hits.

FIG. 13—THIS MILK COLUMN forms later in the sequence.

You can look forward to giving your imagination a workout as you figure out what sensor to use, how to use it, and how to light the subject—not to mention thinking up an interesting picture in the first place.

Each situation will be slightly different, but to get you started we'll cover first some basic principles on the camera side of things, and then look in detail at how the Freeze Frame produced the photos shown here.

As we said in the opening, the essential idea is that you're going to be exposing the film with a brief flash of light while the camera shutter is held open, rather than the usual way of lighting the subject and briefly opening the shutter. The first obvious implication of this is that the photography must be done in the dark—not darkroom dark necessarily, where every tiny little crack must be sealed against light, but dark—a moonless-night-in-the-country kind of dark.

Sensor selection is usually pretty obvious. If the event that you want to photograph makes a sound (like a popping balloon), use the microphone. If the event is very quiet, make arrangements for the event to interrupt a light beam. In the case of the milk drop, we found that milk was surprisingly reflective of infrared, and we were able to exploit this. Some events (like an exploding firecracker) produce a flash and pop giving you a choice of sound or light sensors.

After setting up the strobe and sensor, you will need to do some trial events to get the proper sensitivity and delay settings for the Freeze Frame. Since you won't be shooting any pictures, you don't have to do this part in the dark. You can get a pretty good preview of the photo just by watching the event when the strobe flashes. Persistence of vision will hold the image on your eye's retina for a short time, and you can get a feel for whether the delay is right or needs to be shorter or longer. The range of delay is from 0.5 millisecond to 12 milliseconds when S2 is set to "short" and 10 milliseconds to 0.25 second when set to "long."

Proper placement of the flash makes a big contribution to the quality of the photo. For example, backlighting the subject slightly (placing the strobe so that it lights the subject from behind) will keep any background clutter from showing up on film. When backlighting, make sure the strobe doesn't flash directly into the camera lens or close enough to cause lens flares, unless you want them. Strategically placed "light baffles" can make things that you don't want in the photo, such as supports for the subject, disappear by keeping them in shadow. Sheets of cardboard would be our choice material, but we used books or whatever else we could lay our hands on.

When you're trying to freeze motion, you need brief flashes of light. Strobes that are too "smart" can produce a flash that is amazingly long; we figure several milliseconds judging from the blurred results of our first shots. Switch your flash to its "dumb" (manual) mode and minimum energy settings if you get blurred results. If you are not able to do this, switch to another flash. A modern Vivitar 636AF was smarter than we were, so we wound up using an inexpensive and ancient Vivitar 253 for all of the shots shown here.

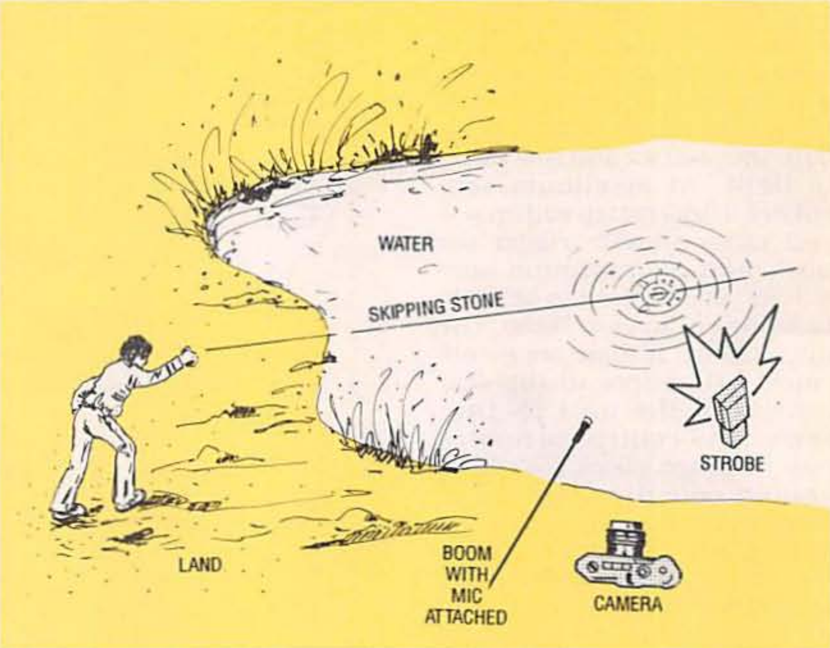


FIG. 14—TO CATCH A STONE SKIPPING ACROSS WATER, we set up the camera on shore, and supported the flash and microphone sensor out in the water to get them closer to the action.

FIG. 15—THIS STONE was in the middle of skipping when we "caught" it.

You can use whatever film you're used to; these shots were done on Kodachrome 64 with aperture settings ranging from f8 to f11. We used a fairly long lens (35–80mm zoom) because taking some of these shots was a messy proposition and we wanted to keep the camera as far away as possible. Remember, the larger the f-stop, the greater the depth of field. That is important when you're not completely sure where all the pieces of a subject will be when the shot is taken.

A tripod was used to free up hands needed elsewhere, but the camera can be handheld without much fear of blurring because the strobe will stop the action. A cable or other remote release can be used to open the shutter, but our Minolta Maxxum 7000 had a self timer that we used instead. We found that a 2-second exposure was long enough to let us take a picture without rushing, and short enough to keep the film from being exposed.

As the battery in a strobe ages, it takes longer for the unit to charge high enough to fire again. That can become an annoying delay if the flash is inadvertently fired during setup. The ARM/SAFE switch keeps that from happening. Leave the switch in the "safe" position until you're ready to shoot a picture, then switch it to "arm."

Once we finished setting and adjusting the camera, strobe and subject placement, delay times, sensitivity, and other adjustments, the general sequence for all shots was the same:

1) Arm the Freeze Frame and activate the self timer

2) Darken the scene
3) Pray while waiting for the shutter to open
4) Do the event
5) Wait for the shutter to close and relight the scene
6) Figure out what went wrong and do the next one

Balloons and darts

Figures 5 and 6 were shot with the microphone sensor to pick up the sound of a water-filled balloon bursting. The microphone was placed close to the subject, just out of the frame. No protection against splashes was needed in the case of the water balloon because splashing is minimal—most of the water just falls and forms a puddle.

In the case of the water-filled balloons, the SENSITIVITY (R8) setting was important because the event didn't generate much more noise than the self-timer opening the camera shutter. (With too much sensitivity, the strobe triggered when the shutter opened.) With air-filled balloons, the SENSITIVITY is not as critical because the balloons generate a louder sound when they pop.

The SHORT/LONG switch (S2) was set to "short" for those shots with the DELAY control (R12) set for a very short period. In fact, it was the shortest possible delay in most of the photos. The balloons were all sitting on an up-ended spray-can lid for support. Light baffles kept the support from being lit.

Balloons and pellets

Figures 7 and 8 were produced by shooting at a balloon with an air rifle (the balloon in Fig. 7 is filled with air and the one in Fig. 8 is filled with water). The sound sensor was used, and the report of the gun provided the event trigger. The SENSITIVITY control was set to minimum. The rifle was securely clamped to a tripod about 4 feet from the target and carefully aimed during set-up. Several sheets of corrugated cardboard were used as a back-stop for the pellets. We chose a pump-type air rifle rather than a cartridge-powered one because, by pumping it the same number of times for each event, we found it had a more constant muzzle velocity.

Because air balloons are not as messy as water ones, we used them for setup. Simply place a balloon, arm the strobe, shoot the balloon, and see what happens. Don't blink, or you'll miss the part of the event illuminated by the flash. If what you see by the light of the flash is the balloon just sitting there, increase the delay. If you don't see any balloon, decrease the delay. If you're not sure what you saw, shoot a picture anyway. (There is such a thing as serendipity.)

It's interesting to notice the difference between water balloons burst with a dart and those hit with a pellet. While the dart simply slides in, leaving the water in the balloon almost undisturbed (Fig. 5), the energy from the impact of the pellet sets up a shock wave like that shown in Fig. 8. In some of the photos you can see the pellet as a streak in the right-hand side of the frame.

FIG. 16—A CAPACITOR EXPLODING is really quite a spectacle if you can really see what happens.

Light bulbs and pellets

Shooting at light bulbs with a pellet gun (Figs. 9 and 10) is set up the same way and with similar SENSITIVITY and DELAY settings as shooting at balloons with pellets. Safety first here: Don't forget your protective safety goggles.

Milk drops

This is the "classic" stop-action photo, with a tip of the hat to strobe photography's pioneer, Dr. Harold Edgerton. Since the splash produced by the drop is pretty quiet, the phototransistor is the sensor of choice. We tried the microphone, but couldn't keep the camera shutter from pre-triggering the strobe. This common picture is usually taken by having the drop fall between a collimated light source and photodetector. We tried that with our somewhat less-than-laboratory-grade stands and supports. It was difficult to get the eyedropper we were using as a drop source in just the right position to break the beam. After playing around for a while, we found that milk is surprisingly reflective of infrared. By placing an IR emitter and the sensor facing in the same direction pointing toward the space through which the drop would fall, we got very reliable triggering (see Fig. 11). The SENSITIVITY control was set nearly to maximum.

In these pictures we used the long delay range. By adjusting the DELAY control, we were able to get shots of both the familiar milk "crown" (Fig. 12) and the reaction column that forms later in the sequence (Fig. 13).

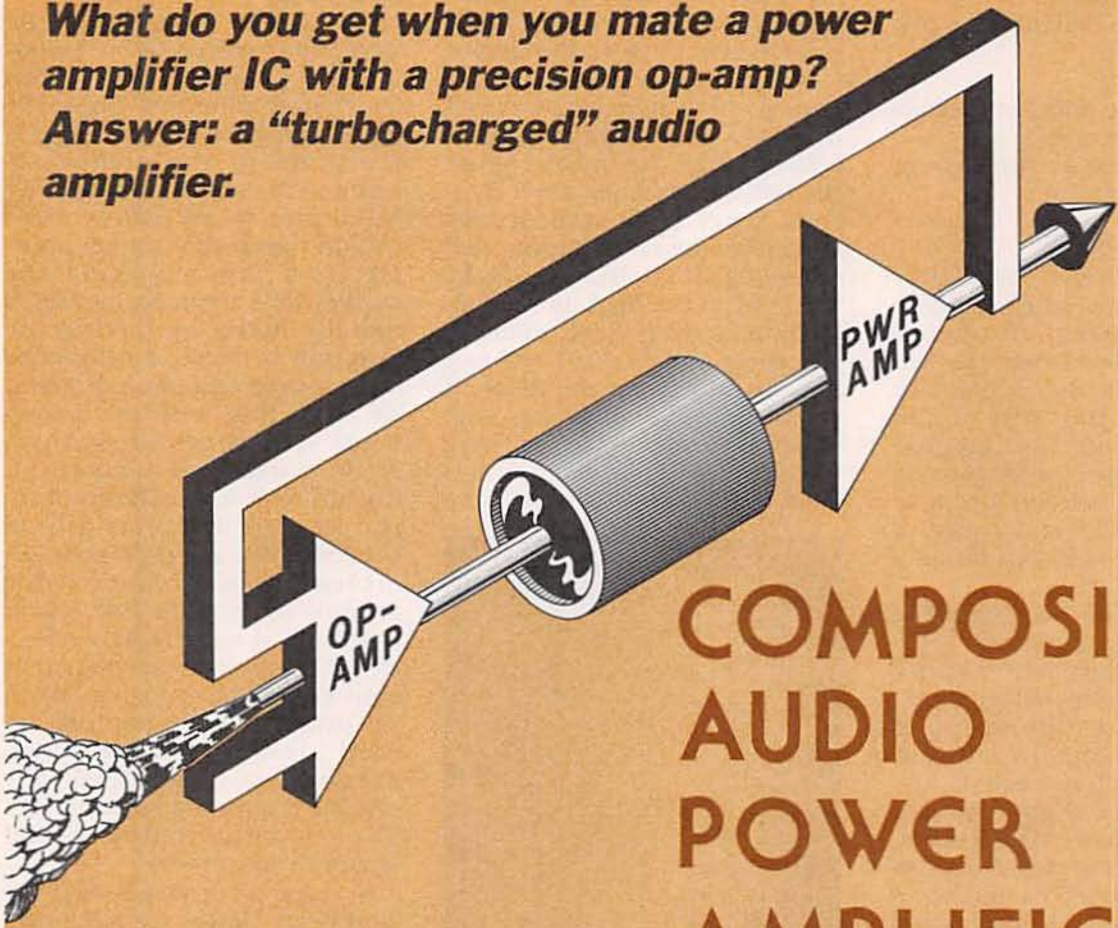
To help visualize the distribution of flow vectors induced by the momentum imparted to the resting fluid by the fluid in motion, we dyed the medium—just kidding. We thought it would look interesting to put some food coloring in the drops; nevertheless, it shows that the fluid that was in the drop winds up in the crown of the splash.

Skipping stones

These were fun. We set up outdoors by the side of a small country lake on a moonless night. A convenient wall gave us a dry place to put the camera and throw rocks from, but the support for the flash was put out in the water to get it closer to the action (see Fig. 14). The microphone was used as a sensor to trigger from the splash of the stone hitting the water. After en-

continued on page 87

What do you get when you mate a power amplifier IC with a precision op-amp? Answer: a "turbocharged" audio amplifier.



COMPOSITE AUDIO POWER AMPLIFIERS

CHARLES KITCHIN, SCOTT WURCER, AND JEFF SMITH

NOW YOU CAN BUILD YOUR OWN high-performance audio amplifiers from inexpensive components and beat the high price of factory-made amplifier modules. The composite amplifiers described here can improve stereo systems and other audio equipment with moderate power output. As you read this article you will probably be able think of many applications for these circuits.

The five souped-up audio amplifiers are made by inserting monolithic power amplifiers in the feedback loops of operational amplifiers. The "turbocharged" composites retain the low distortion and offset of the op-amps and the high-current handling capability of the power amplifiers.

The amplifiers described here are: two simple 10-watt composites, a 33-watt bridge composite, a 40-watt composite with a single-ended summing connection, and a 70-watt composite with two current-summing amplifiers in a bridge configuration. The output power values of all circuits are in root-mean-square (rms) watts.

Figure 1 is the pinout and functional diagram for the Analog Devices AD711JN, the precision, high-speed op-amp that is a part of all the composite amplifiers described here. The op-amps include both bipolar and field-effect transistors fabricated in a process known as BiFET technology. The pinout diagram is for plastic and ceramic DIP's.

Figure 2 is the pinout diagram for the National Semiconductor LM1875, the 20-watt power audio amplifier (power amp) in all of the composite amplifiers in this article. It is packaged in a flat-pack plastic TO-220 case.

Single-unit or low-volume prices on the op-amps and power amplifiers are subject to wide variations among the various vendors. However, calculations based on components from nationally advertised sources show the cost of the composites to be quite low. The component costs for each composite amplifier (except for power supply) were summed and divided by the amplifier's rated output power, and the results averaged out to be less than $1 per watt.

A 10-watt composite

Figure 3 shows the basic composite amplifier circuit with IC2, an LM1875, in the feed-

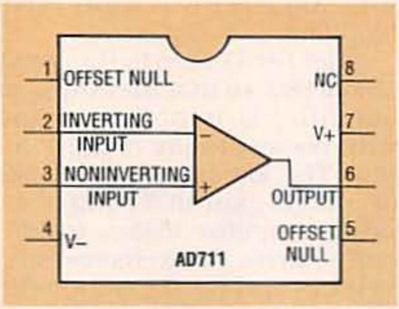


FIG. 1—PINOUT AND FUNCTIONAL BLOCK DIAGRAM for the AD711JN operational amplifier in an 8-pin DIP.

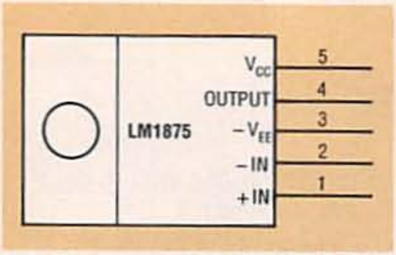


FIG. 2—PINOUT DIAGRAM for the LM1875 amplifier in a TO-220 case.

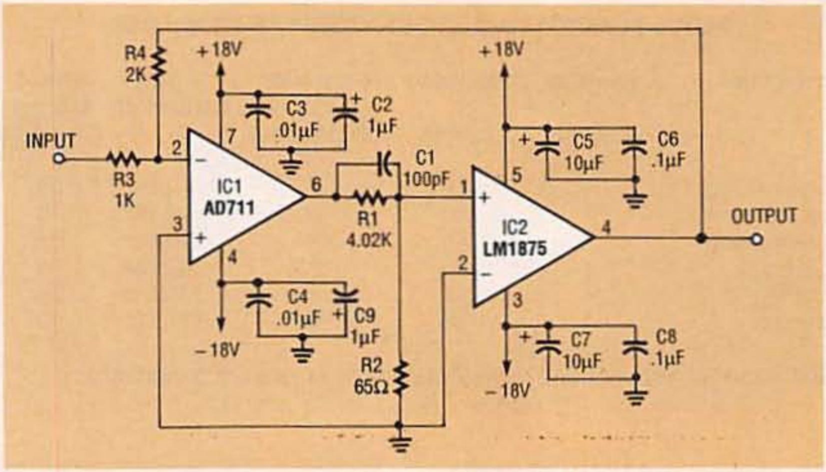


FIG. 4—A 10-WATT INVERTING COMPOSITE AMPLIFIER.

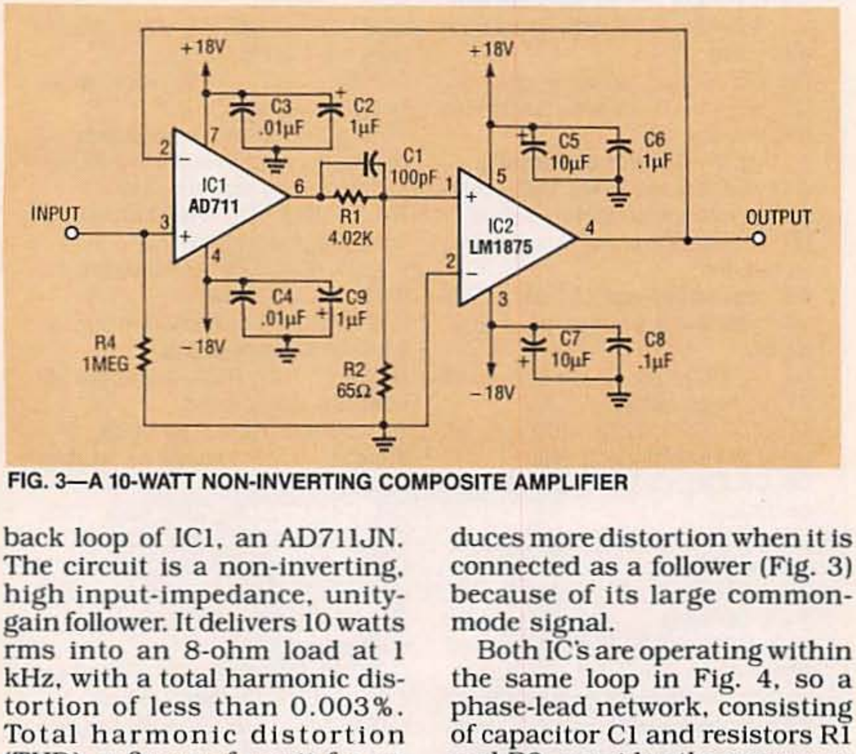


FIG. 3—A 10-WATT NON-INVERTING COMPOSITE AMPLIFIER

back loop of IC1, an AD711JN. The circuit is a non-inverting, high input-impedance, unity-gain follower. It delivers 10 watts rms into an 8-ohm load at 1 kHz, with a total harmonic distortion of less than 0.003%. Total harmonic distortion (THD), a figure of merit for an amplifier, is the total root-mean-square (rms) harmonic voltage in a signal, as a percentage of the voltage at the fundamental frequency. THD should be as low as possible. The maximim offset voltage of this amplifier is 1 millivolt.

The basic composite circuit can also be configured as a low input-impedance inverting amplifier as shown in Fig. 4. That circuit causes approximately 10 dB less distortion than the non-inverting configuration of Fig. 3 because the non-inverting pin of IC1, the AD711JN, is grounded. The AD711JN produces more distortion when it is connected as a follower (Fig. 3) because of its large common-mode signal.

Both IC's are operating within the same loop in Fig. 4, so a phase-lead network, consisting of capacitor C1 and resistors R1 and R2, provides the necessary compensation to stabilize the response of both the AD711JN and the LM1875. This network can be tailored for specific applications by providing a trade-off between bandwidth and phase margin as listed in Table 1.

The THD values given for these circuits include both distortion and noise. At low frequencies, noise is the predominant error source; at higher frequencies, distortion will increase because of the finite open-loop gain of the amplifiers. Even with this frequency-related increase, THD remains extremely low over the entire audio range.

When functioning independently, the THD of the LM1875 power amplifier vs. power output peaks at about 0.5 watt. It produces about 0.05% THD into an 8-ohm load and 0.1% THD into a 4-ohm load at this power level. That variation in THD vs. power level is characteristic of thermal feedback on the IC chip. It is also one of the benefits of thermally isolating an external amplifier within a feedback loop.

FET-input op-amps with low first-stage transconductance (such as the AD711JN) tolerate a larger voltage swing on their inputs than bipolar op-amps without producing the characteristic bipolar op-amp overload distortion. When open-loop gain decreases, producing a larger error on the summing junction, a FET-input op-amp behaves more linearly than a bipolar op-amp, making it the optimum choice as the control amplifier in composite circuits.

Step response is an important consideration in many audio- amplifier applications. The composite amplifiers described here take advantage of the performance features of the AD711JN. For example, the AD711JN has twice the slew rate of the LM1875; if the AD711JN

TABLE 1—PERFORMANCE VS. COMPONENT VALUES

Connection	Resistor 1 (Kilohms)	Resistor 1 (Ohms)	Capacitor 1 (Picofarads)	−3dB Bandwidth	Phase Margin (Degrees)
Non-inverting	4	200	30	1.77MHz	35
Non-inverting	4	100	68	1.58MHz	70
Non-inverting	4	65	100	1.34MHz	85*
Inverting	4	400	30	1.8MHz	25
Inverting	4	200	68	1.6MHz	25
Inverting	4	80	100	890kHz	90*

*Best transient response and highest stability at expense of bandwidth

were slower, the LM1875 could overshoot significantly before it is corrected by the AD711JN. On the other hand, if the AD711JN were much faster than the LM1875, the driver would slew to the supply rail before the buffer could respond.

Higher power composites

The composite circuit concept can be expanded by connecting two or more of them together. High-power amplifiers normally include discrete transistors with high breakdown voltages (typically over 100 volts) and high current-handling ability. Small IC power amplifiers have breakdown voltages in the 30- to 50-volt range. Maximum power delivered to the load is directly related to the supply voltage.

A bridge configuration applies power to the load differentially. Therefore, it can provide twice as much driving voltage to the load as a parallel or current-summing configuration. This permits higher power output from a given supply voltage (assuming that the increased current demand can be met). Also, the slew rate delivered to the load is greater than the slew rate of either of the two IC driving amplifiers.

33-watt composite bridge

The circuit shown in Fig. 5 combines two non-inverting composite amplifiers, A and B, in a bridge or differential output connection. It operates with an overall gain of 30 and it provides 33 watts rms to an 8-ohm load with less than 0.002% THD at 1 kHz. Amplifier C is a DC servo amplifier.

Amplifier D inverts the input signal 180° so that the output of amplifier B is non-inverting with respect to the circuit's input. The low input-impedance of a high-gain inverting composite amplifier makes it difficult to drive. To overcome this, two non-inverting composite amplifiers have been configured as a bridge amplifier, and one of them is driven with a single op-amp inverter.

PARTS LIST

Figs. 3 and 4—10-watt composite amplifiers

All capacitors are 5%, 50 volts, silvered-mica except as stated below.

C3, C4—0.01 µF, 50 volts, ceramic
C5, C7—10 µF, 35 volts, aluminum electrolytic
C6, C8—0.1 µF, 50 volts, ceramic
C2, C9—1 µF, 35 volts aluminum electrolytic

Fig. 5—33-watt composite

All resistors are ¼-watt, 5%, metal-film except as stated below.

R7, R15—1,500 ohms, 5-watt, 20%, wirewound

All capacitors are 50 volts, 5%, silvered-mica except as stated below

C2, C3, C10, C11, C14 to C17—0.01 µF, 50 volts, ceramic
C5, C7, C20, C22—100 µF, 35 volts, aluminum electrolytic
C6, C8, C21, C23—0.1 µF, 50 volts, ceramic
C25–C32—1 µF, 35 volts, aluminum electrolytic
C9, C13—0.47 µF, 20 %, 50 volts, polypropylene
C12, C24—0.27 µF, 20 %, 50-volt mylar

Fig. 7—40-watt composite

All resistors are ¼-watt, 5 %, metal-film except as stated below

R6, R8—1000 ohms, ¼-watt, 1 %, metal film
R7, R16—2000 ohms, ¼-watt, 1%, metal film
R11, R17—1 ohm, 5-watt, 20%, wirewound
R12, R18—0.33 ohm, 5-watt, 5%, wirewound

All capacitors are 50 volts, 5%, silvered-mica except as stated below

C2, C3, C7, C8, C15, C16—0.01 µF, 50 volts, ceramic
C10, C12, C18, C20—100 µF, 35 volts , aluminum electrolytic
C11, C13, C19, C21—0.1 µF, 50 volts , ceramic
C23–C28—1 µF, 35 volts, aluminum electrolytic
C4, C5—0.47 µF, 50 volts, 20%, polypropylene

Fig. 8—70 watt-composite

All resistors are ¼-watt, 5%, metal-film except as stated below

R4, R8, R23, R27—1000 ohms, ¼-watt, 1%, metal film
R5, R9, R24, R28—2000 ohms, ¼-watt, 1%, metal film
R12, R16, R31, R35—1-ohm, 5-watt, 20%, wirewound
R13, R17, R32, R36—0.33 ohm, 4-watt, 5% wirewound

All capacitors are 50 volts, 5%, silvered-mica except as stated below

C3, C4, C7, C8, C14, C15, C22, C23, C26, C27, C30, C31, C37, C38,—0.01 µF, 50 volts, ceramic
C10, C12, C18, C20, C33, C35, C40, C42—100 µF, 35 volts, aluminum electrolytic
C11, C13, C18, C20, C34, C36, C41, C43—0.1 µF, 50 volts ceramic
C46–C57—1 µF, 35 volts, aluminum electrolytic
C2, C5, C25, and C28—0.47 µF, 50 volts, 20%, polypropylene

All semiconductors are Analog Devices AD711JN and National Semiconductor LM1875

Note: AD711JN's are available in single quantities from Active Electronics, Woburn, MA 01801, and LM1875's are available from several *Electronics Now* advertisers.

