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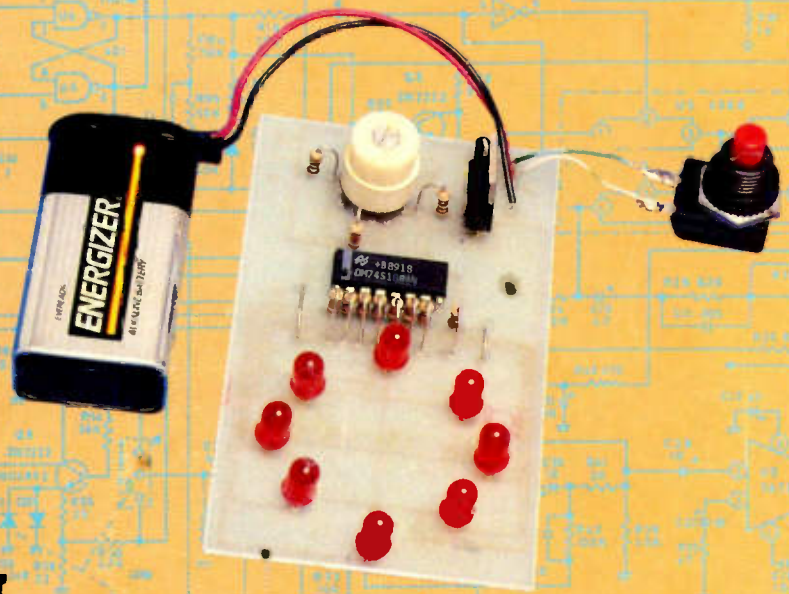
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In case you're not all that familiar with us, we're not a publication for electrical engineers and other wizards. No way, **ELECTRONICS HANDBOOK** is expressly for people who like to build their own projects and gadgets—and maybe get a little knee-deep in tape, solder and wire clippings in the process.

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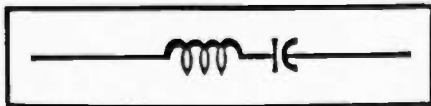
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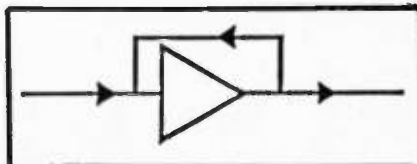


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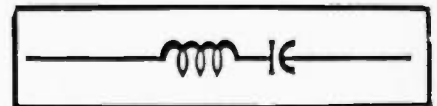
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The Waveshaper
A Switch With A Memory



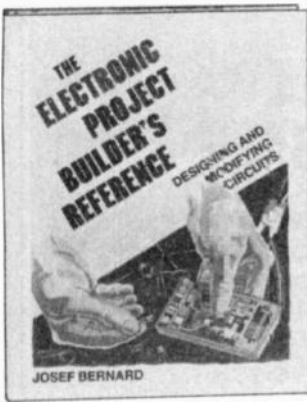
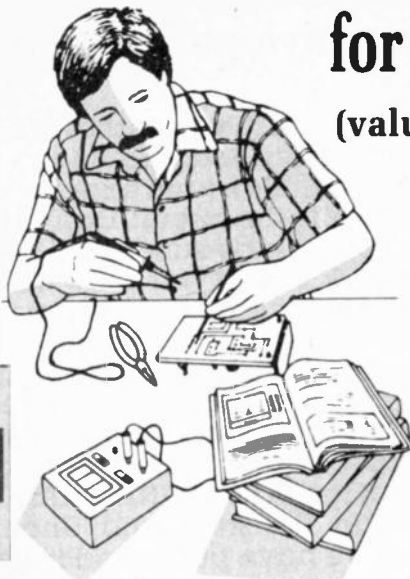
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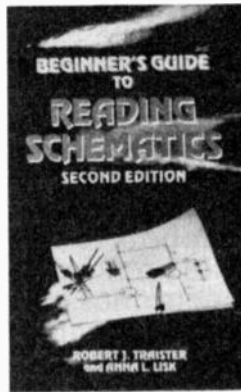
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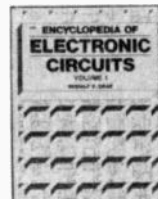
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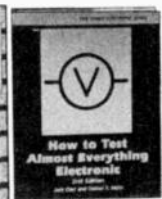
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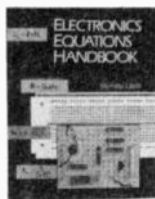


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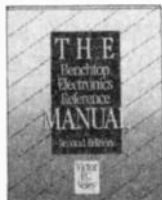
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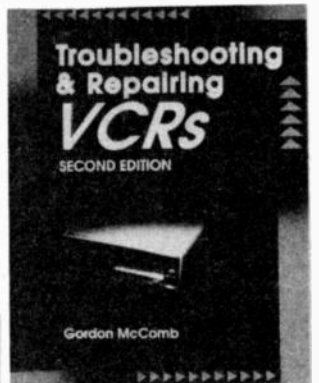
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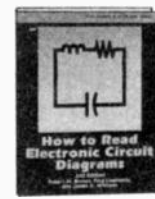
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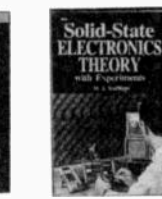
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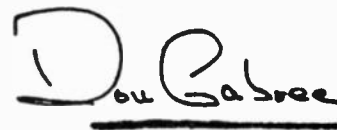
GETTING STARTED WITH ELECTRONIC PROJECTS

Once you've decided to put together the parts that make up a circuit there are several things that you should do before starting actual work. The first is to understand exactly how the circuit works; what each part does in the circuit. Don't just put it together hoping it will work. You can be sure you have put it together properly, so that it'll work, only if you know what each component does to the flow of electricity (electrons) going through it, as well as through the rest of the circuit.

If you don't understand the circuit thoroughly, every part as well as its function, read the article again, carefully, until you do. If that's not enough, look up words you're not familiar with in a good electronics dictionary. Read the "teaching" articles that we include in every issue of the ELECTRONICS HANDBOOK, like the ones on "Capacitors" and "Resistors" and "Understanding Schematic Diagrams" that we have published in previous issues.

Another caution is in order, even if you've worked with electronic parts before but haven't handled integrated circuits (ICs). Be sure to observe these simple precautions:

Don't mount the IC directly into a circuit or solder its terminals into the circuit. Instead, do what experienced experimenters do—solder an IC socket into the circuit (unless you're using a quick-assembly experimenters board, in which case you'll just plug the socket into the board's holes). Also, don't handle the IC any more than necessary, to keep from damaging it with static electricity. Most ICs are sold mounted temporarily in a little piece of anti-static foam. Keep the IC in its foam mount until you're ready to plug it into a socket. Finally, keep excessive heat away from ICs, particularly when putting them into a circuit with a soldering iron (another good reason to use a socket whenever possible).



Don Gabree,
—Publisher

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How would you like to find your own home-brew project in a future issue of the ELECTRONICS HANDBOOK? It could happen. It's up to you! Build your project for yourself...It should have a real purpose. Then, if you think that it is good enough to appear in the ELECTRONICS HANDBOOK, let us know about it...

Write us a brief letter describing your project. Tell us what the project does. Provide us with a legible schematic diagram and a few black-and-white photographs of the project...photos, with good contrast, are important. After we have read your letter describing your project, we'll let you know, one way or the other, whether we would like to purchase your article describing the project.

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ELECTRONICS HANDBOOK

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EDITORIAL DIRECTOR
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FROM THE EDITOR'S DESK

Ask The Editor, He Knows!

Got a question or a problem with a project — ask The Editor. Please remember that The Editors' column is limited to answering specific electronic project questions that you send to him. Personal replies cannot be made. Sorry,

he isn't offering a circuit design service. Write to:

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Inscrutable Japanese TV

Recently I returned from Japan, and I brought a Japanese-model Nintendo and cartridges home with me. Now I find that their TV signal is different from the American signal, and my trusted toy won't work on my set.

Is there a commercially made adapter available, or is it possible to make one? What is the difference between the signals? I will appreciate any help you can give me. You see several of my cartridges are exclusive to the Japanese market and are unavailable here, i.e., Japanese chess, go, and Chinese chess.

—Dale Oldfield, Pinedale, WY

According to the references that I have checked, Dale, there is no difference between Japanese and American television signals. Both nations use the NTSC method of encoding. Assuming that your Nintendo was not damaged in transit, the only reasonable explanation for the incompatibility you've experienced is that Japanese frequency assignments for the various channels are different from ours. That being the case, it may be possible to retune the output of your Nintendo so that it falls on one of the standard American channels. Such an adjustment would probably be effected by tweaking a variable capacitor or inductor. I'd write to Nintendo of Japan and see what they have to say. (Their U.S. affiliate may not know anything about the Japanese product.) Perhaps they will allow you to exchange your Japanese model for an American model if retuning is not possible.

Spies Like Us

Do you have any information about obtaining kits or schematics for the following: electronic dissolution of memory devices, using infrasonic sound waves; ultrasonic sound devices for crowd control; laser or microwave transmitters? Also, do you have information on detecting dentally implanted transmitters used by such agencies as the FBI, CIA, etc. Thank you for your prompt attention.

—R.G. Hellstrom, Lexington, KY

*I'll answer your questions in the order you've presented them. Devices capable of obliterating memory are beyond the editorial scope of this magazine. **Electronics Handbook** is supposed to be "the fun way to learn electronics," and to be honest, R.G., scrambling someone's brains with infrasonic acoustic energy doesn't sound like much fun—not for the victim, anyway.*

*Ultrasound devices designed to intimidate dogs and other attackers are available from a variety of sources. **Information Unlimited (P.O. Box 716, Amherst, NH, 03031)** offers several plans and kits. Note that ultrasound devices by themselves may not be sufficient to control a large, hostile crowd of people, particularly if they all stick their fingers in their ears.*

I assume that your interest in laser and microwave transmitters stems from a desire to eavesdrop on a building with restricted access, where it would be impossible to plant a microphone. The Russians used this method to spy on our embassy in Moscow during the early sixties. They concealed a cavity resonator

*inside the Great Seal of the United States, which hung above our ambassador's desk, and bombarded the resonator with a beam of microwave radiation whenever they wanted to listen in. The beauty of the scheme was that the cavity resonator was a passive device and thus almost impossible to detect. I don't have any information on microwave eavesdropping, but an article entitled "Build the Laser Listener" by Richard Pearson, which appeared in the October 1987 issue of **Radio-Electronics**, tells all you need to know about laser eavesdropping.*

*Detecting the presence of a transmitter is accomplished by intercepting its signal. Professional spooks rely on expensive scanning receivers for this purpose, but all you really need is an ultra-sensitive field-strength meter capable of being tuned over the frequency range of interest—typically, 50 to 500 MHz. **Information Unlimited** offers plans and kits for a bug detector that should serve your needs.*

Just as the eighties are remembered as the decade of personal computing, it may well be that the nineties will be remembered as the decade of personal espionage. There are shops now in New York and other large cities where spy gadgets of all kinds are openly sold, and it's not just the weirdos and PI's who are buying them. People from all walks of life apparently feel the need to spy on those around them. In most cases, when we speak out against the invasion of privacy, it's Big Brother who is the villain, but I'm beginning to feel that Pogo came closer to the truth when he said: "We have met the enemy, and he is us."



Eico 460 Dead at 30

Just by chance I picked up your magazine at a drug store last year. I have since ordered five back issues and have enjoyed them all. My reason for writing at this time is to ask for your help. I have an oscilloscope, an Eico 460, which I ordered from Allied back in 1960 as a kit. It gave me good service for a long time, but now it needs some TLC. I'd like to know where I can get service data for this instrument.

—M. M. Campbell, Woodstock, GA

At one time, Eico was Heath's major competitor, but unfortunately the company went out of business years ago. I imagine that any of the major service organizations that specialize in test instrument repair could fix your scope, but the cost might be prohibitive. You might try **Tucker Electronics (1717 Reserve St., Garland, TX, 75042)** and see how much they charge. Perhaps they would sell you a photocopy of the Eico service data. If any of our readers have service data for the Eico 460 and are willing to help M. M. out of his predicament, drop us a line, and we'll put you in touch with Mr. Campbell.

More Thoughts About Tools

I am writing this letter to call your attention to an article on "Essential Tools for Electronic Construction" by Walter Sikonowicz (Vol. VII of **Electronics Handbook**). The question Walter brings up about straight-line cuts in PCBs is always something of a problem. I priced the Kepro Model MS-6 shear and found it to be rather expensive. The alternative, using a nibbler, gets to be rather tiresome. A friend at work suggested that I try the following company, which specializes in small tools: **Micro-Mark, 340 Snyder Ave., Berkeley Heights, NJ, 07922**. I have xeroxed three pages of their catalog containing alternative devices to deal with this problem. What is

your opinion of these tools?

—Joe Toms, Forest Hills, NY

First of all, thanks for the tip about Micro-Mark, Joe. Their catalog looks like a good one. The devices in question—small, benchtop-mounted table saws and jig saws—are intended for use by model builders, but I see no reason why they should not also do a good job of cutting PCB laminates. Just be sure to use a very fine saw blade. When sawing glass-epoxy, commercial fabricators of PCBs use carbide-tipped blades, because glass-epoxy is a very abrasive and rapidly dulls a conventional steel blade. For home use, however, a conventional carbon-steel blade will be satisfactory. Paper-base phenolic laminates (XXXP) are much less abrasive than glass-epoxy, by the way.

Fast Beat, Slow Feet

I need any information you can provide on a 12 VDC motor-speed control that could be applied to a tape cassette player. I am trying to help a group of young people in a clogging club. Clog dance music is usually fast, and we wish to control the tempo of new tunes while learning them or while teaching new members. Can you help? I am thinking in terms of a chopper-style control.

—R.T. McMillan, Huntington, WV

A friend of mine, a retired professor of electrical engineering, describes clog dancing as one of the few forms of exercise that you don't have to be a masochist to enjoy. Clog dancing, which has its origins in the Appalachian region of the United States, takes its name from the distinctive wooden-soled clogs that the dancers wear on their feet. When the dancers kick up their heels, the clogs make a pleasant clattering rhythm as they hit the floor.

Getting back to the question at hand, R. T., I think that the use of a chopper-style speed control

would, in this instance, be overly ambitious and expensive. All you need to do is insert a 50- or 100-ohm potentiometer in series with the "hot" power lead running to the motor that turns the capstan and take-up reel in your cassette recorder. Increase the resistance (by rotating the shaft of the pot) until the speed has decreased to an acceptable level. Needless to say, you should make these modifications on a cheap, expendable cassette deck. More expensive cassette players will sometimes have a built-in speed adjustment. For example, the Sony Walkman WM-D6 allows the tape speed to be varied by 15%, which might be enough for your purposes. The big disadvantage of trying to control the tempo of music by varying the tape speed is that the pitch of individual notes is also affected. Cutting the tape speed in half, for example, cuts the tempo in half and lowers all the notes one octave, making your fiddle sound like a cello.

How Long Do CDs Play?

I bought a CD of my favorite chart-toppers and it had only 13 cuts, totaling 36 minutes and 44 seconds of music on it. Is there some reason we can't get a full hour or so when we pay \$15 or more for a CD? And what's the most they can put on a CD, anyhow.—Melvin Danzig, Perth Amboy, New Jersey.

You're right, some record producers do put surprisingly small amounts of music on CDs. It seems to be the decision of the company to put out just what the artist (and the A & R supervisor) want to release on a new disc. They could easily put more music out at little increase in cost to them; at least 60 minutes. Up to 70 or more minutes can be fitted on today's CDs. For example, Arista has 25 tracks for a total of 72 minutes, 30 seconds on the recently-released Monkees **Then and Now** CD.

NEW PRODUCTS PARADE



HAM-TIME

Just when you think that you have seen it all, you find that you haven't scratched the surface.

From **ECode Systems, Inc.** we find that they have introduced a digital clock simulator, designed primarily but apparently, not exclusively, for the Ham radio operator that will make life easier around the "Radio Shack" and appropriately called "**Ham-Time.**"

If you are not into Ham radio, you might adapt it to numerous other practical functions in your daily routine, such as your photographic darkroom. Its versatility will challenge your imagination.

For the Ham radio operator, however, the Ham-Time is designed for both Desktop and Laptop computers. It will let you give function to your idle MS-DOS computer. In the "Radio Shack," Ham-Time provides the perfect way to check local and GMT quickly. The built-in time zone displays allow you to quickly determine the time anywhere in the U.S.A. and Canada or, for that matter, anywhere in the world, with a user programmable screen.

Specifically, the Ham-Time performs the following functions:

- Local/GMT dual display
- Snooze Alarm
- U.S. time zone display
- Audible time indicator
- Sports/Laboratory dual timer
- Fully functional alarm clock
- Event count-down timer
- 12 hour or 24 hour modes
- Cities of the world time zone display
- User programmable time zone display

HAM-TIME

- Local / GMT dual display
- Snooze alarm
- US time zone display
- Audible time indicator
- Sports / Laboratory dual timer
- Fully functional alarm clock
- Event count-down timer
- 12 hour or 24 hour modes
- Cities of the world time zone display
- User programmable time zone display



The "Event" timer allows the user to count down the amount of time remaining in a given event. This counter can be set from one second to 99 minutes. It counts off the time in 1/10th second increments. The timer can be suspended at any time. When restarted, the timer begins from the suspended value. The user also has the option of having an audible alarm sound when the event has counted down to 00:00. The "Event" counter comes in handy for timing speeches and presentations, or code practice. The large display makes it easy to read the remaining time from across large rooms.

The "Lap" timer allows the user to keep track of event times within a total amount of time. Perfect for auto racing, sporting events, or laboratory experiments. The counter increments in 1/10 second intervals. The function keys control the counting of both the lap time and the total time. The space bar of the PC can be used as a convenient way to control the lap time. The large number display makes it easy to read and record time results as they happen.

The U.S. "Time Zone Display" provides a quick way to get the time across the country. This display provides a means to check the time in a remote part of the country you are planning to call or make schedule arrangements. The time can be displayed in both 12 hour and 24 hour modes, continuously being updated on



the minute.

The "Cities Around The World" time display allows you to keep track of the time anywhere in the world. The display can be operated in either 12 hour or 24 hour mode. This display can be customized by preparing a text file to substitute specific cities and/or call signs in the same geographic areas. This display can be extremely helpful in understanding when international news events are taking place or making schedule arrangements with other stations.

For readers who are interested, "Ham-Time" has a modest price of \$24.95 and requires: CGA or EGA graphics adapter, MS-DOS 2.1 or later and 128K memory, available in 3.5 or 5.25 inch disks. Address questions to **ECode Systems, Inc., 335 West Virginia, Phoenix, AZ 85003 (602) 257-1826.**

ANALOG/DIGITAL DMM

Soar's 3200 Series 3-1/2 digit multimeters combine the features of a state-of-the-art digital multimeter with an analog bar graph display. The high-resolution 3200-count digital display delivers the resolution of much costlier 4-1/2 digit meters for measurements above 2,000 counts. The 32-segment bar graph display is ideal for readings that change—peaking, nulling and observing trends. These DMMs are simple to use. Just select your function with the handy 8-position rotary switch and test. The meter automatically selects the range with the greatest accuracy and resolution. The function and measurement range are even shown on the LCD



display. Touching the RANGE button on Models 3220 and 3230 prevents the instrument from changing ranges, which saves time for repetitive go/no-go checks. Both models also have an audible continuity feature which causes the meter to beep when the circuit under test is closed. After pressing the DATA-H button on Model 3230, the meter captures the measurement, beeps, and locks it on the display so you can focus your attention on the probes and circuit. With this data hold feature, the DMM automatically updates for each new measurement. All 3200 Series multimeters come with safety test leads, operator's manual, batteries, spare fuse, and 3-year warranty. And each meter is priced under \$100. For further details write or call: **HMC Co. P.O. Box #526, Canton, MA 02021 (617) 821-1870.**

DESOLDER STATION

OK INDUSTRIES addresses the problem of desoldering PCB's with high thermal demands by introducing a new high power desoldering station. The SA-600 design incorporates a unique high capacity nozzle, high power heating element and quick-rise vacuum pump (21"Hg) to optimize efficiency.

The SA-600 offers a safe 20V handpiece with a 65W heating element for excellent heat recovery and temperature stability. The high mass desoldering nozzles provide superior heat capacity, allowing efficient solder flow at lower temperatures. Featuring vacuum and hot air blow functions, the SA-600 has a variable temperature range of 660° F (350° C) to 840° F (450° C).



This desirable combination of high vacuum pressure for suction and high heat capacity nozzles contribute to the SA-600 being a performance leader for desoldering and rework operations.

The SA-600 is sold through OK Industries authorized distributors at a list price of \$557.50. For more information, contact **OK Industries, Inc., 4 Executive Plaza, Yonkers, N.Y. 10701 or call: 1 800-523-0667.**

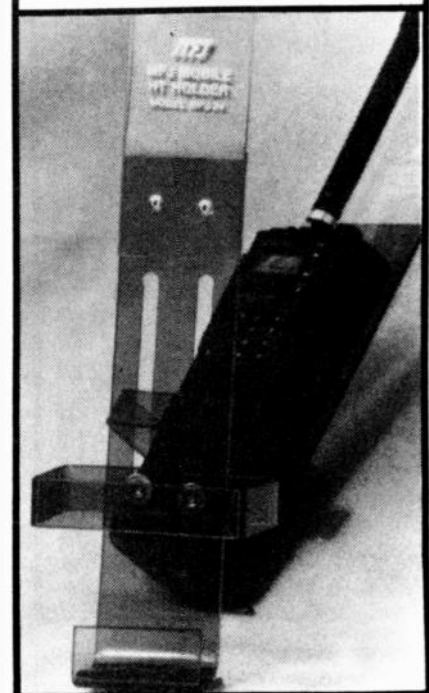
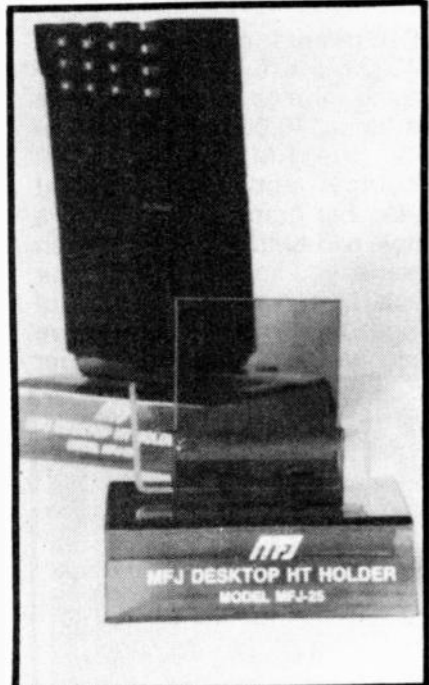
HANDHELD HOLDERS

MFJ Enterprises, Inc. announces the release of new Mobile and Desktop HT Holders for only... \$9.95 each.

These handy new MFJ HT holders help you make sure your handheld stays where you put it—in your car or on a crowded table or desk. MFJ-24 has a strip of durable plastic that bends to fit snugly over your car door, front seat or other area.

MFJ-25 stands on your table or desktop.

They're an economical way to help guard against dropping your expensive HT. Both units provide for both large and small HTs.



For more information contact any MFJ dealer or **MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, MS 39762, or call (601) 323-5869, Telex: 53 4590 MFJSTKV, FAX: (601) 323-6551, or order toll free at 800-647-1800.**

NEW PRODUCTS PARADE

DIGITAL MULTIMETER

Beckman Industrial's Model RMS225 is a full function, auto-ranging, 4-digit multimeter that combines 10,000-count resolution, true RMS measurement accuracy, and a 41-segment analog bar graph display. With a simple two-button menu selection scheme, you can engage the four special measurement modes of Range Lock, Probe Hold, Relative Mode and Auto Min/Max. Other



features include a battery-saving Auto Power Down mode and Overload Alert, which warns you if the meter input ratings are exceeded. The high performance, dependable, and easy-to-use Model RMS225 comes complete with test leads, protective holster, self-resetting fuse, and a 3-year warranty.

For further details, contact HMC, 33 Springdale Avenue, Canton, MA 02021, Phone (617) 821-1870, FAX (617) 821-4133.



PROGRAMMABLE SOLDERING STATION

From Contact East a new programmable soldering station that has a tamper-proof temperature setting, quick heat up, and increased thermal recovery permitting consistent, high quality soldering, with less dwell time on multilayered boards and heavy ground planes. Temperature can be set on the digital key pad, from 400° to 899° F, with an accuracy of +/- 0.9° F. Once the temperature is set, unauthorized personnel cannot change the setting without the programming card. The temperature memory system allows the iron to be shut off and turned on without having to reset the iron each time. The housing, iron and cord are made of static-dissipative material—ideal for static-safe areas. Resistance to ground is less than 2 ohms, and leak voltage is less than 0.6mV.

Priced at \$299.00, hobbyists may find the cost a little steep for their workbench but for the hobbyist who has everything, this has to be the ultimate in soldering iron stations.

The station comes complete with iron-holder, sponge, programming card, 50W iron (with A1016 tip) and operates on a 115VAC (3 wire cord).

For additional details and/or information, write or call Contact East, 335 Willow Street, North Andover, MA 01845 (508) 682-2000.

SHORTWAVE/AIRCRAFT RECEIVERS

From Ramsey Electronics, Inc., Do-It-Yourself kits to build a Shortwave Receiver that will tune in the world with a 12" antenna (SR-1 \$27.95). This little Receiver can receive any 2MHz portion from 4 to 11 MHz. A true superhet with smooth varactor tuning, AGC, RF gain control, plenty of speaker volume and runs on a 9V battery. With SC-1 Shortwave Converter Kit (\$24.95), it can convert your car radio to two switchable bands, each 1MHz wide—tunable on your car radio dial... An opportunity to add some fun to your drive time.

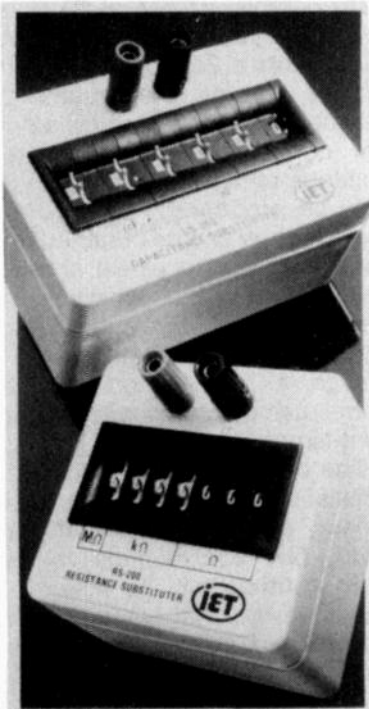


Aircraft Receiver (AR-1 \$24.95) kit lets you listen to exciting aircraft communications. Picks up planes up to 100 miles away. The AR-1 receives 110-136 MHz AM air band with smooth varactor tuning, superhet with AGC, ceramic filter, adjustable squelch, excellent sensitivity and lots of speaker volume. It runs on a 9V battery and is ideal for air shows or just hanging around the airport. 30 page manual not only provides step-by-step instructions but provides details on "pilot talk" also.

Detailed instruction manuals make these kits easy and fun to assemble. For more information contact Ramsey Electronics, Inc., 793 Canning Parkway, Victor, N.Y. 14564. (716) 924-4560, FAX (716) 924-4555.

DIGITAL DECADE SUBSTITUTERS

Substitution boxes are economical, indispensable tools used in a variety of engineering, design, troubleshooting and service applications. With convenient



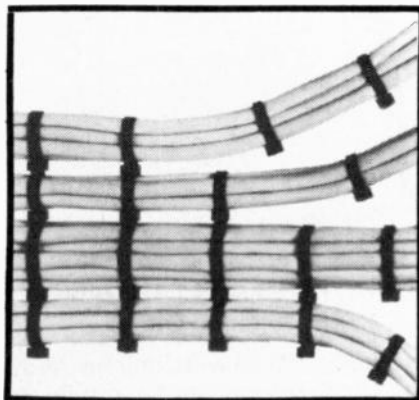
side-by-side thumbwheel switches, you can easily dial in the desired resistance, capacitance or inductance value.