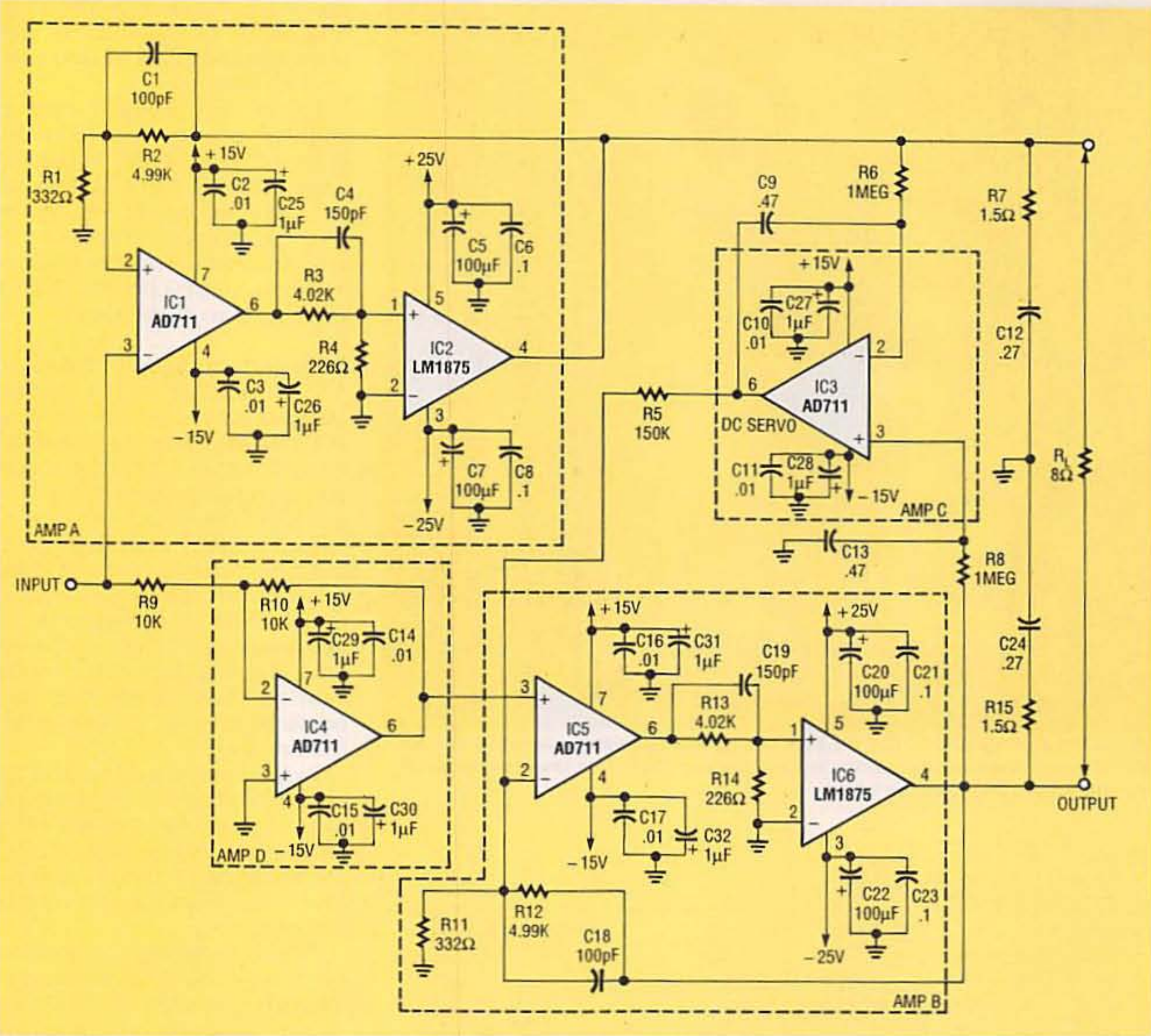


FIG. 5—A 33-WATT BRIDGE COMPOSITE AMPLIFIER.

Figure 6 shows the authors' prototype for the 33-watt bridge amplifier. The four AD711JN's are shown mounted in the middle of the circuit board (white patches), and the two LM1875's are shown mounted on the heatsink (black surface).

The DC servo amplifier

The compound composite amplifiers of Figures 5, 7, and 8, all include DC servo amplifiers that share a common function although some of their internal components vary. The DC servo in Fig. 5 (Amplifier C) will sense any net *difference* in DC voltage appearing across the load—and therefore any DC current through the load. The amplifier will servo any net difference in DC output voltage through amplifier B, thus minimizing wasted power. The output of each composite passes through a low-pass filter that removes AC signals from the servo loop.

If the output of amplifier A were *more* positive than the output of amplifier B, the output of servo amplifier C would become *less* positive. Its output would then drive amplifier B, which inverts the polarity again. This inversion makes amplifier B's output increasingly *more* positive until the two DC output voltages are equal.

The single servo amplifier in the Fig. 5 circuit forces the DC offsets of the other amplifiers into equality, but does not remove them. Any DC voltage applied to the circuit's input will still appear at both LM1875 outputs, amplified by the circuit gain. Therefore, the maximum voltage swing or "headroom" available will be reduced, and if appreciable, maximum output power will be reduced. If DC voltage is present on the input source, capacitive input coupling is necessary.

A 40-watt composite amplifier

The circuit in Fig. 7 combines the outputs of two non-inverting composite amplifiers. Output current is summed with resistors, and the output is referenced to ground. The output from the first composite, amplifier B, is coupled to the non-inverting input of amplifier A. No

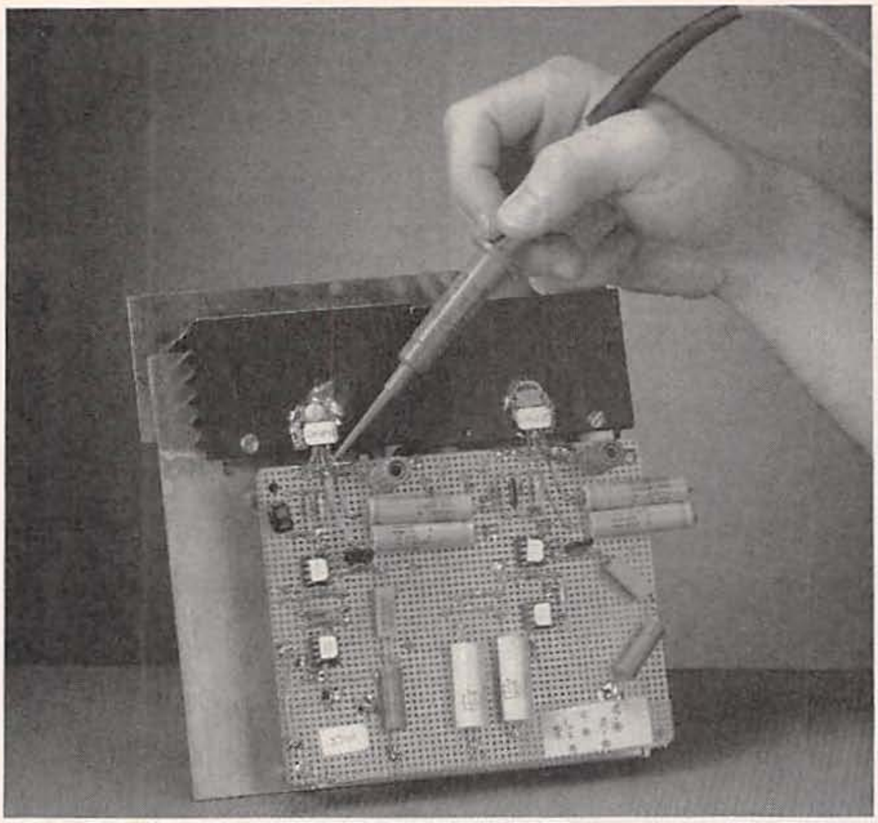


FIG. 6—THE AUTHORS' PROTOTYPE FOR THE 33-WATT composite amplifier. The two LM1875's are on the black heat sink at top, and the four AD711's are the white patches in a square pattern on the circuit board.

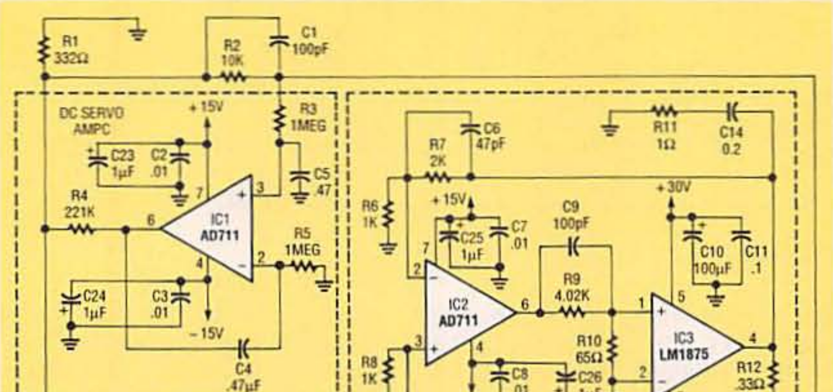


FIG. 7—A 40-WATT COMPOSITE AMPLIFIER that includes a single-ended summing connection.

phase inversion is needed because the two outputs are simply added together. Amplifier C is a DC servo that differs from its counterpart in Fig. 5 because its input is referenced to ground. It connects to the inverting input of amplifier B, and nulls any DC offset at that composite's output.

The circuit of Fig. 7 delivers slightly more power than the bridge circuit of Fig. 5, but the bridge circuit has a faster slew rate. The circuit of Fig. 7 also has its output referenced to ground. It delivers 40 watts rms with less than 0.0029% THD at 1kHz into an 8-ohm load.

A 70-watt composite amplifier

The circuit of Fig. 8 delivers 70 watts rms into an 8-ohm load at 1 kHz with only 0.003% THD. It combines two of the current-summing amplifiers of Fig. 7 in a bridge. The current-summing amplifiers give the necessary high output-current handling capability. A differential output is obtained by connecting the two pairs of current-summing amplifiers in the bridge configuration that allows the composite to drive ± 34 volts into a 8-ohm load.

Two DC servos keep the DC output voltage at both output pins at zero. As with the other circuits described here, any offset would cause the amplifier to lose "headroom" or clip unsymmetrically.

Figure 9 shows the authors' prototype 70-watt composite amplifier. Four AD711's are shown as white blocks on the circuit board (lower left), and three more are shown on the circuit board at lower right. The four LM1875's are shown in a horizontal row on the heat sink (gray area) above the circuit boards.

Figure 10 is a graph showing THD (including noise) vs. power output plotted from the authors' breadboard versions of the circuits described in this article. For comparison purposes the plot of THD vs. power output for the LM1875 as a stand-alone device has been taken from the National Semiconductor data.

Building the amplifiers

These circuits can be built with dual or quad versions of the AD711 if you want to save board space. The AD711JN met all of the op-amp requirements,

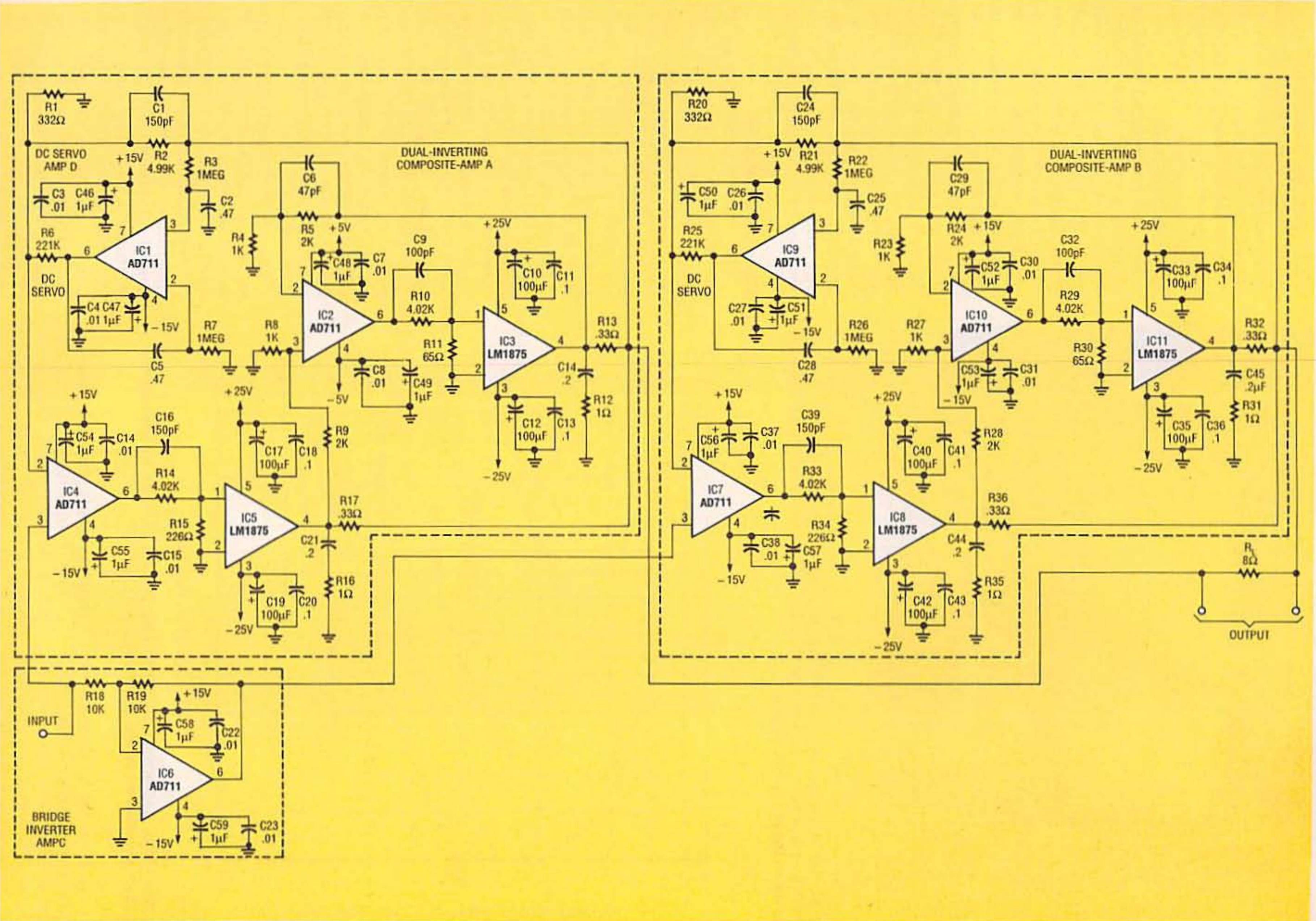


FIG. 8— A 70-WATT COMPOSITE AMPLIFIER

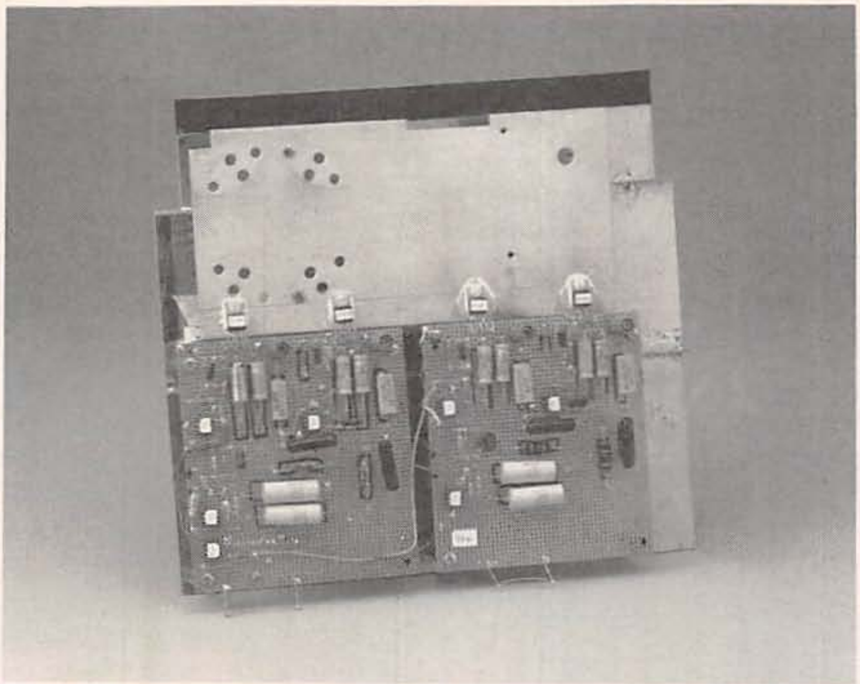


FIG. 9—THE AUTHORS' PROTOTYPE FOR A 70-WATT composite amplifier. The four LM1875's are in a row on the heat sink at the top, and the seven AD711's are the white patches on the two circuit boards.

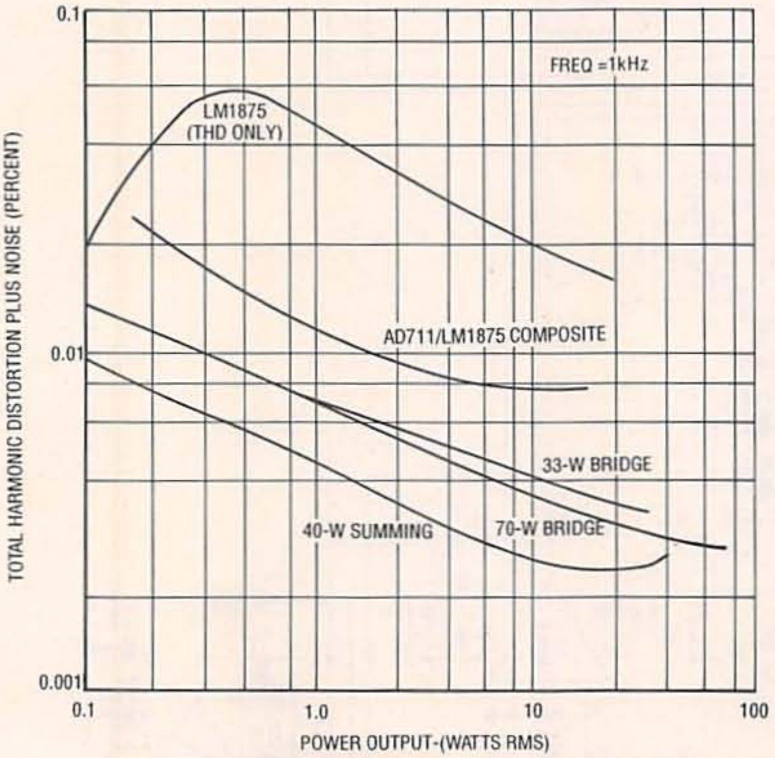


FIG. 10—TOTAL HARMONIC DISTORTION vs. POWER OUTPUT for the composite amplifiers discribed in the text and a stand-alone LM1875.

but additional components might be needed for circuit stability if other op-amps are substituted. The Parts List specifies the components selected for optimum circuit performance.

The composites have amplifiers within their feedback loops, so the differing frequency response poles of each amplifier could interact, causing circuit instability. Therefore, proper grounding and component layout are important. Build all circuits on a ground plane. Inadequate circuit grounding and layout can increase THD by an order of magnitude.

Keep all component leads as short as possible, and connect signal grounds to the ground plane. The plane and the power grounds are tied to the common connection of the power supply's filter capacitors.

Power supply bypassing is important in these circuits. Locate the by-pass capacitors as close as possible to the IC's when building the circuits. Separate all high-current carrying wires or other conductors from low-current or high-impedance conductors. Keep input and output leads as far apart as board space will allow.

The power supplies

The circuits must operate at the specified voltages to reach the power levels stated here. Those are typically ±25-volts DC for the LM1875 power amplifiers and ±15-volts DC for the AD711JN's. The highest power output is reached when the LM1875's are powered from ±30-volt-DC (their maximun safe rating), and the AD711JN's are powered by ±15 volt-DC.

Mount all LM1875's on heatsinks, but use an oversize heatsink when operating any LM1875 at ±30 volts, its maximum limit. The LM1875 dissipates 2 watts with an idle current of 70 milliamperes at ±15 volts. However, dissipation rises to 6 watts with an idle current of 100 milliamperes at ±30-volts.

The LM1875's limit the power supply voltage excursion of minus about 2.5 volts on top and bottom. For a ±18-volt supply the limit is about 15 watts rms into an 8-ohm load, and for a ±15-volt supply it is about 10 watts rms. Estimate your voltage requirements to obtain the power needed for any specific application. Remember that low supply voltages mean cooler running circuits and higher circuit reliability. R-E

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WE ALL KNOW THE STORY: WE'RE ON the phone in one room and need to be in another. So we lay down the first phone, go to the other phone and pick it up, go back to the first room and hang up that phone, and then go back to the second phone—the one we needed to be on in the first place. Or maybe we don't go back and hang up the first phone, so that when we finish our conversation we forget that it's off-hook—and then wonder why we didn't get the important long-distance call that we were expecting.

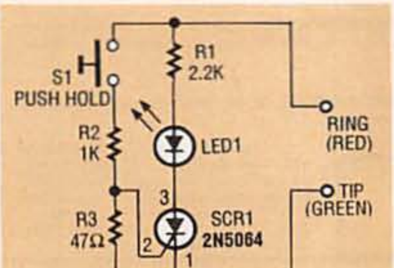


FIG. 1—HOLD-MODULE SCHEMATIC. When S1 is pressed, the SCR fires and places LED1 and R1 across the phone line. The line voltage drops to about 20 volts, which holds the connection to the phone company's central office.

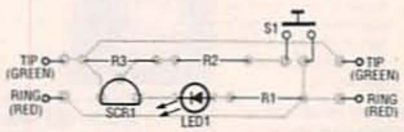
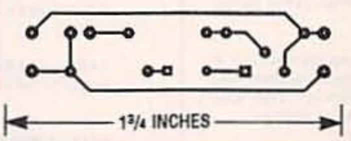


FIG. 2—PARTS-PLACEMENT DIAGRAM. You can make a PC board from the foil pattern we've provided and mount the parts as shown here, or use perforated construction board with point-to-point wiring.



FULL-SIZE hold-button foil pattern.

PARTS LIST

- R1—2200 ohms ¼-watt, 5%
- R2—1000 ohms, ¼-watt, 5%
- R3—47 ohms, ¼-watt, 5%
- LED1—light-emitting diode, any color
- SCR1—2N5064, TIC47, MCR104 or equivalent silicon-controlled rectifier
- S1—Normally-open pushbutton switch
- PC board or perforated construction board, enclosure, wire, solder, etc.

If the above scenario is more real than you'd like to admit, we have a design for a simple and cheap little automatic hold module. It's so cheap (about $2.00) that you can make one for each of your phones.

How it works

As you can see from the schematic in Fig. 1, the hold module connects across the phone line. When all phones are on-hook, there is about 36 to 48 volts DC across the module. When S1 is pressed, the SCR fires and places LED1 and R1 across the phone line, which causes the voltage to drop to about 20 volts. Enough current flows to keep the SCR conducting when S1 is released. It's also enough current to keep the connection in the phone company's central office, so the phone is on hold. When any phone is picked up, the load of that phone causes the line voltage to drop to about 6 volts. At that point there is not enough current through the SCR to keep it conducting, so it turns off. When the phone is placed back on hook the line is released. Indicator LED1 glows when the hold is engaged. The gate of SCR1 is kept from floating and turning on when S1 is open by R3, and R2 limits the turn-on current through the SCR's gate.

The SCR (a 2N5064 or equivalent) has a 200-volt forward and reverse blocking voltage. The maximum ring voltage on the phone line is 140 volts. The 2N5064's minimum hold current is 5.0 mA at 25 degrees C.

Assembly

We have included a PC-board foil pattern for the hold module although it is simple enough to build on perforated construction board with point-to-point wiring. Figure 2 is the parts-placement diagram for the board. Select a small case for the project, or mount it inside your telephone. The prototype was installed in a telephone outlet box with a built-in modular jack, and a modular plug was added. That allows the hold module to be in-

continued on page 74

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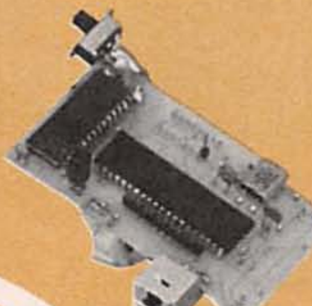
To us, "Not commercially available" means "Let's build our own!" This article describes a multifunction infrared (IR) remote control system—a transmitter and receiver—that you can build in one evening. The system is designed to control four different types of devices: switches, servo motors, a stepper-motor robot (see **Radio-Electronics**, April 1991), and a dual digital potentiometer IC. Only one kind of device can be controlled at a time, but enough technical information is included in this article for you to adapt the remote-control system to almost any application.

IR transmitter theory

The IR transmitter is based on IC1, an INS8048L microprocessor that attains high-speed operation with very low power consumption. That microprocessor is responsible for driving and reading the 16-key keypad and generating the 40-kHz modulated infrared drive signal. Let's take an in-depth look at how those two tasks are accomplished.

A schematic depiction of the 16-key keypad is shown in Fig. 1. If you're interested in the "down and dirty" program details, a fully documented machine language listing (IRXMIT.ASM) is available as part of a self-unarchiving ZIP file called IRSYSTEM. EXE on the RE-BBS (516-293-2283, 1200/2400, 8N1). The keypad used in this project was from All Electronics Corp., PO Box 567, Van Nuys, CA 91408 (800) 826-5432, (part No. KP-16). Any functionally equivalent keypad can also be used. Each key contact surface inside the keypad is an intersection of a particular row and column. As you can see from Fig. 1, the 0 key is an intersection of row 1 and column 1, and the 9 key is an intersection of row 4 and column 3. Although the layout of the keys in Fig. 1 doesn't match the actual



layout of the keys on the keypad, Fig. 1 is electrically correct. Also, while the 5×5 grid allows up to 25 keys, the actual keypad has only 16 keys.

Rows 1 through 5 are normally held at a TTL high level. To determine which key has been pressed, IC1 successively applies TTL logic lows to each row from 1 to 5, and then reads the output of the columns. When a key is pressed, its row and column are shorted together, and the low applied to the row is transferred to the column (which is normally held high). As an example, if row 1 is being scanned and the 0 key is depressed, a low will be read by IC1 at column 1. That low will be decoded as a "0." A succession of "0" characters will be sent as long as you hold the 0 key depressed. Table 1 shows how the pins on the back of the keypad connect to the pins on the microprocessor and the corresponding microprocessor ports.

Infrared transmitter

The enemies of the infrared signals that emanate from the transmitter are incandescent light, fluorescent light, and sunlight. Large amounts of

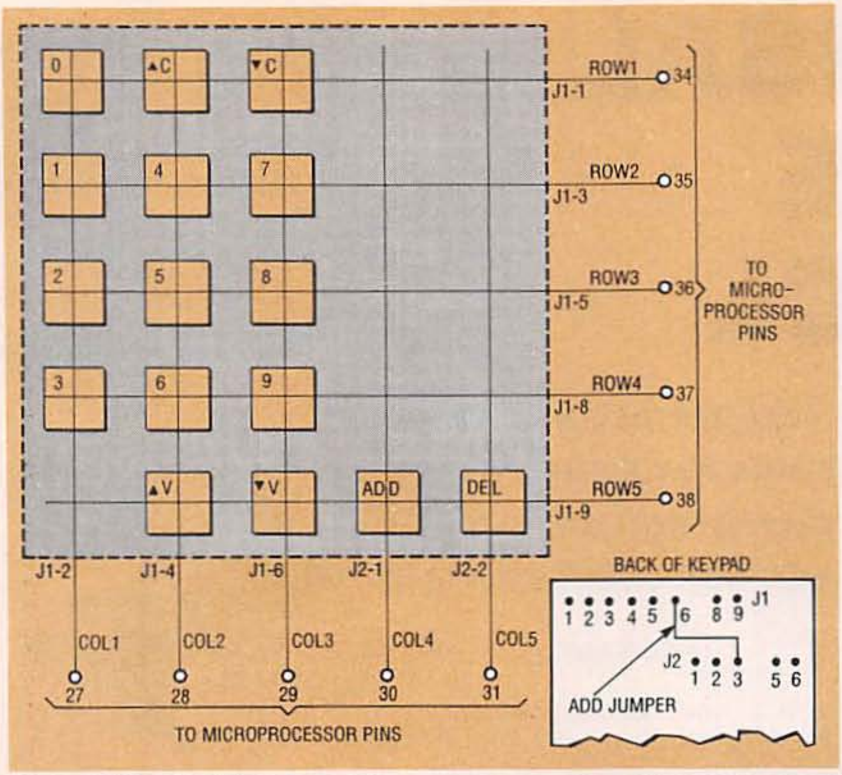


FIG. 1—KEYPAD SCHEMATIC. Each key contact surface is an intersection of a particular row and column. The physical layout of the keypad does not match the electrical layout.

TABLE 1
KEYPAD CONNECTIONS

Keypad (see Fig. 1)	Microprocessor Pin	Port
J1-1	34	P17
J1-2	27	P10
J1-3	35	P24
J1-4	28	P11
J1-5	36	P25
J1-6	29	P12
J1-8	37	P26
J2-1	30	P13
J2-2	31	P14
Also jumper J1-6 to J2-3 on back of keypad		

modulated, noisy infrared energy are produced by those light sources. Most of the interference is modulated in the 50- or 60-Hz range. A simple red plastic filter will screen out some of the noise, but to overcome the extraneous infrared interference, the transmitted infrared signal must be modulated at a high carrier frequency. In our system, the carrier frequency is 40 kHz—which is required by the GP1U52X receiver module used.

The IR transmitter schematic is shown in Fig. 2. The 40-kHz carrier originates at pin 11 of IC1 (ADDRESS LATCH ENABLE, or ALE) which provides a square wave that is exactly one fifteenth of IC1's oscillator frequency. In our system, that is 6 MHz divided by 15, or 400 kHz. The 400-kHz signal is applied to the CLK input of IC3, a 4017 CMOS decade counter which is configured to divide by 10 to obtain the desired 40-kHz carrier.

The resultant 40-kHz signal at pin 12 of IC3 is gated by the output port P15 (pin 32) of the microprocessor and fed to pin 3 of inverter/driver IC4, a 4049 CMOS inverting buffer. That buffer serves two purposes: First, it inverts the idle state of IC3 so that MOSFET Q1 is turned off when no characters are being transmitted. Second, it provides sufficient drive to the gate of Q1 so that maximum infrared energy is emitted by the infrared LED's.

As stated before, the 40 kHz carrier signal at pin 2 of IC4 drives Q1's gate which turns Q1 on and illuminates two IR LED's (LED1 and LED2) producing a 40-kHz modulated IR signal. A logical "1" is a 1-millisecond pulse of IR light and a logical "0" is a 0.5-millisecond pulse. Each bit is separated by at least 0.5 millisecond to allow the IR detector to synchronize. Figure 3 depicts how a transmitted character "9" would look on an oscilloscope. The transmitted "1's" and "0's" are comvined in groups of eight to form 16 distinct characters as shown in Table 2. To avoid sequence errors and to allow the receiver to synchronize between transmissions, a 50-millisecond idle period is placed between transmission of each character.

Infrared receiver

The receiver, whose schematic is shown in Fig. 4, is based on the Sharp GP1U52X IR module, and the INS8048L microprocessor. The IR receiver detects and decodes the IR signal from the transmitter. Once again, if you want the raw details, consult the machine code listings IRSWITCH.ASM, IRSERVO.ASM, IRRECROB.ASM and IRPOT.ASM, which are part of the ZIP file called IRSYSTEM.EXE on the RE-BBS.

The GP1U52X IR Receiver/Demodulator is a hybrid IC/infrared detector. A PIN (positive-intrinsic-negative) photodiode feeds an amplifier and limiter that provides a strong, clean signal which is filtered to remove all frequencies outside the 40-kHz passband. The resultant signal is demodulated to provide a waveform minus the

TABLE 2
KEYPAD CHARACTERS

Key	Row	Col	Binary
0	ROW1	COL1	00001111
UP C	ROW1	COL2	10100101
DW C	ROW1	COL3	10110100
1	ROW2	COL1	00011110
4	ROW2	COL2	01001011
7	ROW2	COL3	01111000
2	ROW3	COL1	00101101
5	ROW3	COL2	01011010
8	ROW3	COL3	10000111
3	ROW4	COL1	00111100
6	ROW4	COL2	01101001
9	ROW4	COL3	10010110
UP V	ROW5	COL2	11000011
DW V	ROW5	COL3	11010010
ADD	ROW5	COL4	11100001
DEL	ROW5	COL5	11110000

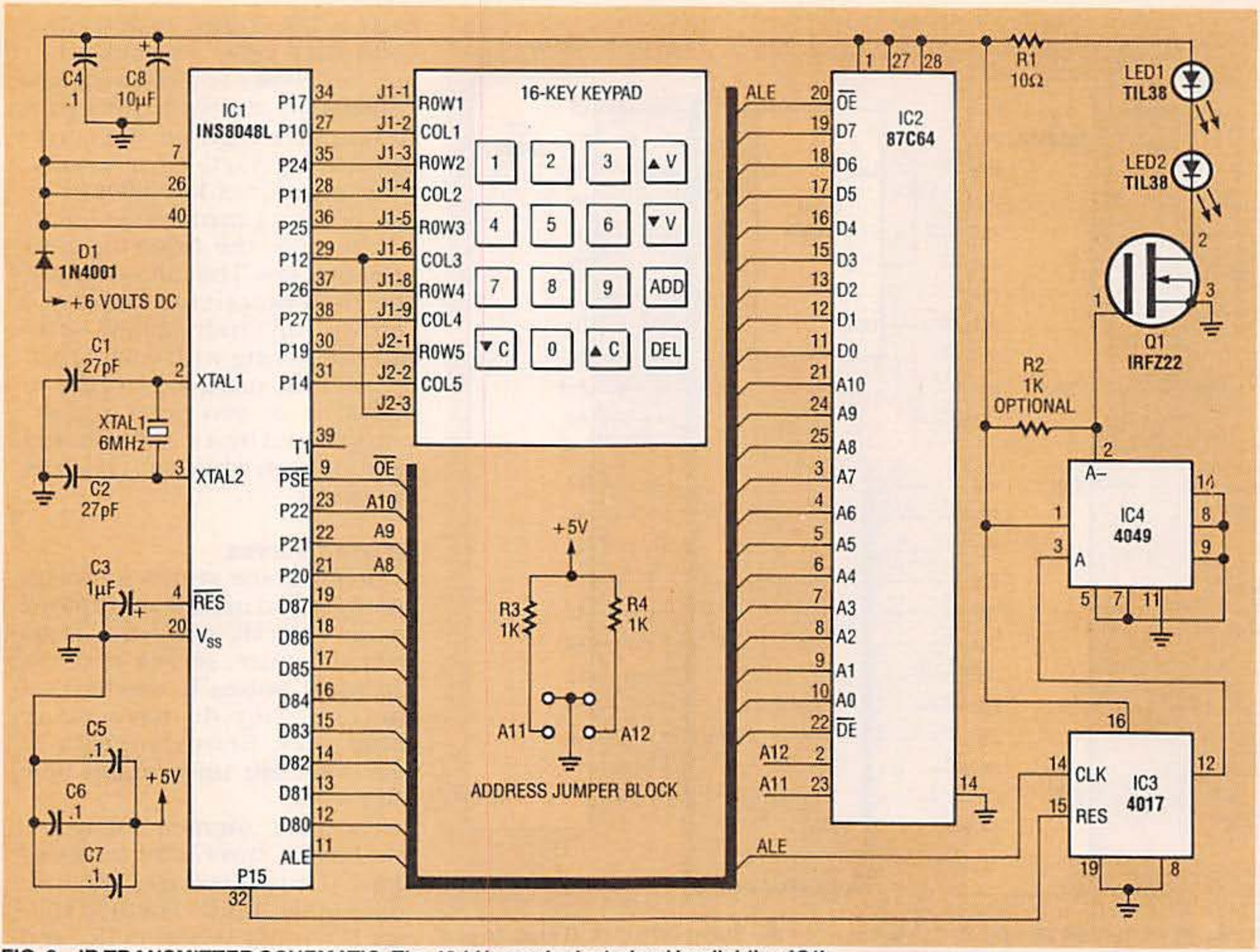


FIG. 2—IR TRANSMITTER SCHEMATIC. The 40-kHz carrier is derived by dividing IC1's oscillator frequency (6 MHz) by 15, to get 400 kHz, which is divided by 10 by IC3.

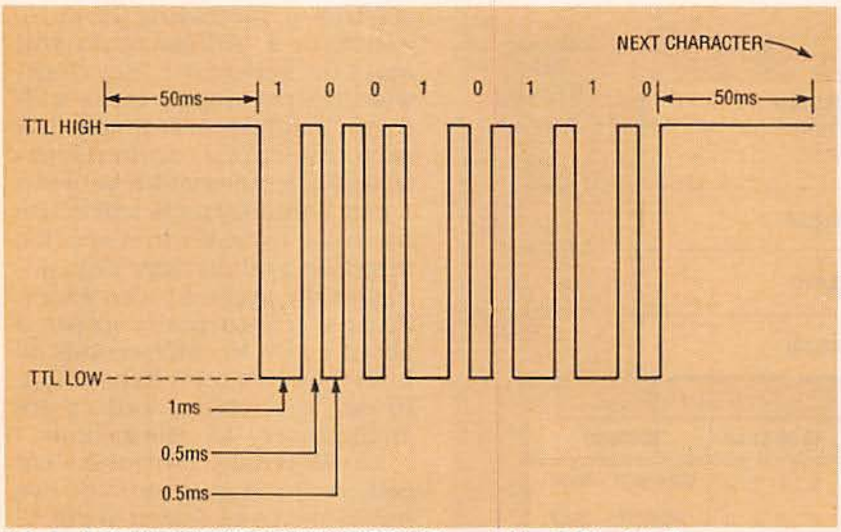


FIG. 3—A TRANSMITTED CHARACTER "9" would look like this if seen on an oscilloscope. The transmitted "1's" and "0's" are put together in groups of eight to form 16 distinct characters as shown in Table 2.

carrier.

The demodulated signal is presented to IC1 via the event counter input (T1, pin 39). At this time the program residing in IC2 (an 87C64 EPROM) takes over. The idle state of the GP1U52X is normally high. As soon as the output pin of the IR detector transitions low, IC1 starts an internal timer to measure the incoming pulse width. Depending upon whether the pulse width is 0.5 or 1 millisecond, a binary 0 or 1, respectively, is stored in a holding register. Once 8 bits are received, IC1 attempts to match the 8-bit word with a term in its internal table to determine which character has been received. How the received character is used depends upon which one of the four functions is selected.

Transistors, buffers, & relays

See Fig. 5 for program-selection information. IRSWITCH.ASM, the first of four programs contained in the EPROM, is selected by jumpering both address jumpers (A11 and A12).

Basically, keys 1–8 on the keypad select ports P10–P17 (pins 27–34) of IC1 respectively. The TTL logic levels at P10–P17 can turn on a switching transistor,

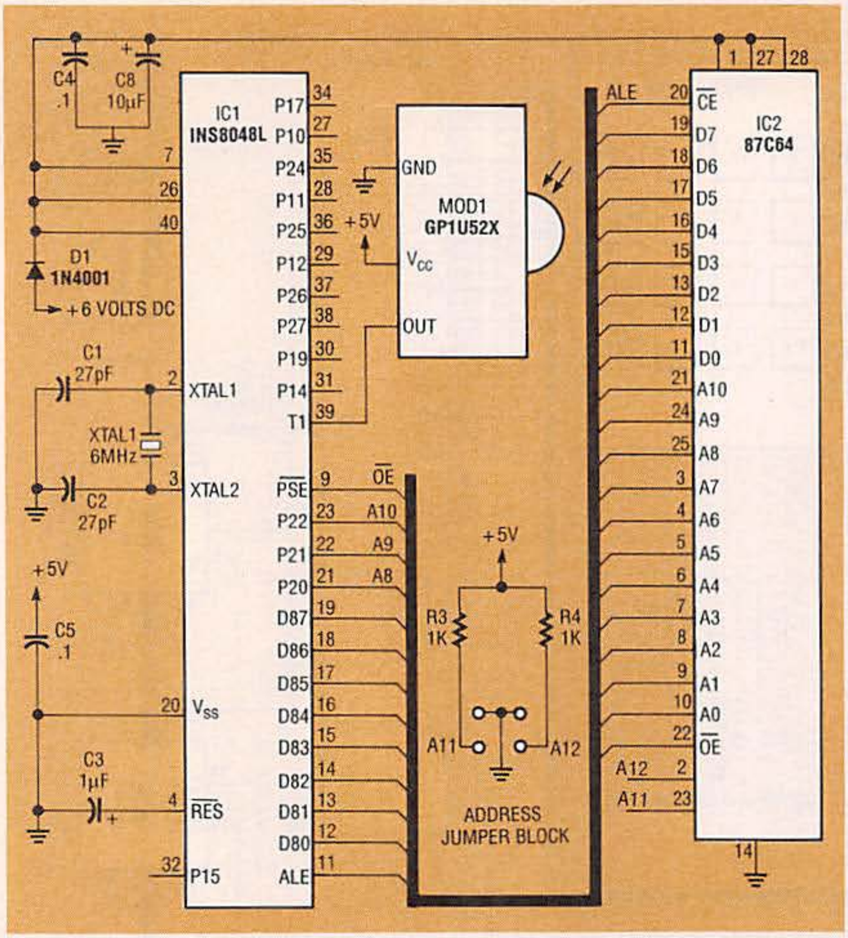
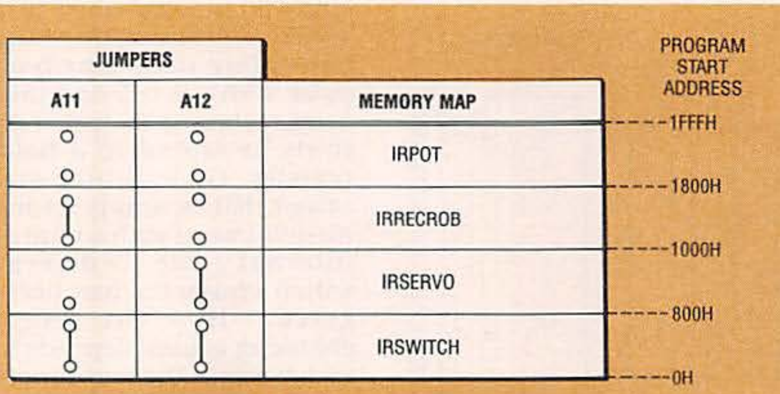


FIG. 4—IR RECEIVER SCHEMATIC. It is based on the Sharp GP1U52X IR module and INS8048L microprocessor. The GP1U52X is a hybrid IC/infrared detector that provides a strong clean signal for later filtering and demodulation.



A12 A11	A10 A9 A8	A7 A6 A5 A4	A3 A2 A1 A0	ADDRESS
J J	0 0 0	0 0 0 0	0 0 0 0	IRSWITCH = 0000H
J 1	0 0 0	0 0 0 0	0 0 0 0	IRSERVO = 0800H
1 J	0 0 0	0 0 0 0	0 0 0 0	IRRECROB = 1000H
1 1	0 0 0	0 0 0 0	0 0 0 0	IRPOT = 1800H

JUMPER ON=0 OR J
JUMPER OFF=1

FIG. 5—PROGRAM-SELECTION INFORMATION. Four different programs (IRSWITCH.ASM, IRSERVO.ASM, IRRECROB.ASM, and IRPOT.ASM) are stored in the receiver's EPROM. The programs are selected via jumpers A11 and A12.

drive a TTL buffer, or activate a solid-state relay. Pressing the ADD key allows any following key depression of keys 1 through 8 to output a high on the corresponding port. Conversely, pressing the DEL key followed by any of keys 1 through 8 signals IC1 to take the following port selection low. That allows any of the eight outputs to be turned "on" or "off" individually without interfering with each other. To see this, use a logic probe to check P10 as you press ADD or DEL followed by a 1. ADD 1 should take P10 high while DEL 1 returns P10 to low.

Driving servos

Hobby-grade servos are commonly found in radio-controlled model aircraft and cars. However, because servos convert electrical pulses to mechanical motion, they do have many other uses. Servos are easy to use once you understand how they work.

The most common hobby servos have a three-wire termination: positive voltage, ground, and signal input. Positive voltage is usually +5-volts DC and the signal is a TTL-compatible variable-width pulse. A 1.5-millisecond pulse will center the servo rotor. Increasing the pulse width to 2 milliseconds will move the servo rotor fully clockwise. Decreasing the pulse width to 1 millisecond moves the servo rotor fully counterclockwise. So, a pulse width between 1 and 2 milliseconds will cause the rotor to travel in a specific direction and distance depending on the applied pulse width. Pulses are normally applied about every 16 milliseconds to hold the servo rotor in position. In our application, pulses are applied every 45 milliseconds.

The IR remote control system can control a maximum of two hobby servos as shown in Fig. 6. The program IRSERVO.ASM, which is selected by jumpering only A12, is used to drive them. The servos are operated by pressing the UP V and DOWN V keys for counterclockwise and clockwise rotation, respectively. The 0 key will center the selected servo rotor. Selection of servos 1 and 2 is performed by pressing 1 for servo 1 and 2 for servo 2. The drive signal for servo 1 originates at pin 27 of IC1 (P10) and the drive signal for servo 2 originates at pin 28 (P11). When servo 1 is active, a high is present at pin 35 of IC1 (P24), and when servo 2 is active, a high is present at pin 38 (P27). You can use those outputs to drive LED indicators with a PN2222 transistor, as shown in Fig. 6.

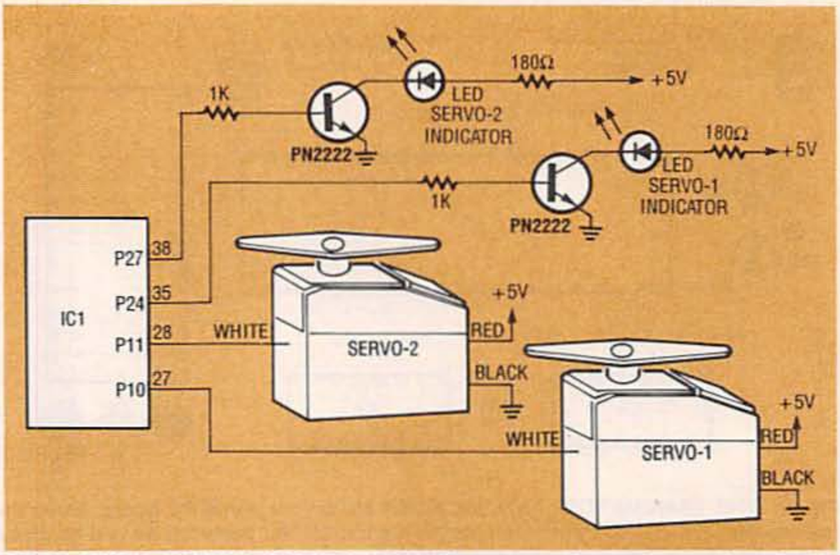


FIG. 6—THE IR REMOTE CONTROL SYSTEM can control a maximum of two hobby-grade servos. The LED's indicate which servo is active.

Robot remote control

Do you remember Ken the robot from the April 1991 issue of **Radio-Electronics**? He had a mind of his own, but the IR remote-control system will let you teach him some manners. The IR system gives you override control of Ken's motions. You will need to change or reprogram the original 8748H microcontroller with the new version of the machine language, IRROBOT.ASM, which is included in the ZIP file IRSYSTEM.EXE on the RE-BBS. (A new, preprogrammed 8748H containing IRROBOT.ASM is available from the source given in the Parts List.)

The IR receiver unit, which must be mounted directly on the robot, decodes the UP V key as forward, DOWN V as reverse, UP C as left, and DOWN C as right. The 0 key stops Ken in his tracks. If you want Ken to roam as he originally did, the DEL key puts him in his roving mode. All of the key combinations and codes used to manipulate Ken, as well as details on how it's done, can be found in the header section and main body of the program IRRECROB.ASM (included in IRSYSTEM.EXE). That program is set by jumpering only A11. Figure 7 details the connections between the IR receiver unit and the robot.

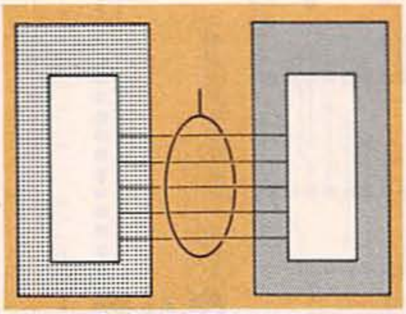


FIG. 7—THE IR RECEIVER can be mounted on Ken the robot (see Radio-Electronics, April 1991) to give you full control over him.

Remote potentiometer

Program four, IRPOT.ASM, remotely controls a digital potentiometer. The DS1267 dual solid-state potentiometer (made by Dallas Semiconductor) is composed of 256 resistive sections. Tap points are provided between each resistive section, and each tap point is accessed

PARTS LIST—TRANSMITTER

All resistors are ¼-watt, 5%.

R1—10 ohms
R2–R4—1000 ohms

Capacitors

C1, C2—27 pF, ceramic disk
C3—1 µF, 35 volts, tantalum
C4–C7—0.1 µF, Mylar
C8—10 µF, 10 volts, electrolytic

Semiconductors

IC1—INS8048L microprocessor (National)
IC2—87C64 EPROM with transmitter program installed
IC3—MC14017 CMOS decade counter
IC4—MC14049 CMOS inverting buffer
D1—1N4001 diode
Q1—IRFZ22 MOSFET
LED1, LED2—TIL38 infrared light-emitting diode

Other components

XTAL1—6-MHz crystal

Miscellaneous: On/off switch, 16-key keypad (All Electronics part number KP-16 or equivalent), PC board, plastic case, 6-volt battery, ribbon cable, wire, solder, etc.