These substitution boxes are used to set resistance, capacitance and inductance values for engineering, design, troubleshooting and service applications. Just dial in the desired value using convenient side-by-side thumbwheel switches—no fumbling with multiple slide or rotary switches. Different colored switches separate the various impedance ranges. Since the impedance values are set and read directly, no mistakes can be made as with rotary or slide switch decade boxes. There's no need to examine groups of switches—simply read one number. Made of

high impact plastic, these substituters are very portable and reduce clutter on a busy lab bench. Four series of substitution boxes are available: RS Series sets resistance; CS Series sets capacitance; RCS Series sets both resistance and capacitance; and LS Series sets inductance. For details contact: **HMC, P.O. Box 526, Canton, MA 02021 — (617) 821-1870**

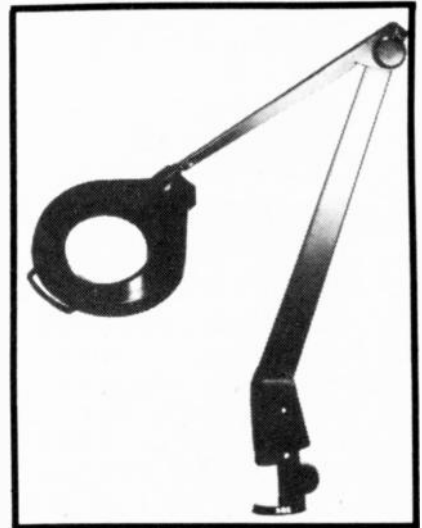
CONTINUOUS LENGTH CABLE TIES

Strap Loc™ Continuous Length Cable Ties reduce the need for stocking many different lengths of cable ties. The ties are cut from a spool, assembled with a lock, and used like any cable tie. No special tools are required. Waste is dramatically reduced because any excess can be reused. Unique features include ability to fasten and bundle large objects, separate and space wires and cables, fasten through panels, and multiple wrapping for extra high tensile strength applications. Stainless



steel and nylon locking device features low insertion force, instant locking, and infinite adjustability. Strap Loc™ Continuous Length Cable Ties are now available in two new smaller package sizes (250 Ft. & 500 Ft.) for added convenience and ease of use.

For more information call or write: **ADVANCED CABLE ELECTRONICS CORP., P.O. BOX #1291, Westboro, MA 01581, Tel: (508) 366-0669.**

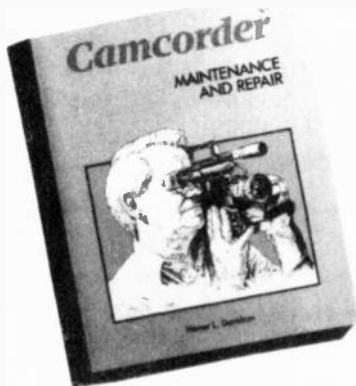


ILLUMINATED MAGNIFIER

The stylish 8MC Series lamps utilize a 22-watt circline fluorescent tube to cast an even glow on your task for optimum brightness and accuracy. It reduces eyestrain and fatigue by combining the two key factors in aiding vision—light and magnification. The contemporary "floating arm" lets you position the light source with the touch of a finger, and keeps it in place so your hands remain free to perform other tasks. The 5-inch crown optical glass lenses are available in 3-diopter (+75% magnification) and 5-diopter (+125%). Another option is an 11-diopter (+275%) lens system with a 3-inch viewing area. For precise inspection, a 4-power, 16 diopter lens system is offered which meets government standard MIL-STD-2000.

For more details, contact **HMC, 33 Springdale Avenue, Canton, MA 02021. Phone (617) 821-1870, FAX (617) 821-4133.**

NEW BOOK REVIEWS



CAMCORDER MAINTENANCE AND REPAIR

By Holmer L. Davidson

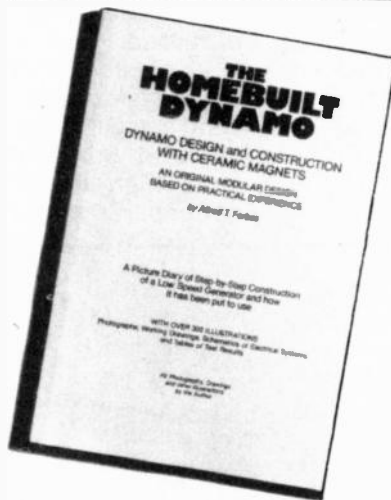
To most people, video equipment seems delicate and complex. Thus, whenever a camcorder or VCR fails to operate, their first thought is not How can I repair this?, but Where can I find a repair man? That's the way I felt, too, until I read the new book by Holmer Davidson and learned that a wide variety of common ills can be cured at home using nothing more than a voltmeter, a screwdriver and some common sense.

The author begins by introducing us to the various video formats such as VHS, VHS-C 8mm, Beta, and a handful of derivatives. We learn the mechanical and electronic principles on which these machines operate. Lots of good diagrams make the discussion easy to follow. Once we understand how these devices work, the author discusses maintenance, that is, how to clean and lubricate the machines so that they stay in good working order. He also addresses the problem of battery care and charging.

Videotape cassettes can sometimes cause problems, too, so there is one chapter devoted to cassette maintenance and repair. The bulk of the book, however, concerns itself with what to do when the unthinkable happens, when your expensive camera or VCR grinds to a halt despite your

best efforts at maintaining it in good condition. Excellent mechanical drawings show how to dismantle equipment without damaging it: Key anatomical features are illustrated in numerous photographs. The author targets common sources of trouble, such as motors and switches, and shows how to test and repair them using a DDM and some simple tools.

Every owner of video equipment should realize that sooner or later a malfunction will occur. When it does, *Camcorder Maintenance and Repair* will help you set things right and perhaps avoid an expensive trip to the repair shop. The book costs \$16.95 and is available from **TAB Books Inc., Blue Ridge Summit, PA, 17214-9988**. Or ask for it at your local bookstore.



THE HOMEBUILT DYNAMO

By Alfred T. Forbes

Like ostriches with their heads in the sand, Americans by and large ignored the dangers of their dependence on foreign oil during the eighties, but Iraq's invasion of Kuwait last August shattered their complacency. People think more about energy these days, and some even dream of generating their own electrical power. If you are one of these people, this new book by New Zealander Alfred

Forbes may interest you. *The Homebuilt Dynamo* is a step-by-step, 182-page guide to the construction of a low-voltage, 3-phase AC generator and rectifier—what we would call an alternator. Based on high-energy permanent magnets, Mr. Forbes' design is unique in that it develops considerable power at relatively low speed. Maximum rate output is 1,000 watts at 740 rpm. Depending on the rate of rotation and the manner in which the coil windings are connected together, output voltages between 12 and 36 VDC may be produced. Power to turn the armature can be obtained from a windmill, a water wheel, or even a stationary bicycle, which is the method employed by the author. He uses the power generated to charge a battery and light his home using low-voltage fluorescent lamps.

The book has over 300 illustrations and is printed on high-quality glossy stock. Instructions are clear, but considerable mechanical aptitude will be needed to duplicate the author's work. *The Home Built Dynamo* is available for \$65 (U.S.) from **Todd-Forbes Publishing, P.O. Box 3919, Auckland, New Zealand**. Price includes airmail delivery.



INVENTING: CREATING AND SELLING YOUR IDEAS

By Philip B. Knapp, Ph.D.

The setting is a cheerless basement laboratory. In the dim

light we see a strange machine that appears to have been thrown together from junk parts. Standing next to the machine, a man badly in need of a haircut and shave is busy making adjustments with a screwdriver. Oops! He must have turned the wrong screw, because the machine begins to shake and emit puffs of smoke. Before the man can correct his mistake, the machine lets out a dying gasp and explodes, sending gears and springs flying through the air like shrapnel. The man dives beneath a table, then peers out cautiously. We see in his soot-covered face a mixture of surprise and stubborn determination, and we know that it won't be long before he's built a new version of his silly machine.

Who is this character, anyhow? He is a typical inventor, as seen through the jaundiced eyes of a Hollywood scripwriter. Little wonder, then, that to many people the word *inventor* is synonymous with *crackpot*. The first thing Philip Knapp does in his new book is to lay to rest the hackneyed stereotype of the inventor. Dr. Knapp, himself an accomplished inventor with 20 patents and more than 50 inventions to his credit, portrays the inventor as a creative problem-solver, someone more in tune with reality than most of his detractors. The author goes on to show us what inventing is really like, using some of his own inventions as examples. We learn the painstaking process by which an idea is transformed into a working prototype.

Once a prototype has been built and tested, the inventor must decide how his device is to be marketed. The first alternative is to sell the invention to a company and collect royalties. For someone with no business experience, this will probably be the best choice. But how do you find a suitable company? Not through one of those classified ads that say "Inventions Wanted." Most of these people make their money on

the gullibility of the inventor, not on the merits of his invention. As Dr. Knapp says, run like hell as soon as anyone asks you for a fee to promote your invention. You'll find the best sales leads for your invention in the business section of most public libraries, and the book explains how to make use of this information. The author also discusses how to negotiate with a company that's interested in your invention. To protect yourself, don't show them the prototype until *after* the contract is signed. Too many inventors have been cheated out of their just rewards by unscrupulous wheeler-dealers.

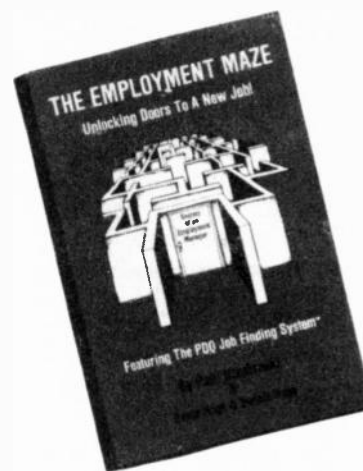
The alternative to selling your invention to a company is to form your own company and manufacture the invention yourself. For most inventors without business experience this could be the road to ruin, but for those who prefer to do it this way, the author furnishes complete information on formulating a business plan, raising capital, dealing with lawyers, setting up a production line, marketing the product, and running the business. What he doesn't cover you can find by reading the books listed in the extensive bibliography.

I think this is a terrific book, and a good value, too. Whether you have a specific invention in mind, or are just curious about inventing in general, *Inventing: Creating and Selling Your Ideas* is a book you ought to read. The price is \$15.95 and the publisher is **TAB Books Inc., Blue Ridge Summit, PA, 17214-9988.**

THE EMPLOYMENT MAZE

**By Paul Dombroski, David Hage,
and Dennis Hage**

As America entered the twentieth century, most of its working citizens were self-employed. They were farmers, or shopkeepers, or lawyers, or a hundred other things; and they were their own bosses. Today, on the threshold of the twenty-first century, the situation



has reversed itself: big corporations and big government dominate the economic landscape, and most people work for someone else. Under such conditions, the key to success may not lie in working hard, but in working someplace else.

Paul Dombroski, personnel manager at an electronics firm in the southwest, along with associates David and Dennis Hage, has written a book that will enable the ambitious job-seeker to find the kind of job he wants. The author advocates establishing a network of influential friends to help in the job search, since the choicest job openings are often filled by personal recommendations and referrals. He tells how and when to respond to employment ads, and how to write a resume that will elicit a response from a personnel manager. Employment agencies are sometimes necessary in a job search; Mr. Dombroski tells how to get the most out of them. Once you've got the attention of a prospective employer, you face one last hurdle: the job interview. How you handle yourself in such an interview is crucial to winning the job you seek. Like or not, you have to sell yourself and convince the employer that he's found a valuable asset. Mr. Dombroski offers welcome advice on how to do this.

NEW BOOK REVIEWS

The Employment Maze is a fast-paced 136-page book that you can read in an hour or two, yet the information it contains could affect the rest of your life. Copies may be ordered from **Paul Dombroski Inc., POB 47604, Phoenix, AZ, 85068**. Price is \$12.95 plus \$2.00 for postage.



CUSTOMIZE YOUR HOME ENTERTAINMENT SYSTEM By Steve Sokolowski

Popular author Isaac Asimov recently marked a milestone in his long career with the publication of his 300th book. I mention this because it appears as if Steve Sokolowski has his sights set on Dr. Asimov's record: this is the third book of Steve's to be reviewed this year, and it looks like his best to date. This time out, Steve brings us a collection of easy-to-build projects designed to add new features and enjoyment to a TV, VCR, or stereo system. The roster of projects consists of 22 items: tunable notch filter, audio delay line, equalizer, noise reducer, low-voltage power amplifier, two-watt audio amplifier, four-watt audio amplifier, rear-speaker ambience amplifier, bass-boost filter, stereo audio control, VU meter, audio power meter, stereo simulator, infrared audio transmitter and receiver, surround-sound decoder, VCR AC controller, stereo adapter for TV,

tone controller, stereo audio switch, and various power-supply circuits to power the projects presented.

In addition to the projects, there are chapters on TV and VCR theory, assembly tips, reading schematic diagrams, making printed circuit boards, and soldering. The book is thus a self-contained introduction to project building that will appeal to the beginner as well as the more experienced hobbyist. Most projects require only two or three integrated circuits and a handful of other components, so you can assemble them quickly and inexpensively. PCB layouts accompany most of the projects.

Customize Your Home Entertainment System is an excellent book of projects, reasonably priced at \$15.95. Order from **TAB Books Inc., Blue Ridge Summit, PA, 17214-9988**, or your local bookstore.



DESIGN AND APPLICATION OF SMALL STANDARDIZED COMPONENTS By the Staff of Stock Drive Products

As electronic enthusiasts we share a common interest: we like to build things, great Rube Goldberg-style contraptions with whirring and clicking parts, gadgets that amaze our neighbors and cause even the most tolerant spouses to grit their teeth. This is our role in life, and we play it with

gusto. For inspiration, we read *Electronics Handbook* and half a dozen other electronics magazines, which, out of courtesy to our publisher, shall remain nameless here. These magazines provide a vital forum for the dissemination of the new ideas and techniques in the field of electronics. However, most projects are not strictly electronic devices; they have a mechanical structure as well, yet I can think of no popular periodical that addresses mechanical concepts in the same way that magazines like *Electronics Handbook* and others treat electronic concepts. As a result, the mechanical part of a project is often approached with little or no theoretical insight. Things are put together in a trial-and-error fashion from whatever mechanical parts are at hand, and it is a testament to human ingenuity that many of these projects work at all.

As an antidote to the current deplorable state of mechanical knowledge, let me recommend the *Design and Application of Small Standardized Components*, an easy-to-understand guide to the theory and application of mechanical components like pulleys, belts, gears, motors, and so on. This book was prepared by the staff of Stock Drive Products, a major supplier of small, precision mechanical components. The purpose of this book is to explain in simple language how best to apply the mechanical components that Stock Drive Products sells. Of course, the information applies equally well to components from other manufacturers.

Chapter One is a compendium of useful mechanical data, most of it in chart form, dealing with such things as conversion factors, moments of inertia, properties of metals, properties of plastics, characteristics of finishes and coatings, and practical hints for mechanical design.

Chapter Two is an excellent, thorough introduction to the

design and application of gears and gear trains. Let me point out, however, that most home projects should probably be constructed with belts, chains, and pulleys, since these are easier for the novice to lash together than a gear train. But for those times when you just can't avoid using gears, Chapter Two will pull you through.

Chapter Three is about electricity, probably nothing that you don't already know. Chapter Four is about motors, and here there is likely to be lots that you don't know. The treatment of stepper motors is especially thorough.

Chapter Five deals with spring motors, handy devices that can replace an electric motor or a counterweight in certain applications. Shaft couplings and universal joints are discussed in Chapter Six. Belt drives, chain drives, and pulleys are explained in Chapter Seven, which for most readers will be the most important chapter of the book. This chapter is augmented by an extensive set of center-distance tables which make the design of belt-driven systems easy.

Chapter Eight is all about shafts and bearings, Chapter Nine deals with techniques for the damping or elimination of vibration, and the book ends with a final chapter on elements of robotic design.

To sum up, the *Design and Application of Small Standardized Components* is a 784-page handbook of practical mechanical design. You don't have to be a mechanical engineer to understand it, and you won't go broke buying it, since the price is just \$7.95 (soft cover) or \$12.95 (hard cover). This book is available from **Educational Products, P.O. Box 606, Mineola, NY, 11501.**

THE BEGINNER'S GUIDE TO RADIO CONTROL SPORTS FLYING

By Douglas R. Pratt

The flying of radio-controlled model airplanes dates back to at

least the 1940's, and possibly earlier. Back in those days, you not only built your own airplane, you built the transmitting and receiving equipment as well, and you had to have a ham license to use the equipment. Things have changed considerably since then. Factory-built transmitters and receivers are readily available, and you don't need a ham license to use them. You can still build your own airplane, if you wish, or you can buy one that's ready to fly.



Before you even consider buying a plane and an R/C control system, however, I suggest that you take a look at Douglas Pratt's new book, *The Beginner's Guide to Radio Control Sport Flying*. In it, you'll find all the information necessary to get started in R/C modeling. Mr. Pratt is special-projects director of the Academy of Model Aeronautics, the national organization for model fliers. He knows a lot about planes and flying, and he conveys what he knows with good-natured enthusiasm.

One of the things that the author stresses is the desirability of joining an R/C modeler's club. For the beginner, clubs provide camaraderie as well as free advice from more experienced members. In addition, clubs carry insurance that protects their members, so if you lose control of your plane and it crashes through someone's window, the insurance company pays the bill.

Most of the book is devoted to the technical aspects of R/C flying. For example, the author discusses the operation of transmitters, receivers, and servos. He stresses the importance of periodic testing of the control system to prevent possible disasters in the air. And he tells how third-order intermodulation from other nearby transmitters can cause you to lose control of your plane.

Construction tips are sprinkled liberally throughout the book. There is even advice on choosing a plane. For the beginner, a plane that is easy to build and easy to control makes sense. You want a plane that is slow and stable, not something designed for high-speed aerobatics. If your flying space is limited, an R/C helicopter might be the answer. On the other hand, someone with lots of space, who likes peace and quiet, might prefer an R/C sailplane.

With the exception of the sailplane, all planes need an engine of some sort. The bigger the plane, the bigger the engine required. Most beginners start out with an economical, 2-stroke engine. These are ignited by glow plugs and burn a mixture of methanol, nitromethane and oil, with methanol being the major constituent. Since the fuel is very flammable, caution is necessary. Diesel and gasoline-powered engines are also available. In recent years, 4-stroke engines have become popular, especially with scale modelers, who prefer the realistic rumble of a 4-stroke engine to the thin whine of a 2-stroke. A large 4-stroke engine may put out 3 horsepower and cost as much as \$3,000.

Douglas Pratt's book was a pleasure to read, and I recommend it without hesitation to anyone contemplating the purchase of an R/C model plane. *The Beginner's Guide to Radio Control Sport Flying* costs \$9.95 and is published by **TAB Books Inc., Blue Ridge Summit, PA, 17214-9988.**

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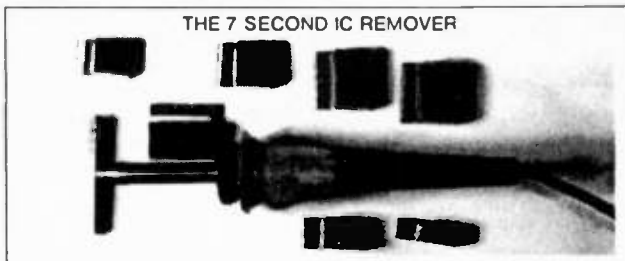
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| 2 BATTLE HYMN REPUBLIC | 29 JINGLE BELLS | 55 DEAR OLD NEBRASKA U. |
| 3 CAISSONS GO ROLLING | 30 KING OF ROAD | 56 THE EYES OF TEXAS |
| 4 CALL TO COLORS | 31 LA CUCARACHA | 57 ABOVE CATUGA'S WATERS |
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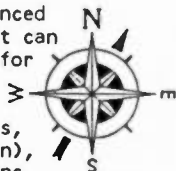
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DESIGN YOUR OWN OP-AMP CIRCUITS



By William R. Hoffman

From its introduction almost two decades ago, the simple, lowly operational amplifier (op-amp) has probably become the most used functional analog circuit "block" in semiconductor history. From that first IC circuit, called the 709, has come all of today's analog semiconductor circuits, from high performance low noise preamplifiers to large, high power amplifier stages. The basic circuit, usually composed of a differential input stage followed by one or more voltage gain stages, and ending with a push-pull output circuit configuration, can be made to do almost anything from analog amplifiers and filters to digital comparator functions. And because of the universal availability and low cost, as well as simplicity of designing with them, even the home experimenter can successfully create a large variety of circuit functions with only a pencil and paper and pocket calculator.

SOME BASIC INFORMATION

To begin with, let's look at some of the op-amp's characteristics, so we can learn some basic things about them, necessary for us to do our own design work. Their inputs (there are two, one marked + or non-inverting, and the other marked - or inverting) is

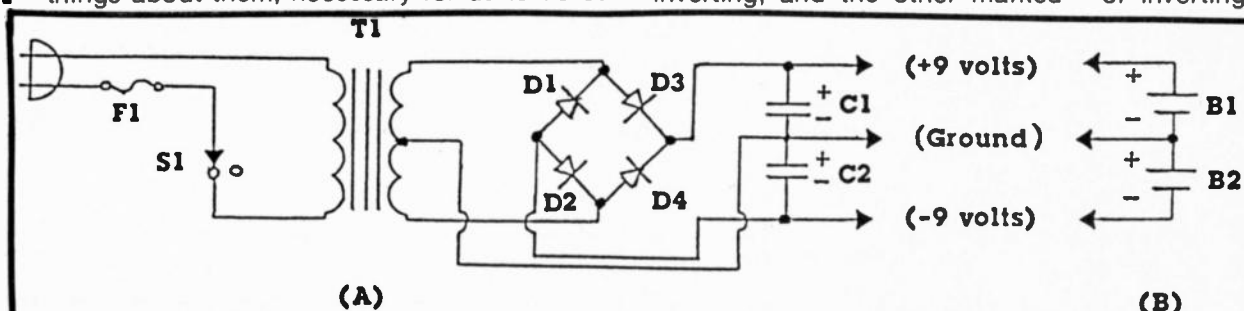
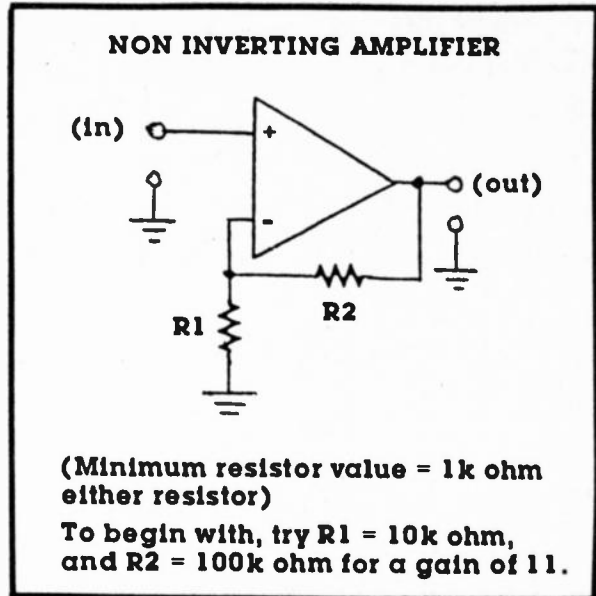
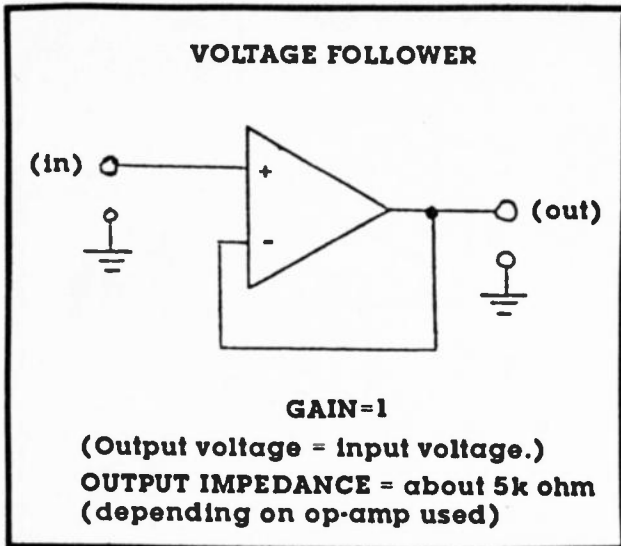


Fig. 1. (A) is AC operated power supply for op-amp circuits. F1 is a 1/4A fuse. T1 is a small 120V to 12V power transformer rated at 100mA or more with a center tapped secondary. D1 to D4 are small silicon diodes rated at 1A with at least 50V PIV. C1 and C2 are 470 uF 16V capacitors. For the battery supply (B), simply connect two 9V carbon-zinc transistor radio batteries as shown.

where we apply the signal or reference input into the IC. If we choose the non-inverting input, then the output will have the same phase as the input.

considerable gain; the input signal can be amplified up to many thousands of times, and the output

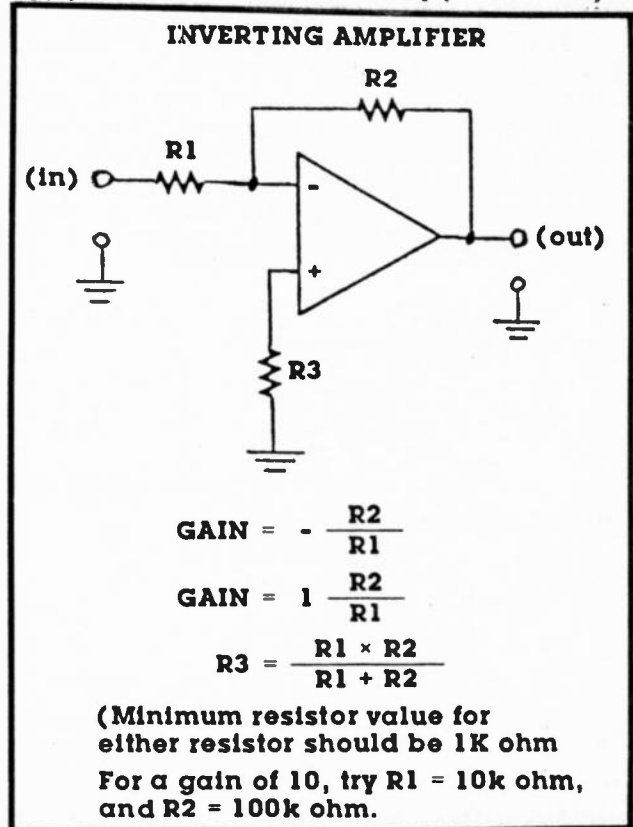
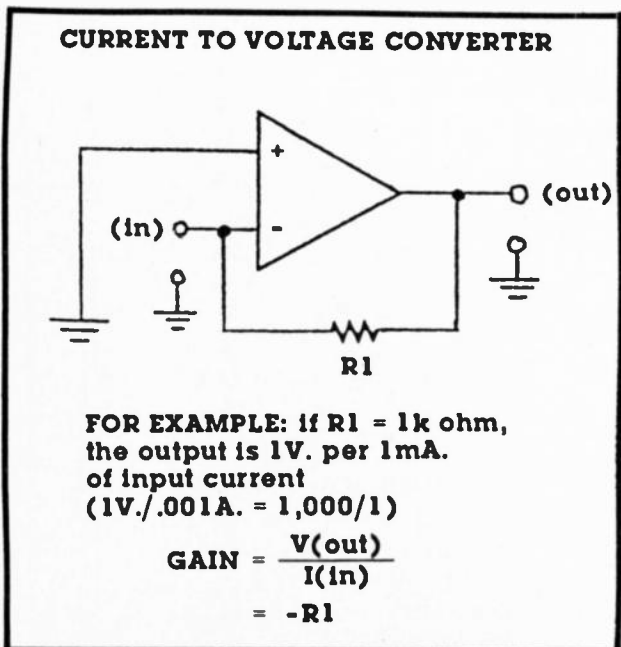


However, if we go into the inverting input, then our output will be an inversion of the input signal. Both can be used, and each has a specific application. Note that the input impedance for the non-inverting input is very high; very little current is used from the source signal to produce an output. On the other hand, the inverting input, because it is where the feedback is applied from the op-amp's output, has an impedance near zero ohms. Therefore, an input resistor must always be used to protect the source of the input signal. The only other rule to remember is that the input voltage must NEVER exceed the supply voltages going to the op-amp from the power supply, not even for a fraction of a second or the circuit will be damaged and the IC will fail completely.

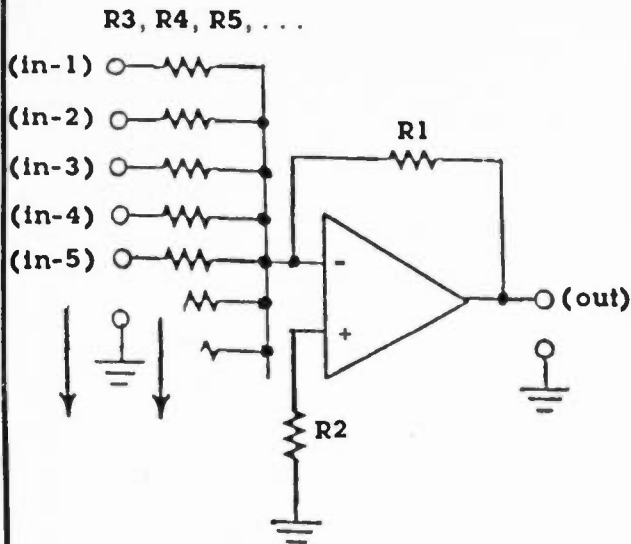
impedance is usually low enough that the circuit can put out many milliamperes of current with voltage swinging from just a little less than the positive supply voltage to just a little less than the negative supply (typically +/- 12V. from a +/- 15V. supply).