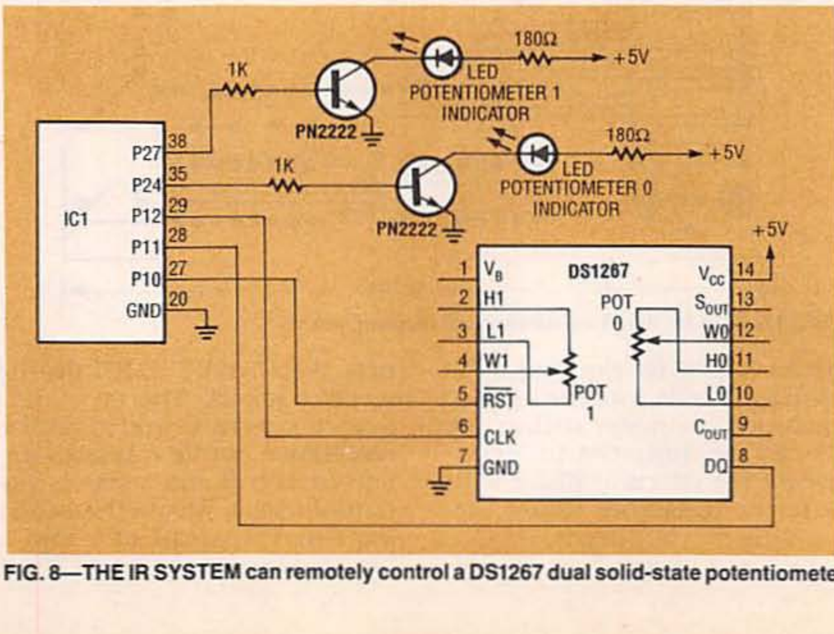


FIG. 8—THE IR SYSTEM can remotely control a DS1267 dual solid-state potentiometer.

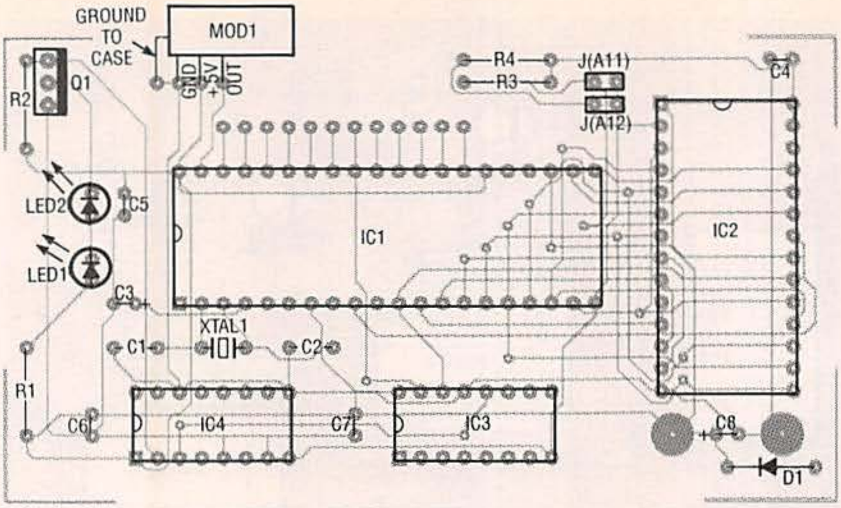
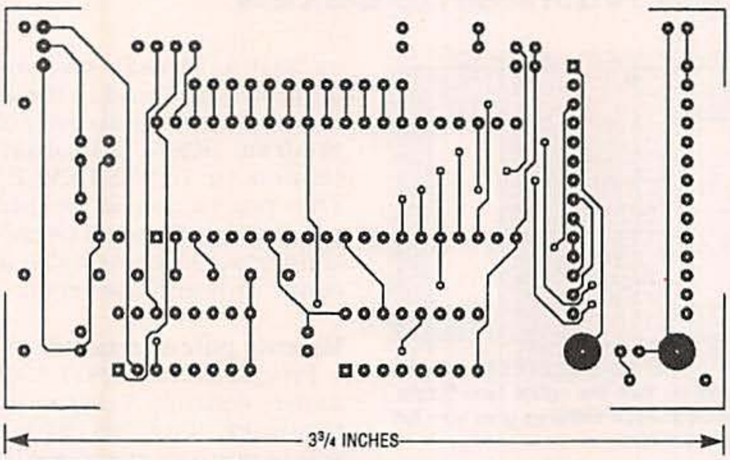
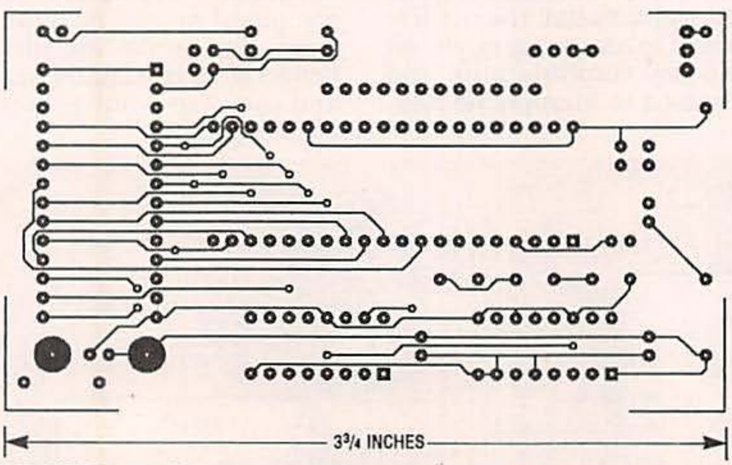


FIG. 9—THE TRANSMITTER AND RECEIVER are on the same PC board. Build the transmitter first, checking off each part in the transmitter parts list as you go. Put it aside when done, and then build the receiver.



COMPONENT SIDE for the IR transmitter and receiver boards.



SOLDER SIDE for the IR transmitter and receiver boards.

by the wiper. By clocking a 17-bit digital code into the DQ pin, each potentiometer within the IC can be adjusted independently. The part is available with different resistance values, depending on your needs.

Figure 8 shows how to connect the DS1267 to IC1 on the receiver board. The UP V and DOWN V keys raise and lower the resistance, while 0 selects potentiometer 0 and 1 selects potentiometer 1. We use the 0 and 1 keys here instead of 1 and 2 because the DS1267 data sheet labels the potentiometers as 0 and 1. Again, pin 35 of IC1 is high when potentiometer 0 is active, and pin 38 is high when potentiometer 1 is active. You can also use the LED indicator circuits connected to pins 35 and 38 of IC1. Both jumpers A11 and A12 must be removed to access IRPOT.ASM.

PARTS LIST—RECEIVER

All resistors are ¼-watt, 5%.

R1, R2—not used
R3, R4—1000 ohms

Capacitors

C1, C2—27 pF, ceramic disk
C3—1 µF, 35 volts, tantalum
C4, C5—0.1 µF, Mylar
C6, C7—not used
C8—10 µF, 10 volts, electrolytic

Semiconductors

IC1—INS8048L microprocessor (National)
IC2—87C64 EPROM with receiver programs installed
IC3, IC4—not used
D1—1N4001 diode
Q1—not used
LED1, LED2—not used

Other components

XTAL1—6-MHz crystal
MOD1—GP1U52X IR detector module (Sharp), or Radio Shack part number 276-137

Miscellaneous: On/off switch, PC board, two jumper blocks, wire, solder, etc.

Note: A complete kit of parts for the transmitter and receiver (not including a battery and case) is available for $49.00 plus $3.00 S&H from Fred Eady, PO Box 541222, Merrit Island, FL 32954. Check or money order only. For technical assistance call 407-454-9905.

Common factors

The receiver and transmitter circuitry are almost identical, and they are built on the same PC board. Parts common to both circuits have the same part number, and parts added or removed from one of the circuits will have corresponding part numbers added or removed. So, when a particular part number that's contained in both circuits is mentioned, the part performs the same function in both circuits. When a part contained in only one of the circuits is mentioned, The reference is limited to that particular circuit.

The first and most important part common to both circuits is

Continued on page 76

BUILD A POWER CONTROLLER FOR AUTOMOTIVE ACCESSORIES

Add that custom touch to your automotive accessories with our power-controller module.

DAVID J. SWEENEY

ADDING ACCESSORIES TO A CAR OR truck was once a simple chore. Just run some heavy wire from the car battery to the load, through the fire wall to the dashboard, and connect the wires in series with a fuse and a toggle switch and the job was complete. With that huge, high-current switch mounted on a bracket strapped to the dashboard, a flip of the wrist would activate the new accessory and testify to the owner's expertise and initiative.

But a plain old toggle switch hanging from the dashboard doesn't cut it anymore; it presents a tacky, unprofessional appearance in today's motor vehicles. Besides looking bad, an old-fashioned lever switch could make you look bad, too. If you were to leave the power on when the ignition key is off, you could kill the battery.

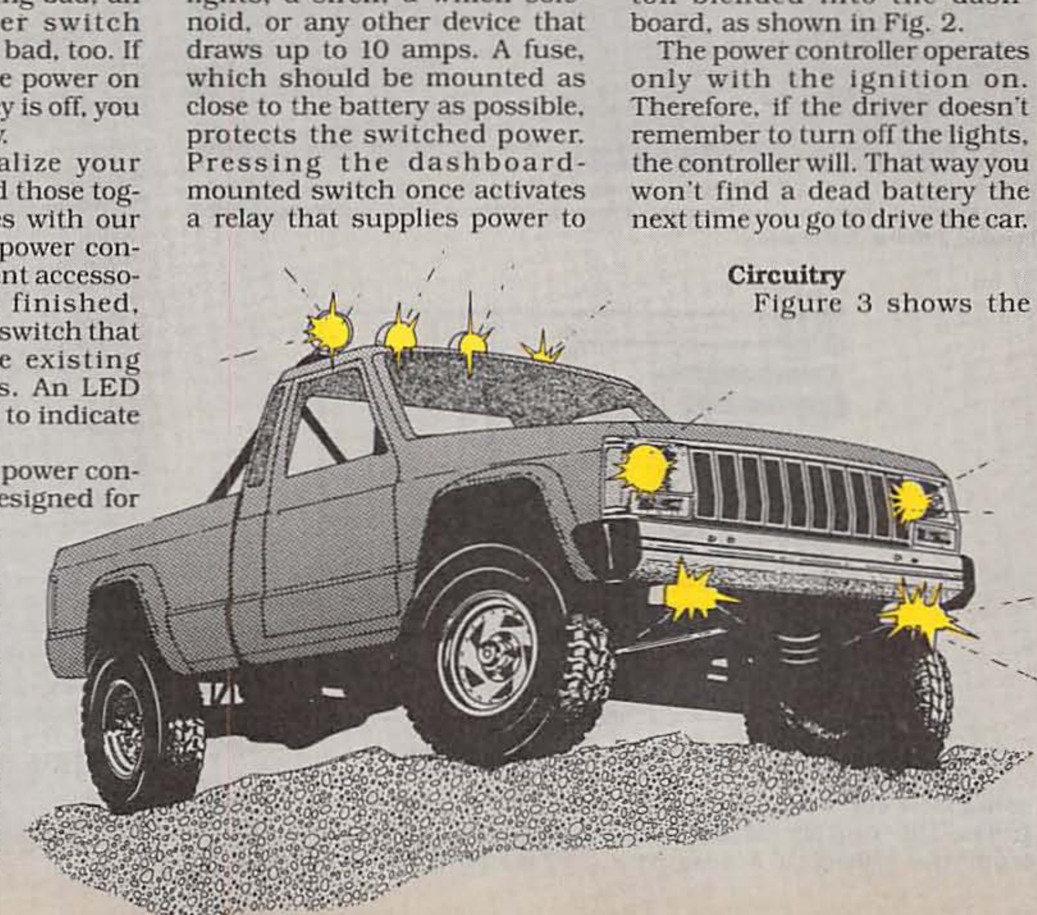
You can personalize your dashboard and avoid those toggle-switch headaches with our simple pushbutton power controller for high-current accessories. When you're finished, you'll have a "smart" switch that blends in with the existing dashboard controls. An LED can also be installed to indicate the power state.

The motor vehicle power controller is specially designed for under-the-hood mounting. It is designed to switch a high current when it receives a positive-going pulse from a momentary switch. It could also be controlled by a specialized device like a remote control radio receiver. Pulses from a 555 timer IC could be used to trigger the power controller to flash warning lights.

For pushbutton use, only a thin control wire runs to the dashboard, which helps make mounting easy. As shown in Figure 1, a small switch, with an LED power indicator, controls power to a load, which could be lights, a siren, a winch solenoid, or any other device that draws up to 10 amps. A fuse, which should be mounted as close to the battery as possible, protects the switched power. Pressing the dashboard-mounted switch once activates a relay that supplies power to the load; pressing the switch a second time disconnects power from the load.

The author designed the power controller for a pair of quartz halogen lights that he added to his car. The power controller delivers the 8 amps required for the fog lights, and it's controlled from a tiny pushbutton blended into the dashboard, as shown in Fig. 2.

The power controller operates only with the ignition on. Therefore, if the driver doesn't remember to turn off the lights, the controller will. That way you won't find a dead battery the next time you go to drive the car.



Circuitry

Figure 3 shows the

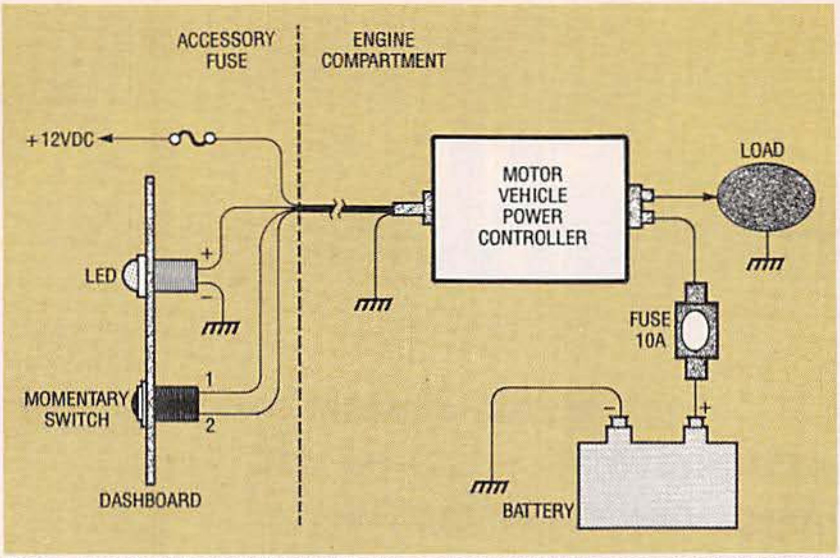
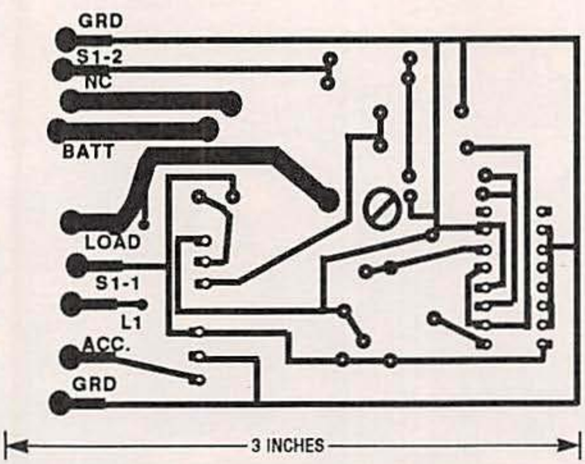


FIG. 1—THE POWER CONTROLLER lets a small pushbutton control power to a load that draws up to 10 amps.

FIG. 2—THE AUTHOR DESIGNED the power controller for a pair of quartz halogen lights that he added to his car. The lights are controlled from a tiny pushbutton switch blended into the dashboard.



FOIL PATTERN for the power controller.

schematic for the power controller. The controller is powered from the vehicle's accessory switch, so the load can receive power only when the ignition key is in the "on" or "accessory" position. Relay RY1 does the high-current switching (up to 10 amps), and its coil requires only 38 milliamps.

When you turn on the ignition switch in your car and press S1, capacitor C3 charges, causing pin 2 of IC1 (we only use half of a CD4013 dual flip-flop) to toggle high. The high output from pin 2 of IC1 is applied to the gate of FET transistor Q1, which in turn energizes relay RY1. The relay connects the load (up to 10 amps) to the car battery. After C3 discharges, a subsequent high from S1 will toggle the flip-flop again, opening RY1's contacts. Capacitor C2 resets the flip-flop to ensure that pin 2 is low and that the load is disconnected when the accessory voltage is first applied. FET transistor Q1 can easily drive an extra relay in parallel with RY1,

PARTS LIST

All resistors are ¼-watt, 5%.
R1—10,000 ohms
R2—3300 ohms
R3—1000 ohms
R4—2200 ohms
R5—1500 ohms
R6—10,000 ohms
R7—2.2 megohms

Capacitors
C1—0.1 µF, ceramic
C2—0.02 µF, ceramic
C3—0.3 µF, ceramic

Semiconductors
IC1—CD4013 dual flip-flop IC2—LM7812 12-volt regulator
Q1—IRF511 field-effect transistor (FET)
D1—1N914 diode
LED1—light-emitting diode (choose color to match existing lighting on dashboard)

Other components
S1—momentary SPST pushbutton switch (choose one that closely matches existing switches on dashboard)
F1—10-amp fuse
SO1—5-pin DIN socket
PL1—5-pin DIN plug
RY1—12-volt, 10-amp relay (Radio Shack part number 275-248, or equivalent)

Miscellaneous: PC board, 10-amp terminal strip, inline fuse holder, aluminum plate, encapsulating material, wire, solder. etc.

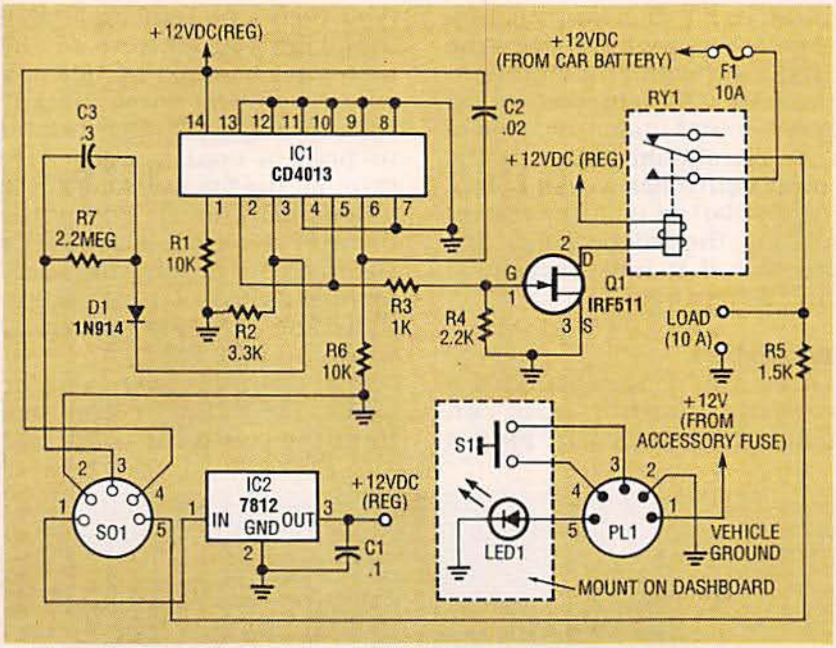


FIG. 3—POWER-CONTROLLER SCHEMATIC. Because the power controller is powered from the vehicle's accessory switch, the load can receive power only when the ignition key is on.

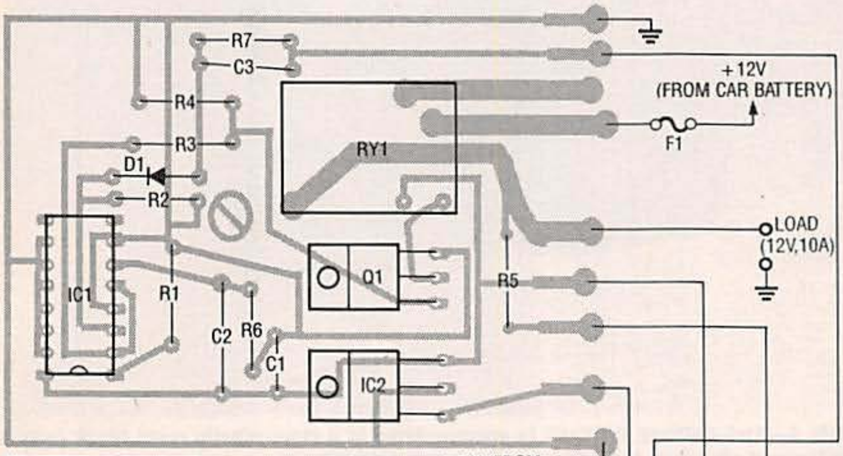


FIG. 4—ALL OF THE PARTS mount on a single-sided PC board for which we've provided the foil pattern.

in case you want to control a second 10-amp load. (Do not connect two 10-amp loads to one relay.)

An LM7812 12-volt DC regulator (IC2) provides a stable voltage to run the circuitry, regardless of fluctuations in the vehicle's power. Capacitor C1 provides decoupling for RY1.

Construction

All of the parts for the power controller should be easy to find at most electronics supply houses. The electronic components are mounted on a single-sided printed circuit board as shown in Fig. 4. We've provided the foil pattern for the PC board in case you want to make your own. Otherwise, use point-to-point wiring and perforated construction board. Be sure that the gauge of the wire you use for the load connections can handle 10 amps.

A DIN socket (SO1) provides the low-current external connections to S1, LED1, accessory power, and ground. A matching DIN plug (PL1) plugs into SO1 to make those connections. (The load's power and ground connections should be separate from the DIN connector). The DIN connector also makes it easier to change a power-controller module in case of failure,

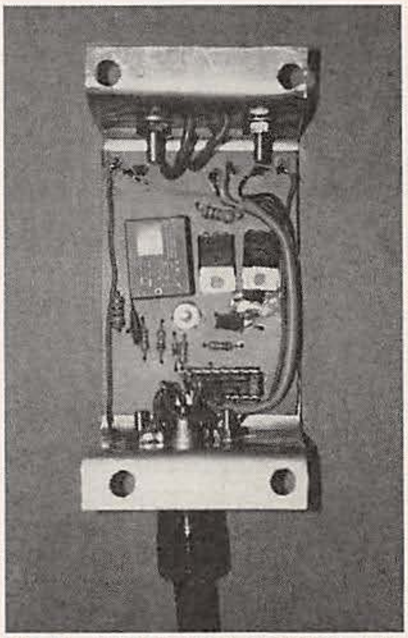


FIG. 5—THE POWER-CONTROLLER board is mounted on a 0.064-inch aluminum plate bent into a U-shaped frame. The DIN socket and the terminal strip are mounted on the sides of the U-bracket.

without having to disconnect any wiring. If you don't have a 5-pin DIN connector, you can use 4-conductor phone wire to connect the module to power, ground, LED1, and S1. If you do that, you must ground the LED to the dashboard or any chassis ground as shown in Fig. 1. A terminal strip provides the connections from the load to the relay contacts.

To make the power controller as durable as possible in a car's engine compartment, the circuit board was mounted on a 0.064-inch aluminum plate bent into a U-shaped frame, as shown in Fig. 5. The DIN socket and the terminal strip were mounted on the sides of the U-bracket. The entire circuit was then encapsulated in a clear plastic resin block (the product is called Casting Resin) as shown in Fig. 6. Encapsulation is not necessary, but it helps the circuit withstand the vibration, humidity, and temperature extremes found under the hood of a car. You should make sure the power controller works before encapsulating it. After encapsulation, the unit becomes "disposable" if it fails because it can't be repaired.

Installation

After you've encapsulated a working module, you can mount it in your car. Find a place for the module somewhere under the hood away from a high heat source. (For example, avoid the exhaust-manifold side of the engine.) Route the control wire through the fire wall and connect it to the switch and LED indicator, which you should mount in the driver's compartment. Be sure to drill the mounting holes slowly in plastic.

Snaking wires through a fire wall can be difficult. Sometimes there's a plastic plug that can be removed to gain access to the interior of the car from the engine compartment. Be sure to weatherproof such openings after the power controller is installed so your car won't be drafty. If there's no removable plug in the fire wall, try to snake the new wires through an opening where existing wires already pass through. It's often helpful to poke a coat-hanger wire through the fire wall and to use a hook bent on the end of the hanger to pull the wires through in much the same manner as an electrician uses a fish tape to snake electrical wires through walls.

Next connect power from the load to the controller, and then from the controller to the car battery. After checking all the connections, install fuse F1. You should now be ready to sit behind the wheel, turn on the ignition, and operate the load that is connected to the power controller.

You can expand the design of the controller to incorporate two relays, both powered by Q1, or to connect something to the normally-closed (NC) side of RY1. However, building an additional power controller might be just as easy. Once you get used to the convenience of our motor-vehicle power controller, you could end up adding a number of custom pushbutton-controlled accessories to your automobile. **R-E**

FIG. 6—THE ENTIRE CIRCUIT is encapsulated in a clear plastic resin block help it withstand vibration, humidity, and temperature extremes.

RAY M. MARSTON

555 OSCILLATORS

Put the 555 time to work as a Schmitt trigger or as the heart of light and temperature alarms and drivers, a metronome, and a continuity checker.

TWO PREVIOUS ARTICLES (SEPtember, page 58 and October page 69 explained the operation of the popular and versatile industry-standard 555 timer IC as a monostable and astable multivibrator. They gave examples of its use in accurate time delay or oscillator circuits.

This third article starts by discussing the 555 as the key component in a Schmitt trigger circuit. It goes on to explain the role of the 555 in various astable multivibrator or oscillator circuits with many practical applications. Those circuits include light- and dark- as well as hot- and cold-actuated alarms. Other circuits are a code practice oscillator, a door buzzer, a continuity tester, a signal generator, and a metronome. Various light-actuator and relay-driver circuits are included.

Schmitt trigger

Figure 1 is the pinout and functional block diagram for the 555 timer IC. In previous articles it was pointed out that for a 555 in the time-delay operation mode, timing can be precisely controlled by one external resistor and one capacitor. For astable operation as an oscillator, the free-running frequency and duty cycle can be accurately controlled with two external resistors and a single capacitor.