The op-amp has only one output where, as indicated above, the signal may be either an inverted or non-inverted copy of the input. Depending on the feedback resistance, the op-amp can also have

Finally, we need to know about the power supply for the circuit. Most op-amps can run on supply voltages from +/- 4V. to +/- 15V. with little change of circuit performance. And with their high efficiency design, they typically consume only a few milliamperes of current making a small, unregulated AC supply or even two batteries a very practical way of



SUMMING AMPLIFIER



$$V_{out} = - (V_{in-1} + V_{in-2} + \dots)$$

SET: $R1 = R3 = R4 = R5 = \dots$

$R2 = 1k \text{ ohm}$

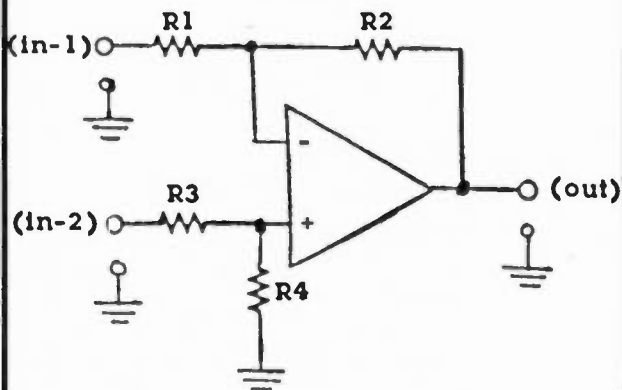
Minimum value of all resistors = 1k ohm

Typical value of all resistors is 10k ohm (except R2)

NOTE: input impedance of all inputs is equal to input resistor value (R3, R4, etc.)

powering them. For the circuits described here, if we wish to use them continuously, a power supply circuit consisting of a transformer, some rectifiers, and some filter capacitors is shown in Fig. 1. Most of the parts necessary can be found in a well stocked experimenter's junk box. If not, they are readily available from most any electronics parts supplier. You should be able to build the power supply for under \$15.00, even from brand new parts. If you build it, just be careful with the input wiring: 120V AC can be a shock

DIFFERENCE AMPLIFIER



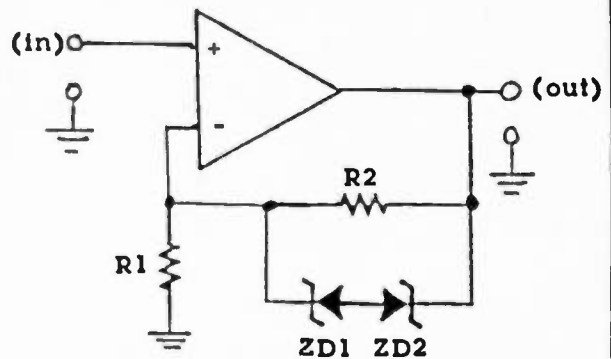
$$V_{out} = V_{in2} - V_{in1}$$

$R1 = R2 = R3 = R4$ (at least 10k ohm)

Typical value for all resistors is 10k ohms.

hazard. Also, when wiring the rectifiers and filter capacitors, be sure you get the polarities correct! The entire circuit can be built on or in a small sheet metal box, with the wiring on a couple of terminal strips.

LIMITER (CLIPPER) AMPLIFIER



$$\text{GAIN} = 1 + \frac{R2}{R1}$$

$R1, R2$ minimum value = 1k ohm

$ZD1 = ZD2$ = set voltage to clip at.

To start, try: $R1 = 10k \text{ ohm}$

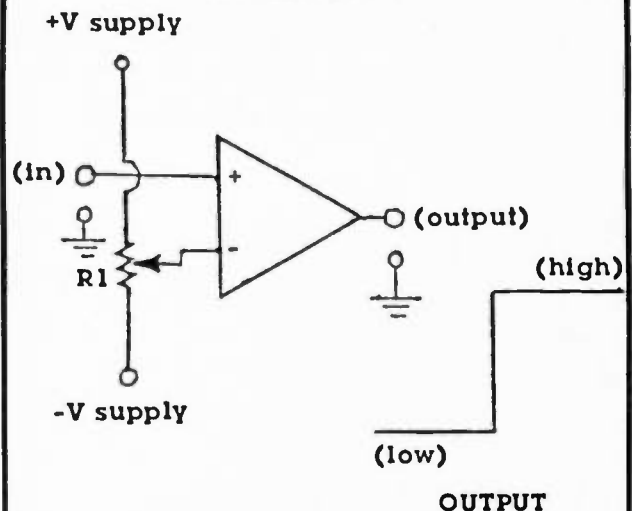
$R2 = 20k \text{ ohm}$

$ZD1, ZD2 = 2.2V.$

HELPFUL REMINDERS

Some hints. Like all good circuit layouts, be sure and keep the input and output away from each other. This will help prevent oscillation. Also, if you will be running more than a foot or so of wire from the power supply to the op-amp, be sure and add some 0.1 uf. 50V. capacitors from each of the power supply lines to

COMPARATOR



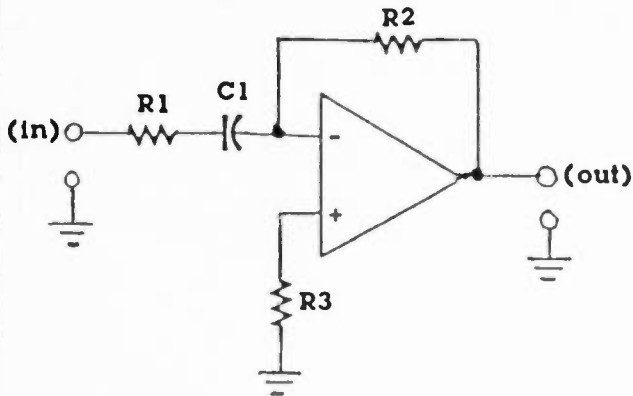
$R1 = 100k \text{ ohm}$ potentiometer

(Adjust for desired output transition voltage level.)

NOTE: +V and -V should be the same as the op-amp power supply.

ground. Do this near the op-amp power supply pins, to help prevent any possibilities of oscillation. With this in mind, let's start looking at some of the op-amp circuits.

DIFFERENTIATOR



$$\text{SET: } C1 = \frac{1}{f \times R2}$$

$$R2 = \frac{1}{f \times C1}$$

R3 = 1k ohm

For a gain of 10: (typical)

R1 = R2 ÷ 10

To start, try:

R1 = 1k ohm

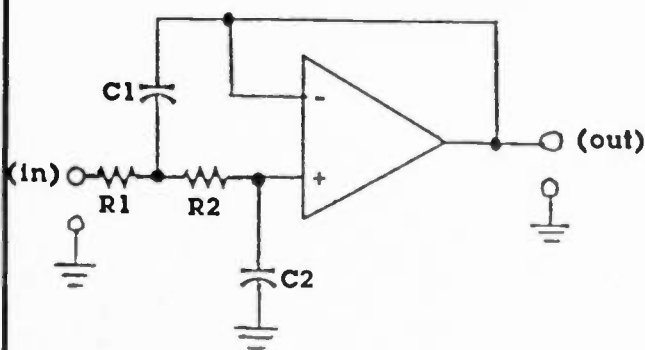
R2 = 10k ohm

C1 = 0.1 uf

LOTS OF CIRCUITS

On the following pages are 18 op-amp circuits complete with design equations and some suggested circuit component values to help you get started. Note that none of the diagrams show any pin numbers or power supply connections since these may change from IC to IC. Consult the data sheets which come with the IC's you purchase to determine their locations and operating values.

ACTIVE LOW PASS FILTER



$$\text{SET: } R1 = R2$$

$$C2 = C1 \times 2$$

$$f = \frac{1}{6.28 \times C \times R}$$

AND WHERE:

C1 = C × 1.4

C2 = C × 0.7

GAIN IN BAND = 1

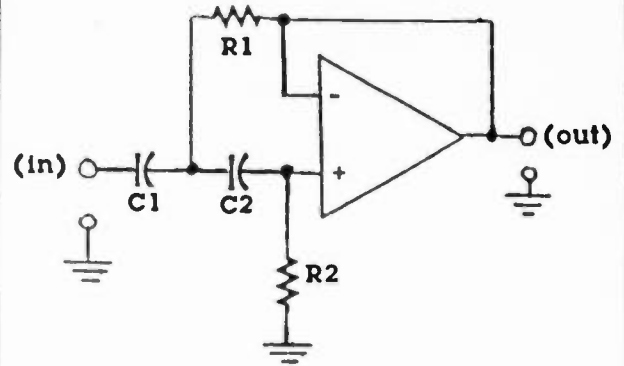
For: 10kHz filter

R1 = R2 = 27k ohm

C1 = 1000 pf

C2 = 500 pf

ACTIVE HIGH PASS FILTER



GAIN (in band) = 1

SET: R1 = R2 = R

$$f = \frac{1}{6.28 \times C \times R}$$

C1 = C × 1.4

C2 = C × 0.7

FOR A 100Hz FILTER:

R1 = R2 = 100k ohm

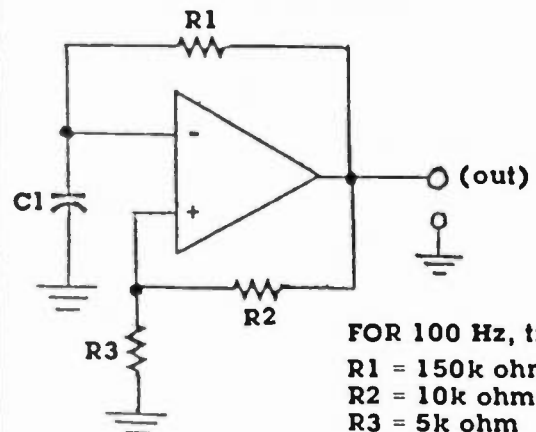
C1 = .02 uf.

C2 = .01 uf.

AMPLIFIER CIRCUITS

We have a choice of amplifier types. Linear INVERTING or NON-INVERTING are the basic amplifiers we are mostly familiar with. They can amplify weak signals from a pickup cartridge or microphone for use with a stereo, or the weak signals from a light sensor to detect when a beam is interrupted; the uses are almost endless. The only difference between the two is just what their names imply: one inverts the signal at its output, the other doesn't. The VOLTAGE FOLLOWER is a simple variant on the amplifier stage: it has no gain, but serves to isolate the input signal from whatever is connected as a load. The current gain of the amplifier

FREE RUNNING MULTIVIBRATOR



FOR 100 Hz, try:

R1 = 150k ohm

R2 = 10k ohm

R3 = 5k ohm

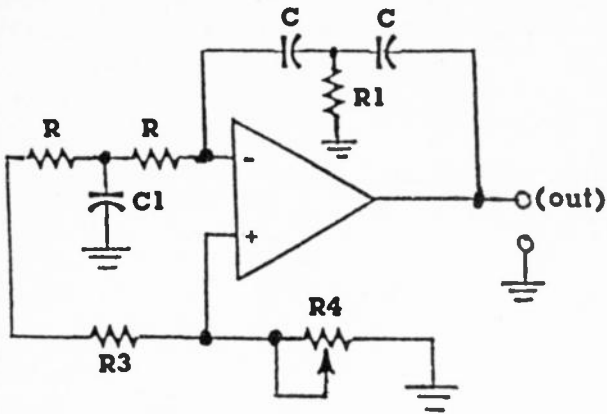
C1 = .01 uf

SET: R2 = R3 × 2

$$f = \frac{1}{6.28 \times R1 \times C1}$$

(R2 or R3 should not be less than 1k ohm.)

FIXED OSCILLATOR



SET: $R3 = R4 \times 10$

$R1 = R \div 2$

$C1 = C \times 2$

$$f = \frac{1}{6.28 \times R \times C}$$

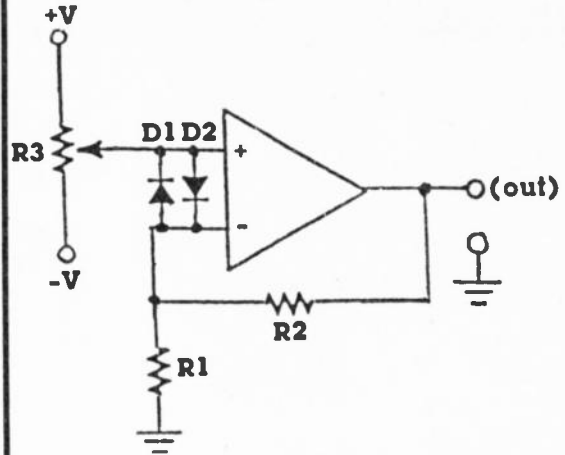
Adjust $R4$ for steady oscillation.

For a 1kHz oscillator, use:

$R3 = 100k$ ohm $R4 = 25k$ ohm potentiometer
And $R = 1k$ ohm, and $C = 0.15$ uf.

(it has no voltage gain) will allow a very high high impedance source (like a transducer of some kind) to drive a low impedance load (like a meter or a lamp). The SUMMING AMPLIFIER and DIFFERENCE AMPLIFIER are both linear like all the others, in addition they allow us to add two or more signals together and get an algebraic sum or difference at any given moment—these actually perform an arithmetic function for us! The METER AMPLIFIER is just what its name says, an amplifier just to drive a meter so that we can measure the level of a signal or compare two signals. This can be used with the summing and

ADJUSTABLE \pm VOLTAGE SOURCE



SET:

$R1 = R2$ (1k ohm minimum)

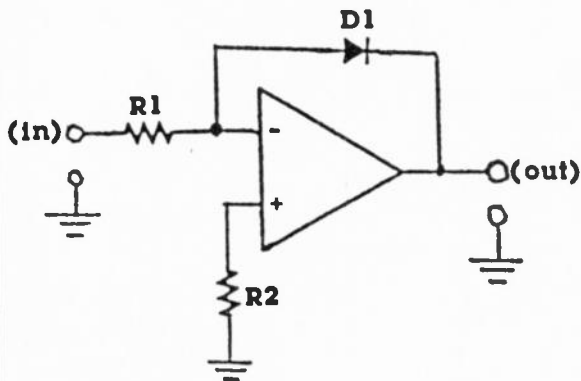
$R3 = 100k$ ohm potentiometer

$D1, D2 =$ any small silicon diodes

NOTE: +V and -V should be the same as the op-amp power supply.

difference amplifiers for special functions, such as reading the simultaneous output of two stereo channels, or with the difference circuit, read the separation of the signal—a very versatile combination. The LIMITING AMPLIFIER also does what the name implies—limits or clips our signal if it exceeds the circuits set limit. And finally, the LOG AMPLIFIER does a very curious thing: it converts the linear input signal to a logarithmic one at the output; it is the simple basis of a compressor or expander circuit (expander as it is shown). As it is, a positive input signal will come out with a positive expansion: it can be used to make a decibel scale reading meter along with the meter amplifier above.

LOGARITHMIC AMPLIFIER



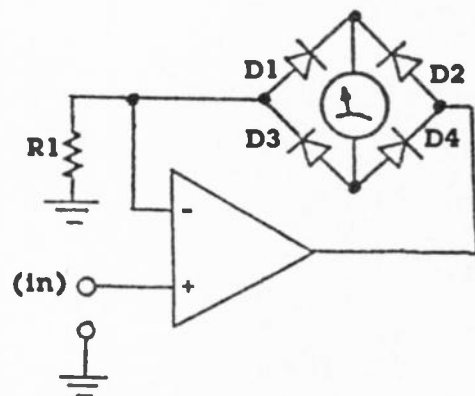
$R1 = 10k$ ohm

$R2 = 1k$ ohm

$D1 =$ any small silicon diode.

For output to operate a meter, the input must only be a positive (+) voltage.

METER AMPLIFIER

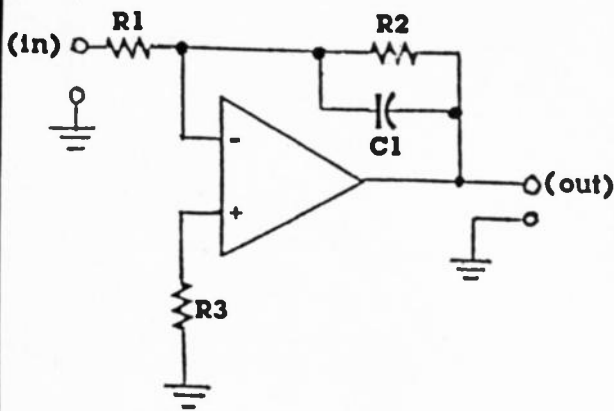


CIRCUIT GAIN = 1

$R1 =$ same as resistance of meter movement

$D1 - D4 =$ any small silicon diodes.

INTEGRATOR



GAIN: 10

SET:

$R1 = R2 \div 10$	TO START, TRY:
$R2 = \frac{1}{f \times C1}$	R1 = 10k
$C1 = \frac{1}{f \times R1}$	R2 = 100k
$R3 = \frac{R2}{R1}$	C1 = 0.1 uf

ANALOG FILTERS

These are, as the name implies, filters for cutting off or removing parts of the signal frequencies input to them. For example, the HIGH PASS FILTER will eliminate low frequency noise or rumble from a stereo system, while the LOW PASS FILTER may be used to eliminate hiss or other high frequency noises. Both of these filters give a 12 db per octave cutoff response, which is quite fast. Also, by carefully choosing our cutoff values, we can use them with multiple stereo amplifiers to create a hi-fi "bi-amplified system" with an amplifier each for the tweeters and woofers in our speakers.

WAVEFORM GENERATORS

For those interested in amplifier testing, or checking digital circuit functions, these are two very useful circuits: the FREE RUNNING MULTIVIBRATOR and the FIXED (sinewave) OSCILLATOR. The former generates a continuous train of pulses whose rate is set by the capacitor in the circuit, while the latter will make very good sine waves for testing a high fidelity amplifier for power and distortion.

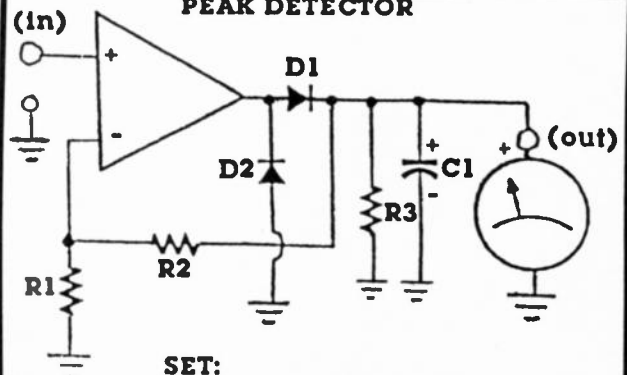
WAVESHAPERS

Sine or pulse (or music) waveforms can be altered by the DIFFERENTIATOR or INTEGRATOR circuits. The differentiator will create short, sharp spikes with each input wave to the circuit, while the integrator will take an input waveform and create a sloping, ramped version of it. Both of these circuits are commonly used in making electronic music, or used in creating special musical effects along with the output of an electric guitar or organ.

MISCELLANEOUS CIRCUITS

The CURRENT TO VOLTAGE CONVERTER does just what the name implies; makes a value of input current into a specific value of output voltage. It can operate a buzzer or light when a photo sensor connected to its input detects darkness, or a changing light input. For those needing an ADJUSTABLE VOLTAGE SOURCE this circuit can provide an adjustable output which can be anything from just a little bit less than the positive power supply to a little less than the negative supply voltage. This will make a good reference to operate a power supply regulator circuit, since its output is too low to operate a radio or tape player directly. The PEAK DETECTOR is an especially good circuit for those who need to read power or signal levels since it will momentarily hold a peak value making it much easier to read. This is especially good for those who do tape recording or want to determine the power of their stereo. Finally, the COMPARATOR will act like a digital circuit, changing its output voltage from full negative to full positive when the varying input voltage goes higher than the reference input voltage. As a threshold detector, it can sense when a certain level of darkness is reached when detected by a photocell, or compare two voltages and operate an alarm when something has changed.

PEAK DETECTOR



SET:

$$\text{store time} = R3 \times C1$$

$$\text{GAIN} = 1 + \frac{R2}{R1}$$

(all resistors are
1k ohm minimum.)

D1, D2 = any small
silicon diodes.

TO START: try (for 1 sec. hold time)

R3 = 100k ohm

C1 = 10 uf

R1 = 10k ohm, R2 = 100k ohm

USING THE CIRCUITS

As it has already been suggested, there are many ways to use these circuit function "blocks" especially in combinations. The possibilities are almost endless! Don't be afraid to experiment, a circuit failure, due to an incorrectly installed part or incorrect wiring, should be easily corrected—most won't do any harm to the IC, which in any case is easily replaced if a failure occurs. Good luck! ■

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Procedure

Figure 16 shows the circuit diagram for this experiment. You'll note the pin numbers for the IC aren't included on the diagram. For those, you'll have to refer to Fig. 17, which shows pertinent 74151A data. For its convenience, you'll use an 8-pin DIP switch in conjunction with 10KΩ resistors (resistors). For the Select and Strobe lines, finally, you'll use the normally open switches.

1. With the power off, insert the 74151A IC and the 10KΩ resistors on the breadboard.
2. Connect the eight 10KΩ resistors to the DIP switch as illustrated in Fig. 16. Connect the opposite end of each of these resistors to the +5V supply. The second terminal of each switch is to be connected to a common ground.
3. Connect the IC V_{CC} pin to +5V, connect the GND pin to common ground.
4. Next, connect the trainer data switches to the Select and Strobe lines on the IC, using Fig. 17 as a guide. Initially, set SW1 to the "up" position.
5. Connect the trainer Y LED to the F output, and connect the B LED to the B output.

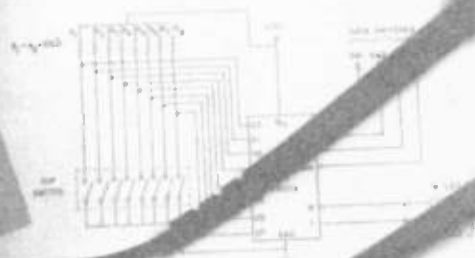


Fig. 16 Circuit for Experiment 2



Fig. 17 Pin diagram for 74151A

7. Turn the power on. The Y LED on your trainer should be on. If it is, the B LED should be on. If you don't observe these conditions, the power and check your connections.
8. From the present input conditions, on the inputs, you can observe the output will be enabled.
9. Set the appropriate DIP switch to "up" and verify your trainer's results in terms of the selected input D, each number of the selected data lines to the appropriate specification in Fig. 18.

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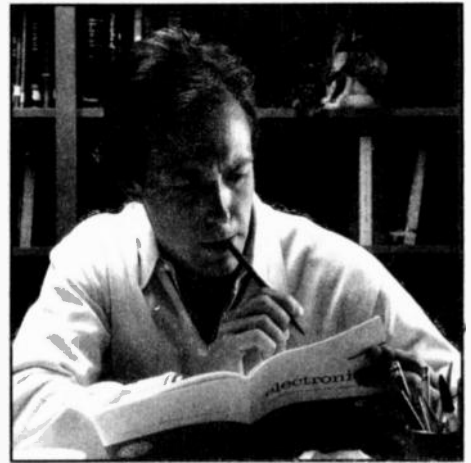
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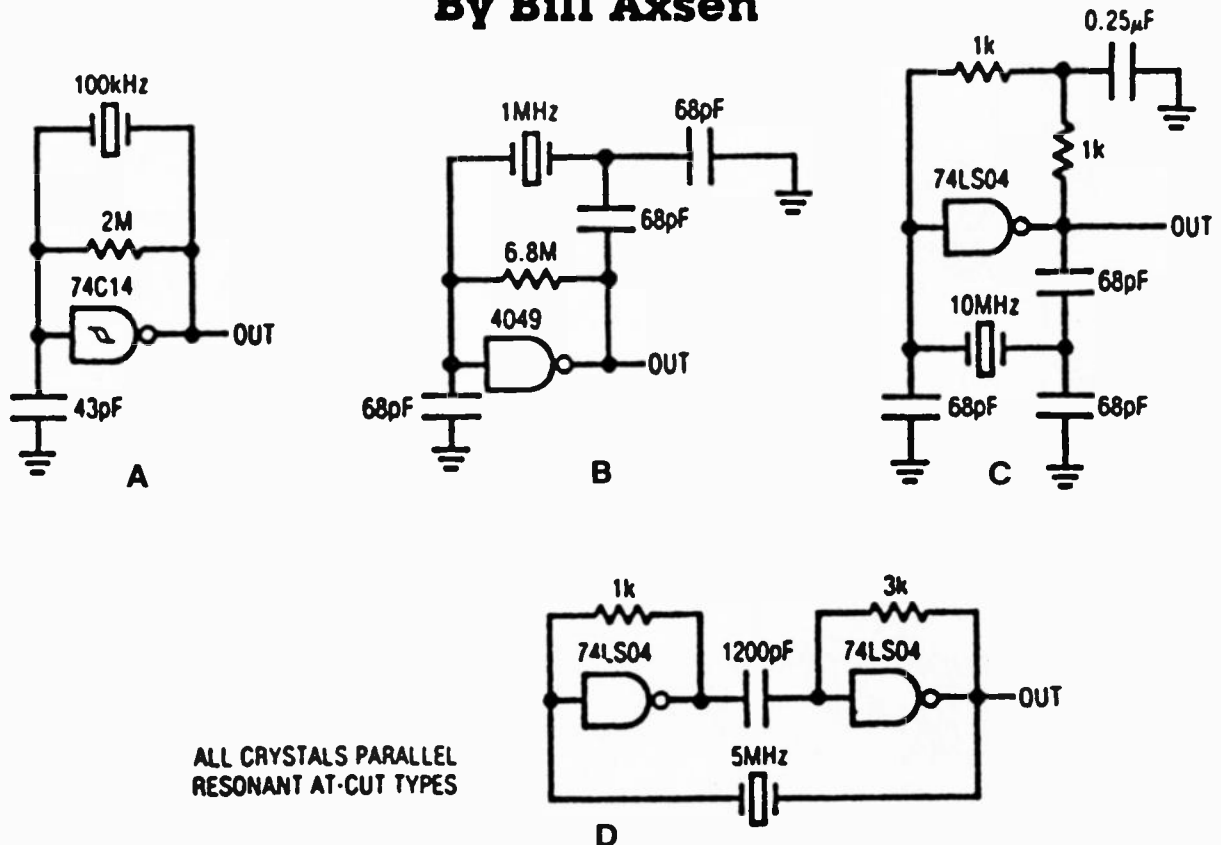


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CRYSTAL OSCILLATORS

By Bill Axsen



ALL CRYSTALS PARALLEL
RESONANT AT-CUT TYPES

Gate Oscillators

Those of us who have used crystal oscillator circuits know how useful they can be. For those who have not, now may be the time to familiarize yourself with these extremely useful circuits. With few exceptions crystal oscillators are used in digital or communication equipment. They supply a highly stable frequency source which cannot be obtained by LC oscillators, at relative bargain prices. Crystal oscillators are found in digital watches, calculators, digital meters, and transmitters, just to name a few applications.

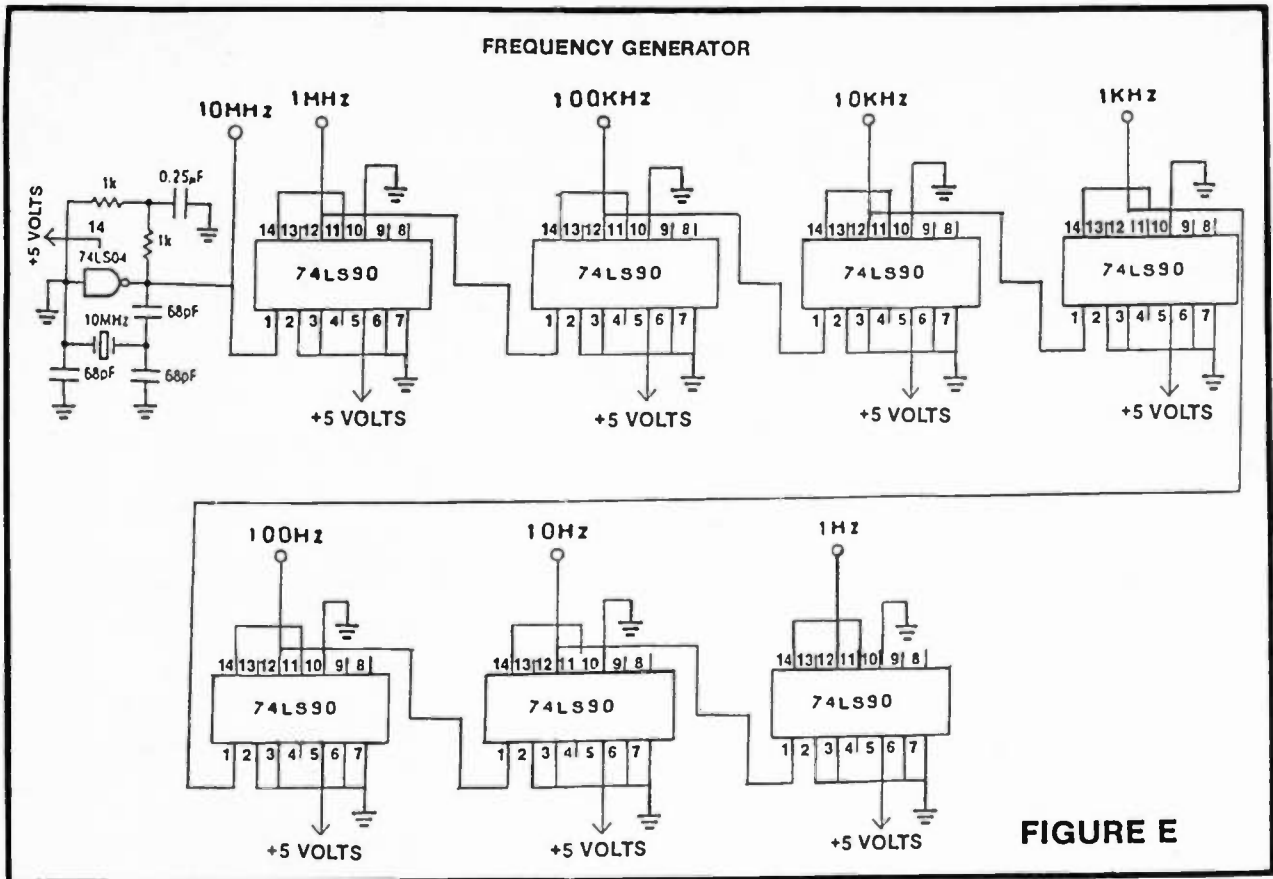
The circuits in this article were chosen, for the most part, because they don't require exotic parts and have a minimum parts count. You should be able to find the majority of the parts in your junk box. In circuits which do require "non standard hobbyist parts" a reference will be made in the article where these parts may be obtained.

With the exception of two-frequency generator circuits, circuits described in this article were taken

from the Linear Technology's, Application Note 12, Circuit Techniques for Clock Sources. If you are interested in a more in-depth explanation of the circuits described, it is suggested that you write to Linear Technology at the following address and ask for Application Note 12.

Linear Technology Corporation
1630 McCarthy Blvd.
Milpitas, CA 95035-7487

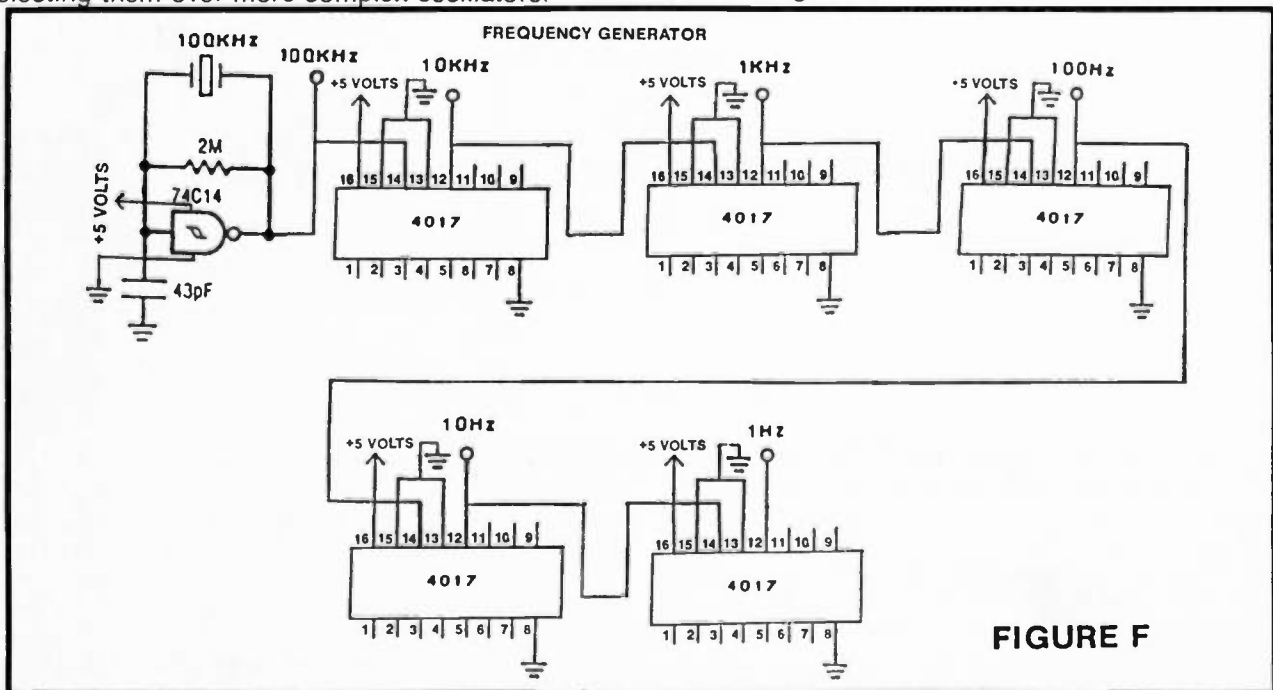
Circuits "A" - "D" are typical gate oscillators which, as you can see, require only a minimum number of parts. These gate oscillators are worth mentioning because they work so well. If you have ever worked with gate oscillators, you know how temperamental they can be. Usually their operation is intermittent or they fail to oscillate; or you spend all day tuning the all-too-familiar trimmer capacitor trying to get them to oscillate. There are even cases where substituting one chip manufacture's IC for another will cause the circuit to fail to oscillate.



Gate Oscillators

There may be the oddball occasion in which one of these circuits fails to operate. It is therefore, suggested that you test the oscillator in your circuit before you incorporate it into your design. Even though this problem occasionally happens, these gated oscillator circuits are so easy to build and require so few parts that you will find yourself selecting them over more complex oscillators.

The author has used circuit "A" a CMOS Schmitt trigger to calibrate equipment, as a clock in a frequency counter, and even as a source of clock pulses for a digital clock. By using a 7490 decade counter or a 4017 counter/divider you can divide the output frequency to obtain highly accurate frequencies below the oscillator frequency. Schematics of two professional quality frequency generators are shown in Figure "E" and "F."



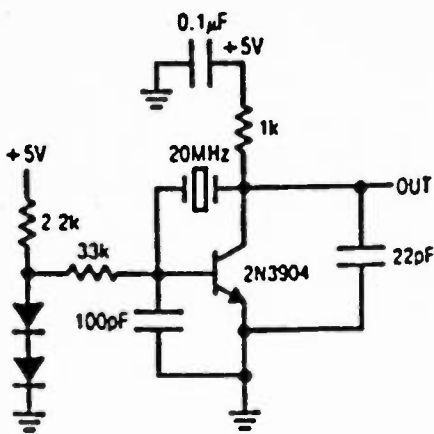


FIGURE G

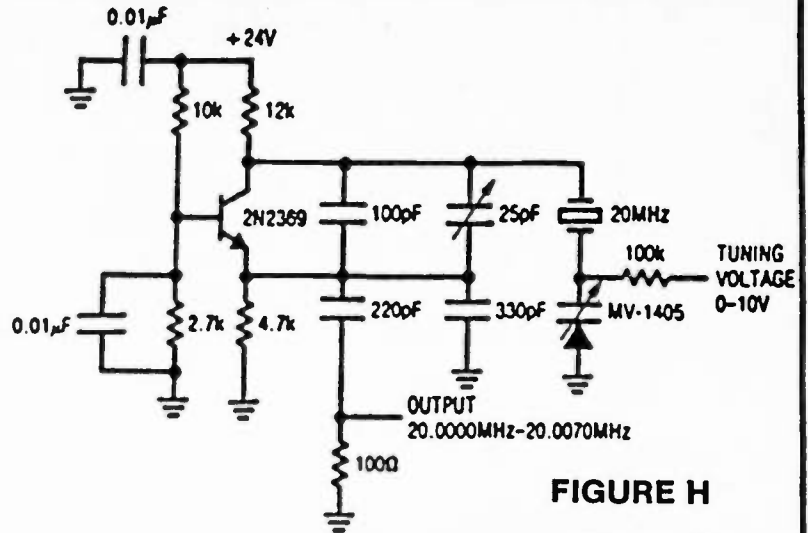


FIGURE H

VOLTAGE CONTROLLED CRYSTAL OSCILLATOR (VCXO)

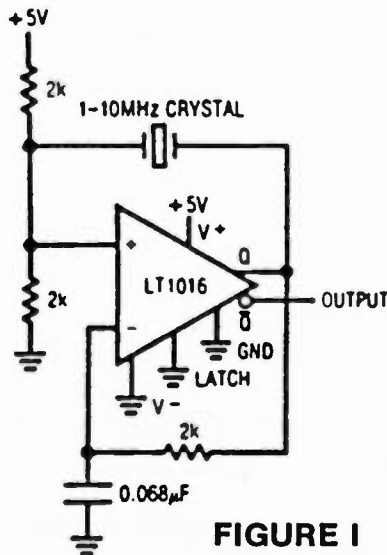


FIGURE I

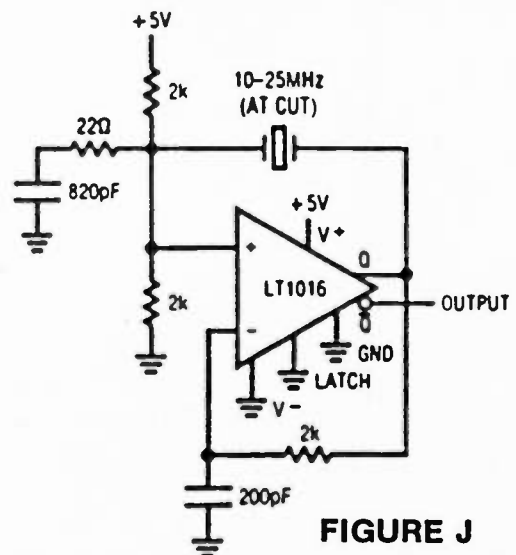


FIGURE J

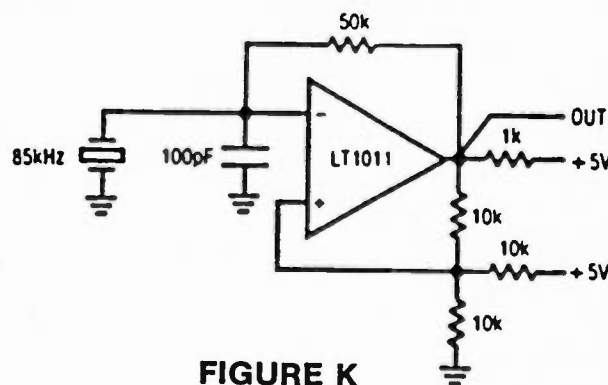


FIGURE K

CRYSTAL STABILIZED RELAXATION OSCILLATOR

For those of you who like working with transistor circuits, "G" and "H" should be of interest. Circuit "H" is an especially interesting circuit since it is a voltage controlled crystal oscillator (VCXO). This circuit could easily be converted to a low power, narrow bandwidth FM transmitter by applying a 0-10 volt audio signal to it.

Circuits "I," "J" and "K" round out our discussion of

crystal oscillators. These circuits use comparators to make crystal oscillators. While the integrated circuits used in these oscillators may not be standard "hobbyist" IC's, you can obtain them by writing to Linear Technology and finding out where, in your city, the nearest distributor of Linear Technology parts is located...From that point you are on your own...Have fun!

CIRCUIT FRAGMENTS



Reading about electronics can be fun and instructive, but the only way to become a knowledgeable technician is to get hands-on experience, by actually connecting resistors and capacitors together in circuits that do something. These circuits can be as simple as turning a light on or off, or making some kind of alarm sound. As long as we have a power source and a load connected together by wires, we have a functioning circuit.

Another way to think about circuits is to consider one part the input, and another part the output. This is notably true of amplifiers. The circuits in the following Circuit Fragments section are like this; they all do something.

These projects are comparatively simple—and each uses fewer parts than those in our **Workbench Projects** and **IC Testbench** sections. If you study them and put several together you will increase your understanding of how all electronic components and circuits work.

SWL's SUPER SIGNAL BOOSTER

Super sensitivity is the feature of this two-transistor shortwave preselector. It provides overall gain as high as 40 dB from 3.5-30 MHz.

Diode D1 protects against excess gate voltage caused by nearby transmitters, while Q1 serves as an emitter follower to match the medium output impedance of the FET transistor to the low input impedance of the receiver.

Since Q1 is a MOSFET type with a gate that's very sensitive to static changes, Q1 must be handled with a short-circuit across all leads until just before power is applied. Also, a soldering iron must not be applied to Q1's leads unless they are shorted.

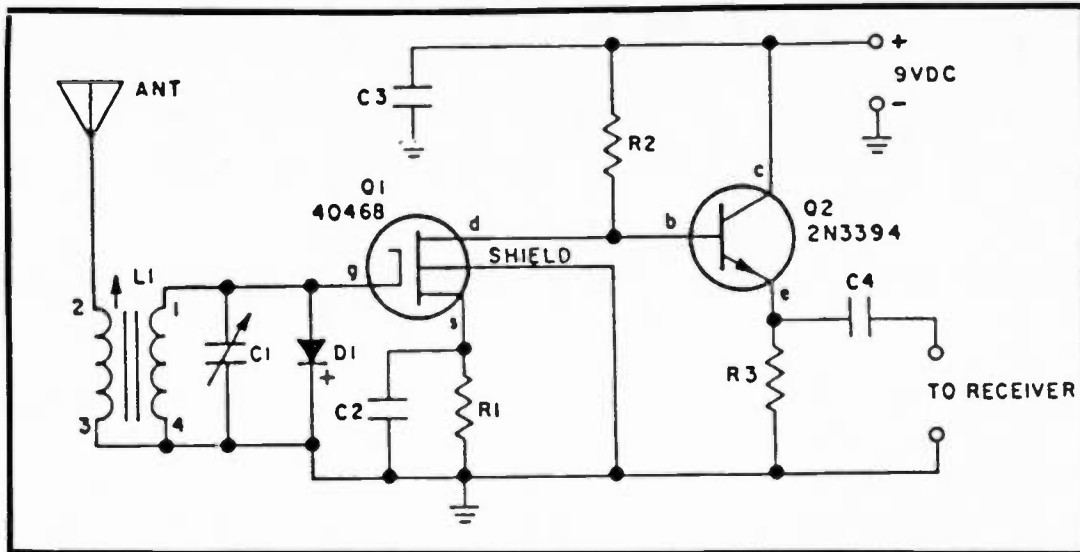
L1's connections are specified in the instructions supplied with the coil. A short length of RG-174U coaxial cable should serve as the connection between

the preselector output and the receiver with which the unit is to be used.

PARTS LIST FOR SWL'S SUPER SIGNAL BOOSTER

C1—365-pF tuning capacitor
C2, C3—0.05-uF, 25-VDC capacitor
C4—470-pF, 25-VDC capacitor
D1—1N914 diode
L1—Antenna coil: 1.7-5.5 KHz use Miller B-5495A, 5.5-15 MHz use Miller C-5495A, 12-36 MHz use Miller D-5495A
Q1—RCA 40468 FET transistor ((Do not substitute)
Q2—2N3394 npn transistor
R1—470-ohm, ½-watt resistor
R2—2400-ohm, ½-watt resistor
R3—4700-ohm, ½-watt resistor

SWL's SUPER SIGNAL BOOSTER



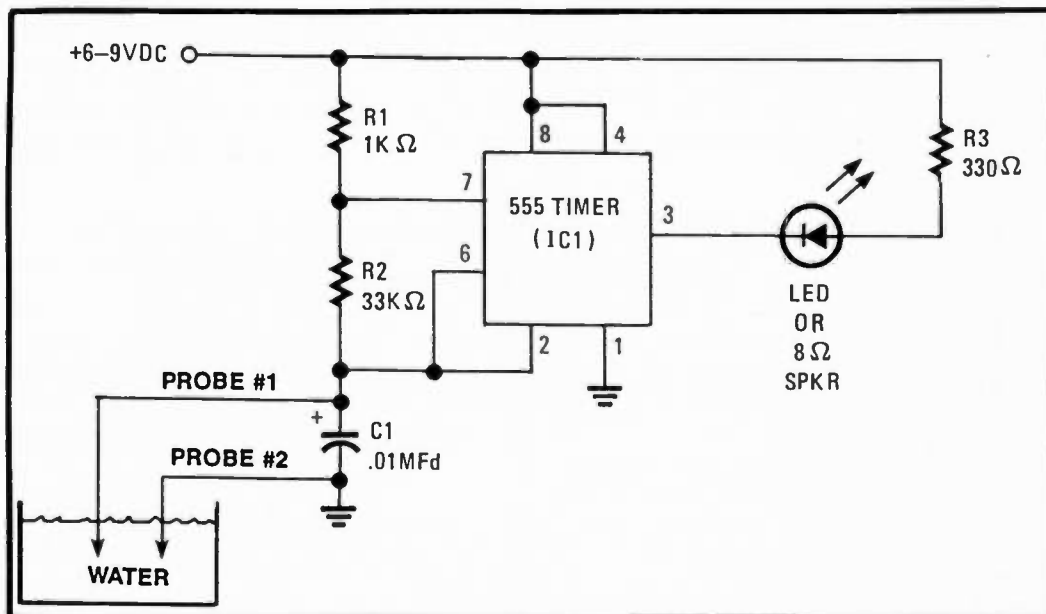
LIQUID LEVEL DETECTOR

This circuit was designed to alert the automobile owner when the fluid container for the windshield wiper container was nearing empty, at which point it will light an LED diode, strategically placed on or near the dashboard for convenient observation.

If you like sound better than visual indicators, you can substitute an 8 ohm speaker in place of the LED. All that is required for this adjustment is to remove the

LED and connect one lead of the speaker to pin #3 of the IC chip and connect the other lead of the speaker to ground. Be sure that the 330 ohm resistor is still connected to pin #3 to complete the circuit.

While this circuit is designed primarily to alert you when the liquid is low in your windshield wiper container, it can be applied to numerous other liquid containers. Let your imagination take over.



PARTS LIST FOR LIQUID LEVEL DETECTOR

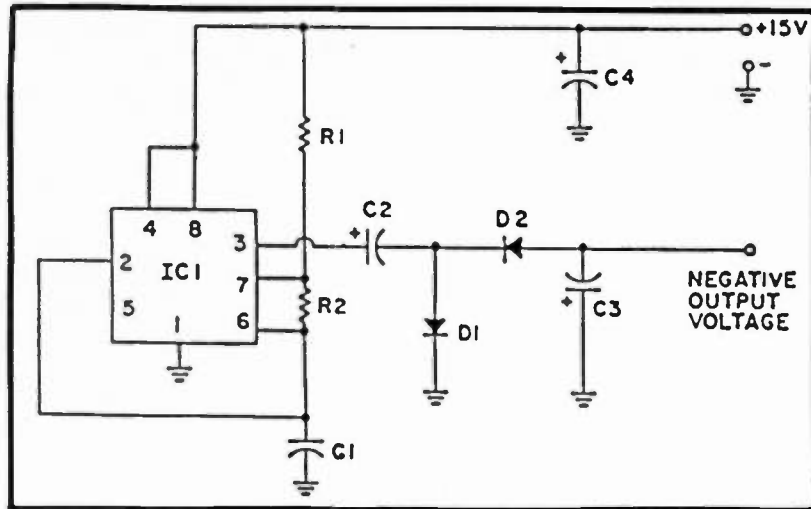
C1— .01 Mfd Disc capacitor
IC1— 555 timer (Integrated Circuit)
LED— light emitting diode or 8 ohm speaker
R1— 1K ohm resistor, ¼ watt

R2— 33K ohm resistor, ¼ watt
R3— 330 ohm resistor, ¼ watt
 —6 to 9VDC power supply

NEGATIVE POWER SUPPLY

Many operational amplifiers operate from a dual-polarity power supply. For low current applications, it may be easier to construct this negative power supply using one IC, rather than rectifying from the power line or transformer. IC1 operates in an astable mode

with essentially square wave output at pin 3. C2, C3, D1 and D2 form a full-wave voltage doubler circuit which produces approximately minus 14 volts with no load at the negative output terminal. The circuit will deliver 12 volts into a load of 1000 ohms.



PARTS LIST FOR NEGATIVE POWER SUPPLY

- | | |
|--|--|
| C1— .01- μ F ceramic capacitor, 15 VDC | IC1— 555 timer |
| C2, C3, C4— 15- μ F electrolytic capacitor, 25 VDC | R1— 1,000-ohm, $\frac{1}{2}$ -watt resistor |
| D1, D2— 1N4148 diode | R2— 10,000-ohm, $\frac{1}{2}$ -watt resistor |

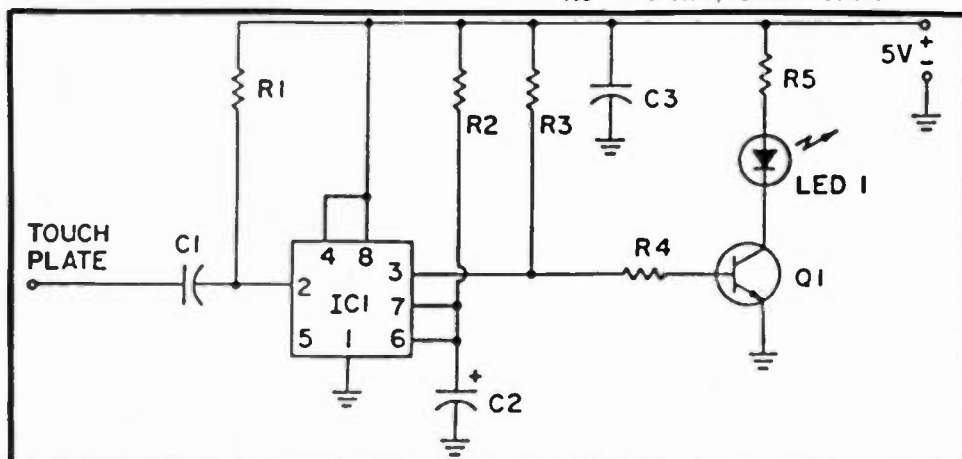
TOUCH CONTROL

Have you ever been in an office building where the elevator up-down buttons aren't switches at all, but work by touch? You can build a similar touch control circuit using a 555 timer IC. The circuit shown operates an LED, but you can easily modify it to control a doorbell or any other device. IC1 is connected as a one shot or monostable multivibrator with the trigger input, pin 2, wired to a high-impedance network. When the input terminal is touched by a finger, stray AC voltage pickup is impressed upon pin 2 of IC1, causing it to trigger. This causes pin 3 to go positive and provides forward bias to Q1 which illuminates the LED. R2 and C2

determine the time interval that LED 1 is illuminated, and for the values shown is about 3 seconds. The circuit is not fussy about power supply voltage.

PARTS LIST FOR TOUCH CONTROL

- | |
|--|
| C1— 0.01- μ F ceramic capacitor, 15 VDC |
| C2— 1.0- μ F electrolytic capacitor, 15 VDC |
| C3— 0.1- μ F ceramic capacitor, 15 VDC |
| IC1— 555 timer |
| LED1— large LED |
| Q1— 2N4401 |
| R1— 10,000,000-ohm, $\frac{1}{2}$ -watt resistor |
| R2— 4,700,000-ohm, $\frac{1}{2}$ -watt resistor |
| R3, R4— 4,700-ohm, $\frac{1}{2}$ -watt resistors |
| R5— 470-ohm, $\frac{1}{2}$ -watt resistor |



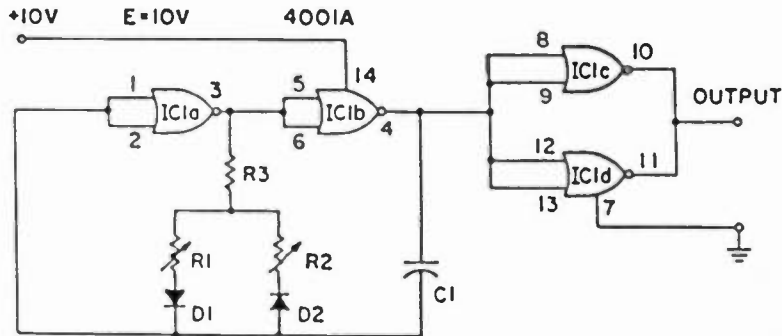
BASIC PULSE MAKER

Need a basic square-wave generator for all those digital projects? This quad NOR gate 4001A CMOS chip which can be easily obtained, stands ready to do the job with great simplicity. Note the two pots, R1 and R2. These govern both frequency and duty-cycle (symmetry), via diodes D1 and D2. C1 determines the overall frequency range. A C1 value of 0.1 μ F, produces a range of about 11 to 2500 Hz. Using a 0.2 μ F value, the range is about 4 to 700 Hz. The remaining two gates (pins 8-13) act as buffers, to

isolate the oscillator from the effects of circuit loading. Duty cycles of almost 10 to 1 can be obtained.

PARTS LIST FOR BASIC PULSE MAKER

- C1—0.1- μ F capacitor for 11-to-2500 Hz range, 0.2 μ F capacitor for 4-to-700 Hz range
- D1, D2—1N4148 diode
- IC1—4001 A quad NOR gate
- R1, R2—500,000-ohm linear-taper potentiometer
- R3—1000-ohm resistor



TELEPHONE VOICE

The "telephone voice" effect is usually created by passing a voice signal from a high quality microphone through a bandpass amplifier—a device that attenuates the frequencies on both sides of a selected frequency. Bandpass amplifiers are also effective at providing mid frequency boost-presence, as it's called in hi-fi terms.

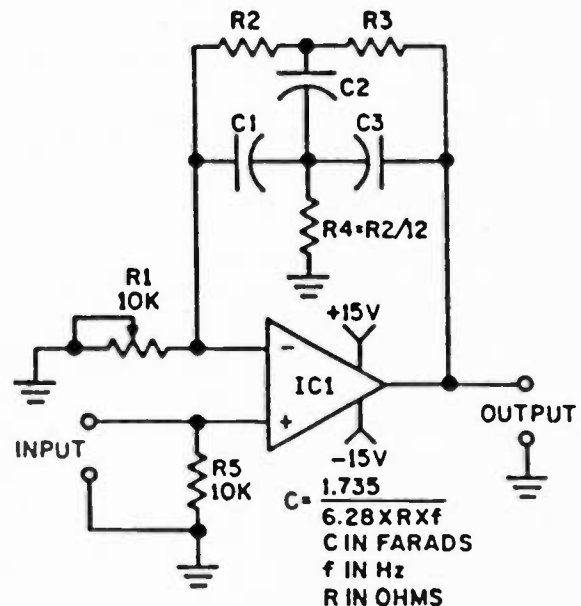
The center frequency of this bandpass amplifier is determined by the values of C1, C2, C3, R2, R3, and R4. The exact frequency can be determined from the formula shown. To start, assign a value of 100,000 ohms to R2 and R3 (use 1/2-watt resistors). To avoid hum pickup, the unit should be assembled in a metal cabinet. Potentiometer R1 serves as the Q-control; it determines the degree of boost at the center frequency.

R5 connects to the non-inverting (+) input of the IC, R1 between ground and the inverting (-) input. No pin connections are given because the IC is available in many different configurations.

Of course, you could find a carbon microphone "button" and matching transformer to create the effect naturally, but that's not how it's done in the big city, bub!

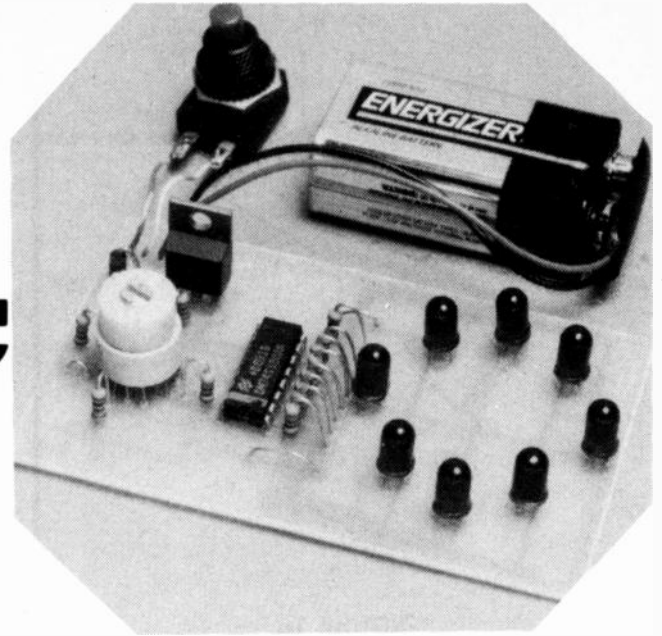
PARTS LIST FOR TELEPHONE VOICE

- C1, C2, C3—(C1 equals C2 equals C3, see formula)
- IC1—Type 741 opamp
- R1—10,000-ohm pot
- R2, R3—(R2 equals R3, see text)
- R4— $R4 = R2/12$
- R5—10,000-ohm, 1/2-watt resistor



BUILD AN ELECTRONIC COMPASS

By Steve Sokolowski



Throughout the centuries, man has been fascinated by magnetic fields. When discovered some thousand or so years ago, that the earth was encapsulated by this same phenomenon, scientists of that day unearthed a startling fact. By having a small piece of magnetized steel suspended in the air by twine, the needle always pointed to the north. The uncovering of such a strange occurrence eventually led to the highly accurate navigational equipment used today.

Not until four years ago, the ancient compass was catapulted into twenty-first century technology. By combining the miniaturization of mechanical as well as integrated circuitry; techniques, not available until recently; the Dinsmore Instrument Company of Flint, MI. was able to perfect the electronic compass. With this article, we will introduce you to the Dinsmore Digital Compass. And hopefully spark some interest in the development of some other high tech compass projects of your own.