It is worth recalling that the 555 can be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200 milliamperes, or drive TTL circuits. The 555's features include normally on and normally off outputs.

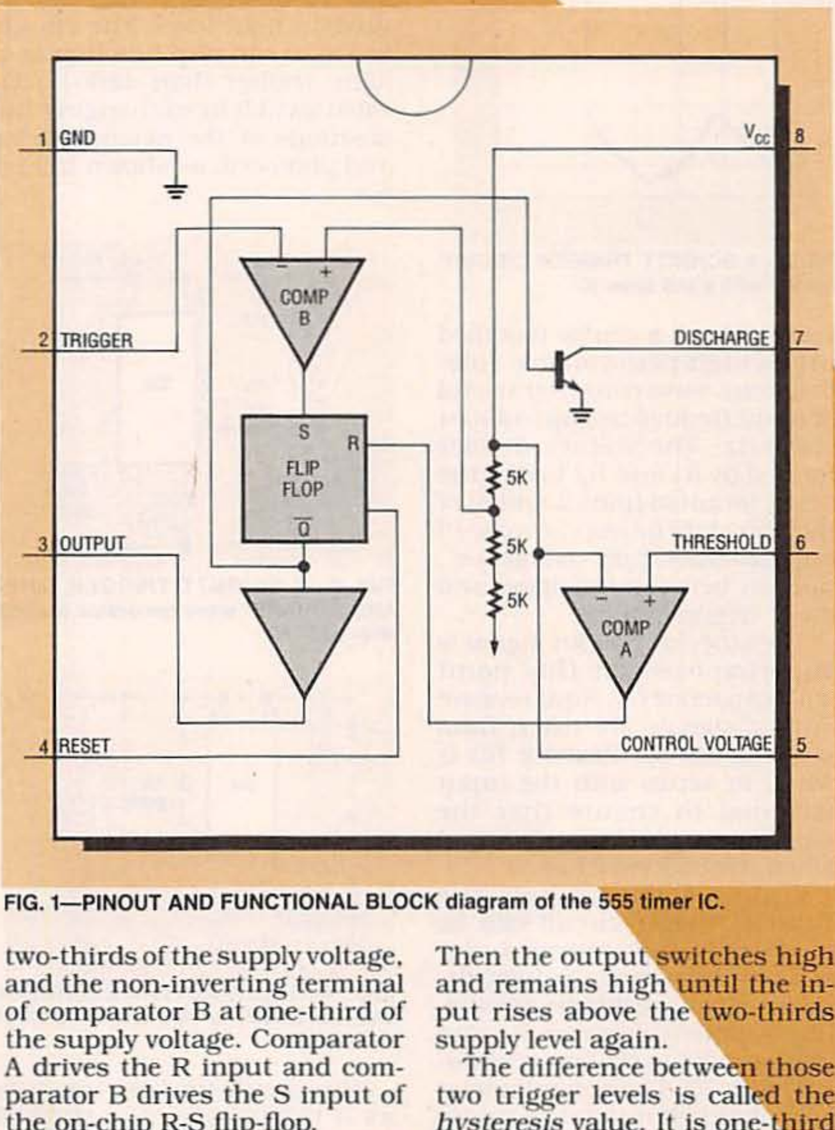


FIG. 1—PINOUT AND FUNCTIONAL BLOCK diagram of the 555 timer IC.

Figure 2-a illustrates the 555 IC as the active component in a Schmitt trigger circuit. Notice that the 555's TRIGGER pin 2 and THRESHOLD pin 6 are connected to form an input terminal. External input signals are applied directly at that point. The OUTPUT pin 3 becomes the output terminal.

Internal comparators A and B (see Fig. 1) are biased with an on-chip voltage divider. That divider biases comparator A at two-thirds of the supply voltage, and the non-inverting terminal of comparator B at one-third of the supply voltage. Comparator A drives the R input and comparator B drives the S input of the on-chip R-S flip-flop.

When the input voltage of the circuit in Fig. 2-a rises above two-thirds of the supply voltage, the 555 output switches to its low state. It remains there until the input voltage falls below one-third of the supply voltage. Then the output switches high and remains high until the input rises above the two-thirds supply level again.

The difference between those two trigger levels is called the *hysteresis* value. It is one-third of the supply in Fig. 2-a. That large hysteresis makes the circuit useful in signal conditioning where noise and ripple must be rejected, as shown in Fig. 2-b.

Figure 3 shows how the cir-

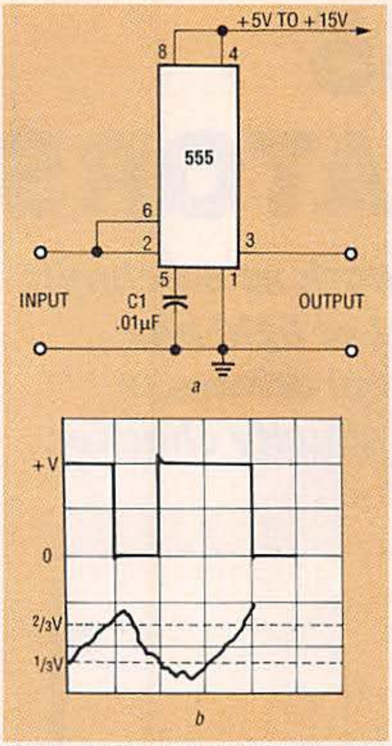


FIG. 2—A SCHMITT TRIGGER CIRCUIT formed with a 555 timer IC.

cuit in Fig. 2-a can be modified into a high-performance sine-to square-wave converter useful at input frequencies up to about 150 kHz. The voltage divider formed by R1 and R2 biases the input terminal (pins 2 and 6) of the 555 at its quiescent value of one-half the supply voltage (i.e., midway between the upper and lower trigger values).

The sine-wave input signal is superimposed on this point with capacitor C1. Square-wave output signals are taken from pin 3 of the IC. Resistor R3 is wired in series with the input terminal to ensure that the sine-wave signal is not distorted when the 555 switches.

Figure 4 shows how the Schmitt trigger circuit can be made into a dark-activated relay actuator by wiring the light-dependent voltage divider consisting of potentiomenter R1 and photocell R2 to the input terminal of the IC. The potentiometer and photocell resistance values are nearly equal at the middle of the light-activation range.

The inherently high input backlash or hysteresis of the Schmitt trigger limits the usefulness of this circuit to very specialized light-sensing applications. A more useful relay-driving, dark-activated switching circuit is shown in Fig. 5. It acts as a fast comparator rather than a true Schmitt trigger. The THRESHOLD pin 6 to internal comparator A of the 555 is tied permanently high by resistor R3, while the output of the light-sensing potentiometer R1 and photocell R2 voltage divider is applied to TRIGGER pin 2 of comparator B.

The photoresistive element for this circuit can be any cadmium-sulfide photocell whose resistance is between 470 ohms and 10 kilohms at the desired turn-on light level. The circuit in Fig. 5 can also function as a light- (rather than dark-) activated switch by exchanging the positions of the potentiometer and photocell, as shown in Fig. 6-a.

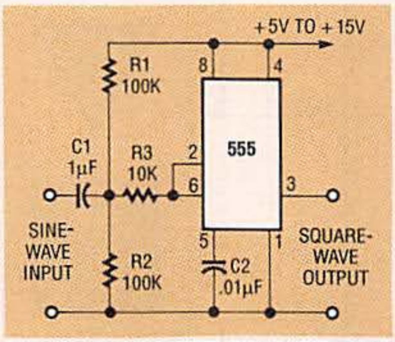


FIG. 3—A SCHMITT TRIGGER SINE-AND SQUARE- wave generator formed with a 555 IC.

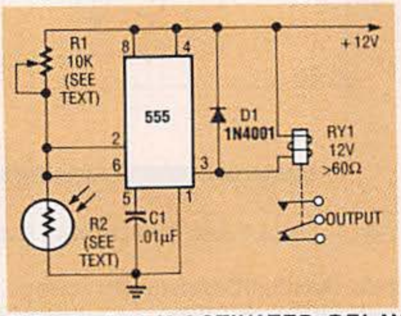


FIG. 4—DARK-ACTIVATED RELAY SWITCH BASED on the 555 has a lot of hysteresis.

The circuit can also function as a temperature-activated switch by substituting a thermistor with a negative temperature coefficient for the photocell, as shown in Figs. 6-b and 6-c. (A thermistor with a negative temperature coefficient decreases in resistance as temperature increases.) The thermistor for this application must have a resistance value between 470 ohms and 10 kilohms at the desired turn-on temperature. Thermistors are typically packaged as radial-leaded disks, and their resistance values are specified at 25° C.

Stable of oscillators

The 555 in the astable multivibrator or oscillator mode has three outstanding advantages over other kinds of oscillators:

- Excellent frequency stability with variations in supply voltage and temperature.
- Frequency variable over a wide range with a single potentiometer control.
- Low impedance output that can source or sink currents up to 200 milliamperes.

Figure 7 shows the 555 as the semiconductor IC in a Morse-code practice oscillator. The circuit is an oscillator with its frequency variable from 300 Hz to 3 kHz by adjusting tone control potentiometer R3. The sound volume of headphone Z1 can be varied with potentiometer R4, and the headphones can have any DC resistance from a few ohms up to a few megohms. The oscillator circuit draws no quiescent current until the normally-open Morse key connects the circuit to the 5- to 15-volt supply.

Figure 8 shows the 555 as the semiconductor device in a simple electronically actuated door buzzer. Pushbutton switch S1 connects the 555 to the 9-volt battery, and the output of the IC is coupled to speaker SPKR1 through capacitor C4. Capacitor C1 produces a low supply-line impedance, ensuring ade-

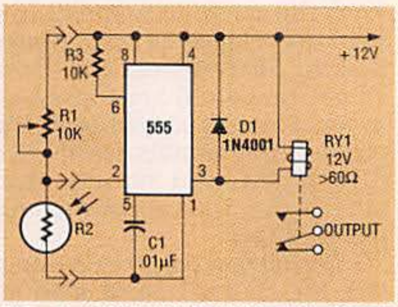


FIG. 5—MINIMUM-BACKLASH, DARK-ACTIVATED relay based on the 555.

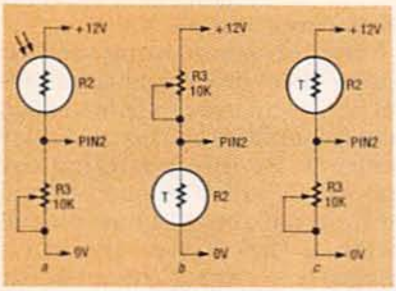


FIG. 6—ALTERNATIVE SENSOR CIRCUITS for Fig. 5 provide actuation by light (a), under-temperature (b), and over-temperature(c).

quate output drive current to the speaker when S1 is closed. The circuit generates a monotone buzzing sound set by potentiometer R2.

Figure 9 shows the 555 as the semiconductor component in a continuity tester that generates an audible tone only if the resistance between the test probes is less than a few ohms. The circuit's operation depends on an output tone that sounds only if the RESET (pin 4) is biased positive to about 600 millivolts or greater by sensitivity potentiometer R5. Pin 4 is normally pulled to ground by resistor R2, so no tone is heard.

For the buzzer in the circuit of Fig. 9 to sound, the two probe tips must touch, connecting R2 to the output of the reference generator formed by resistor R3 and Zener diode D1 through sensitivity potentiometer R5. Potentiometer R5 must be carefully adjusted so that a buzzing sound is barely audible. Consequently, if the resistance between the probe tips exceeds a few ohms when a continuity test is being made, the buzzing tone will not be heard. The circuit draws several milliamperes whenever S1 is closed, even if the probe tips are not touching.

Figure 10 shows the 555 functioning as a signal generator for testing both audio and radio-frequency circuits. The circuit oscillates at a frequency of a few hundred hertz when S1 is closed. Its square-wave output is very rich in harmonics, and those can be detected at frequencies up to tens of megahertz with a radio receiver. The signal level can be varied by adjusting potentiometer R3.

In Fig 11 the 555 is the active component of a metronome with a beat rate variable from 30 to 120 beats per minute. The beat rate can be set by adjusting potentiometer R3, and the beat level can be set by adjusting potentiometer R4. This circuit is a modified version of the stan-

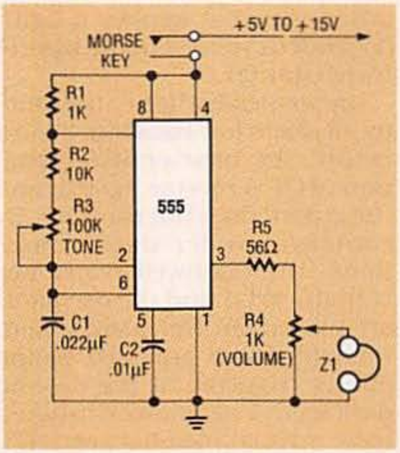


FIG. 7—CODE-PRACTICE OSCILLATOR with variable tone and volume.

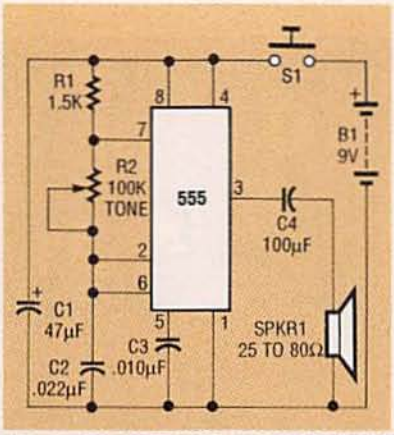


FIG. 8—ELECTRONIC DOOR BUZZER based on the 555.

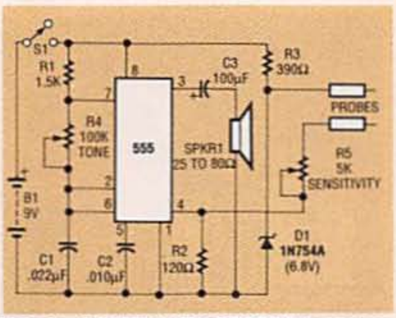


FIG. 9—CONTINUITY TESTER based on the 555.

dard astable multivibrator in which the main timing network is driven from OUTPUT pin 3 of the IC.

When the output switches high, C1 charges rapidly through diode D1 and resistor R1 in series to generate a beat pulse only a few milliseconds long. When the output switches low again, C1 discharges through potentiometer R3 and resistor R2 in series to provide an *off* period of up to two seconds (30 beats per minute). The output pulses are fed to speaker SPKR1 through level-control potentiometer R4 and buffer transistor Q1.

LED flashers and alarms.

Figures 12 to 14 show the 555 in LED flasher applications in which the LED's have equal *on* and *off* switching times. With the component values shown, each circuit flashes at a rate of about one flash per second.

The circuit in Fig 12 has a single-ended output. Either a single LED (or LED's in series) can be connected between the OUTPUT pin3 and GROUND pin 1 of the 555, and all LED's turn on and off together. Resistor R3 sets the *on* current of the LED's.

The circuit in Fig. 13 is similar to that of Fig. 12, but it has a double-ended output connection. The LED's above pin 3 are

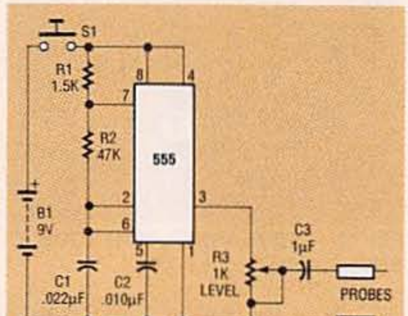


FIG. 10—SIGNAL GENERATOR based on the 555

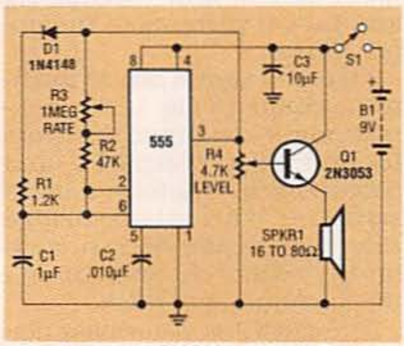


FIG. 11—METRONOME CIRCUIT based on the 555.

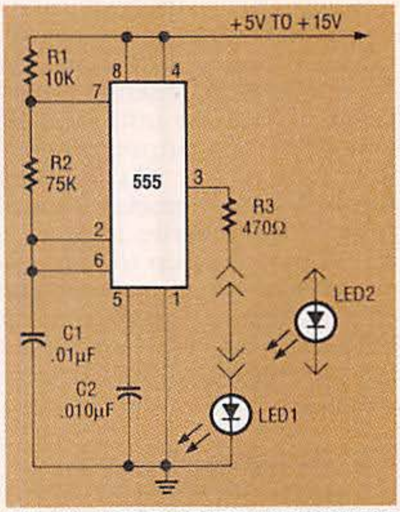


FIG. 12—LED FLASHER WITH SINGLE-ENDED output.

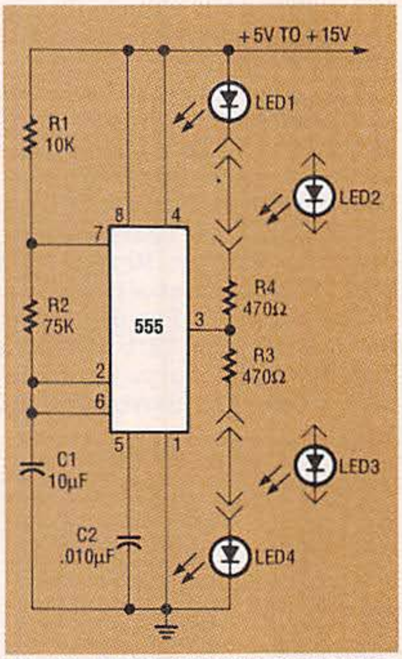


FIG. 13—LED FLASHER WITH DOUBLE-ENDED output.

on when the LED's below pin 3 are off, and vice versa. Resistor R3 sets the *on* currents of the lower LED's, and resistor R4 sets the *on* currents of the upper LED's.

Figure 14 shows how to modify the circuit in Fig. 12 for automatic dark-actuation. Resistors R3 and R4, photocell R1, and potentiometer R2 form a light-sensitive Wheatstone bridge that triggers the 555 through bridge balance-detector Q1 and the RESET pin 4 of the IC.

The oscillator is normally disabled by resistor R6, which pulls RESET pin 4 close to zero volts. The circuit oscillates only when pin 4 is pulled to a positive voltage greater than 600 millivolts. That can be achieved only by turning on Q1.

As one arm of the Wheatstone bridge, resistors R4 and R5 apply a fixed half-supply voltage to the emitter of Q1. The photocell and potentiometer form the other arm that applies a light-dependent voltage to the base of transistor Q1.

Under bright light, the photocell offers low resistance. As a result, the base-emitter junction of Q1 is reverse biased, and the circuit does not oscillate. By contrast, under dark conditions, the photocell resistance is high, so Q1 and the oscillator are biased on. Normally, potentiometer R2 is adjusted so the 555 is triggered at the desired dark level. The photocell should have a resistance between 470 ohms and 10 kilohms under this condition.

The precision gating method described can trigger a variety of 555 oscillator circuits to form useful audible alarms and relay drivers. By interchanging the photocell with the potentiometer, or replacing the photocell with a thermistor having a negative temperature coefficient, those circuits can be triggered by increases or decreases beyond preset values in either light or temperature. Figures 15 to 17 illustrate practical examples of such circuits.

Figure 15 shows an automatic heat- or light-actuated relay driver. The circuit works with any 12-volt relay having a coil resistance greater than about 60 ohms. When actuated, the circuit triggers the relay RY1 on and off about once per second.

A heat-or light-activated monotone alarm is shown in Fig. 16. When triggered, this circuit

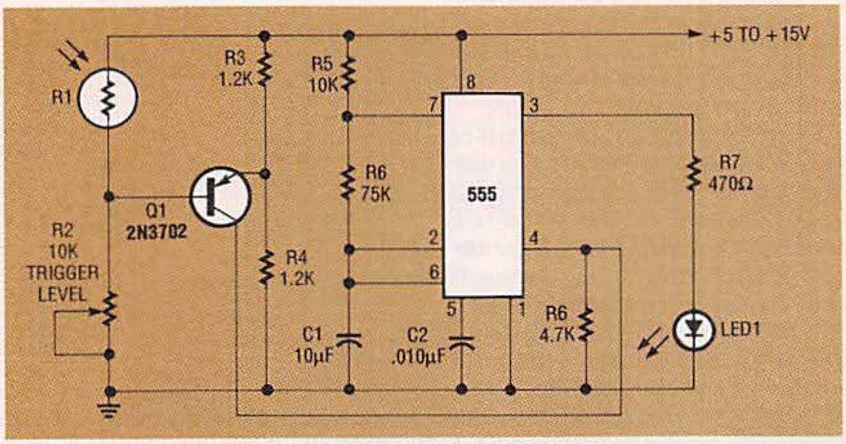


FIG. 14—AUTOMATIC (DARK-ACTUATED) LED FLASHER.

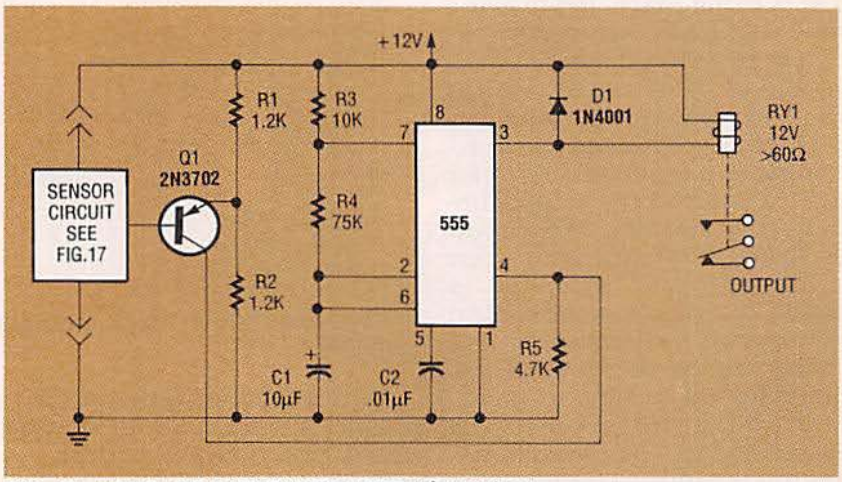


FIG. 15—HEAT- OR LIGHT-ACTUATED relay pulser

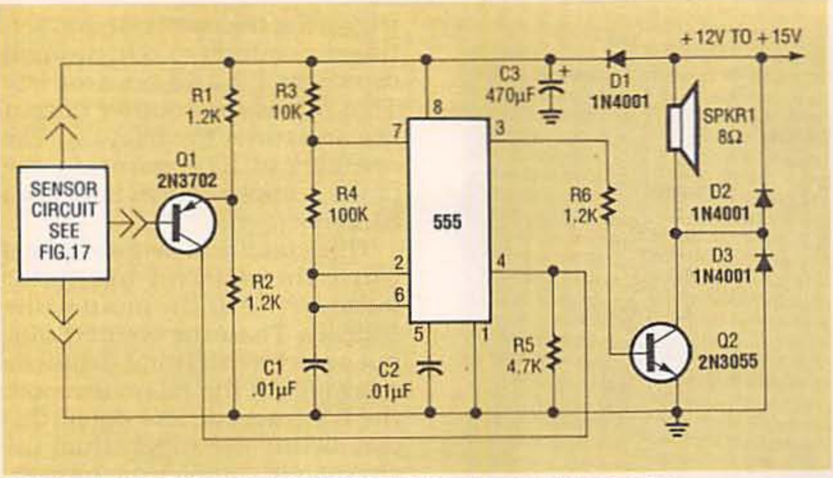


FIG. 16—HEAT- OR LIGHT-ACTUATED medium-power 800-Hz alarm.

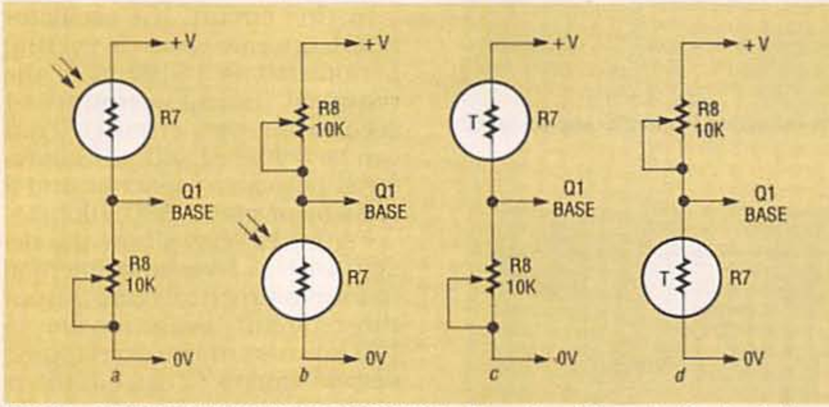


FIG. 17—ALTERNATIVE SENSOR CIRCUITS for Figs. 14 or 15 for actuation by darkness (a), light (b), under-temperature (c), or over-temperature (d).