The Compass Sensor

If one could look inside the compass sensor, he would see something similar to the illustration in Figure 1. Here, a small magnet is allowed to pivot freely around for "Hall-Effect" switches. When pointed north, the miniature magnet turns slowly to align itself in parallel with the earth's magnetic field (or field of flux). When aligned, the attraction supplied by the bar magnet closes the #1 "Hall-Effect" type switch, thus giving a logic "0" at its associated output pin (pin 3), while the others remain at logic "1." If the compass sensor was pointed to the south, the same occurrence would take place, but this time, the #3 "Hall-Effect" switch would close. This closure would

deliver a "0" at the pin 3 output of sensor #3 while all others would remain high ("1").

This scenario is just great if there were only four compass directions or headings. But there are eight. So, what happens if the sensor's bar magnet is pointing between sensor #1 and #4? If this is the case the output pin on BOTH the #3 and #4 sensor will deliver a logic "0." For example, say, you were facing North West. If LEDs were connected to all four output pins, the North and the West LEDs would light. Indicating Northwest. If you were to make a 180 degree turn, the compass sensor would light both the East and South LEDs indicating a heading of Southeast.

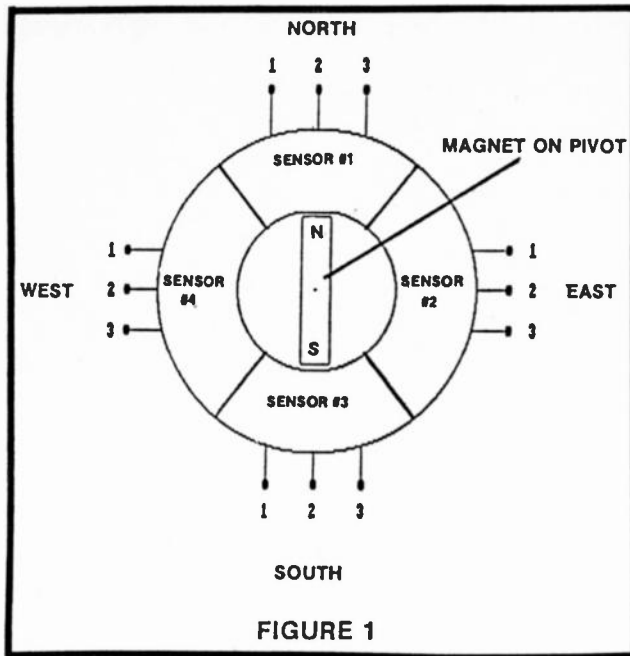


FIGURE 1

To show the relationship between all eight compass headings and output data, take a look at table 1. This listing shows which output pin will deliver a logic "0" for each compass heading.

For example, say that the compass sensor is facing North. The Hall-effect Sensor #3 will deliver a ground (or logic 0) to pin #3 of the device. If the anode lead of an LED were connected to this pin, while the cathode had a positive 5 volts on it. The LED will light. Indicating a heading of NORTH.

The same would hold true if the compass was facing West. But this time, the Hall-effect Sensor #4 will place a ground on the anode of another LED, while the output of Sensor #1 will go high. So, if a number of LEDs were placed in an 8 point circle pattern, we can easily indicate the standard compass headings just by lighting the appropriate LED.

How It Works

Figures 2 and 3 show the schematic diagram for our Electronic Compass. As you can see, the compass

sensor requires only a handful of inexpensive components. But to make the compass display all eight headings rather than having a dual output, we have included an integrated circuit to the final design.

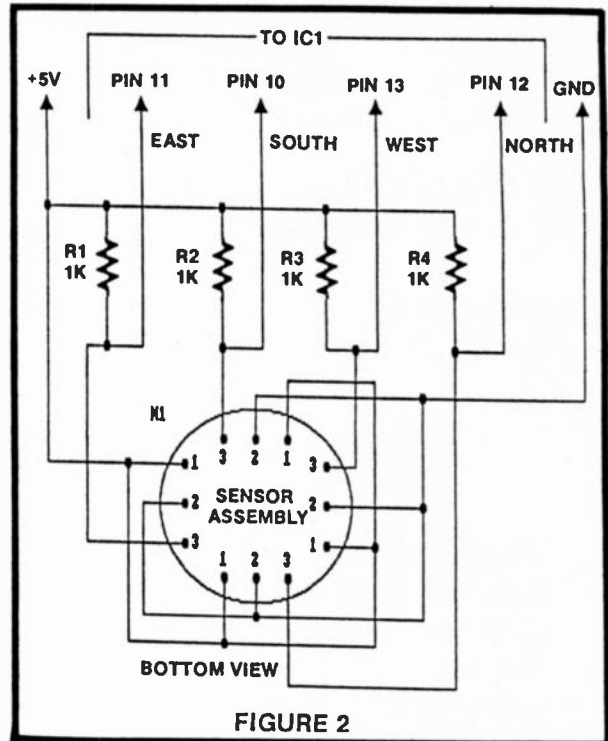


FIGURE 2

The 74188 (IC1) is a Programmable "Read Only" Memory (32 words 8 bit/word See Figure 4). When programmed, the chip can easily create a situation that will eliminate the lighting of two LEDs to indicate intermediate compass headings such as north east, south west, etc. The #74188 senses the dual input from the Dinsmore compass sensor then lights the one, and only one, LED that corresponds with this data.

Table 2 shows the internal programming of the #74188. The Binary output from the Dinsmore sensor is weighted 1,2,4,8. Here, we will indicate this as D0, D1, D2 and D3 respectively. The sensor data output is

74188 COMPASS PROGRAM

COMPASS HEADINGS	BINARY INPUT				74188 OUTPUT							
	D3	D2	D1	D0	B0	B1	B2	B3	B4	B5	B6	B7
NORTH	1	0	1	1	0	0	0	0	1	0	0	0
SOUTH	1	1	1	0	1	0	0	0	0	0	0	0
EAST	1	1	0	1	0	0	0	0	0	1	0	0
WEST	0	1	1	1	0	0	1	0	0	0	0	0
NORTHEAST	1	0	0	1	0	0	0	0	0	0	0	1
NORTHWEST	0	0	1	1	0	0	0	1	0	0	0	0
SOUTHEAST	1	1	0	0	0	0	0	0	0	0	1	0
SOUTHWEST	0	1	1	0	0	1	0	0	0	0	0	0

NOTE: 74188 OUTPUT, "1" = LED ON "0" = LED OFF

TABLE 2

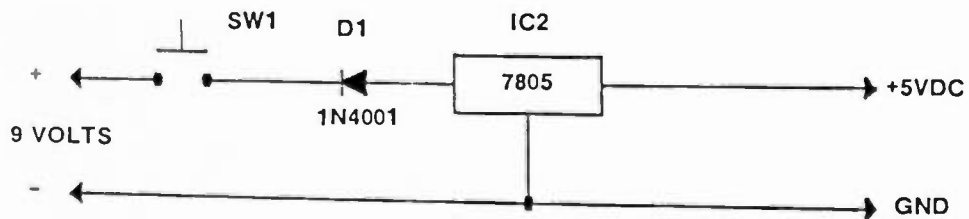
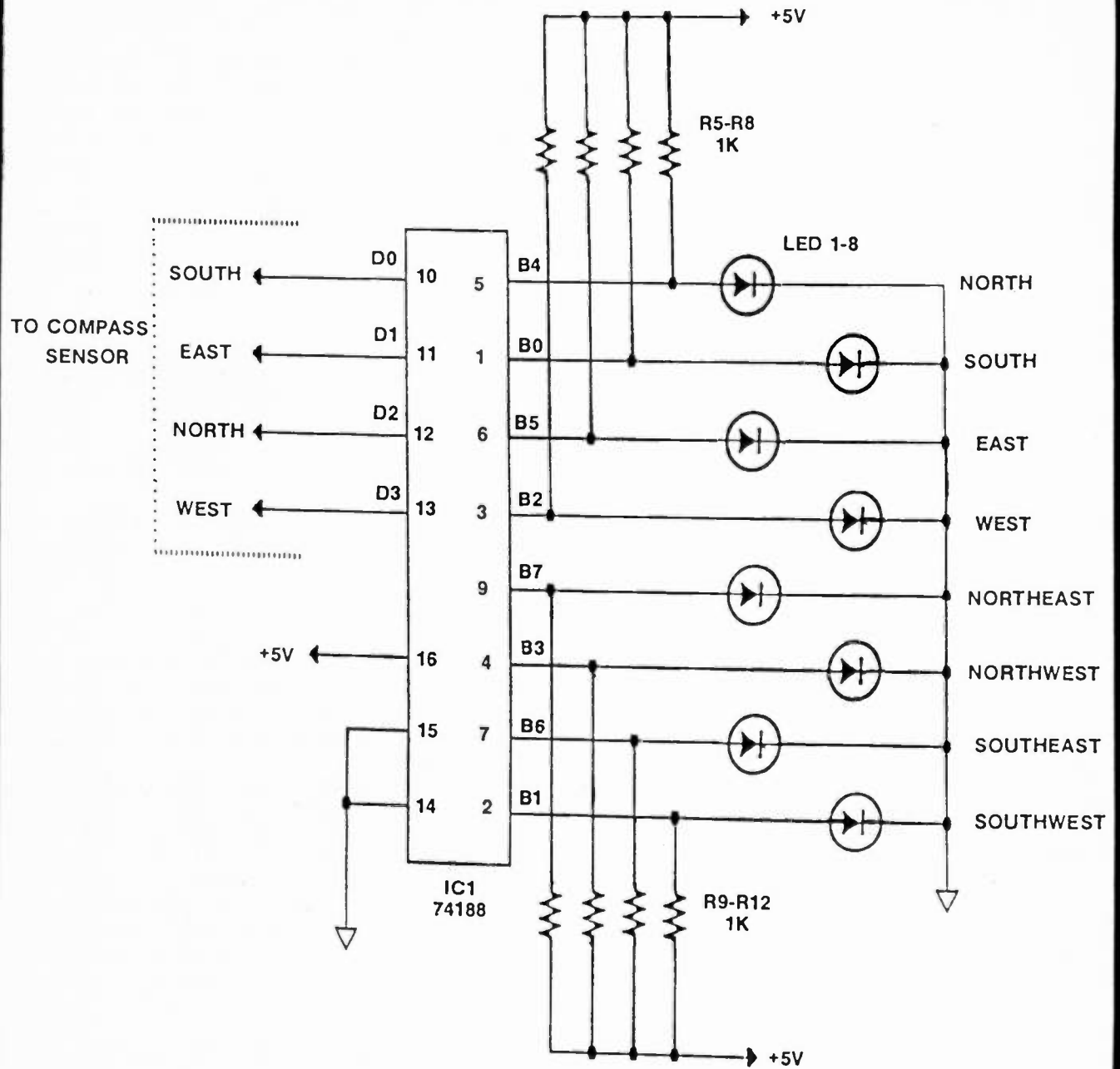


FIGURE 3

then wired to pins 10 to 13 (pin 14 is tied to a logic "1" level) of the #74188 ROM chip. The output terminals (B0 to B7) are programmed in such a way as to place a logic 1 at the output pin that will light the appropriate LED. When connected to an LED whose cathode leg is wired to ground, a difference of potential between the two terminals is present. This voltage difference will light the appropriate LED.

COMPASS HEADINGS	DATA OUTPUT			
	D3	D2	D1	D0
NORTH	○	○	○	●
SOUTH	○	○	●	○
EAST	○	●	○	○
WEST	●	○	○	○
NORTHEAST	○	●	○	●
NORTHWEST	●	○	○	●
SOUTHEAST	○	●	●	○
SOUTHWEST	●	○	●	○

● = LED OUTPUT ON (LOGIC 0 LEVEL)

TABLE 1

Seeing that the #74188 is a device that makes use of an open collector output, eight loading resistors in the range of 1K ohm must be connected to each output leg. The other side of the resistors are shorted together and brought to the +5 volt supply.

The Electronic Compass was meant to be a hand held device. So incorporating a 9 volt battery as the power supply is a must for its operation. But, by applying 9 volts to an IC that was manufactured to withstand only 5 volts would be a foolhardy

proposition. So to knock the input voltage down to the needed 5 volt level, we have used a #7805 voltage regulator (IC2 TO-220). This IC not only limits the output to 5 volts but it also provides a constant voltage to the circuit even if the battery used had another life in a portable radio.

The only drawback to this circuit is the massive current requirements to light LEDs and to power the #74188, which require about 90mA for normal operation. For this reason, the Electronic Compass was not meant to be in constant operation. For momentary operation, SW1 was added. Here the spring return button is pushed only when compass headings are required. Then released to conserve battery life which, by the way, should be an alkaline.

Programming the #74188 PROM

The programming of the #74188 requires you to assemble the circuit presented in Figure 5. Here the simulated data output from the compass sensor is delivered to the #74188's input pins (10 to 13) through four single pole double throw switches. The output, requiring a logic 1 output can be selected by using a 1 pole 8 position rotary switch (1 pole 10 position will also be satisfactory).

When purchased, the virgin #74188's B0 to B7 outputs are all at logic 0 levels. To program a logic 1 at any one of 256 memory locations, an internal "fuse" must be blown. By applying power that is well over the normal operating voltage, internal fuses can easily be opened. Here, in Figure 5 this "over voltage" is 12V. So that you don't destroy adjacent fuses from high current, a 330 ohm resistor is placed in series with the arm of the rotary switch. To allow the insertion and removal of the programmed IC, a 16 pin IC socket should be used.

The power required by the programmer is quite unique, but not impossible to find. Surplus mail order houses sell inexpensive DC power supplies that deliver ±5VDC as well as ±12VDC with a current of about 50mA. When wiring the circuit, just verify the polarity and level of each output with a volt meter. Then connect the appropriate voltages in place.

Once your programmer in complete, check the wiring and inspect for solder bridges. When all

74188 PROGRAMMABLE READ-ONLY MEMORY PINOUT (32 WORDS - 8 BITS/WORDS)

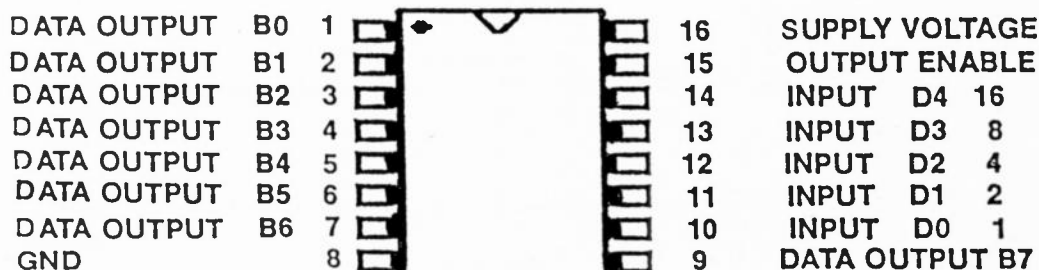


FIGURE 4

connections have been "inspected" for problems, the time has come to program the logic data onto the non-volatile memory of the #74188.

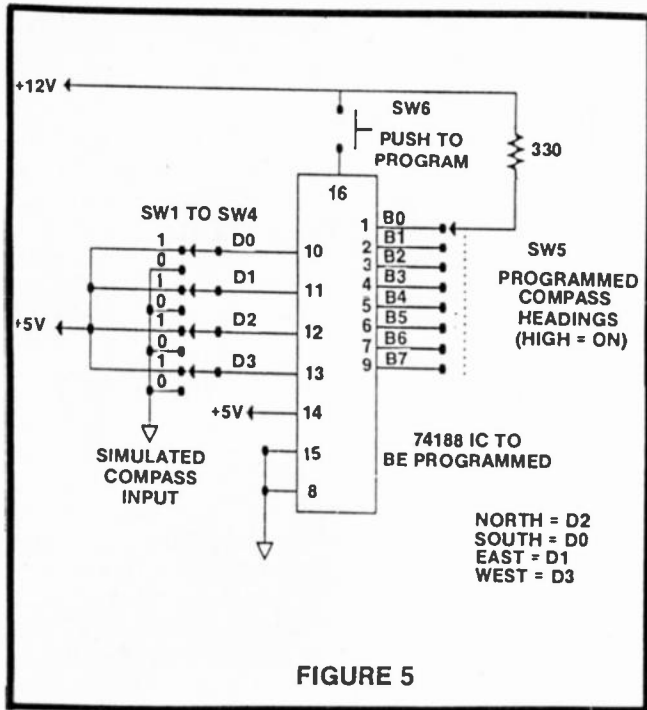


FIGURE 5

Step-By-Step Programming of the #74188

To start, place a fresh #74188 chip into the 16 pin IC socket, observing the proper orientation of the chip. Then turn on the power. Using the data input switches (SW1 to SW4), apply the following binary code:

D3	D2	D1	D
1	1	1	0

This code will simulate the compass' NORTH output. With the appropriate data applied, turn the SW5 to its B4 position. Then press SW6 (Program Switch) for an instant. Don't hold SW6 down longer than 2 seconds. **This will destroy the IC.** When programmed, place D0 switch back to its logic 1 position.

Next, let's program the SOUTH output by flipping the D1 switch to logic 0. SW5 should be in position B0. Press SW6 to program a 1 at this point. Return SW2 to logic 1.

EAST can be programmed by flipping the D2 switch to logic 0. SW5 should be at position B5. Press SW6 to program. Return the data switch to logic 1.

Programming WEST can be accomplished by flipping the D3 switch to logic 0. SW6 in position B2. To program, press SW6. Return D3 to its logic 1 position.

NORTH EAST is programmed by flipping both D0 and D2 to logic 0. SW5 is in its B7 position. Press SW6 to program. Return data switches to logic 1.

NORTH WEST can be programmed by flipping both D0 and D3 to logic 0. SW5 should be in position B3. Again, press SW6 to program.

SOUTH EAST is programmed by setting D1 and D2 to logic 0. SW5 should be set to its B6 position. Press SW6 to program.

Final SOUTH WEST can be programmed by applying a logic 0 level to both D1 and D3. SW5 is placed in its B1 position. Press SW6 to program.

This completes the programming of the #74188. But there is an easier way to get the same results. How? Consider purchasing a pre-programmed PROM from Suncoast Technologies, Spring Hill, Florida. Why not let them do the work, why should you?

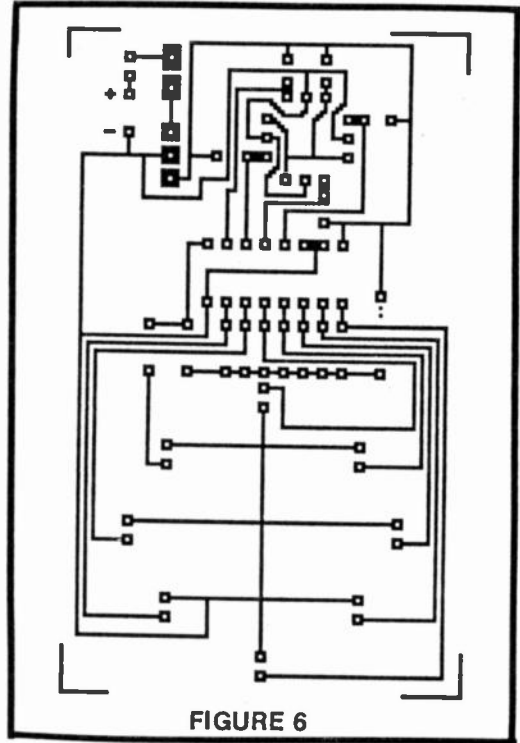


FIGURE 6

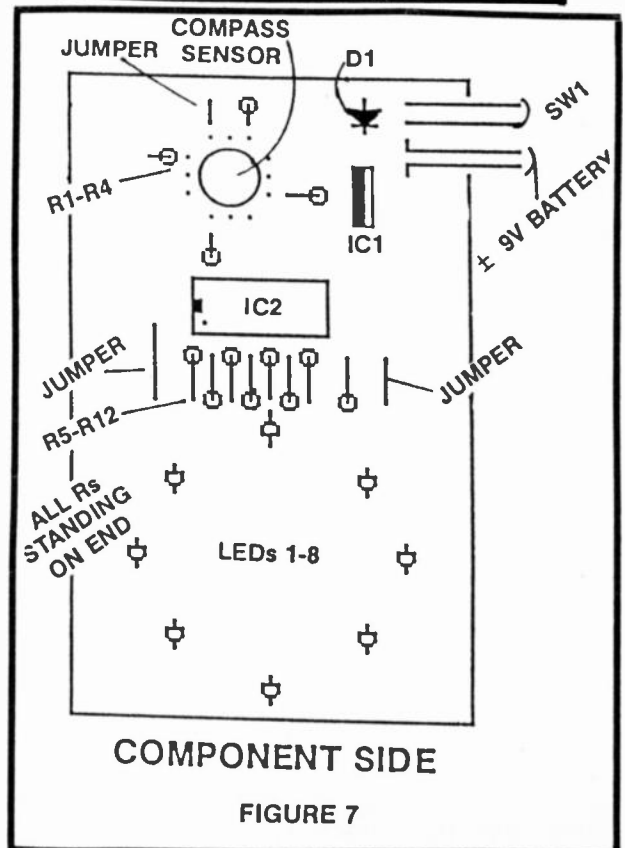
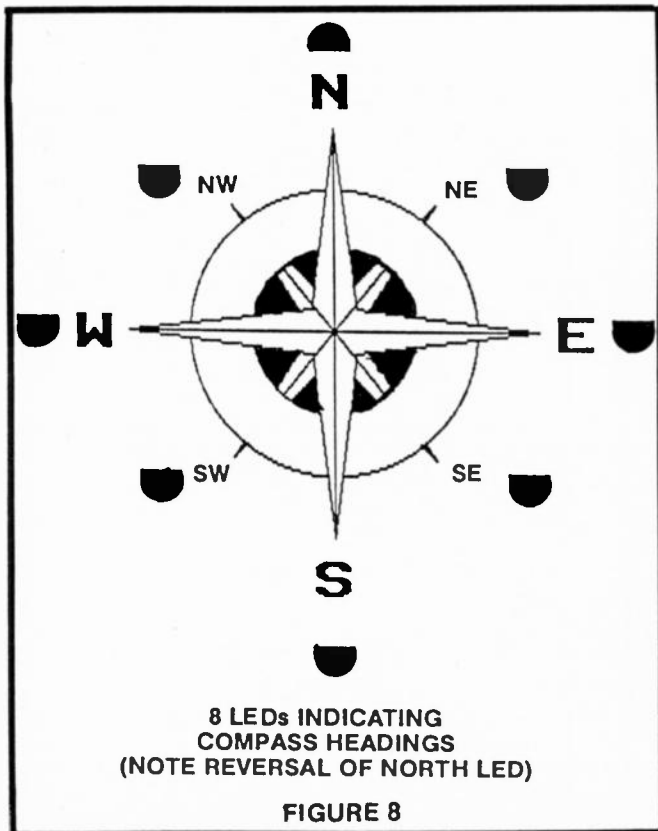


FIGURE 7

Construction

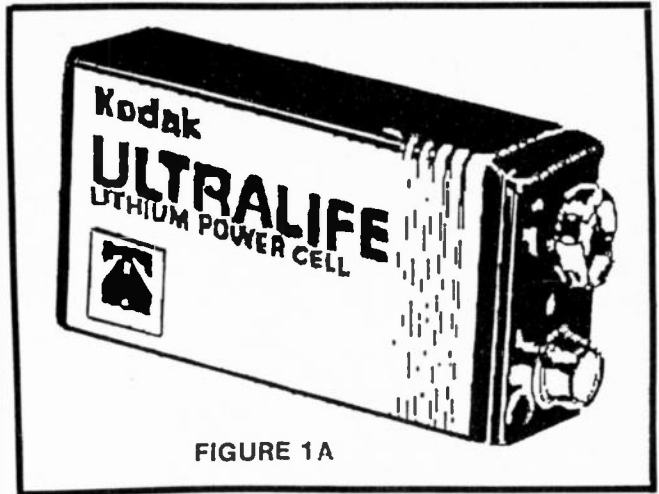
The wiring of the Electronic Compass is relatively simple. But the compass does require the use of many polarity sensitive components. Such as the LEDs, ICs and most of all, the compass sensor itself. To help minimize the burnout of the fragile components, Figure 6 shows the 1:1 artwork for the circuit board, while Figure 7 illustrates the component layout. If you follow the layout diagram, you should have no problem in the construction of the circuit. Just remember to double check all component orientation before soldering. All orientation is shown on Figure 6. Care must be taken when installing the LEDs in their appropriate holes. All LEDs have their cathode leg connected to ground. Note that the placement of the LED indicating North is in reverse to all others (See Figure 8). Also note that the PC Board requires three jumper wires that must be installed.

With all the LEDs and resistors installed on the board, the last components to be soldered are the compass sensor, IC1, and IC if you wish, IC1 can be installed on a 16 pin DIP socket. By using a socket, destructive heat generated by the soldering iron can be eliminated altogether, without worrying about "blowing" the device. While soldering the compass sensor and voltage regulator, a heatsinking material should be clipped on their leads before applying heat. A simple alligator clip can be used as such a device. But be careful when removing it since it will be hot to the touch. If care is not taken, severe skin burns can occur.

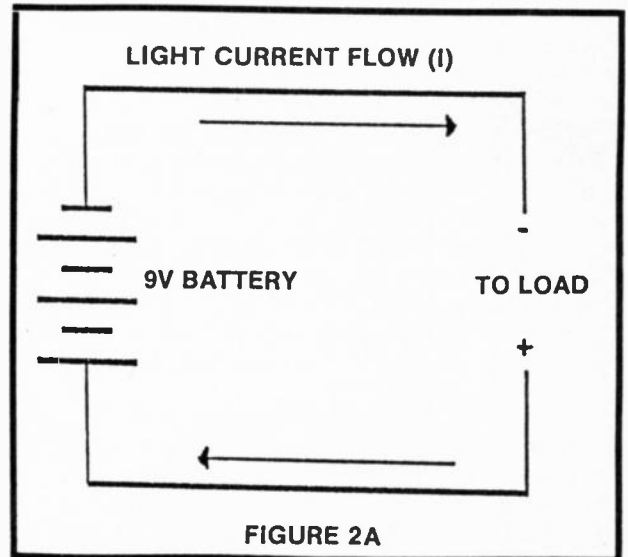


The final wiring of the compass takes the form of the 9V battery clip and the push button. These parts can be wired in any number of ways, but for clarity,

we've included copper traces on the PC Board where they can be soldered. These locations will provide a strong connection point for the series circuit as well as enhancing the appearance of the overall project.



When properly assembled, the Electronic Compass draws about 100mA of current for its operation. Standard carbon 9v batteries can deliver this amount current but for only a brief period. To overcome this problem, it is recommended that the Electronic Compass be powered by high quality alkaline or lithium batteries. While higher in price, these premium batteries will be able to handle the current requirements of the project. Eveready, Kodak (See Figure 1A and the "copper top" (Duracell), to name a few, will power the compass for months without a battery replacement.



If you're like me, you have a junk box full of inexpensive 9v batteries. So why not use these? Sure you can. But you need to put some basic electronic theory into practice. Figure 2A illustrates how the current of a common battery flows through the copper interconnecting wires to its destination, the load, which represents how much power must be delivered by the battery for the normal operation of the circuit. It is expressed as RESISTANCE. In our case, the LOAD is represented by the Electronic Compass. By making use of the formula:

CURRENT (I) = VOLTAGE (E)/ RESISTANCE (R)

you can see that if the load resistance increases, the current being consumed by the circuit decreases. In contrast, if the load resistance decreases, the current requirements increase.

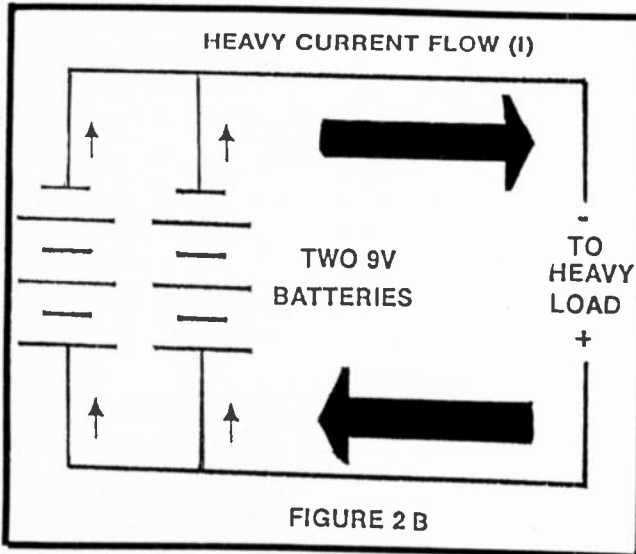


Figure 2B shows a simple series hookup containing a 9v battery and a Load. If the load resistance is in the range of 5000 ohms, the current being drawn will be 1.8mA (or .0018 Amps $I=E/R$ $I=9/5000$). With a current this low, a standard carbon composition battery will have no problem driving the load for long periods of time. But on the other hand, with a load resistance of 90 ohms as, in our compass, the current that is needed will be 100mA (or .1A) An extremely large amount of energy for a carbon battery to deliver. But hold on a minute, we can increase the current handling of the battery by wiring two batteries in parallel. This can be seen in Figure 2B.

Think back for a moment to those thrilling days of yesteryear (school days). If two batteries are tied together in parallel, the total current is equal to the sum of BOTH sources. Or in other words, Total current is equal to the current from battery one plus the current from battery two. ($I_{total} = I_1 + I_2$). So if we take two 9v battery clips and solder them in parallel as shown in Figure 2B, to the provided holes in the pc board, and snap a couple of transistor radio batteries in place, the current requirements for our Electronic Compass will be easily met without purchasing expensive alkaline substitutes. The total driving current of the two batteries will be significantly increased, thus providing the power needed by the compass circuit.

Cigarette Lighter Adapter Power Option

When completed, the Electronic Compass can be housed in a small PLASTIC box for hand-held use. Just make sure that you have enough room inside for the batteries. However, the compass is not restricted to tramping through the woods. By adding an inexpensive adapter to the completed circuit, the compass can also have frequent use in either your car or boat. This device is a Cigarette Lighter Plug (See Figure 3A. Since the compass utilizes a 7805 voltage

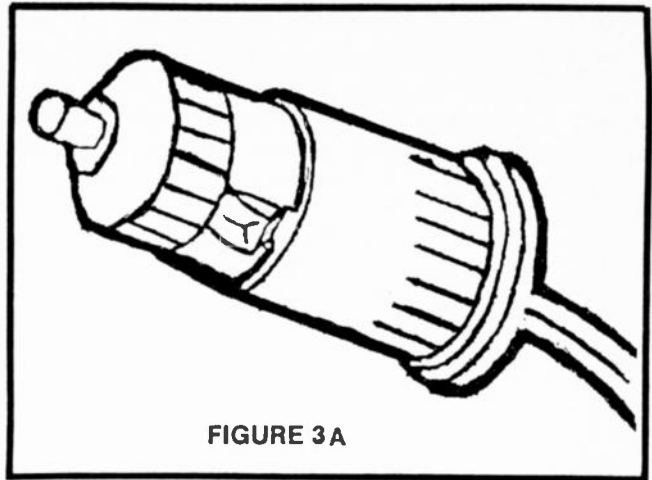


FIGURE 3A

regulator, any DC voltage in the range from 6 to 25 VDC can be used to power the device. Car and boat batteries are of the 12 volt variety, which present no problems. The adapter plug is an inexpensive item that can be purchased at any Radio Shack store or from electronic mail-order suppliers. When your adapter arrives, take a look at Figur 4A for a diagram showing the proper wiring. Note that one of the two line cord wires has a white stripe on it. This stripe called a "tracer" is used to indicate the positive (+) lead. In contrast, NO trace, obviously, is the negative lead (-).

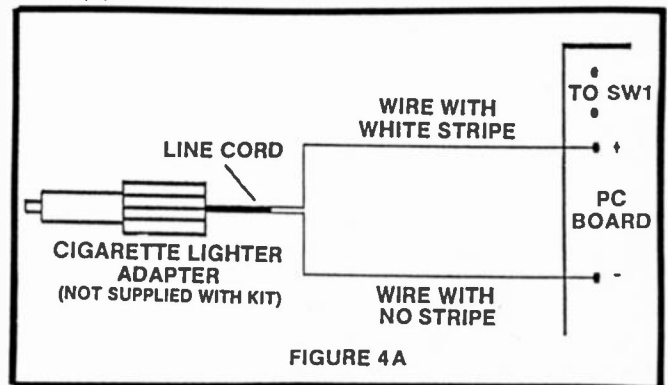


FIGURE 4A

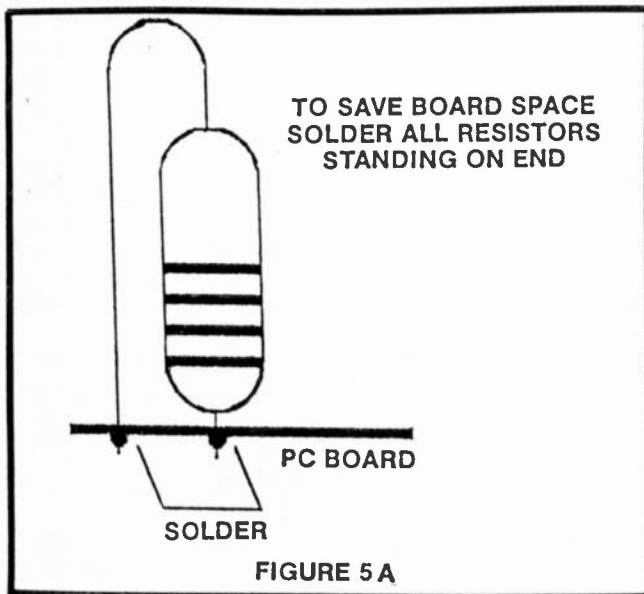
To install the adapter, unsolder and carefully remove the 9v battery clip from the board. Clean out each hole with a desoldering tool or solid piece of wire if solder somehow flowed inside. With our polarity requirements in mind, take the adapter's tracer lead, insert it into the hole requiring positive voltage (+), and solder it into place. The nontracer lead is to be installed and soldered to the remaining hole. When complete, "check" the board for any unwanted solder splashes before plugging in the adapter.

Now, sitting in your car or boat, take the adapter plug and insert it into the cigarette lighter. Holding the compass parallel to the ground, press SW and note which LED lights. This indicates the direction the compass is being held.

Another option that you might want to consider if using the cigarette lighter adapter, is the permanent removal of switch SW1, because when the engine of the car or boat is turned off, voltage to the vehicle's cigarette lighter will be cut off, thus removing power from the compass. Just remember to place a jumper wire between the two SW1 PC Board holes.

Testing

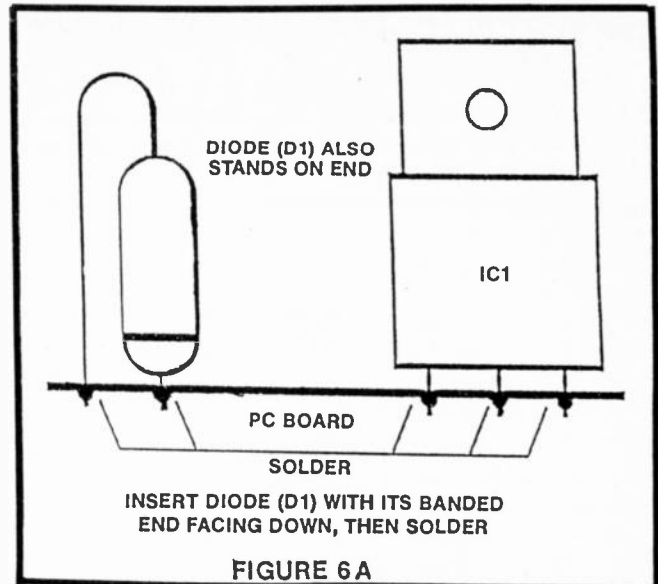
When the PC Board is inspected under strong light to ensure that there are no solder splashes or bridges, take a 9 volt alkaline battery and connect it to the provided clip. Facing a known direction, hold the compass in parallel to the ground. Press SW1 and note the lighting of the appropriate LED. Slowly spin around and check for the advancement of the LEDs as they light and extinguish in the proper sequence. If the north LED doesn't light, double check to see if the device was inserted in the proper direction. If no LED lights, check to see if a positive 5 volts is present at pin 16 of IC1. Also check for proper grounding of IC1's pin 8. If no voltage is present, check IC1 for proper insertion and finally, check diode D1. It might be open or reversed on the board.



Added Assembly Instructions

If you choose to assemble the compass using a home brewed PC Board or by purchasing the complete kit from **Suncoast Technologies** there are a few things you must be made aware of. All resistors must be installed and soldered while standing on end (See Figure 5A.). By placing components on end, precious PC Board space is saved. And at 50¢ a square inch, you can appreciate this saving.

Diode D1 is another component that must be soldered on end. Unlike the resistors, diodes have a polarity and they must be installed in a certain way. If not, the compass just won't work. Figure 6A shows the proper installation procedure for D1. Note that the banded end of the diode is facing downward. Also it's installed with the body towards the 7805 voltage regulator (IC1).



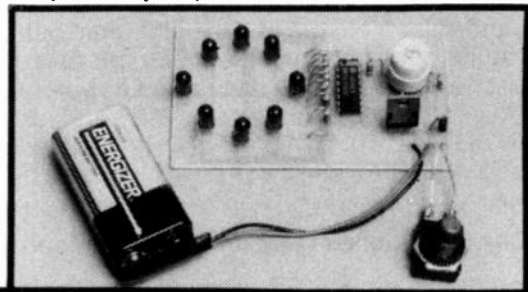
By taking these simple precautions, the Electronic Compass will provide years of dependable service. And best of all, you can say, "I built it."

If you wish to house your compass, a metal case is definitely a No-No. The earth's magnetic field will be interrupted and erroneous reading will result. The compass housing should be made only of plastic. Boxes of this type are readily available and inexpensive. And can be found at any Radio Shack store.

Whichever troubleshooting or housing technique you use to get your Electronic Compass at the stage of final assembly, just remember that the use of a printed circuit board in any project will pay for itself in no time and will provide trouble-free operation for years to come. ■

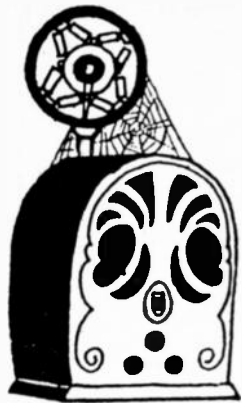
PARTS LIST FOR THE ELECTRONIC COMPASS

- R1 to R12—1K ohms ¼W Resistor
- IC1—Programmed #74188 ROM
- IC2—#7805 5V Voltage Regulator (TO-220)
- D1—1N4001 Diode
- LED1 to LED8—Standard Red Light emitting diodes
- M1—Compass Sensor
- MISC.—Plastic Housing, Printed Circuit Board, 9V Battery, Battery Clip

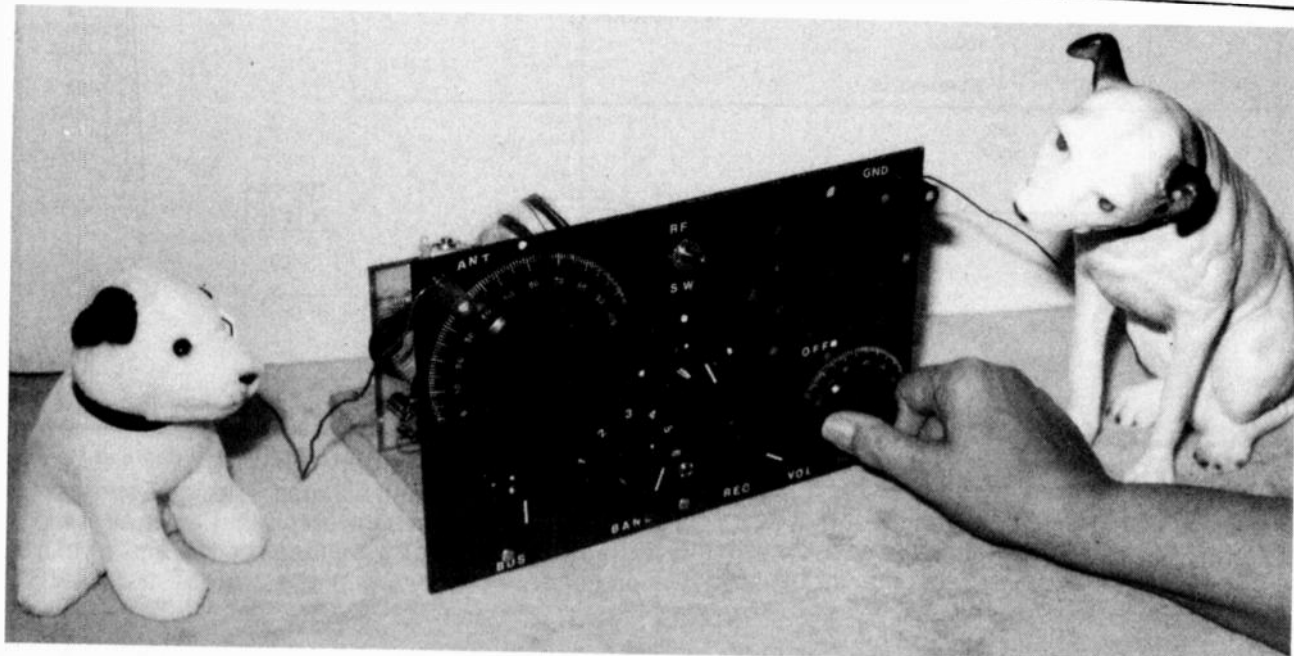


THE FOLLOWING ARE AVAILABLE FROM:
SUNCOAST TECHNOLOGIES
P.O. BOX #5835
SPRING HILL, FL 34606

Complete Compass kit containing Compass Sensor, PC Board, Programmed #74188, Resistors and LEDs (Less Plastic Housing): \$24.00. Available separately: Compass Sensor \$15.00; PC Board \$5.00, Programmed #74188 \$3.00. Please add \$2.50 (Shipping & Handling) for all U.S. orders and \$3.50 (Shipping & Handling) for Canadian orders. Payable in U.S. funds and/or Money-orders only. Florida residents must include Sales Tax.



ANTIQUE RADIO CORNER



BUILD YOUR OWN VARIO- COUPLER RECEIVER

By Homer L. Davidson

Back in the late twenties and early thirties the vario-coupler coil assembly was used for tuning and feed back operations in the one or two tube shortwave receiver. Since these vario-coupler units can only be found with antique radio collectors, and they cost plenty, this tuning coil assembly was made from PVC pipe and a foam disc (Fig. 1). Actually, these vario-coupler parts cost less than a buck fifty, plus the coil wire.

The 3½ inch PVC pipe coupling can be picked up at most plumbing supply stores. This makes a very sturdy coil form. The foam ball, disc, brass tubing and wooden dowel can be found at most hobby stores. Even the front panel and bottom chassis are made of scrap masonite and wood pieces. Although, this all-wave receiver may take a little time to build, it will take you back on a nostalgia trip to the early days of radio, and it's worth every minute of it.

The Circuit

The allwave receiver should operate from the broadcast band down to the 20 meter band. The circuit consists of a FET regenerative transistor and a low power audio IC (Fig. 2). C1 is switched directly to the main coil of the shortwave bands and switched to the primary coil (L1) for broadcast operation.

Coil L2 and C2 tune the entire bands. SW2 switches in the different tapped coil windings of L2. Varactor diode (VD1) provides adequate bandsread tuning or station separation. L3 provides feedback operation when rotated. This movable coil helps in regeneration control and separating stations. The main regeneration is controlled by R5. The entire receiver circuit is constructed on a single PC board.

C8 picks up the weak audio signal and is fed to the volume control (R7). Isolation capacitor (C9) couples

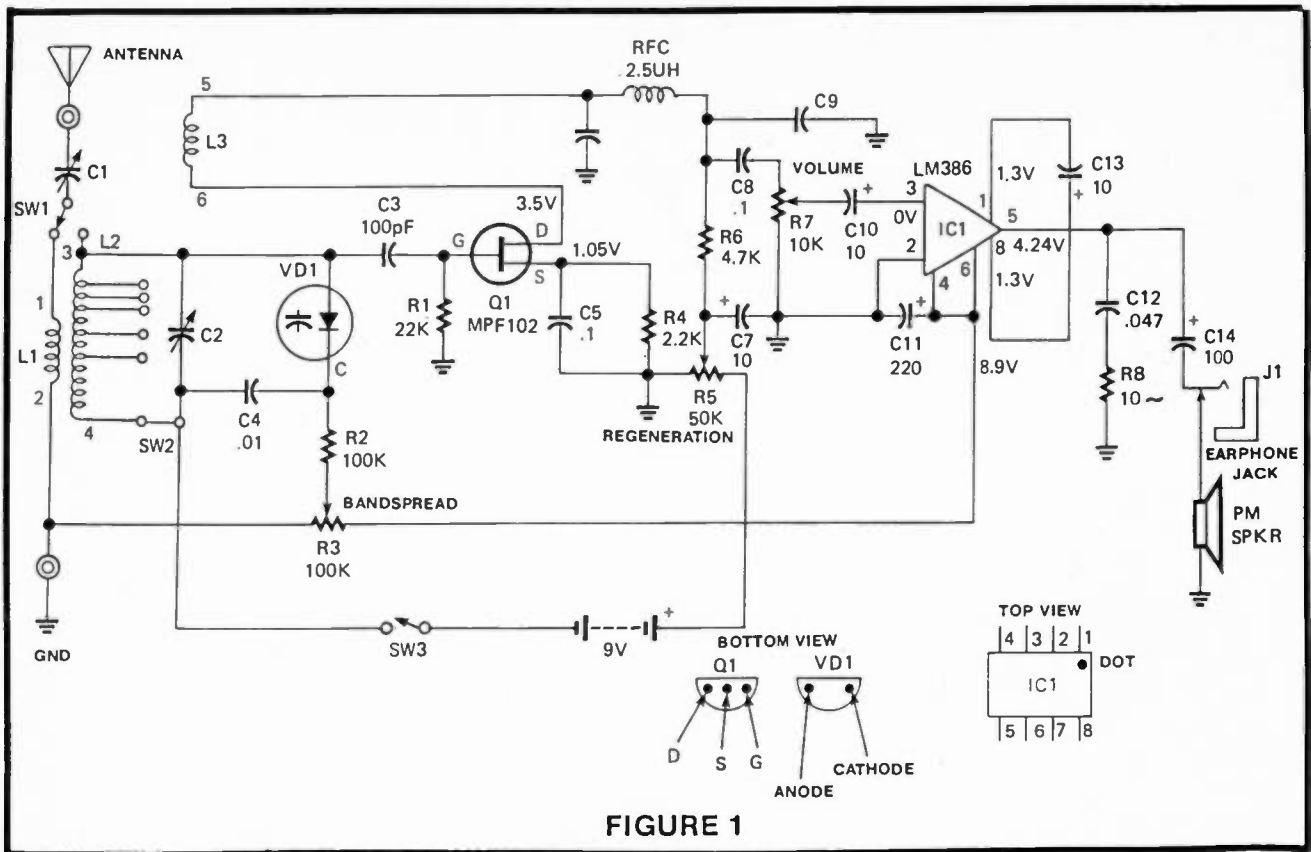


FIGURE 1

Figure 1. The complete circuit of the RF regeneration and audio circuits. Only two solid-state devices are used (Q1 and IC1).

the audio signal to pin 3 of the audio output IC1. This little amp can drive a 3 or 4 inch PM speaker with the loudest signals. Earphone reception is best when

tuning in the squealing stations. The small speaker is out of the circuit when the earphones are in operation with J1. The small all wave receiver operates from a 9 volt battery.

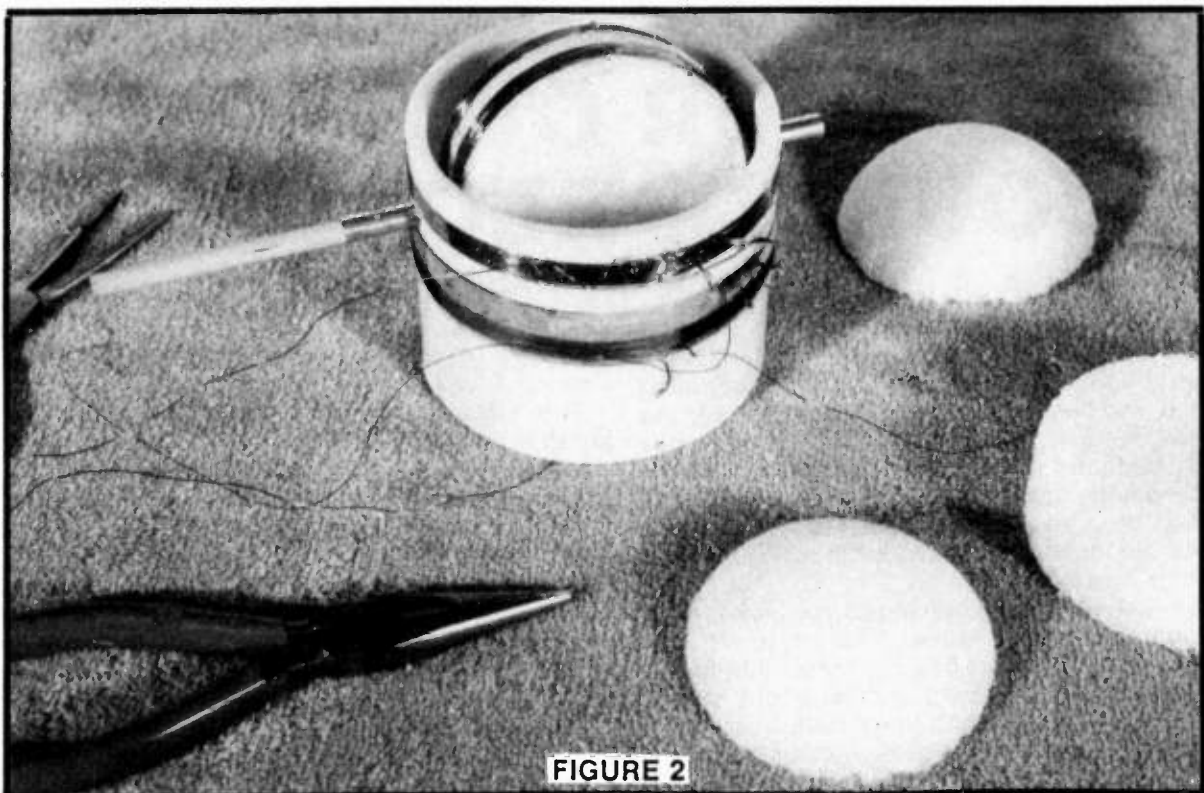


FIGURE 2

Figure 2. The variable or vario-coupler coil (L3) construction on a foam disk with rod and metal commutators. L3 contains 16 turns of number 22 enamel wire.

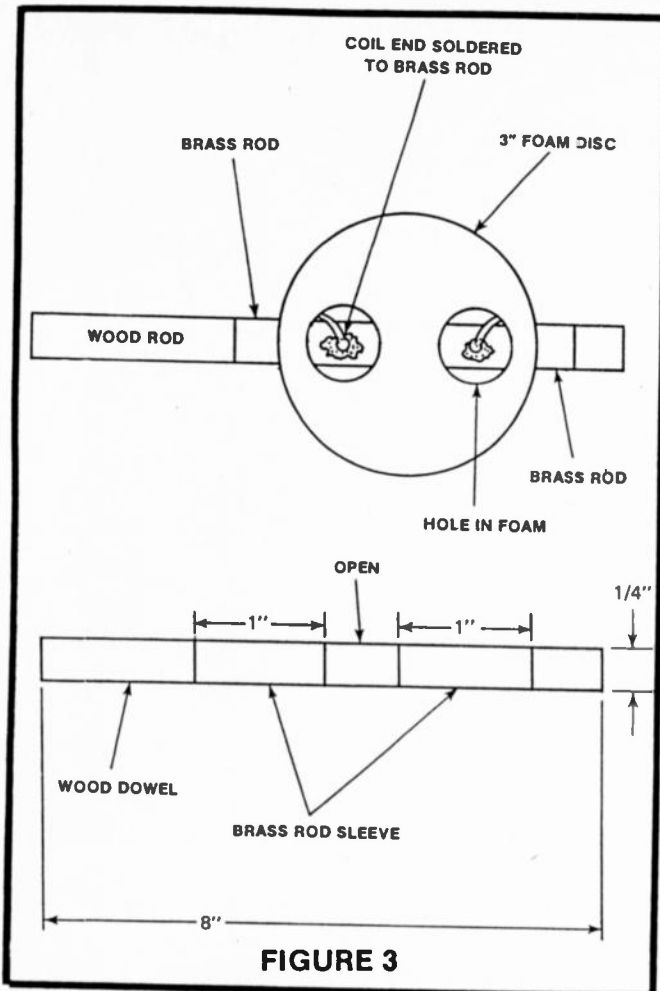


Figure 3. The rotating rod is made up of a 1/4 inch wood dowel, brass rod and 3 inch foam disc. The brass sections are cemented to the wood rod.

Remodeled Capacitor

Although, the variable capacitor shown in the photo is one of those antique types picked up for \$2.00 at an antique radio show, there are still a few 365 PF variable capacitors around. Look in the junk box, old radios, flea markets, and at antique shows. Use the RF section found in the two stage variable capacitor of the older AM tube radio.

Remove all but three rotor plates of the variable tuning capacitor. This is not a new trick as it was done many years ago. Rotate the plates completely out of the stator plates. Start breaking off the back plate by bending the aluminum plate back and forth. Be careful not to damage the stator or remaining rotor plates. Remove the remaining piece with a pair of long nose pliers. Leave only three remaining rotor plates. You can check the total capacity with plates meshed together with 2 capacitor tester, if handy. The total capacity of the modified tuning capacitor should be between 100 and 145 PF. Make sure the rotor plates do not touch the stator plates at any time.

Vario-Coil Construction

The inside dimension of the PVC coupling coil form is 3 1/2 inches inside and approximately 4 inches outside. The tickler coil (L3) can be mounted on a 3" diameter round ball cut into or a 3 inch polystyrene

disc. The disc should be at least 1 1/4 inches wide to wind L3 on the edge. The disc may be cut from a 1" flat piece of foam. Drill a 1/4 inch hole down the center of the disc to accept the tuning rod (Fig. 3). Make sure the 1/4 inch wood dowel will go through the hole. Now, wind coil L3 with 16 turns of number 22 enameled wire. Hold coil in place with tape until cement is applied over the winding. Wind 8 turns on each side of the wood dowel.

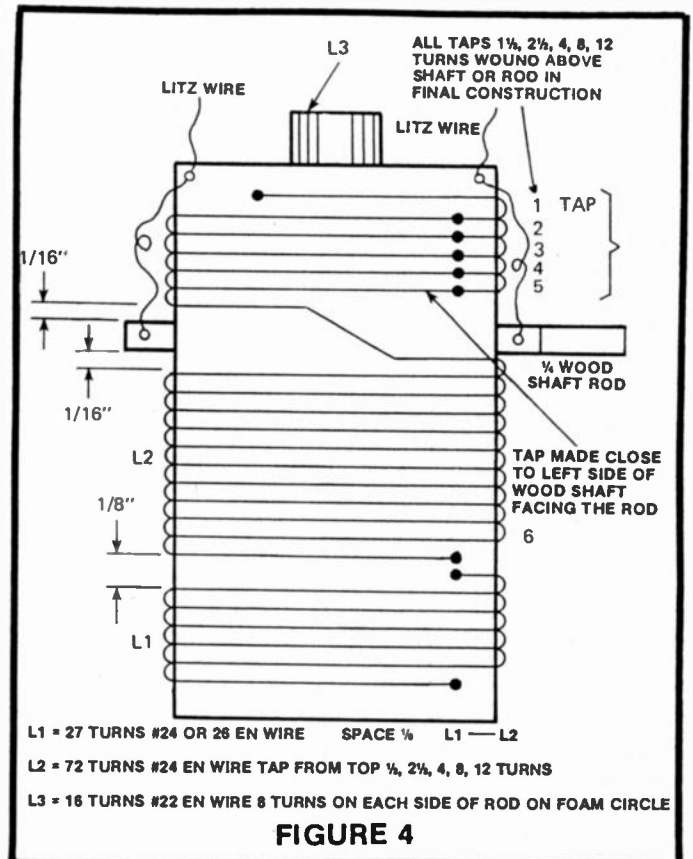
Cut out two 1/2 inch holes in the polystyrene coil form towards the center so the two leads of L3 can be soldered to the metal brass commutator rods. Scrape off the enamel at both ends. Tin the coil ends and push the wires into the foam material towards the large holes. Solder the wire to 1" metal tubing.

Prepare The Rod

Cut off the 1/4 inch wood dowel to approximately 8 inches—longer if the vario-coupler sets toward the back of the chassis. Cut two, 1 inch pieces of brass tubing to fit over the wood dowel. The brass tubing and foam disc or ball can be found at most hobby or craft stores. Cement the brass tubing at one end and start the other piece about 1/2 inch away at the middle (Fig. 4). Let the cement set a couple of hours while winding the main coils L1 and L2.

Coil Form Preparation

Center the large PVC coil form. Drill a 1/4 inch hole through the center and 1 1/2 inches down from the top of the plastic pipe for the rod of L3. Drop down 1/8 inch and drill 1/8 inch hole to start L2. Drill two more 1/8 inch



L1 = 27 TURNS #24 OR 28 EN WIRE SPACE 1/8" L1 — L2
 L2 = 72 TURNS #24 EN WIRE TAP FROM TOP 1/4, 2/4, 4, 8, 12 TURNS
 L3 = 16 TURNS #22 EN WIRE 8 TURNS ON EACH SIDE OF ROD ON FOAM CIRCLE

Figure 4

Figure 4. The complete PVC coil form with L1, L2 and L3. Note that L1 is wound at the bottom of L2.