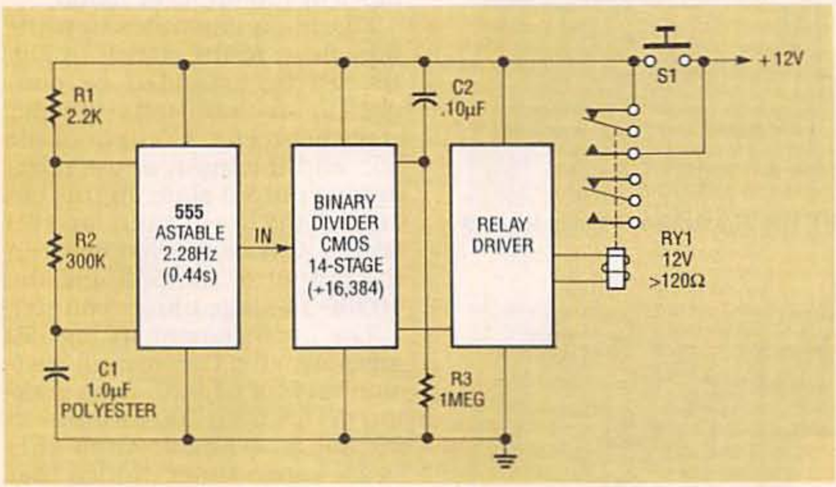


FIG. 18—A 60-MINUTE TIMER based on the 555.

generates a buzzing sound at about 800 Hz. Several watts of power are drawn from speaker SPKR1 through buffer transistor Q2. The resulting high speaker output current could transfer ripple voltage to the power supply so diode D1 and capacitor C3 protect the circuit from that interference. Diodes D2 and D3 clamp the inductive switching spikes of the speaker, protecting Q2 against damage.

Alternative sensor circuits that can automatically activate the circuits of either Figs. 15 or 16 are shown in Fig. 17. If light actuation is desired, the sensor should be a cadmium-sulfide photocell. If the circuit is to be triggered when light level *falls* to a preset value (dark actuation), the circuit of Fig 17-a should be used. If the circuit is to be triggered when the light intensity *rises* to a preset value (light actuation), the circuit of Fig 17-b should be used.

If you want temperature actuation, use a thermistor with a negative temperature coefficient as the sensor. For under-temperature operation, use the circuit of Fig. 17-c; for over-temperature operation, use the circuit of Fig. 17-d. Regardless of the kind of operation desired, the sensor element must have a resistance value between 470 ohms and 10 kilohms at the desired trigger level.

Long-period timers

A 555 can function as a superb manually-triggered relay-driving timer when it is connected in the monostable or pulse-generator mode. In practical applications, such a circuit will not generate accurate timing signals of more than a few minutes because they require an electrolytic capacitor with a high capacitance value. Electrolytic capacitors typically have wide tolerance values (−50 to +100%) and large and unpredictable leakage currents.

If the 555 is to be the active component in long-period timers, the external circuitry must include a capacitor other than an electrolytic. Figure 18 shows, as a block diagram, the principles behind a design for a 60-minute relay-driving timer. In this case, the 555 is organized in the astable mode. It has its output connected to the relay driver through a 14-stage binary divider IC. That configuration gives an overall division ratio of 16,384.

If the output of the 555 is set to zero at the start of an input count, the output will switch high upon receiving the 8192nd input pulse. The circuit will remain high until the 16,382nd pulse arrives. At that time, the output will switch low again, completing the normal operating sequence.

In Fig. 18, the timing sequence is initiated by closing S1, which connects the supply to the circuit, simultaneously

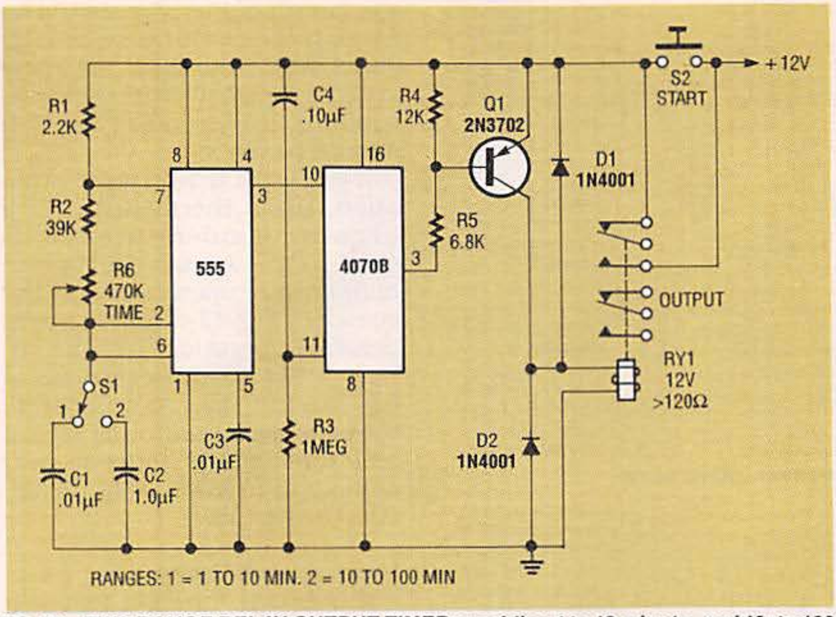


FIG. 19—TWO-RANGE RELAY OUTPUT TIMER providing 1 to 10 minute- and 10- to 100-minute intervals.

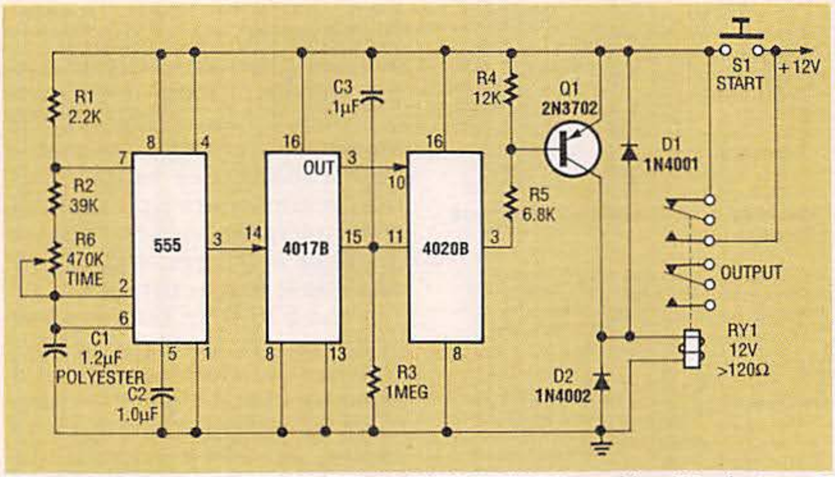


FIG. 20—EXTRA-LONG PERIOD RELAY OUTPUT TIMER provides 100-minute to 20-hour intervals.

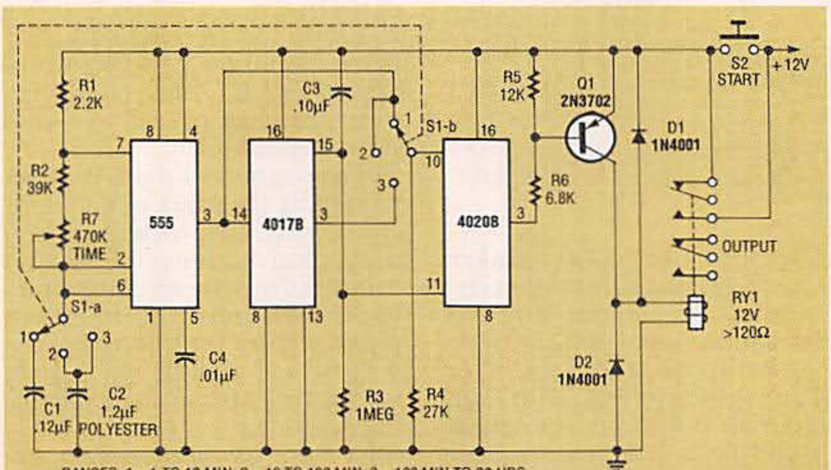


FIG. 21—WIDE-RANGE TIMER COVERING 1-minute to 20-hour intervals in three decade ranges.

triggering the oscillator and setting the counter to zero through capacitor C2 and resistor R3. That drives the counter output low and turns the relay on. The contacts of RY1 maintain the power supply connection once S1 is released.

This condition is maintained until the 8192nd oscillator pulse arrives at the input of the counter. Then the counter output switches high and turns the relay off. As the relay turns off, the contracts of RY1 open, disconnecting the supply from the circuit and completing the operating cycle.

In this circuit, the oscillator must operate with a cycling period that is 1/8192nd of the required timing period (0.44 second for this circuit). That can be achieved with a 1 microfarad polyester capacitor and a resistor of about 300 kilohms.

Figure 19 shows how the design in Fig. 18 is implemented to form a practical relay-output timer circuit useful for one to 100 minutes in two overlapping decade ranges. That circuit is powered from a 12-volt supply. The relay must have a coil resistance of 120 ohms or more.

Figure 20 illustrates how the time delay of the circuit in Fig. 19 can be extended by connecting an additional divider stage between the output of the 555 and the input of the relay-driving output state. In this circuit a divide-by-ten 4017B CMOS IC is connected between the output of the 555 and the 4020B 14-stage binary counter.

The arrangement in Fig. 20 gives an effective overall division ratio of 81,920, thus making delays from 100 minutes to 20 hours available from this single-range timer. Notice that both of the divider IC's are automatically reset by the series combination of capacitor C3 and resistor R3 when switch S1 is closed.

Figure 21 shows to modify the circuit in Fig. 20 to make a wide-range general-purpose timer that covers one minute to 20 hours in three decade-based ranges. The divide-by-ten stage is active only when switch S1-a is at position 3. R-E

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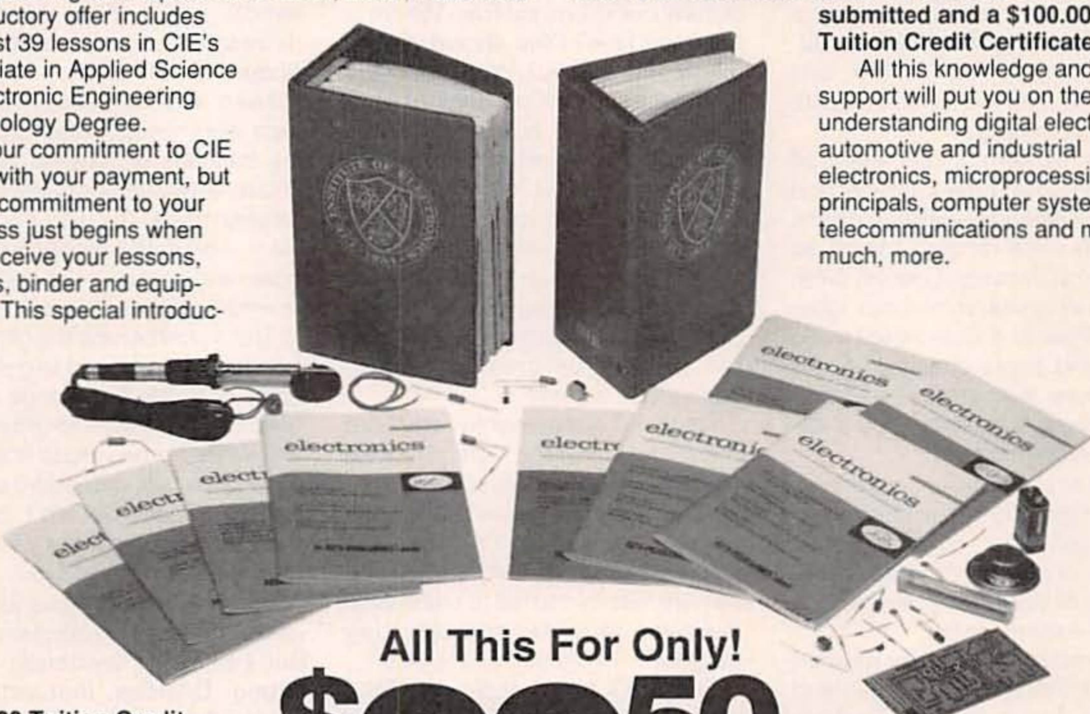

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Distant FM reception, UFO resources listing, UHV and VHF amplifiers, TV/FM booster circuits, and pseudoscience research.

DON LANCASTER

Judging from the letters and helpline calls, there's clearly a bunch of interest in alternate-science and pseudoscience topics among **Electronics Now** readers. Some genuinely believe, and others (like me) find these subjects fascinating reading.

The two centermost secrets to all hardware hacking are curiosity and a sense of wonder—which explains why such wide-ranging topics as specialty hardwoods, Grecian urns, Buckeyball research, rubber iguanas, the *Powder & Bulk Solids* trade journal, and tinaja questing all are vastly more mainstream to hardware hacking than they would appear at first glance.

I come at all this from a traditional formal engineering background. I strongly believe in such things as the laws of thermodynamics, and the value of performing simple and verifiable experiments.

I also realize that getting relevant and accurate results in the lab end up nearly always to be the exception, rather than the rule. I am a highly skeptical inquirer, albeit one who very much loves to run a stick over the bars of establishment cages. And I'm someone who always likes to encourage people to think things out for themselves.

As a researcher, I feel there is a fuzzy something out there that I'll call *the edge*. This side of the edge, things seem (at least to me) "probably true." On the far side of the edge, things appear "probably false." To determine which side of the edge a subject currently lies on, I'll often first apply the laws of physics and my ability to perform experiments. Second, I'll ask what the laws of statistics have to tell us on the odds of an occurence and on the data sample sizes. And third, I'll try to apply Ockham's razor to find out if there is a simpler explanation or a more likely underlying cause.

After that, I'll ask some crucial cultural questions such as: Where is the cash flow? (You should always follow the money.) Who benefits? Who loses? What psychological or other needs are being filled in all those persons involved? Could this make a good hoax?

Were magic cookies involved? Are there any personality disorders? What irrelevant links are there to religions, conspiracies, or any politics? Has this ground ever gotten plowed before? How thoroughly? By whom?

Do things seem *slightly* ratty? Are there "just enough" noise, loose ends, conflict, and missing pieces to fit the way the real world actually works? Are all of the t's dotted and the i's crossed, rather than vice versa? Are results carried to eight-decimal-place precision conspicuously absent?

Finally, I'll try to apply my "likes water, looks like a duck, and quacks like a duck" filter. Especially if eggs are about to be laid.

All of which leads up to my...

Thoughts on UFO's

On to today's story. You see, I was abducted by a UFO enthusiast. Yup, a close encounter of the zeroth kind.

Actually, I guess I did pay him to be abducted. Mike Sherlock runs a great (and incredibly low cost) secret hideaway escape in the most remote portion of New Mexico's wilderness outback. The *Black Range Lodge*.

Mike is a sometime Hollywood type who has gathered great heaping bunches of footage into what, uncut, is twelve hours of video tentatively titled *The UFO Marathon*. He is now in the process of editing down and securing the rights for its eventual commercial release.

This material runs the gamut from fully professional and largely impeccable network-TV footage on down (wayyy... on down) to grainy black-and-white home videos from southern Florida box-only addresses. The special effects wouldn't even rate the cutting room floor of a 1950's grade-Z sci-fi horror flick.

For once, I am at a loss for words. To call this "lore" is condescending. But calling it "evidence" is too strong. Besides, that word "evidence" has vastly different meanings to an engineer, a lawyer, or a priest. So a neutral working definition, the UFO *resource base*, is the sum total of the available words and images on this topic that are reasonably coherent and more or less relevant to the subject.

After sitting through a full twelve hours of video and then some, I have come to three tentative conclusions on UFO's:

(1) The scope, breadth, and depth of the UFO resource base is much larger than I thought it was.

(2) The potential credibility of at least a significant subset of the UFO resource base appears to be higher than I expected.

(3) The current UFO resource base represents a multimillion dollar *industry* that now employs thousands on an international basis,

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both in and out of government.

UFO Magazine appears to be the leading industry trade magazine, and the highest profile watchdog group is the *Skeptical Inquirer*. The best directory on the subject is the new *Almanac of UFO Organizations*. It's written by David Blevins, published by *Phadera*, and stocked by *Arcturcus*, among others. It's sort of a combined *Thomas Register* and *Michelin Guide*. I'd give it a four ET rating.

Our resource sidebar for this month shows you many of the leading places to go for further information on UFO's and any related phenomena—both pro and con. Treat it as you would any other resource listing.

And a related contest...

As for our contest this month, just answer the question *Are we alone?* in 70,000 words or less and send it in to me. There'll be dozens of my usual *Incredible Secret Money Machine II* books, along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all.

Be sure to send all of your entries directly to me here at *Synergetics*, rather than over to the **Electronics Now** editorial offices. The entry deadline will be extended for any responses arriving from fifty light years or more away. Especially if they don't have tinajas.

Long distance FM

We have had quite a few entries in our ultra-long distance FM reception contest, so I thought we might review what can and cannot be done here.

With most problems, there are usually both technical and cultural solutions. Judging from the absolute outrage *Post-Newsweek Cable* has caused locally by dropping all quality FM station coverage here in the Gila Valley, I suppose such things as petition drives, suitably annoying the politicians, rattling the Corporation Commission's cage, encouraging the competition, or promoting translators could be effective.

So would changing listening habits. And newer FM transmission schemes are in the works with much higher effective ranges, especially for stereo. But I'm voting with my wallet; I simply prefer not to send any of my hard-earned cash any longer to those whom I feel are clearly biting the hand that feeds them.

At any rate, broadcast FM stations transmit in a frequency range from 88.1 to 107.9 MHz on channels spaced 200 kHz apart. This is in a portion of the radio spectrum where thermal noise ultimately limits distance reception—although daytime ignition noise can become dominant in urban areas.

FM reception of any nearby stations can become complicated by *multipath*, where the signals bounce around any nearby hills and structures. Steel or wire present in buildings can also act as partial or total shields. And any strong nearby station that's close in frequency to a weaker distant one can also give you fits.

Urban solutions tend to center on small directional antennas with deep nulls, in shielded transmission lines that are carefully matched, and in good receiver selectivity.

For remote rural areas, plain old low signal strength will usually be the main problem. But no matter where you are, the higher you can get your antenna, and the nearer you can get to a straight shot at the transmitter, the better your received signal.

FM signals are often horizontally polarized and travel best in a line-of-sight. In the basin-and-range Southwest, it is to have many stations come booming in on most any mountaintop from hundreds of miles away—on the cheapest receivers with zilch for an antenna. But distant reception can get difficult fast if you lose line-of-sight.

Many contest entries suggested putting an antenna on the mountain and then rebroadcasting somehow.

Perhaps as a *passive repeater* (two unpowered back-to-back antennas that work surprisingly well in special instances); an *active repeater* (isolated rebroadcasting on the same frequency to prevent feedback); a *translator* (low-power rebroadcasting on some other frequency); or an *optical link* (which sends out highly directional modulated light pulses). Sadly, these don't seem too practical for me, since either going clandestine or hassling the Forest Service or BLM would be involved. There would also be lightning and power problems.

The *gain* of an antenna is simply how much better it works in its best direction than a comparable *isotropic* antenna that accepts signals equally well from any direction. Raising the gain of your antenna by a mere three decibels is the same as having the station *double* the transmitted power. The standard baseline FM antenna is called a *dipole* and is shown in Fig. 1-*a*. The dipole has a "figure-8" pattern which gives it a peak gain of around two decibels above isotropic.

The dipole can be reduced in size by using twinlead with its 0.7 velocity factor. Figure 1-*b* shows the standard hang-it-on-the-wall indoor FM Tee antenna. But don't forget that this antenna has a "figure-8" reception pattern, so pick your wall accordingly.

If one dipole is good, then more of them should be better. A group of dipoles form an *array*. It turns out that you do not have to power all of your dipoles. Some of them can be *passive* or *parasitic* elements. The first parasitic element goes behind your dipole, and is called a *reflector*.

One or more additional parasitic elements can go in front of the dipole, and are called *directors*. Usually, there is only a single reflector but multiple directors. The directors are usually shorter than the reflector. Those two clues tell you which way to initially "point" any antenna.

Figure 1-*c* shows you one popular arrangement for active and passive antenna elements called a *Yagi* array. Yagi antennas are compact, have high gain, and exhibit stong front-to-back ratios.

Yagi antennas can be designed for a single station, for the entire FM band, or for all of FM and television combined. Broadbanding is done by changing the sizes, lengths, and positioning of the elements. All other things being equal, the narrower the bandwidth, the higher the antenna's gain.

Ferinstance, a single-channel, five-element Yagi might have a gain of 11 dB. That same antenna broadbanded could have only a 5-dB gain. Thus, a single-station FM Yagi will usually deliver a stronger signal than will an "all band" TV antenna.

Since they obviously would have to be expensive special orders, you'll normally build your own custom-cut Yagi antennas. One secret to narrow band and high gain is to use *very thin* directors. I've posted an FMYAGI.PS design program to my *GEnie* PSRT. We might look at this program some more in a future column. Let me know if you are interested.

Yes, antennas can be stacked. But doing so often isn't worth the hassle. The second antenna at best adds only three decibels to what you've already got. And without proper impedance matching, you can actually *degrade* your signal.

While Yagi-style FM antennas are often the simplest and best, there is another Hacker alternative. This one is called a *rhombic* antenna. It is just a parallelogram of wire sent either around or across your room. Figure 2 shows the details.

Inherently, a rhombic has a much larger area and thus (when properly designed, properly aligned, and used in a proper location) intercepts more signal for a potentially higher gain. Large (70-foot) FM outdoor double rhombics can reach a mind-numbing 28 decibels of gain! Broadband, yet.

But there is so much that can go wrong with a rhombic design, and so much cut and try is involved that you might want to save this as a last resort. And then only when there are no strong local stations.

One useful paper on rhombic antennas is *Improved Antennas of the Rhombic Class*, run in the March 1960 *RCA Review*. You also might want to check *Try a Rhombic FM Antenna* in the January 1982 issue of *Audio*.

More info on Yagis, rhombics, and antennas in general can be found in any of a number of college or ham texts. The ARRL's *Antenna Book* or the *Antenna Engineering Handbook* by Jasik are typical classics on the subject.

Reception of FM signals can end up more art than science. So, if you are interested in only one particular FM station and all else fails, try black magic. Change the antenna direction and position it to try to find a local hot spot. You could try extra pieces of conductor in or near your

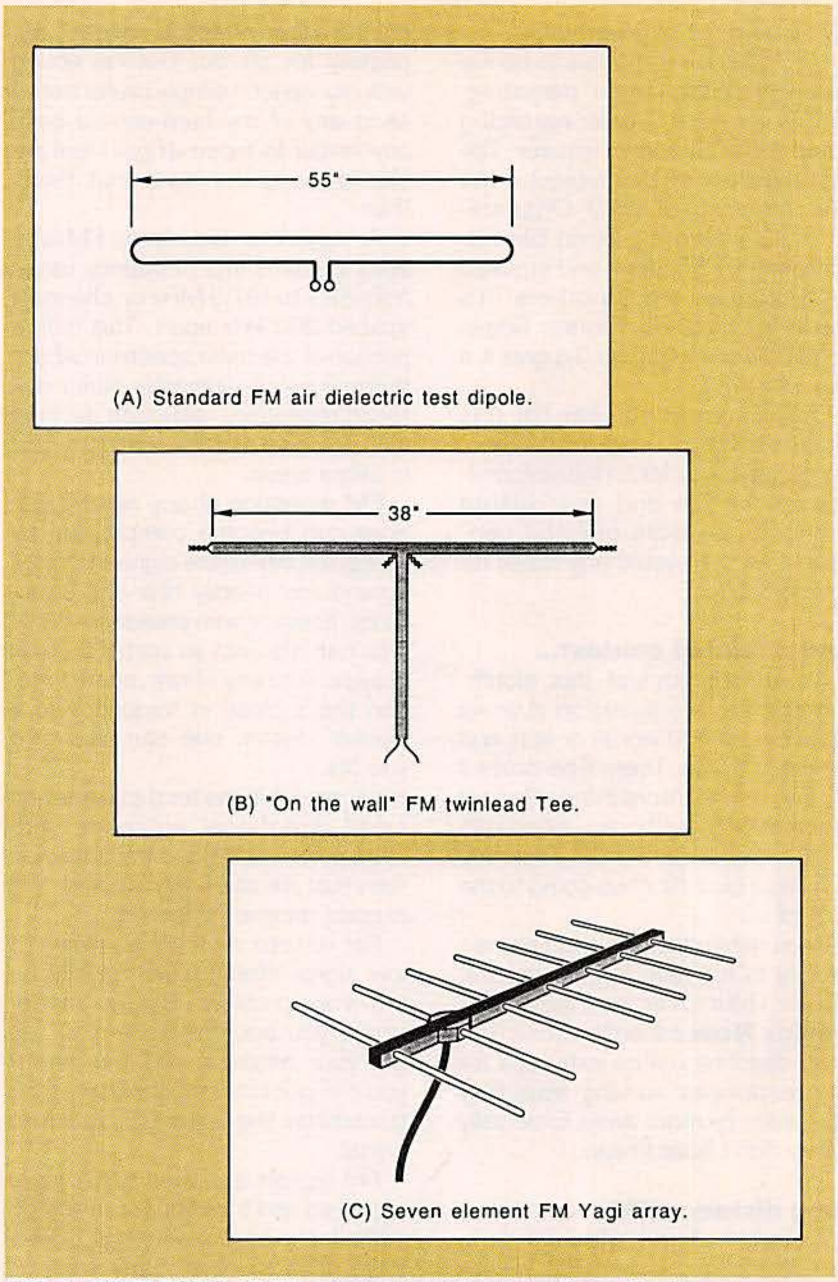

FIG. 1—SOME POPULAR FM antennas based upon ordinary dipoles.

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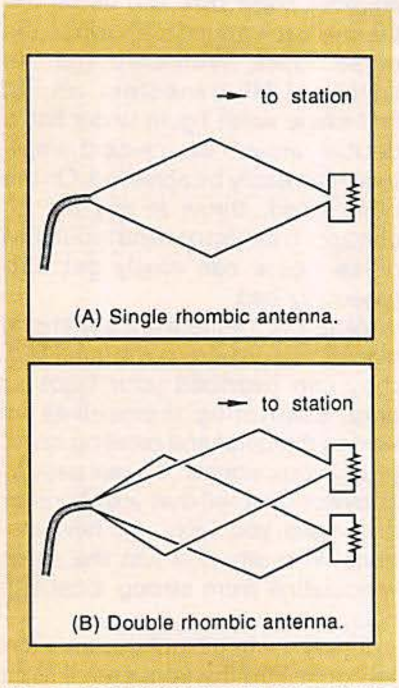

(A) Single rhombic antenna.
(B) Double rhombic antenna.