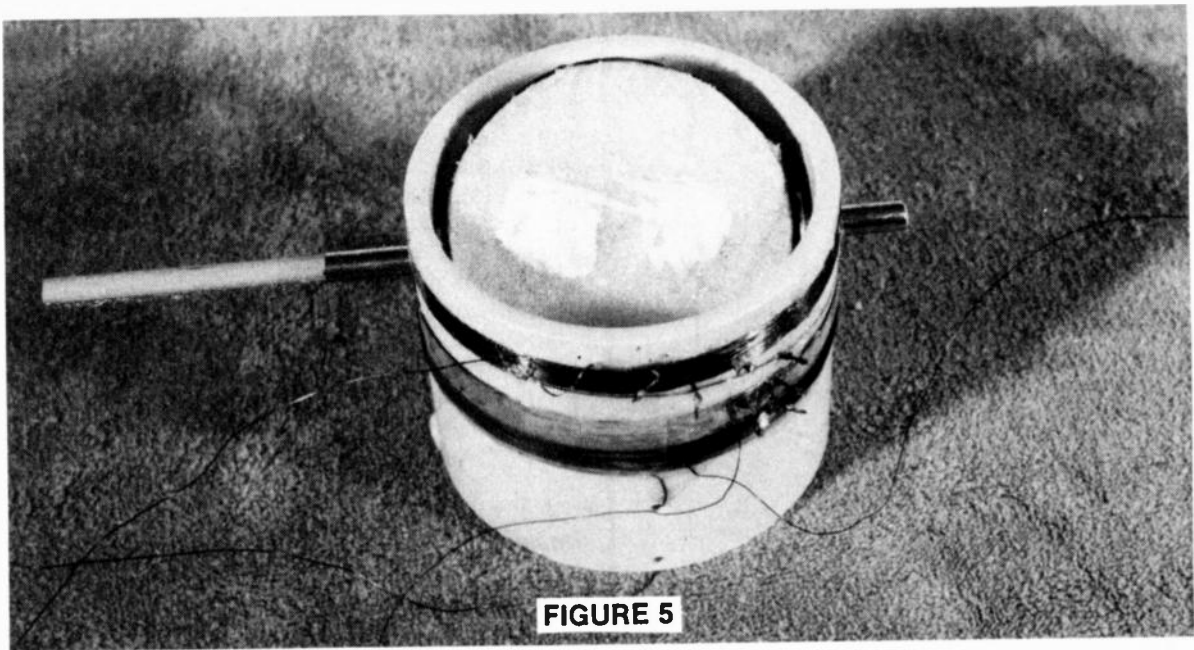


FIGURE 5

Figure 5. Notice the cemented areas of coil L3 inside the foam with two fiber washers at each end of the coil area.

holes at the top and off center of the rod holes to hold the wire or metal commutator. Wind the first 12 turns in the 1/4 inch space above the brass commutator rod. Then close-wind the rest of L2 to a total of 72 turns.

Start at the top of the coil, form and wind 12 turns of number 24 or 26 enameled wire for L2. Tap the coil 1/2, 2 1/2, 4, 8 and 12 turns (Fig. 5). The six position rotary SW2 will switch in the various coil taps. Place a piece of scotch tape over the coil lead to hold the coil in place. Twist the wire without cutting it to make each coil tap. Try to keep them on the right side close to the PC board. Tinn the tap and coil ends after the coil is cemented in place with a dab of clear rubber silicone cement.

Start L1 about 1/8 inches away from the bottom side of L2. Wind L1 with a total of 27 turns of number 24 or 26 enameled wire. Hold the coil in place at several points with tape, until cement or coil dop is applied. All coils are close wound except the top of L2 which straddles the metal commutator rod.

Mounting L3

L3 is mounted on the brass-wood dowel piece, inside the large coil area. Insert the brass end of the dowel through coil form and place a fiber or plastic washer over it. Push the dowel clear through L3 form and place another washer on the opposite end. These washers keep the coil centered and prevent rubbing on the coil form. Leave 1/4 inch of metal tubing stick out the rear end (Fig. 6).

Rotate L3 from the opening so the coil ends can be cut off and soldered to the metal tubing pieces, then solder each coil end to the brass tubing. Double check the coil continuity at the brass ends with an ohmmeter. Center the coil and cement the coil foam to the rod area with rubber silicone cement. Let the cement dry before rotating L3.

The commutator pieces can be made up of number 14 copper wire or brass strips. Letz wire also works well here. Cut two pieces of Letz wire 10 inches long.

Wrap the wire through the small hole twice, leaving 1 1/2 inches to connect to the metal rod. Tinn the Letz wire and solder to the metal rod end. Cut the wire leads off as close as possible to PC board. The other end will tie into the PC board.

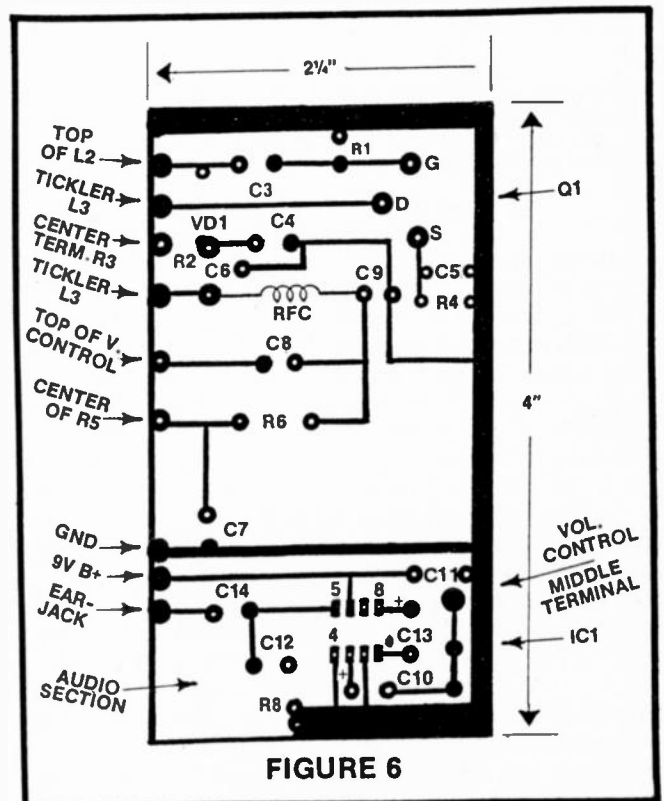


FIGURE 6

Figure 6. The PC wiring layed out on a 2 1/4 x 4" piece cut from a larger PC board.

The PC Board

Cut the PC board 2 1/4 x 4" from larger PC stock. The audio circuit was placed at the bottom of the board

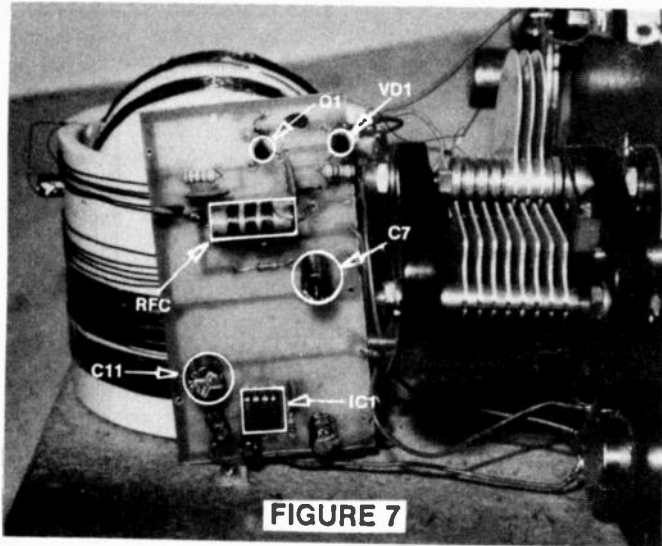


FIGURE 7

Figure 7. Mount all parts in respective holes and solder each component as mounted.

with a ground strip separating the audio and RF section. Layout both the RF and audio section on the PC board (Fig. 7). Double check the PC wiring after being placed on the foil side. Make sure the layout wiring is not loose on the board. Notice that the audio output connections are at the bottom of the board.

The RF regeneration circuit is placed at the top of the board. The coil terminals of L2 and L3 are brought out high to correspond with the coil connections. Use larger PC terminal connections for all wiring that connects to the PC board. After the board has been etched drill all holes for parts and connections. Now, the entire board may be tinned for better connections.

Mounting The Parts

First, mount the 8 pin IC audio output socket. Mark terminal 1 on the top side and bottom side of the board for terminal reference. Be careful in soldering small IC socket prongs to PC wiring to prevent overlapping excess solder. Mount each component and solder each terminal. Watch for correct polarity of electrolytic capacitors and the varactor diode (Fig. 8).

The tuning control R3, regeneration R5 and volume control R7 can be connected together. The other two control wires should be twisted together and soldered into the PC board. Either mark the center terminal wire or check it out with the ohmmeter. Make the coil tap connection short and direct as possible to SW2.

Mount IC1 (LM 386) after all soldering is completed. Check the dot on top of IC to match with the dot on PC board. Solder in Q1 by using a heat sink or the long nose pliers to dissipate the heat from the soldering iron. Although the MPF 102 FET transistor is quite hardy it is prudent to protect the terminals from excess heat. Likewise, use the pliers to dissipate the heat when soldering in the varactor diode (VD1).

Solder C1 directly to the antenna post. Run the capacitor wire to the center switch terminal (Fig. 9). Connect the hookup wire to the top side of L2 and RF side of L1. Solder the 9 volt battery clip with the red wire to B+ and black wire to common ground. Make sure the ground post and all ground connection ties in each control, variable tuning capacitor, SW2 and PC

board tie together. Now go over the entire wiring of the board and components tied to it.

Chassis Construction

The front panel was made up of a piece of scrap hard masonite with two coats of black car enamel paint sprayed on it. The rear chassis may be cut from pine or composition board. Cut both panels to the correct dimensions (Fig. 10). Drill all holes in the front panel with different size bits. The speaker hole may be one large one or several small holes representing a circle. Drill all holes before painting the front panel.

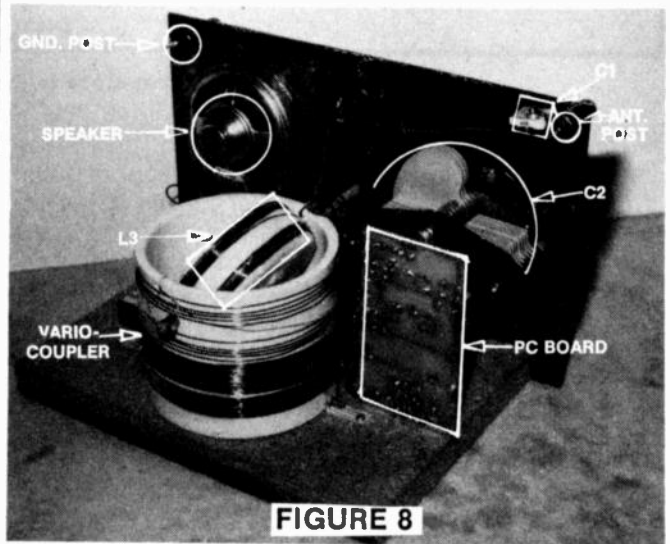


FIGURE 8

Figure 8. Back side view of receiver with antenna capacitor (C1) soldered to the antenna post terminal.

Testing

After all wiring is completed, check all connections once again. It's a little disheartening to put a project together and it doesn't work the first time. Connect the outside antenna and ground to the all wave receiver. Turn the volume control on full. Start with the tickler coil (L3) straight up and down; which is perpendicular to L2 and L1. Turn SW2 to the broadcast band or last tap. Rotate the regeneration coil to almost wide open. You should now hear a squeal in the headphones.

Rotate the large tuning control and notice all the various squeals and whistle noises as it is rotated. Each squeal is a station. If you get no squeal or whistle noise, reverse the coil connections of L2. Stop the tuning control at the loudest squealing noise. Back down the regeneration control until you hear a pop or the station comes in. Slowly rotate the vario-coupler coil to improve the signal. This coil can be fairly touchy on shortwave stations but will help the feedback action and separation of stations. Rotate the bandsread control to separate the various stations.

Now, go to the high end of the shortwave band. Adjust each control, as with the broadcast band. Rotate the vario-coupler and regeneration control until feedback occurs. Turn C2 until you hear some loud whistling noises. Back off the regeneration control. If the high band will not oscillate, move the coil wire closer together between the top coil connection and tap 1.

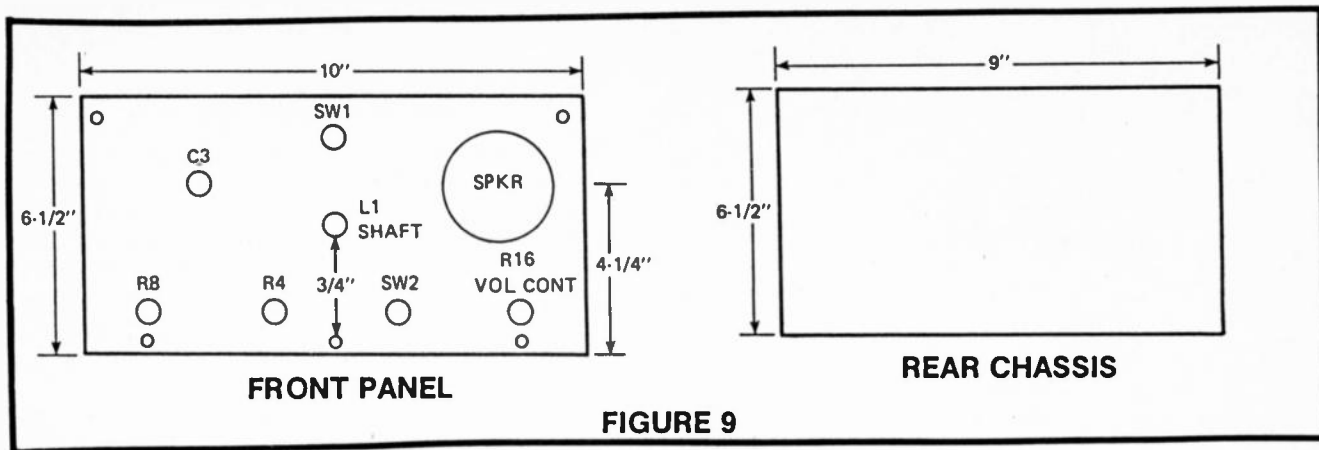


Figure 9. Dimensions of the front and rear panels.

Remember, every squeal is a station. Lower the regeneration control until the squeal just about quits. Now slowly move the vario-coupler coil. By adjusting coil L3 and R5 together stations can be tuned in for the loudest volume. After a few trips it is easy to tune up the regeneration circuits. Switch SW1 to SW or direct connection to L2 when listening to shortwave stations. When tuning in broadcast stations, switch SW1 to the RF winding L1. Remember, shortwave listening is best at night or early morning hours.

Troubleshooting

If by chance, no stations can be tuned in, check for voltage measurements on the Q1 and IC1 terminals. Shut off the switch when the voltage is real low on all terminals. Remove IC1 from the socket. Now check for correct voltages at Q1 terminals and terminal 6 of IC2. If the voltages are normal, suspect IC1 is plugged in backwards or defective. Q1 may be checked with a transistor tester or diode test of the DMM.

With normal voltages, click the center terminal of

the volume control (R7) with a small screwdriver. You should hear a click or low hum. This indicates the audio section is normal. Now check the voltages in the RF and regeneration section.

Reverse tickler coil leads (5 & 6) when there is no feedback squeal or noise. Rotate the vario-coupler so the tickler coil is inside the main coil form. Connect the antenna coil switch directly (SW) to the main coil and try once again. Accurate voltage, resistance and transistor tests should locate a defective component or improper wiring. Check the schematic for voltage measurements. Push together and widen shortwave coils to bring in the different bands.

The allwave vario-coupler receiver can bring back many memories to the old timers out there who constructed shortwave receivers from scratch. This receiver can take you back into time, when building receivers was the way of life. Constructing, operating and owning one of these relics can be a lot of fun, even if they are produced with solid-state devices. Happy listening... ■

PARTS LIST FOR THE ALL WAVE VARIO COUPLER RECEIVER

Q1—MPF 102 FET transistor.
 IC1—LM 386 audio IC.
 C1—10 to 80 PF trimmer capacitor.
 C2—Modified 365 PF variable capacitor (see text).
 C3 & C6—100 PF disc capacitors 50 V.
 C4—.01 UF disc capacitor 50V.
 C5 & C8—.1 UF disc capacitors 50V.
 C7, C10 & C13—10 UF 35 volt electrolytic capacitors.
 C9—.002 disc capacitor (2 - .001 capacitor in parallel).
 C11—220 UF electrolytic capacitor 35 V.
 C12—.047 UF disc capacitor
 C14—100 UF 35 V electrolytic capacitor
 R1—22K ½ watt resistor.
 R2—100K ½ watt resistor.
 R3—100K variable linear control.
 R4—2.2 K ½ watt resistor.

R5—50 K variable linear control.
 R6—4.7K ½ watt resistor.
 R7—10K audio taper control.
 R8—10 ohm ½ watt resistor.
 VD1—Varactor diode 35 PF #MV 2109.
 L1, L2 & L3—See text.
 RFC—2.5 UH choke coil #6302.
 SW1—SPDT switch.
 SW2—6 position rotary switch #10YXD62.
 SW3—On/Off switch on rear of R10.
 J1—Closed circuit earphone jack.
 SPKR—3 or 4 inch 8 PM speaker.
 MISC.—8 pin IC socket, antenna and ground terminals, coil wire #24 or 26, hookup wire, PC board, chassis board and front panel, etc.
 VD1, C1 SW2 and RFC may be purchased at:
Circuit Specialist, Inc.
P.O. Box 3047
Scottsdale, AZ 85271-3047.



THE EXPERT'S GUIDE TO PROJECT BUILDING

By Walt Sikonowiz

By Watching Out For Noise, You Can Build a Project That Works Right...The First Time.

Project-Building is supposed to be, and generally is, a challenging and entertaining adventure. Yet, there are times when it can turn out to be a miserable disappointment, all because of a pesky little gremlin known as electronic noise. To the electronic engineer, noise is a catch-all term that refers to any signal appearing someplace where it does not belong. Even if you have constructed just a few projects, chances are that you have been introduced to noise, whether you realized it or not. While noise cannot be eradicated completely, it can be effectively minimized once you understand its origins. In most instances, the key to a noise-free project lies in good construction practice, so let's examine some of the techniques used by skilled project builders.

When dealing with electrical interference, it is helpful to define two classes of devices; noise sources and noise receivers. Noise originates at some source and appears in another electronic circuit, the receiver. Almost anything can be a noise source. Some of the more common ones are automobile alternators, arcing motors, the ever-present 60-Hz power line, high-voltage or high-current electronic circuits, and digital logic. Similarly, almost any electronic circuit

can be a receiver, although high-gain, low-level, high-impedance stages are often the most susceptible. While the source and receiver may belong to two different pieces of equipment, they may just as well be different stages of a single piece of equipment.

Coupling

In order to transfer energy from the source to the receiver, some form of coupling must exist. The two important modes of coupling consist of an electromagnetic field or a common ground impedance between the two circuits in question. Consideration of an electromagnetic field is usually broken down into two subcases: electric-field coupling and magnetic-field coupling. A high-voltage, low-current circuit radiates energy chiefly through an electric field, whereas high-current, low-voltage circuitry radiates predominantly through a magnetic field. Most noise sources radiate through both fields, but it is easier to deal with one field at a time.

Let's begin with electric-field coupling, also known as capacitive coupling. In Figure 1 we have voltage source V_1 , with internal impedance R_{G1} , driving a load, R_L . This voltage generator might be anything—a

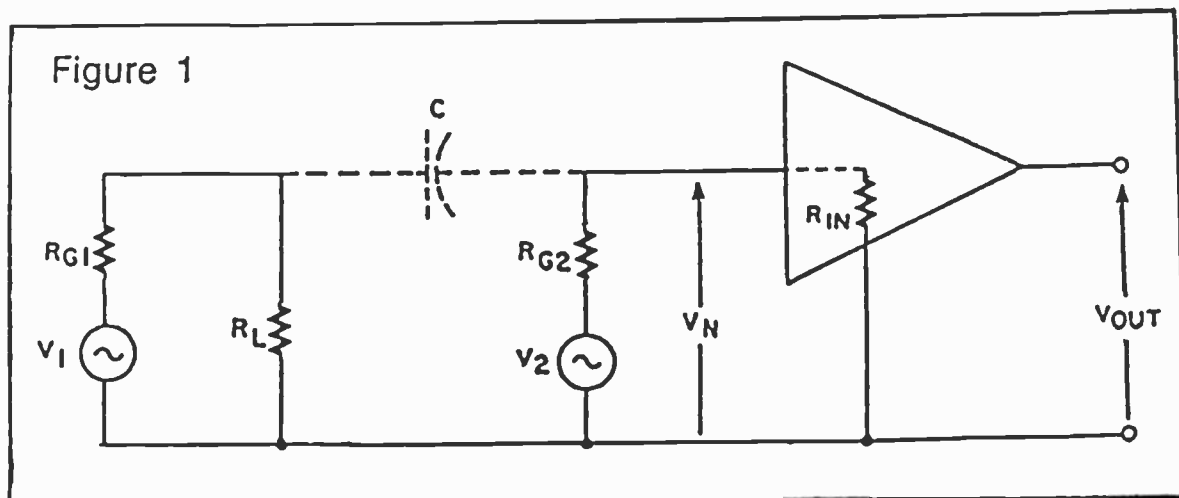


Figure 1. Electric-field coupling between two adjacent circuits can cause interference problems, particularly if a low-level stage is close to a moderate-level or high-level stage.

transistor, op-amp, logic gate, or even an alternator; the exact nature of the source is unimportant. Nearby, we have a second voltage generator, V_2 with an internal impedance of R_{G2} . An amplifier, with input impedance equal to R_{IN} , is supposed to amplify V_2 . However, electric-field coupling between the two circuits exists through stray capacitance C . Now, C 's capacitance will be very small. As an example, consider that the capacitance between two closely spaced #22 wires amounts to less than 40-pF per foot of wire. Despite the small magnitude of capacitance C , however, it can result in the appearance of a noise voltage, V_N , across the amp's input impedance. We are in trouble if V_N is a significant fraction of V_2 's magnitude, and the situation is hopeless if V_N equals or exceeds V_2 .

To see what determines the size of noise voltage V_N , note that current from generator V_1 can flow in a complete loop: first through R_{G1} , then through C , and finally through R_{G2} and R_{IN} back to source V_1 . Since R_{G2} is effectively in parallel with R_{IN} , and since V_N is developed across this parallel resistance combination, we are interested in the equivalent parallel resistance, which we abbreviate as $R_{G2} // R_{IN}$. Basically, what we have here is a voltage divider— R_{G1} , C , and $R_{G2} // R_{IN}$ —across V_1 . The noise voltage caused by V_1 will be increased by the following factors: 1) an increase in the magnitude of V_1 ; 2) an increase in the frequency of V_1 , since C 's impedance drops at higher frequencies; 3) a decrease in source-to-receiver distance, because this increases C ; and 4) an increase in the equivalent parallel resistance, $R_{G2} // R_{IN}$.

Voltage and Frequency

It is apparent that high-voltage, high-frequency circuits are the most trouble-some noise sources, as far as the electric field is concerned. Digital logic is one of the most common examples of this type of circuitry. Signal swings are large—between five and fifteen volts usually. Furthermore, even though the repetition rate of the pulses or square waves involved

may be low, these signals still have a high harmonic content. For example, pulses with a 5-nano-second rise-time have significant harmonic energy right up to 30 MHz., even if the repetition rate is much less than that.

At the receiving end, the most noise-susceptible circuits will have high impedances and operate at low levels (that is, with small V_2). This latter factor, low levels, is very often accompanied by high gain. Common examples of such noise-sensitive circuits are: high-gain FET preamps, low-level analog comparators, and op-amps with large feedback resistors.

Assuming that you cannot change the design of the source and receiver circuits, the only practical method of reducing noise from an electric field is to minimize the coupling capacitance. Separation of the two stages helps; at least an inch or two should intervene between the circuits. Separation beyond this distance will reduce pickup still more, but the noise level does not drop as quickly as it does over the first inch or so.

Shielding.

More effective than separation is the use of a metallic shield when pickup is severe. In Figure 2, the two possible methods for shielding are diagrammed. Figure 2A shows a conductive metal shield, grounded to source common, that completely encloses source V_1 . Electric-field coupling between source V_1 and the shield is symbolized by capacitor C_1 . Outside the shield, another stray capacitance, C_2 , exists between the shield and the equivalent parallel resistance, $R_{G2} // R_{IN}$. (The rest of the amplifier has been deleted because, so far as we are concerned here, its only important characteristic is R_{IN} .) An electric field exists within the shielded enclosure; however, the field outside the shield is zero everywhere. This comes about because, at least ideally, the entire surface of the shield remains at ground potential. Since the external field is zero, no

energy is transferred across stray capacitance C_2 .

In part B of Figure 2, the grounded metallic shield envelops the receiver. Energy transfer occurs between source V_1 and the grounded shield via C_1 . The field within the shield is zero since the shield is at ground potential. As a result, no noise is picked up by the receiver.

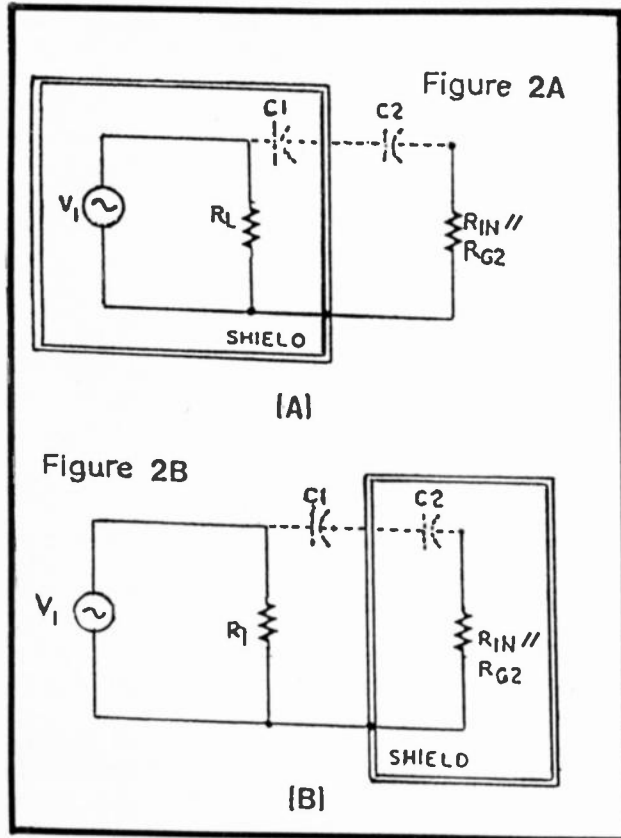


Figure 2. A grounded shield is very effective against capacitive coupling. The shield may be applied either around the noise source (A) or around the circuitry where noise is being picked up (B). Aluminum is a good shield metal as are copper and steel.

Any metallic sheet makes a good electric shield. Aluminum, a common cabinet material, is excellent at all frequencies. A shield may be placed between

two stages of a single piece of equipment. On the other hand, a grounded metallic cabinet constitutes a shield between a particular piece of equipment and all noise sources in the outside world. The only precaution necessary when shielding is that the shield must be in electrical contact with the circuit's ground. Note that this does not necessarily mean an earth ground, such as a pipe in the soil. Connection to circuit common is all that is ever required.

At this point, you are probably wondering what happens if the source and receiver circuits do not share a common ground connection. We can treat this coupling by means of two stray capacitances, as shown in Figure 3. You should be able to see for yourself that the previously discussed shielding methods still apply. A shield around either circuit, connected to that circuit's ground potential, is all that is required.

Before leaving the electric-field case, let's note that wires may also need shielding if they connect to possible receivers or sources. When wires exit a particular piece of equipment, they may be protected by shielded cable. Likewise, shielded cable may be used within a single piece of equipment when interstage noise coupling is a problem. Often, however, you can obtain the benefits of a partial shield by simply routing wires close to the grounded chassis. The electric field near the chassis/shield is minimal, so any pickup by wires is likely to be small. As a final precaution, keep wiring to low-level circuitry separated from high-level wiring.

Inductance.

Now, let's turn to the magnetic field and Figure 4. The most important aspect of this is that there are two current loops, a source loop and a receiver loop. In the source loop, generator V_1 drives a current I_1 , through load R_L . The current flow is, in turn, responsible for a magnetic field that exists in the vicinity of the source loop.