FIG. 2—THE RHOMBIC FM ANTENNA is humongously large, but it does offer exceptionally high gain over a quite a wide bandwidth.

antenna. In one trial I found that shorting the antenna crossfeed with an aluminum yardstick dramatically improved the results for one target station.

Some FM stations add vertical or circular polarization to their patterns to improve mobile reception, so a non-horizontal antenna might sometimes work better than you would first expect. Try it and see. Should you be mainly interested in one station, call the station and ask what pattern it uses.

One final trick to deal with a noisy FM signal is to reduce its bandwidth. The quickest and simplest way to do this is to switch from stereo to mono. That halves the bandwidth and thus reduces noise by three decibels. Many modern automotive stereo receivers do that automatically.

It is also possible to use low-pass filters (such as the treble control or messing with the loudness curve) to further reduce the perceived noise.

You end up losing the station's high frequencies as well.

We better throw in some obvious safety warnings here: Outside and/or high antennas must have lightning protection. Antennas can kill you if they hit a power line when you are installing one. And any ladders and heights in general could be the cause of nasty to deadly falls. Think!

FM booster amplifiers

Will an FM "booster" amplifier help us at all? Can't we simply make the received signal louder? For a number of reasons, booster amplifiers can be anything from a disappointment to an outright disaster. But, with some care, boosters do have their uses.

For any chosen station, any given receiving antenna at any given place pointing in any given direction, there will be so many microvolts of signal appearing at your antenna terminals. There will also be so many microvolts of *thermal agitation noise* appearing across the antenna terminals. At FM and higher frequencies, the amount of this rural noise usually gets set by the *temperature* of the antenna, and little else. At least for a given bandwidth.

The ratio of those two voltages is known as the *signal-to-noise ratio*. A S/N ratio that can produce 20 dB of limiter *quieting* is needed to give you "good" FM reception. Anything less gets progressively noisier and more annoying.

For a given fixed bandwidth and reception scheme, *there is no known amplifier or other electronic method to improve the input signal-to-noise ratio across your antenna terminals!*

All the booster amplifier can do is amplify *both* the signal *and* the noise together. Thus, if your input signal-to-noise ratio is too low, there is *no way* that *any* amplifier can help you. You just cannot amplify a signal that is not there!

Further, any booster amplifier will add its *own* noise and always *lower* your signal-to-noise ratio. The extra amplifier noise over and above the thermal background is known as the *noise figure*. With care and the latest of UHF transistors, an FM first-stage noise figure under half a decibel (around five percent amplitude) can easily be achieved. On the other hand, throw in any old el-cheapo transistor, and your FM noise figure can easily get outrageously bad.

Worse yet, if there are any strong signals that are also being amplified, they can overload your booster amp, splattering themselves all across the band and creating *spurs* or spurious signals. It's real easy to convince yourself that your booster amp gave you "lots" of new stations; in reality it is just the cross modulation from strong local signals.

Finally, quite a bit of design effort has gone into the front end of most premium FM receivers. Unless your booster has a *better* design than your FM receiver, it is almost certain

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to degrade, rather than improve your reception. Most of those el-cheapo bargain boosters found in the yuppy catalogs will often make your signals *more*, rather than less noisy.

So, what good is a booster? A high-quality and properly designed booster can make up for transmission losses down long cables. They can present a more standard and a better matched load to your antenna. They can make up for a cheaper receiver front-end design—or for standing waves and some impedance unbalances. And they are particularly useful when you want to drive two or more receivers from one antenna at the same time.

Figure 3 shows a simple broadband hacker VHF amplifier you might like to experiment with. It uses a low-cost integrated amplifier from *Mini-Circuits Labs*. Since this is a very wideband circuit, you have to watch for saturation effects from any interfering signals. And thorough shielding is a must. Naturally, adding resonant circuits and limiting your bandwidth can give you *much* better results for the frequencies you are interested in. But that sure makes the design a lot more complicated.

Radio Shack has a newer 15-1108 broadband TV/FM booster that uses a pair of exceptionally hot *Motorola* MRF571 transistors. They have an 8-gigahertz cutoff frequency and an FM band noise figure of only 0.4 decibels! Approximate schematics for the antenna and the base units are shown in Figures 4 and 5.

The antenna unit is made up from a switchable FM trap (just what we do *not* need!) and one fairly low-gain amplification stage and cable driver. The twinlead serves two purposes: It routes DC power up from their base station and downlinks your partially amplified RF signals. The polarity of the DC power determines whether the FM trap gets switched in or out. Ordinary silicon diodes do the switching.

You might like to experiment with eliminating the FM trap. I don't trust its being there at all, even in its supposedly "off" position. To do this, you could try removing L1, L2, R2, and CR2, while replacing L3 with the shortest possible jumper.

The base station is made up of a power supply and another transistor that acts as a line driver or as a distribution amplifier. There's also an adjustable attenuator to optimize the signal levels.

Please let me know about your experiences in the way of receiving distant FM in difficult areas.

New tech lit

Motorola has announced several really exciting new chips. Especially the new MC144143 single-chip *Closed Caption TV Decoder* and its

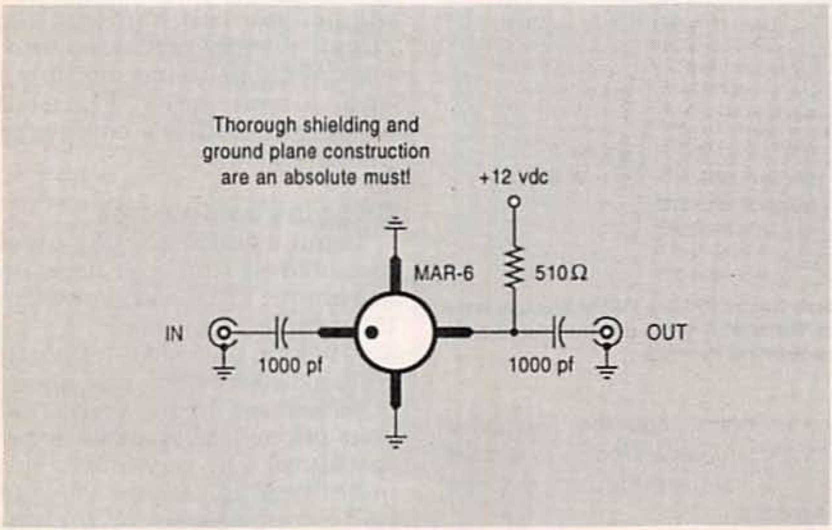


FIG. 3—MINI-CIRCUITS LABS offer a number of ultra low-cost and easy-to-use broadband VHF/UHF amplifiers and kits. This circuit forms an FM booster with a 20-decibel gain and a 1-decibel noise figure. Input and output impedances are 50 ohms. Prefiltering must be used to reject any strong out-of-band signals.

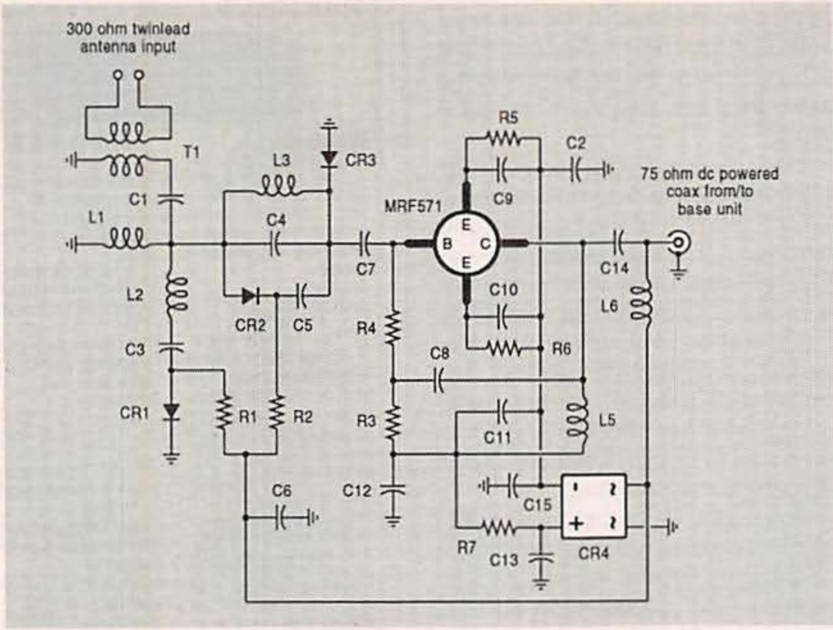


FIG. 4—APPROXIMATE SCHEMATIC for the Radio Shack 15-1108 TV/FM booster antenna unit. The polarity of the DC power routed up the coaxial cable determines if the FM trap will be switched in or out. The low-cost Motorola transistors used have an 8-gigahertz bandwidth and an FM noise figure of 0.4 decibels!

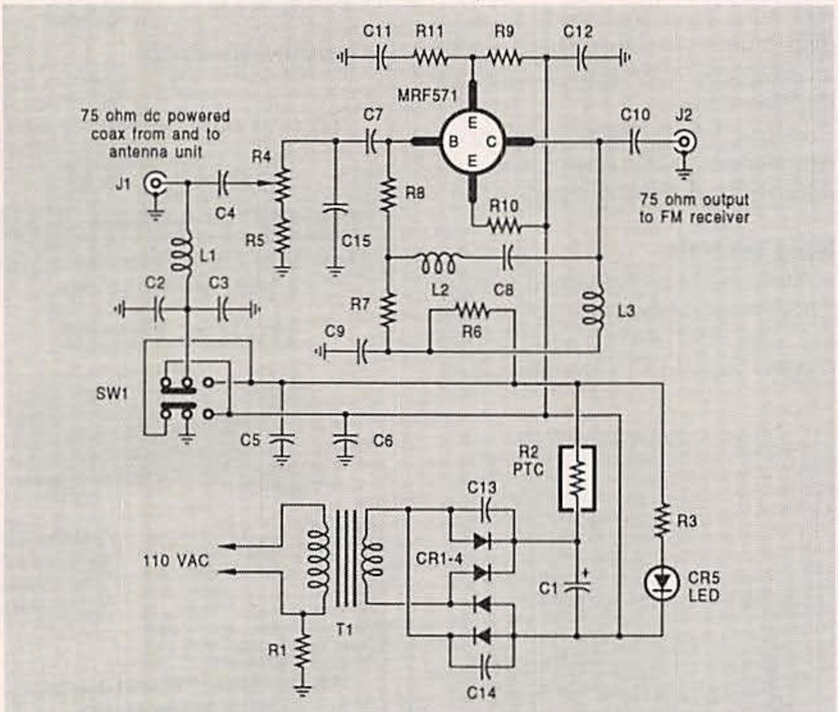


FIG. 5—APPROXIMATE SCHEMATIC for the Radio Shack 15-1108 TV/FM booster base unit. Switch SW1 remotely activates the FM trap. Be careful not to mix up your cables; the DC power on the coaxial cable could cause receiver damage.

new DSP56401 *Digital Audio Transceiver*. Preliminary data sheets and application notes are available from Motorola.

We have a collection of unusual publications this month. Tony Patti still prints his *Cryptosystems Journal* that's big on cryptography and chaos topics. And the *Journal of Computer Game Design* is a great labor-of-love newsletter by Chris Crawford.

Two unique music newsletters are *Experimental Musical Instruments* and *Guitar Digest*. And *Solar Mind* has just introduced its "Holistic Approaches to Technology and Environment."

The folks at *Lindsay Publications* are offering a large number of new titles. These include a turn-of-the-century reprint on *Large Induction Coils*, and a new one on do-it-yourself *Lightning Bolt Generators*. Lindsay has some great free catalogs. These are "must have" hacker resources.

I've been self-publishing quite a few titles these days using my new *Book-on-demand* process. Included are my *Hardware Hacker* reprints II & III, my *Ask the Guru* reprints I, II, & III; my *Blatant Opportunist I*, the new *Resource Bin I*, and my *LaserWriter Secrets* book and disk combo. See my nearby *Synergetics* ad or call for your free hardware hacking brochure for more details.

As usual, we've gathered many of the resources mentioned together into either of the *Names & Numbers* or the *UFO Resources* sidebars. Do be sure to check these out *before* you call our no-charge tech helpline or phone for a free hacker secrets brochure. **R-E**

TELEPHONE HOLD

continued from page 45

stalled in line with any telephone. The PC board has TIP (green) and RING (red) available at two places for the modular jack and plug. However, if you are installing the board inside a phone, you can hardwire the circuit directly across TIP and RING, without using any input and output jacks. Figure 3 shows the author's completed prototype.

Using the hold module

To put a phone on hold, press and hold S1 until you hang up the phone; LED1 will glow when the phone is on-hook. As we said before, the hold is automatically released when any phone is picked up. In the event that your phone line is above or below 40 volts by very much, you might need to vary the value of R1 to compensate for the difference. The hold module will not put a significant load on a telephone line, so you can add as many of them as you like. **R-E**

UNIVERSAL REMOTE

continued from page 56

IC2, an 87C64 8K × 8 CMOS EPROM, which contains the machine language instructions for all functions provided by the remote-control system. The 87C64 is identical to the industry-standard 27C64, except that the 87C64 contains an internal address latch and the 27C64 part does not. For those interested in programming the EPROM, there is a modification you can make to the programmer we ran in November 1991. Send a self-addressed stamped envelope to the author for details (see the parts list). In normal use of the INS8048L, address lines A0–A7 need a separate 74LS373 address latch because the lower eight data and address lines are multiplexed between address and data by the INS8048L processor. Because power consumption must be kept to a minimum, and space is at a premium, eliminating a 74LS373 address latch by using the built-in function of the 87C64 works in our favor.

In both circuits, capacitors C1 and C2 are used by the built-in oscillator of IC1. A 6-MHz crystal (XTAL1) ensures high accuracy for timing routines, and it provides the basis for the 40-kHz carrier on the transmitter module. All 0.1 µF capacitors are standard TTL noise-bypass components, while C8, a 10 microfarad electrolytic, minimizes voltage drop at the battery terminals. Capacitor C3 is used to reset the processor.

In the transmitter, R1 limits current and, along with Q1, allows a high-current 40-kHz pulse to be applied to the IR LED's. Resistors R3 and R4 provide pull-up for address lines A11 and A12. On the transmitter, install jumpers A11 and A12.

The system is designed to operate from a +6-volt DC supply. Diode D1 drops the +6-volts DC down to around +5.3 volts. The system works fine without the diode, but it's best to leave it in the circuit because voltages above +5 volts can lower the life expectancy of semiconductors.

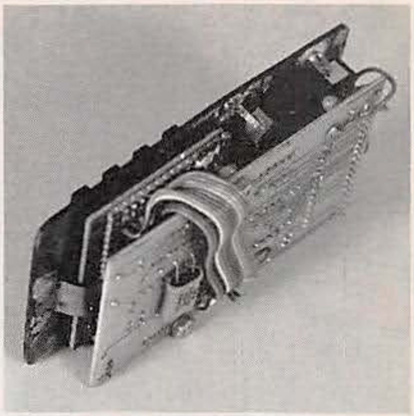


FIG. 10—THE PROTOTYPE TRANSMITTER is housed in a plastic case with a single-sided, copper-clad PC-board blank machined as its top panel.

Building the system

As mentioned before, the transmitter and the receiver are both on the same PC board. You can use the supplied foil patterns to make your own (you'll need at least two), or they are available from the source given in the Parts List. The transmitter and receiver boards are identical except for a few components. Figure 9 shows the parts-placement diagram for both boards. Follow the parts list for the board you are building, and install only the parts in that list. Check off each part as you install it to avoid confusing the two boards. Build the transmitter first, and put it aside when it is done.

Install the capacitors, paying special attention to their polarities. Be sure to install jumpers at the A11 A12 locations for the transmitter only. It's advisable to use sockets in this project. Install the IR LED's and R1. Mount them in any position as long as they can able to radiate IR freely. Gate-pull-up resistor R2 is optional.

Once you are satisfied that all your work is correct, attach the 16-key keypad with a piece of ribbon cable. Cut a piece of copper-clad perforated construction board with holes 0.1-inch on centers to the same size as the keypad. Mount it over the keypad pins and solder the perforated construction board to the keypad pins. This will make it easier to solder and mount the keypad.

A functioning transmitter

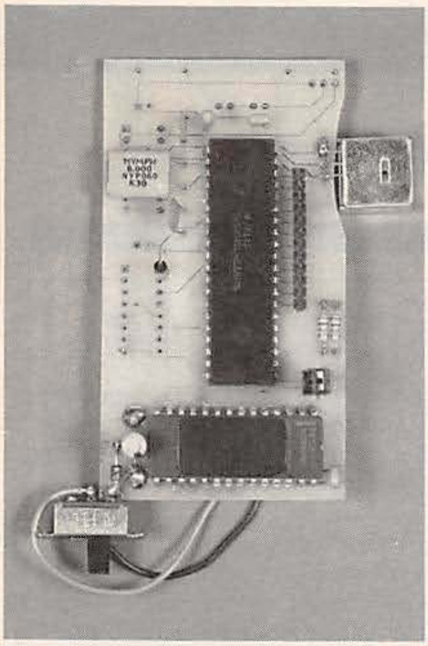


FIG. 11—THE RECEIVER BOARD can be mounted on the project you are adapting it to. You can attach the GP1U52X IR module directly to the PC board as shown here, or run wires to it off-board.

can be tested with the GP1U52X infrared detector module from the receiver. You'll also need a logic probe or scope. Attach a +5-volt DC supply to the GP1U52X (see Fig. 9 for pinout information). Apply power to your probe or scope, which should be connected to the output pin of the IR detector. Apply power to the transmitter and press any key. You should see a change in the scope patterm from the output pin of the IR module if the transmitter is operating properly.

Install the transmitter in a suitable enclosure. A red arcylic lens will improve the appearance of the remote control, but it is not a requirement. The layout of the components on the circuit board is not critical. The prototype is housed in a plastic case with a single-sided copper-clad PC-board blank machined as the top panel (the copper side is installed on the inside of the case). Rectangular openings were cut in the blank for mounting the power switch and keypad. Brass strips, soldered from the copper on the top panel to the copper on the perfboard installed on the keypad, are used to mount the keyboard to the top panel. The prototype has a 6-volt "J"-type battery because of its size and shape. However, any +6-volt DC power source will be satisfactory for this project. The prototype transmitter is shown in Fig. 10.

Now assemble the receiver. Install the parts indicated in the parts list for the receiver and the parts-placement diagram. Attach the GP1U52X to the PC board or, optionally, run wires to it off-board. Be sure to ground the metal case of the module. Install jumper blocks at the A11 and A12 locations as shown in Fig. 11. The figure shows the completed module.

Test the receiver module in the switch mode (jumper A11 and A12 on the receiver). With a logic probe to monitor P10 (pin 27 of IC1 on the receiver), you should be able to toggle P10 by pressing ADD or DEL followed by a 1. ADD 1 should take P10 high while DEL 1 returns P10 to low. If this function works, the rest of the applications will also operate properly. **R-E**

Audio evaluations—A non-mystical approach

LARRY KLEIN

My wife knows far more about computers than I do. In fact, she was working with them professionally in the days when punch cards were the only way to go. Furthermore, she won a science award in high school, regularly use-tested and wrote up VCR's for a home-video magazine, and 14 years ago asked me to marry her. Obviously, an intelligent, clear-thinking young woman ... .

You can imagine my shock when she came home one day with over $100 worth of Estee Lauder cosmetics. She had bought into the female illusion that cheap chemicals in expensive bottles will deliver or restore youth and beauty.

What relevance has all this to the the subject of audio?

Large numbers of intelligent audiophiles continue to seek dreams in expensive containers uninfluenced by cynics such as myself who tell them that they are deluding themselves and depleting their bank accounts for no objective reason. There is no scientific evidence that super-expensive equipment objectively performs better—although they might hear it that way—than the run-of-the-mill products owned by ordinary mortals such as you and me.

Objective/subjective truth

The concept of "objective" is a key confusion block in most audiophile discussions. Music, an audiophile would argue, is a subjective experience, not an objective one. I agree, but *objective reality* exists, and real-world events impinging on our senses are the sources of all of our subjective experiences.

Note that I'm not claiming that an audiophile's subjective experience of quality doesn't exist. I'm saying that the special qualities experienced are usually not being produced by the objective electronic performance of the equipment under evaluation, but reside entirely in the perceptions of the listener. I suspect that other qualities of an amplifier, *e.g.*, its cost, weight, and manufacturer's reputation, might be largely responsible for the superior sound heard by the devout audiophile.

This leads me to question the ethics and good sense of the subjective reviewers who recommend high-end equipment that costs thousands of dollars more than conventional products but which, in truth, sound no better. Happily, there is a way to bypass the "Yes, I hear it, even if you don't" problem. It involves changing the question from "Can you hear the improvement?" to "Can you hear an error signal?"

Nullification

Many years ago, David Hafler, of Dynaco fame, invented a sort of poor man's four-channel system. It consisted essentially of an additional speaker (or a pair of series-connected additional speakers) connected directly across the two hot, or positive, terminals of the amplifier in use. Connecting a speaker in such a fashion feeds it a signal containing only the differences (including those of amplitude and phase) between the two stereo channels. Since out-of-phase "hall ambience" sound is a good part of the difference between the channels on many recordings, feeding it to separate speakers located toward the rear of the listening room provides a worthwhile listening enhancement at very low cost.

Keep in mind that the additional "ambience" speakers are silent when there is no difference between the channels—such as would occur if a mono signal were fed simultaneously to the two channels of a perfectly balanced stereo amplifier.

At some point it occurred to Hafler that the ability to nullify identical signals by a "hot-to-hot" speaker connection could be useful in amplifier testing. A circuit (see Fig. 1) was devised that, in effect, electrically compares the signal going into the amp under test with the signal coming out of it. After adjustment for level differences (using R1) and phase shift, any residual sound that's heard in the null speaker represents the difference between the amplifier's input and output signals. Because the signal (if any) at the null speaker is always much lower in level than the normal program, the normal speaker has to be moved out of listening range to keep its output from overwhelming that of the null speaker.

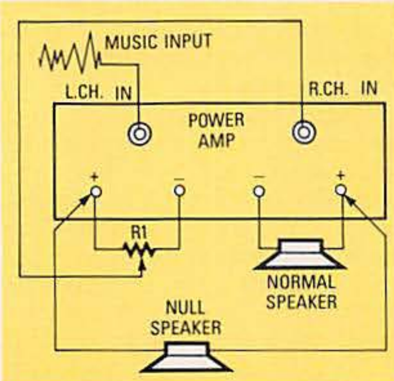


Fig. 1—Circuit for extracting whatever audible differences exist between the input and output of an amplifier.

A perfect amplifier would produce zero signal at the null speaker. In practice, the signal produced is usually low enough so that the error it represents is totally masked during conventional playback by any well-designed conventional amplifier. If one wanted to test the virtues of a particular special speaker cable, it should be used to feed the normal speaker. If the error signal heard from the null speaker is louder (or measures higher) you know that the cable is guilty of introducing unwanted artifacts.

Carver Comparisons

A variant of the nulling technique is used by Bob Carver of Carver Corporation to compare the electrical audio performance—and hence the sound—of two amplifiers. Here, one channel of a reference amplifier and a modified or test amp are connected conventionally to a pair of speakers with a "null" speaker connected across them. (See Fig. 2.) Although not shown in the diagram, there needs to be, of course, a common ground between the two amplifiers and the exact same mono music signal must be fed to both amps. To the degree that the two channels have identical performance, little or no sound will be heard from the null speaker.

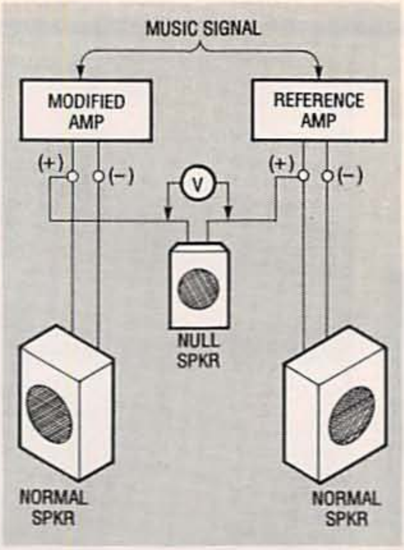
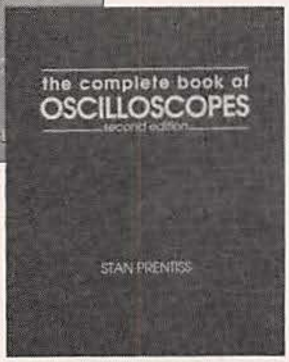


Fig. 2—Connection for comparing one channel of a reference amplifier to one channel of a modified or test amp. The normal speakers, whose purpose is to provide a typical load, are placed out of earshot. The null speaker plays only the difference between the two channels. Theoretically, two identical channels will produce no sound from the null speaker. A meter across the null speaker revealed nulls as low as −70 dB.

In tests where a low-cost amplifier was designed to sound like an amplifier costing thousands of dollars more, nulls as low as −70 dB were measured. Differences of −40 dB will be inaudible due to masking effects.

One would imagine that Hafler's and Carver's test would forever set to rest questions of whether amplifiers sound different, and to what degree. Hafler's test, in addition, would disclose whatever audible flaws exist in an amplifier without the need for a reference or comparison unit. Sad to say, the test techniques have been ignored by testers for audiophile magazines who continues to judge equipment by whether or not it makes them "feel right." But why should we expect any other reaction to tests that would essentially eliminate most or all of the arbitrary judgments and mysticism usually associated with audiophile product evaluations? **R-E**

3610 $28.95



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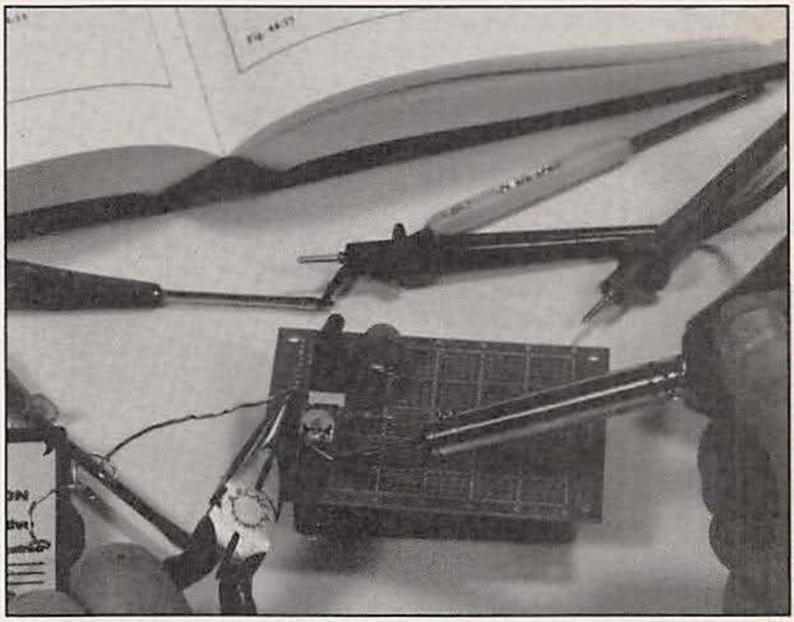

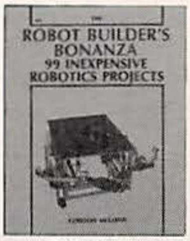

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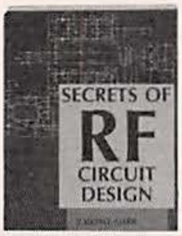

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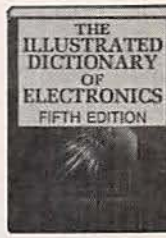

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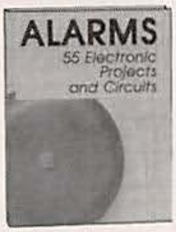

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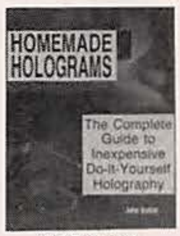

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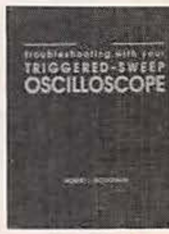

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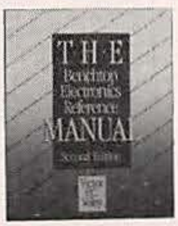

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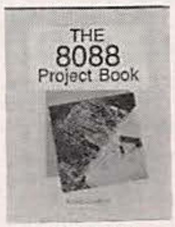

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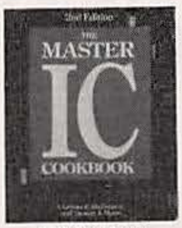

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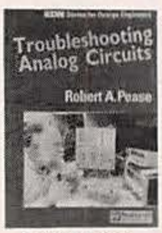

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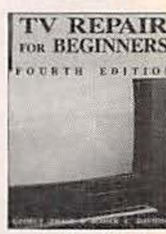

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DRAWING BOARD

Let's build our own video scrambler!

ROBERT GROSSBLATT

We haven't seen very much circuitry yet on our journey through videoland. That's to be expected, though, because video is a subject whose theory you should understand before you start building hardware. As I've already written countless times before, a video signal (shown in Fig. 1) is very complex, with many separate components that are mathematically related to one another.

If you look at a video signal on an oscilloscope, it will appear more or less like the lower waveform in Fig. 1. The most important component of the waveform is the horizontal sync pulse; if you do away with it, the TV won't have any reference for the beginning of a video line, and the resulting image will be misaligned vertically. (See our September column for more on the subject.) The color will also be messed up—without the horizontal sync pulse, the TV won't be able to find the colorburst signal.

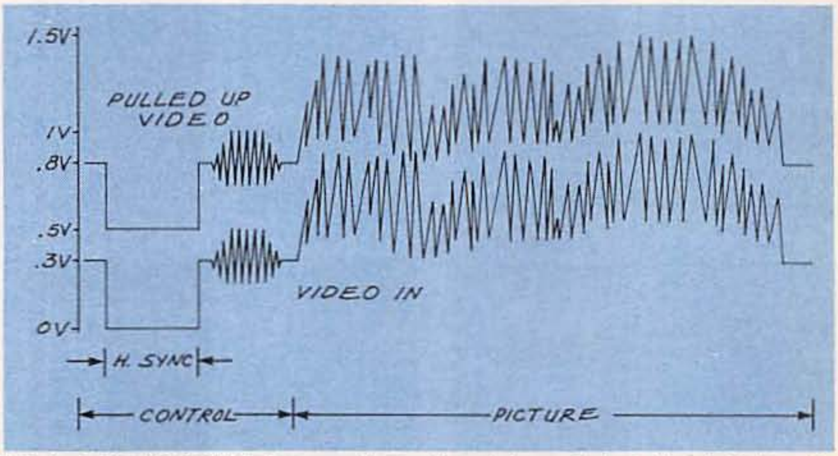

FIG. 1—A VIDEO SIGNAL is normally 1-volt peak-to-peak, but after buffering, the relative voltage level of the signal is raised by 0.5 volts. Then, the only part of the pulled-up video signal that falls below the TTL threshold of 0.8 volts is the horizontal sync signal.

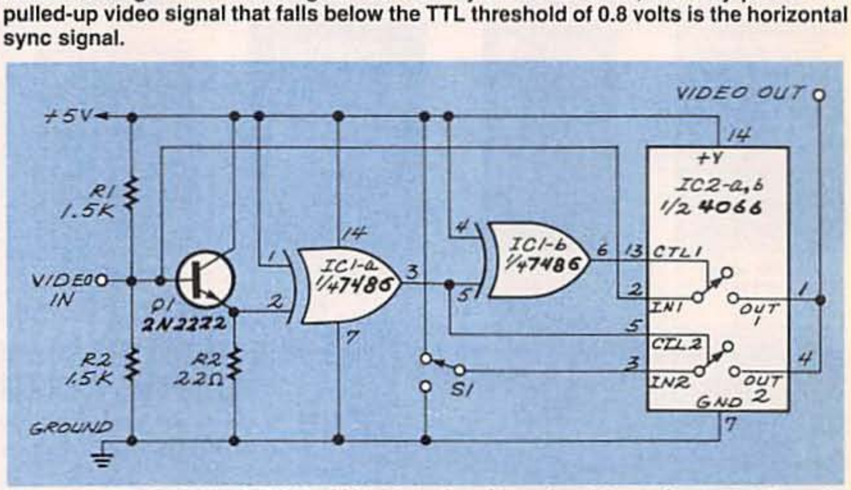

FIG. 2—WHEN S1 PULLS PIN 3 of IC2 high, the video signal loses its sync. When S1 pulls pin 3 low, sync is restored.

Altering horizontal synch

Suppressing the horizontal sync is a simple, inexpensive, and relatively safe way to keep "unauthorized" viewers from receiving a coherent signal. So, to understand better how scrambling works, let's build a circuit that can alter the horizontal sync.

Because we're dealing with composite video, and we intend to play games with horizontal sync, the first thing we have to do is isolate the sync from the rest of the signal. That isn't very difficult—every TV in the universe can do it. Most modern TV's either use a discreet sync separator chip or have the needed circuitry buried in the innards of some custom silicon. That makes things cheaper for TV manufacturers, but it's murder for people like us who have a hard time buying the chip in single quantities.

Fortunately, there's always more than one way to get the job done. In this case, it means looking at the voltage definitions inherent in the video signal, and seeing what we can do with them. Standard video has very strict voltage divisions; everything above 0.3 volts is picture information and everything below 0.3 volts has to be a control signal. (We haven't talked about vertical sync yet, but you'll find that the same voltage levels apply to it, too.)

When you have a 5-volt supply and a signal voltage with a 0.3-volt knee, you should immediately think about standard TTL logic. In that family, everything below 0.8 volts is low, which is exactly what we're looking for. That might not be immediately obvious, so let's go through it.

A video signal is 1-volt peak-to-peak but, by buffering it, the relative voltage level of the signal is raised by 0.5 volts. So, instead of ranging from 0 to 1 volt, the signal ranges from about 0.5 to 1.5 volts. The translated level of the control/picture voltage point is now about 1 volt (see the upper waveform in Fig. 1). You can see that the only part of the pulled-up video signal that falls below the TTL threshold of 0.8 volts is the horizontal sync signal.

The bottom line here is that we can build a sync separator from a standard TTL gate—in this case we'll use a 7486 exclusive-or (XOR) gate. All we have to do, as shown in Fig. 2, is feed the translated and buffered video from Q1 to one input of the gate, and tie the other input of the gate high. (Q1 is part of the buffer that we put together in September to keep your video generator or VCR from being damaged.)

Suppression circuit

If you work out the truth table for yourself, you'll see that the only time the output of the gate is high is during horizontal sync. The output at pin 3 of the 7486 is a TTL-level inverted version of the horizontal sync. That output is fed to another XOR gate, which inverts the signal and gives us a negative-going sync signal. Ability to provide both a positive and negative sync signal is the key attribute of the suppression circuit. We want to build a switch that passes video during the picture portion of the signal and be able to alter the signal during the horizontal sync period. That's what the rest of the circuit does.

The first part of the circuit is a picture/sync separator, and the last part is a picture/sync combiner—sort of. Even though we can put the sync back in, we also have the option of sticking in just about anything else we want in place of horizontal sync.

The combiner uses half of a 4066 analog switch as a double-pole, double-throw switch. (The analog switch contacts close when the control voltage is high.) The outputs of the switch (pins 1 and 4) are combined, but because the control lines of the switches (pins 13 and 5) are connected to mirror images of the horizontal sync signal, we can route the picture portion of the video signal to the switch output when sync is low (pin 6 of the 7486) and route horizontal sync to the switch output when sync is high (pin 3 of the 7486).

The single-pole, single-throw switch (S1) controls the input to pin 3 of the 4066. While it's neat to see the effect S1 has on the video signal when seen on an oscilloscope, this is one of those cases when you're better off seeing the effect on a TV.

Whenever S1 pulls pin 3 of the 4066 high (anything above the expected sync level), the video signal loses its sync and the picture on the TV goes totally haywire. If you've seen scrambled pictures before, you'll recognize it immediately. The left side of the picture will be on the right half of the screen, the right side of the picture will be on the left half. Down the middle of the screen will be the horizontal interval. When S1 pulls pin 3 low, sync is restored and so is the TV picture.

Putting it together

We are not ready to go into the details of the scrambling business just yet, though. A successful scrambler not only has to take the video apart, but it also has to put it back together again. That is quite a bit more difficult. There has to be a way to encode the video signal so that the horizontal sync signal is restored at the right time, and for the right length of time. One outdated way that this can be accomplished is to bury the information in the 31.5-kHz audio subcarrier.

That's not so surprising when you realize that half that frequency is 15.75 kHz—exactly the same as the scan rate of the video lines on a standard color TV. There's not much point in going through all the gory details of recovering suppressed-sync video since it's about as useful as presenting a full tutorial on repairing telegraph lines.

Since suppressed-sync scrambling was figured out by signal pirates about five minutes after it appeared, the people in the television signal scrambling business moved on to more complex methods of screwing up the video signal. The most common method now in use combines a variation on the suppressed-sync method, inverting the video, and performing a lot of weird other stuff. **R-E**

SUPER STROBE

continued from page 37

countering some trouble with false triggering by the sound of the shutter opening, we put the microphone on a tree limb to get it closer to the splash while being careful not to get it in the frame. We covered it with a plastic bag to keep it dry. The SENSITIVITY ended up being set about mid-range. Figure 15 shows one of our efforts at catching a stone skipping across water.

Exploding capacitors

When the editor speculated on what an exploding capacitor might look like, we decided to find out... despite our better judgment. Do not try this at home! The fumes that are generated are noxious and toxic. A fire extinguisher, proper safety clothing and eye-protecting goggles are essential precautions.

We learned that there's not much more to be seen of an exploding capacitor with the strobe than without it. However, the picture that we chose to illustrate what happened (Fig. 16) is slightly more dramatic because the smoke, which would not have shown up otherwise, was illuminated by the strobe. To try to get a more interesting shot, we even piled a group of electronic components on top of the cap thinking we could get a picture of them flying into the air. That might have worked eventually, but when our eyes started to water from the smoke we decided to take a break, and we just never got back to this experiment.

Your turn

These photos and the explanations of how they were set up and shot should get you started. The only rule is that there are no rules; you really get to make them up as you go along. We have a standing bet about how much a golf ball deforms when it's hit. If you find out before we do, let us know. **Electronics Now** will be happy publish the best Freeze Frame pictures we receive. R-E

COMPUTER CONNECTIONS

Gigabyte memory storage

JEFF HOLTZMAN

H*igh-density* is about to take on a whole new meaning for dynamic random-access memories. Hint: In the past RAM density always increased sequentially by powers of two (2, 4, 8, 16, . . .). Earlier this year, IBM introduced 16-megabit DRAM's for its AS/400 minicomputer. The next step for IBM should have been 32 megabits, but that's already old hat. As has been widely reported, IBM is now cooperating with Siemens to develop 64-megabit DRAM's.

More recently, Big Blue announced an even more ambitious international development effort: it will now pool its resources with those of both Siemens and Toshiba to produce 256-megabit DRAM's—bypassing 128 megabits—built with quarter-micron trace widths. It would take 400 of these lines to equal the width of a human hair!

Think about it. When many users are still moving up to 4-megabit DRAM's, nine of those babies to be developed would provide 256 mega *bytes* of memory! That is from 16 to 64 times better than the memory capacity that today's higher-end Windows-compatible workstations limp along on. Now consider a combination of a bank of 64-megabit DRAM's with an Intel P5 CPU and an XGA/DVI graphics subsystem, all on a single chunk of silicon. Soon the serial, parallel, and network port connectors of a computer will take up more space than the electronics!

Imagine the possibilities. We'll buy "dumb" highly stylistic display units with keyboard and stylus inputs (DUKSI's). Each DUKSI will have a socket that accepts a complete computer-on-a-chip, in a multitude of styles. They'll give customized performance for different users, and permit easy upgrades. DUKSI's will be sold retail like Ralph Lauren brand-name clothes in a variety of styles to engineers, technicians, executives, students, and even homemakers.

Neither the DUKSI nor the computer module will cost much to make; they'll be produced by robots and, unless there are drastic changes in global business conditions, they won't be made in the good old U.S of A. Large profits will be generated from designing, selling, and reselling highly stylized, fashion-conscious DUKSI's. People would buy new DUKSI's from time to time, not for technical upgrades, but for personal satisfaction—like buying new clothes.

The DUKSI will be part of every schoolkid's lunch box, every manager's briefcase, every doctor's bag, and every technician's tool kit. Within ten years, they'll connect without wires to all major telecommunications services and provide on-demand connectivity to any node on the networks. Within twenty years, they could connect to all compatible electronic devices—telephone, fax, copier, television, or stereo.

If Microsoft has its way, Windows software will be an integrated part of this encroaching World Net. Recent reports suggest that Microsoft is actively investigating ways to adapt Windows for other environments. Those could include envisioned devices called portable digital assistants (PDA's) and next-generation video games (the "Wintendo" discussed here last time). They

FIG. 1—DATABASE PUBLISHING is a snap with InfoPublisher. Extract the data from one or several joined dBASE, Paradox, Oracle, or SQL Server files, select desired rows and columns, apply formatting, and then export the data to popular DOS and Windows word processors and desktop publishing programs.

might also include office machines (faxes, photocopiers, and telephones), and personal telecommunications, which depend on computers to control access to news, sports, entertainment, and business information.

A chip in the hand

There's good and bad news about Intel's forthcoming P5 microprocessor, sometimes (erroneously) called the 586. The good news is that public hands-on demonstrations (including those for the press) prove it to be screaming fast. It makes smooth-scrolling 3-D animation possible, and it allows text scrolling under Windows almost as fast as character-based text on a 286 under DOS.

The bad news is that introduction of the chip has been delayed until early 1993. Intel apparently wants to make sure that there are no bugs in the P5 and that the company can meet high-volume production demand. That bad news is tempered by the possibility that its later introduction is likely to spur further price cutting in the active 486 microprocessor market.

As for its departure from its usual practice in naming microprocessors, Intel appears to be intent on distancing itself from the chip-clone companies (AMD, Chips & Technologies, Cyrix, NexGen, et al). It is holding an internal contest to develop a new name that does not contain the "86" moniker. It appears that marketing has become more important in selling microprocessors than we would have thought possible.

Intel has signed a deal with VLSI Technology under which VLSI gains rights to x86 technology. VLSI is expected to put that technology to work in building new devices that will be customized for handheld and other portable computers.

However, one recent study shows that the market for handheld and pen/tablet based PC's will not take off as rapidly as was initially expected. According to that study, laptops will gradually drop out of sight between now and 1996. Notebooks will pick up most of the slack and provide the largest share of new growth. Combination stylus/keyboard units are also expected to show significant growth. Pure pen-based systems will just be getting off the ground by then.

Product watch

InfoPublisher, an innovative niche product, functions as an interface between a database and a publishing system. It allows you to extract the information you need and publish it in a form that makes sense. On the database end, InfoPublisher can read dBASE, Paradox, and ASCII text files. It can also connect to SQL-based client-server databases including Oracle and SQL Server.

On the publishing end, InfoPublisher can connect to Word, WordPerfect, and Ami Pro for Windows, several versions of PageMaker, and DOS versions of Word and WordPerfect. InfoPublisher runs under Windows, so its operation is most efficient operating in that environment.

Why would you use InfoPublisher? A database manager allows you to sort and select data, and print reports based on them. Report formatting, however, typically leaves much to be desired. Of course, you could export a sorted and selected subset of your data as ASCII, import it into your word processor or desktop publisher, and format it there. But doing that typically involves a *lot* of grunt work. Imagine formatting each field of a 1000-record database manually. Then imagine having to repeat the whole process after updating your database!

Bridging the gap is where InfoPublisher comes in. It offers a friendly, spreadsheet-like user interface that allows you to query your database, apply formatting, and then export the results for fine-tuning and printing with your favorite printer. The best part is that you can save a query/formatting combina-

Products Discussed

• InfoPublisher ($795), PageAhead Software, 2125 Western Avenue, Suite 301, Seattle, WA 98121. (800) 967-9671, (206) 441-0340.
CIRCLE 000 ON FREE INFORMATION CARD

• NTSC ($25), ItWorks, P.O. Box 7403, Chico, CA 95927. (916) 893-1714.

tion and reuse it again after updating a database.

The program permits the creation of sophisticated database queries. Queries can be specified in a query-by-example (QBE) mode or by typing in SQL commands directly. You can begin in the QBE mode and then edit the SQL statement directly. Unfortunately, the process can't be reversed (you can't return to QBE from SQL). With simple commands you can select any or all columns (fields) of a database, sort rows (records) in ascending or descending order on as many as ten columns, and as an option, use easy-to-customize sort sequences.

You can also replace data (e.g., spell out abbreviations), create query expressions with arithmetic operators and create operators for a flock of functions: greater than, less than, equal, not equal, is null, is not null, is like, is not like, and more. In addition you can combine several expressions with Boolean operators (and, or), create calculated fields in the output table (e.g., price × 1.04 for inflation), and perform related relational joins between several tables.

After performing a query, InfoPublisher presents a work table in which you can rearrange columns, apply formatting (e.g. font, size, bold, and italics) on a row, column, or cell basis, sort the table, specify date and numeric formats, specify capitalization rules, and rearrange data. As an example you might want to change "The Hitchhiker's Guide to the Galaxy" to "Hitchhiker's Guide to the Galaxy.").

InfoPublisher simulates formatting by showing the proper font along with bold and italic attributes, but not point size. Each field can be preceded or followed by a tab, a "soft" return, a hard return, one or more spaces, and an arbitrary text string.

When everything looks right, you export the data. You can set up DDE links between InfoPublisher and, for example, Word for Windows. But performance (even on a 25-MHz 486DX) is pretty slow for a database of any size. You can also cut and paste data through the Windows clipboard, or export data to a separate file.

Let's assume you want to publish a customer database with name, address, and phone number. To separate entries in the printout you want the name to appear in boldface type, followed by the right-justified phone number, with the full address appearing on succeeding lines. In InfoPublisher's Work Table, click the column heading above the customer's name and press the "B" tool on the toolbar. Then click the line beneath the column heading and specify that that field will be followed by a tab.

Then click the corresponding point above the phone number field, and specify that it will be followed by a paragraph mark. When you bring the data into your word processor, set a right-justified tab stop, and voila. (Using styles makes the process even more efficient.)

I found one bug in the program: The fixed-length ASCII import filter caused a general program failure (GPF), and terminated the program. The vendor's technical personnel promised that the bug would be fixed in the next release, which is due to be released around the time you read this.

All in all, InfoPublisher is a pleasure to run. The QBE facility works like a charm, and its ability to save query/format specifications save a tremendous amount of time over traditional methods. The documentation is well written and well produced, but a quick reference guide to the multitude of query and format options is desperately needed. It has some bugs, and the user interface needs tuning, but even in version 1.2, InfoPublisher is a winner in our book.

SCSI hint

Having trouble interfacing two SCSI drives to the same system? I was when I was adding a second drive to my main system. The two drives were made by different manufacturers, and by themselves, both drives worked fine. But as soon as I connected them, things went crazy. The chief symptom was a disturbing clicking sound when I booted the system. Technical information provided by four vendors (drive A, drive B, the SCSI host adapter, and the distributor of the second drive) could suggest little more than making sure that the last drive on the bus had proper terminating resistors. Also they said no two drives should have the same SCSI ID. Big help.

It turned out that the problem was caused by EMI—with emphasis on the *M*. The older drive, a large 5.25-inch model, was apparently generating a large magnetic field that interfered with the newer one, a compact 3.25-inch job. After separating the drives by the distance of several drive-bay positions, the problem went away. Both drives now function as advertised.

Shareware corner

Quick—what's the difference between RS-170 and RS-170A? What's the delay in nanoseconds per foot of 75-ohm RG-59/U coaxial cable? What color do you get when green and blue phosphors on a CRT are both active? How many lines are in n and what is the aspect ratio of the proposed American HDTV system?

The answers, along with a veritable cornucopia of video and television-related data, are available in a DOS program called NTSC. The program was written by Anthony Watts, a TV meteorologist and systems engineer who also designs graphics systems for television weathercasts.

NTSC has six sections: NTSC signal parameters (e.g., sync level, back porch time, and horizontal sync time), a glossary of terms, a calculator for calculating delays and cable lengths, specs for numerous video formats (RGB, SVHS, RS-170, PAL, SECAM, and more), test patterns, and a list of TV-channel frequencies. Mr. Watts has packed more information into this little $25 program than you could get from half a dozen reference books. I'll post a copy on the RE-BBS (516-293-2283). If you prefer, you can contact the address in the sidebar.

Answers (don't cheat): 1) RS-170 is the EIA standard that describes NTSC composite black and white video, and RS-170A is for color; 2) 1 foot = 1.540 nanoseconds; 3) Green + Blue = Cyan; 4) 1125, 16:9 **R-E**

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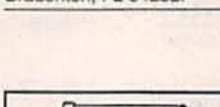

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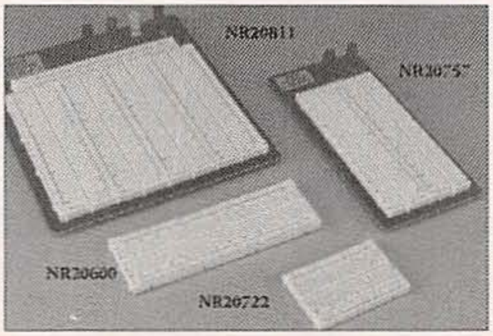

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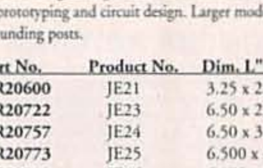

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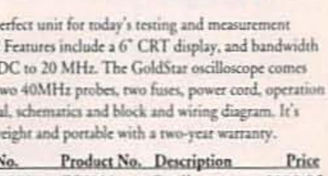

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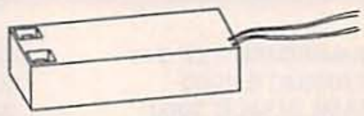

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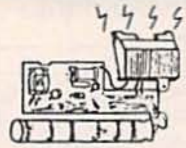

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CONSUMER CORNER

New solid-state and digital TV sets, stereos, and videorecorders are tougher to repair than old-fashioned tube type sets and require special training for the service technician who works on them.

Only a few states have laws requiring competency tests for licensing technicians who repair consumer electronics, but fifteen years ago the International Society of Certified Electronic Technicians (CET) began its own certification program to qualify these technicians and those in industry. To carry the CET designation, technicians must have four years experience and pass a rigid examination on general electronics and a specific area of expertise such as audio or radio-TV.

Many consumers look for a Certified Electronic Technician in the shop when they need any electronic item repaired.

Free Consumer Checklist

A consumer checklist for selecting a service shop is available free by sending a stamped, self-addressed envelope to: Checklist, ISCET, 2708 West Berry, Fort Worth, TX 76109. The list reminds consumers to check such items as "Does the business have the parts for your particular brand?", "Did you get an estimated price?", and "Did you check this company with the Better Business Bureau?"

Modern electronic equipment such as digital TVs or stereos should be repaired by specially trained people.

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