The receiver loop consists of generator V_2 driving a stage with input impedance R_{IN} . (Note that no internal resistances are indicated for the voltage generators since such impedances have a negligible

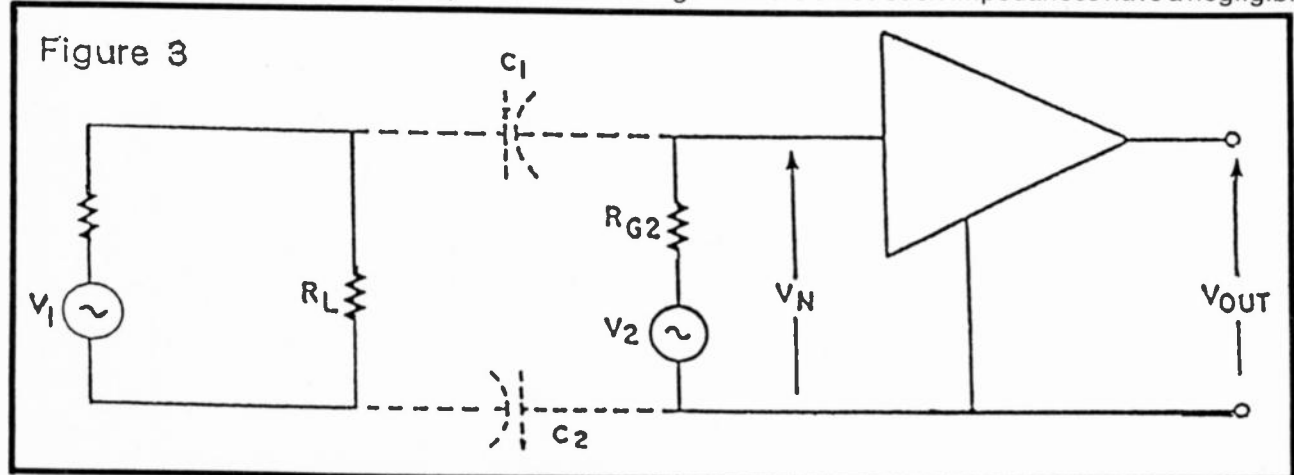


Figure 3. If there is no common ground connection between the noise source and the receiver, electric-field coupling may be represented by two stray capacitances— C_1 and C_2 .

effect here.) In addition, a noise voltage, V_N , which is due to source V_1 , appears in series with V_2 . If V_N is not negligible compared with V_2 , then we must find ways of minimizing the noise pickup.

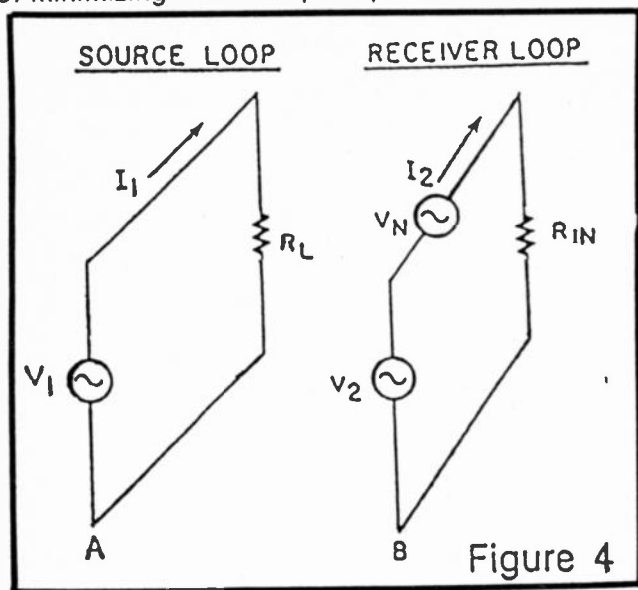


Figure 4. Magnetic-field or inductive coupling requires the existence of two complete current loops. Shielding against a magnetic field is difficult in home construction.

What we have in Figure 4 is a simple transformer, which suggests why magnetic coupling is also known as inductive coupling. Alternating current I_1 generates a changing magnetic field that induces a voltage in any loop it intersects. As Figure 4 shows, the two current loops may be completely isolated. However, points A and B could be connected with no change in the induced noise voltage. Therefore, as was the case with the electric field, we must consider coupling between stages of the same device, or between stages of two separate devices.

Let's examine the factors that cause increased noise coupling: 1) an increase in the magnitude of I_1 ; 2) a decrease in the separation of the two loops; 3) an increase in the frequency of I_1 ; 4) orienting the loops so that their planes are parallel; and 5) an increase in the area of the receiver loop. From the above, several

methods of noise reduction are suggested. First, separate the two loops; in particular, keep high-current stages away from low-level stages. Second, minimize receiver loop area. This applies especially to the wiring associated with a receiver stage. All wires to a jack, a switch, or a potentiometer should be twisted together, thus minimizing pick-up loop area. Third, try to minimize the source loop's magnetic field. This is most conveniently done by using twisted wires again. To see why this is effective, imagine taking the source loop, stretching it, then twisting the wires together. The currents in the twisted pair flow in opposite directions, and because twisting keeps the two wires in close proximity, the magnetic field of one wire cancels that of the other. Even better than a twisted pair, especially at high frequencies, is coaxial cable; for most hobbyist requirements, however, a twisted pair is sufficient to reduce magnetic radiation. Finally, changing the orientation of the source with respect to the receiver often helps. Consider, for example, the magnetic radiation from a power transformer. You may carefully twist the leads but you cannot do anything about the magnetic flux from the transformer coils. Usually, however, some mounting orientation of the transformer will result in minimized pickup in your noise-sensitive stage.

Comparing magnetic coupling with electric coupling, one thing you may have noticed is that the impedance of the receiver has no effect on its susceptibility to inductive coupling. Also, you may have wondered whether a shield would be as effective against a magnetic field as it is against an electric field. The answer is no. Aluminum, which is so effective as an electric shield, begins to be effective against magnetic fields only at higher frequencies (above 100 kHz). At the important frequency of 60 Hz, aluminum is useless. In order to obtain better magnetic shielding, your shield must be a ferromagnetic substance, such as steel. Because it is harder to machine than aluminum, steel is rarely used by hobbyists, even though its magnetic-shielding properties are superior to those of aluminum. At 60 Hz, however, even steel is only partially effective (shielding effectiveness increases with frequency). Special magnetic alloys, such as Mu-Metal, are necessary at low frequencies. All things considered,

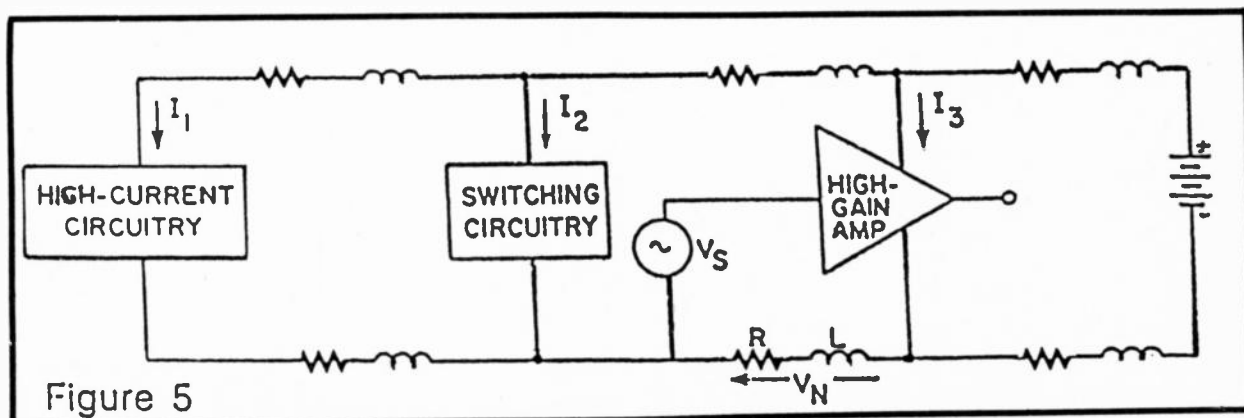


Figure 5. Ground noise can originate in any system where power is distributed in a serial manner. Resistance and inductance on the power lines can create unwanted ground noise.

magnetic shielding is more difficult than electric shielding.

Wiring Problems.

So far we've dealt with stray pickup from a more or less familiar viewpoint—familiar at least in the sense that whenever noise problems occur, the first thing to be blamed is some mysterious, invisible field. Very often, however, the trouble is the handiwork of a more mundane villain: your circuit's electrical wiring.

Figure 5 shows a serial power distribution system, the most common way of delivering power to the various stages of a piece of equipment. Two power leads run from the supply to one stage, and then from there to the next stage, and so on. Such a scheme is simple and generally practical, except when you have the situation shown in Figure 5. Here we have a low-level source, V_s , driving a high-gain amp stage, with resistor R and inductor L representing the resistance and inductance of the interconnecting ground lead. Current I_1 from the high-current stage and current I_2 from the switching stage both flow through the power bus—in particular, through R and L . Since the amp responds to the potential difference between its input and ground leads, any voltage developed across R and L due to I_1 and I_2 appears in series with V_s , and this noise voltage V_N gets amplified right along with V_s .

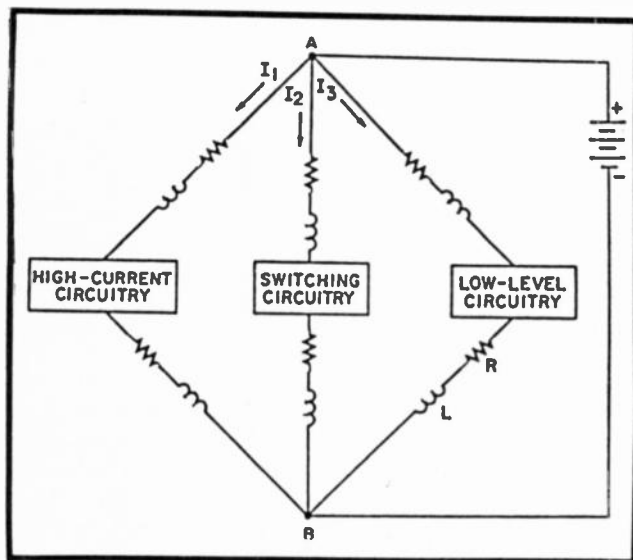


Figure 6. When different types of circuits are sharing a single power source in a parallel distribution system, ground noise is often totally eliminated. The arrangement isolates the various circuit components from their neighbor's power source. The power source should have low impedance and be connected to points A and B by very short wires.

Now let's suppose R and L represent a piece of #22 wire. One foot of #22 has a resistance of 16.14 milliohms, and if I_1 is a direct current of about 61 milliamps, then V_N equals 1 millivolt. This is small, but certainly significant if V_s is also on the order of millivolts. At high frequencies, the impedance of inductance L increases to become the dominant

factor, and this gives us even more trouble. For example, a foot of #22 wire has 4-ohm impedance at 1 MHz, and a whopping 40 ohms at 10 MHz. Needless to say, high-current and high-frequency stages (and this includes our old friend, digital logic) can wreak havoc on low-level circuits.

What can be done? First, current spikes from digital logic may be reduced by bypassing ICs with 1-mfd. ceramic capacitors. These capacitors are applied as closely as possible to the power pins of the various IC packages. Another scheme that is successful at frequencies below 1 MHz is the use of a parallel power distribution system, as shown in Figure 6. Since I_1 and I_2 cannot flow in R or L , they produce no troublesome noise. In order for this system to work well, however, the power supply must have a low impedance and use very short wires.

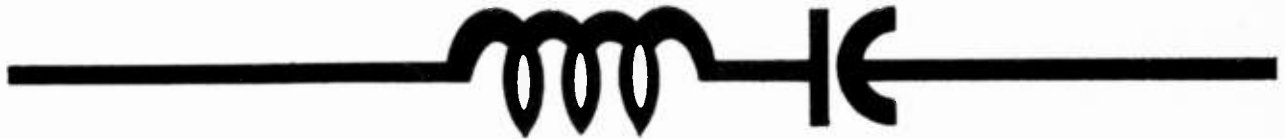
Summary

The key to minimizing noise transmitted through an electromagnetic field lies in separation of the noise source and receiver. Keep high-voltage and high-current circuitry away from stages that carry low-level signals. Be especially wary of digital logic, one of the worst offenders where noise is concerned because of the magnitude and switching speed of the signals involved.

When separation has been carried to its practical extreme and noise pickup is still a problem, put a grounded metallic shield around the noise source or receiver. If signals are being radiated or picked up by wires, use shielded coaxial cable. Sometimes the shield is allowed to carry current, in which case it is grounded at both ends. At other times, we may prefer that the shield carry no current, and it will be grounded at one end or the other, but not both. The question of whether to ground the shield at one end or two is beyond the scope of this article. Since most of you will be building projects from plans rather than designing your own circuitry, the best advice here is that you use the kind of shielded cable specified by the project's designer and wire it exactly as he did.

To avoid the often disastrous noise problems that may arise when incompatible currents flow through a common ground impedance, use a printed-circuit board if one is available. You can either buy a ready-made board or etch your own at home provided the plans are available. If for some reason you prefer to use perboard or wire-wrapping techniques to build a project, do yourself a favor and copy as closely as possible the layout and wiring of the project's PCB. Now, it is true that there are a great many circuits that will never cause any trouble no matter how carelessly they are wired. Unless you know for certain, however, that a project is failsafe, it pays to be smart and copy the designer's original layout. Then, if something should go wrong with the project, at least you'll know that the layout is not to blame. The less you tempt fate, the better your chances are of building a project that works. ■

WORKBENCH PROJECTS



The projects we've prepared for you in this section are more complicated than those in our **Circuit Fragments** section, but they are less complicated than the ones in our **IC Testbench** section.

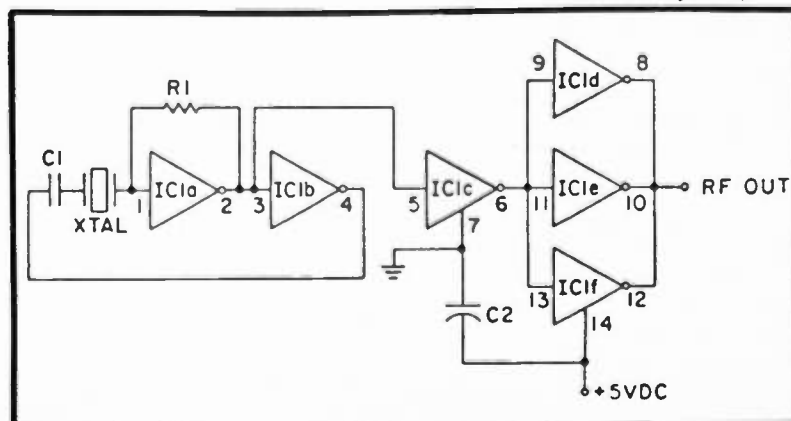
As with any electronics assembly work, be sure you understand how the various parts of the circuit work together and the objective of each component before you start gathering the components together and assembling them. As with any project that uses ICs (integrated circuits) or transistors, be careful to observe precautions regarding overheating their leads. If possible, use sockets instead of soldering directly to their wire leads. If you can't do that, be sure to protect the IC and transistor leads by using long-nose pliers as a heat sink when soldering those leads.

CRYSTAL-CONTROLLED TTL

This inexpensive color-TV crystal of approximately 3.58 MHz can readily be persuaded to oscillate in the following 7404 circuit. The resultant waveform can be divided down via other popular IC chips, such as the 4017 CMOS type.

PARTS LIST FOR CRYSTAL-CONTROLLED TTL

- C1—75-pF mica capacitor, 15 VDC
- C2—0.01- μ F ceramic capacitor, 15 VDC
- IC1—7404 hex inverter
- R1—1,000-ohm, $\frac{1}{2}$ -watt resistor
- XTAL—3.58 MHz crystal (color TV carrier type)

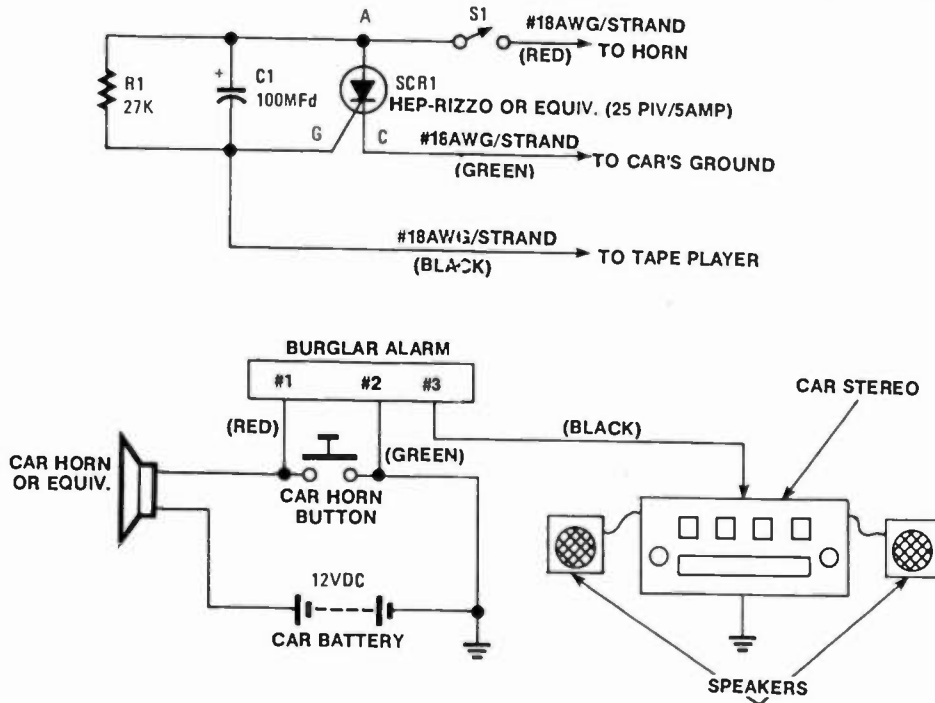


TAPE PLAYER BURGLAR ALARM

The control circuitry for this tape player burglar alarm can be easily concealed anywhere inside your automobile, since it is not much larger than a regular match box. With a little imagination, this device can be adapted to other areas of your automobile...the hood, the trunk, doors, etc...the alarm will be the same.

PARTS LIST FOR THE TAPE PLAYER BURGLAR ALARM

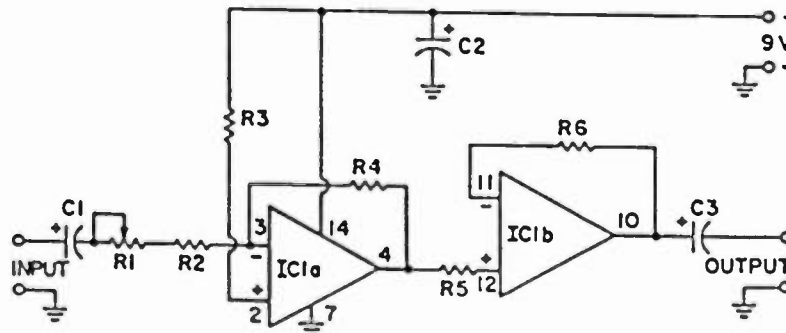
- C1—100 Mfd electrolytic capacitor, 15VDC or better
- R1—27K ohms resistor, ½ watt
- SCR1—HEP-RIZZO or SK3634/ECG5444 (25 PIV/5AMP) or Equivalent
- S1—SPST slide switch (Alarm off)



POWER MIKE AMPLIFIER

A popular accessory to a CB radio is a power microphone. This circuit provides an adjustable gain of 1 to 10 which will increase the output of a dynamic microphone for higher modulation levels without shouting. The circuit has very low output impedance and will drive the microphone input circuit of any CB

radio. IC1A provides voltage amplification and is adjustable by potentiometer R1. IC1B is a buffer amplifier which provides isolation between the amplifier and output terminal. The circuit draws about 7 milliamperes from a 9 volt supply and can be powered by an ordinary 9 volt transistor battery.



PARTS LIST FOR POWER MIKE AMPLIFIER

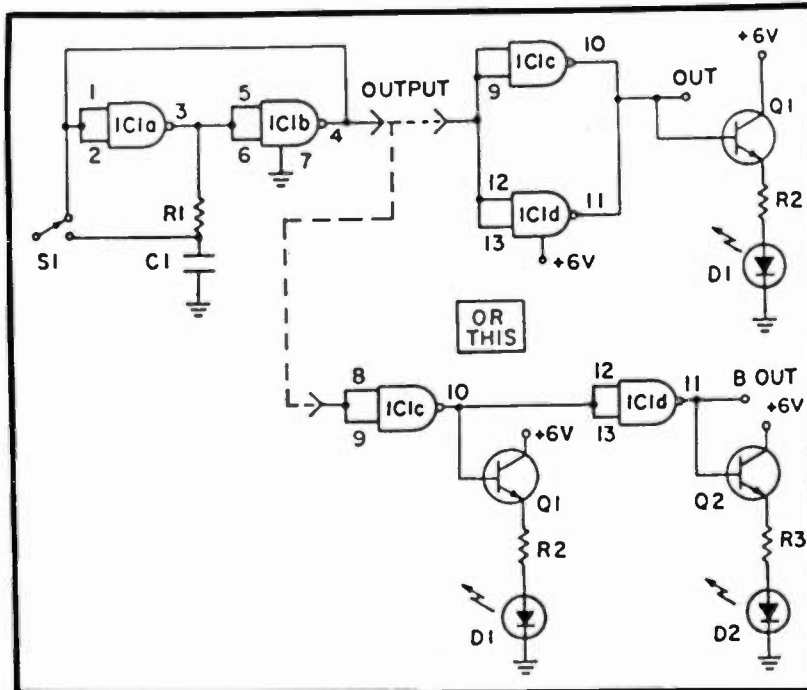
- C1, C2, C3—10- μ F electrolytic capacitor, 10 VDC
- IC1—3900 quad amplifier
- R1—100,000-ohm audio taper potentiometer
- R2—10,000-ohm, ½-watt resistor
- R3—220,000-ohm, ½-watt resistor
- R4—100,000-ohm, ½-watt resistor
- R5—1,000,000-ohm, ½-watt resistor

PUSH-ON, PUSH-OFF

This simple circuit enables a single-pole/single-throw pushbutton switch to function in a push-on/push-off manner. Closing the switch initiates a flip-flop latching action. The extra gates of the 4011 quad NAND chip may be used in parallel for greater output loading or in series to provide an alternate on-off output to external circuits.

PARTS LIST FOR PUSH-ON, PUSH-OFF

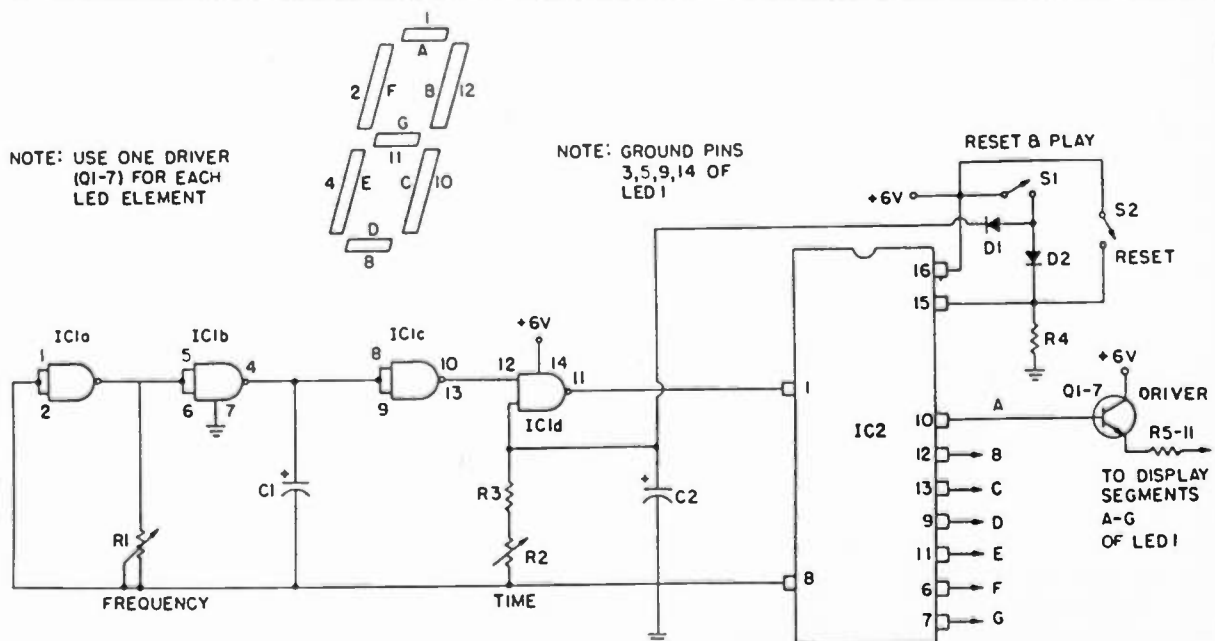
- C1—0.1- μ F ceramic capacitor, 15 VDC
- D1, D2—small LEDs
- IC1—4011 A quad NAND gate
- Q1, Q2—2N4401
- R1—27,000-ohm, 1/2-watt resistor
- R2, R3—1,000-ohm, 1/2-watt resistors



MINI DIGITAL ROULETTE

NOTE: USE ONE DRIVER (Q1-7) FOR EACH LED ELEMENT

NOTE: GROUND PINS 3,5,9,14 OF LED 1



MINI DIGITAL ROULETTE

The clock input terminal connected via a pushbutton switch to the "Basic Pulse Maker" and two to nine players select a number. Then, press the button. The input frequency should be 10-Hz or higher and the Reset may zero the display first, although there is statistically little or no effect upon subsequent outcomes. When the switch is released, the counter holds on one number, which is displayed until reset or new counts arrive. If a Zero appears on the display, it may be assumed that the Bank takes all wagers, thus keeping the system in fresh batteries.

PARTS LIST FOR MINI-DIGITAL ROULETTE

- C1—0.47 to 2.2- μ F electrolytic capacitor, 15 VDC
- C2—100- μ F electrolytic capacitor, 15 VDC
- D1, D2—1N4148 or 1N914 diode
- IC1—4011 quad NAND gate
- IC2—4026 decade counter
- LED 1—DL-750 7-segment common cathode display or equivalent
- Q1 through Q7—2N4401 transistors
- R1—500,000-ohm linear-taper potentiometer
- R2—100,000-ohm linear-taper potentiometer
- R3—10,000-ohm, 1/2-watt resistor
- R4 through R11—1,000-ohm, 1/2-watt resistors
- S1, S2—SPST momentary-contact switches

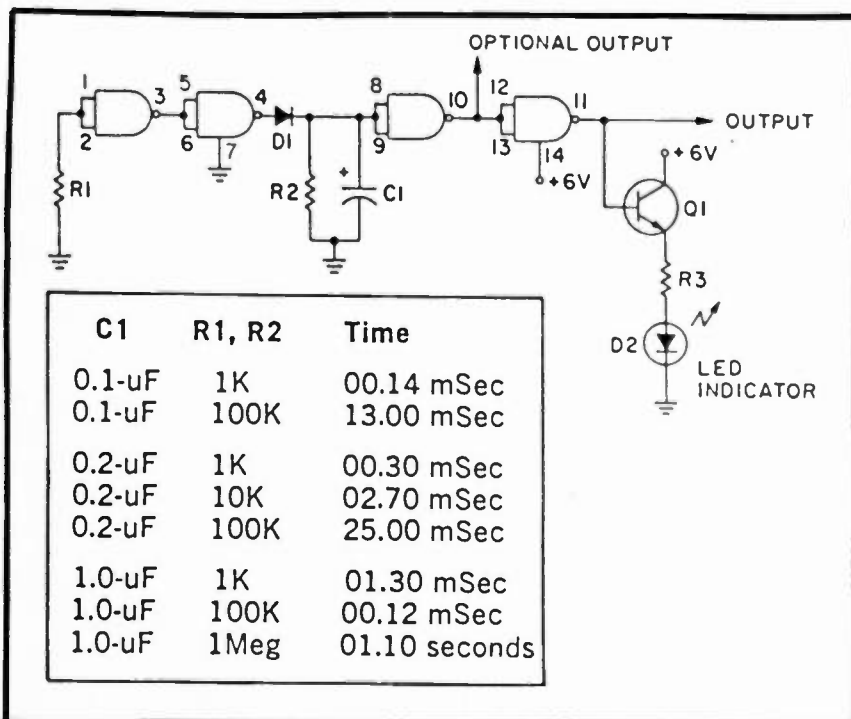
DO IT YOURSELF DELAY

Medium-scale integrated circuits, like the 555 timer, are all very fine, but it is instructive to know how to make do with simple gates. The following circuit, employing a single type 4011 quad NAND, or 4001 quad NOR, provides a hold-in delay, ranging from at least one second down to 20 milliseconds. In operation, when a positive potential is applied to the input, the output follows immediately, operating a relay or some other properly interfaced component. When the input is removed, the output continues high for a period determined by the RC time-constants. The polarity of the output may be reversed by

omitting the last gate section. Like-wise, the input can be enabled low by returning the biasing resistor to the positive supply and applying a negative-going signal.

PARTS LIST FOR DO-IT-YOURSELF DELAY

- C1—see table
- D1—1N4148 diode
- D2—small LED
- IC1—4001A or 4011A quad NAND gate
- Q1—2N4401
- R1—47,000 to 56,000-ohm, 1/2-watt resistor
- R2—see table

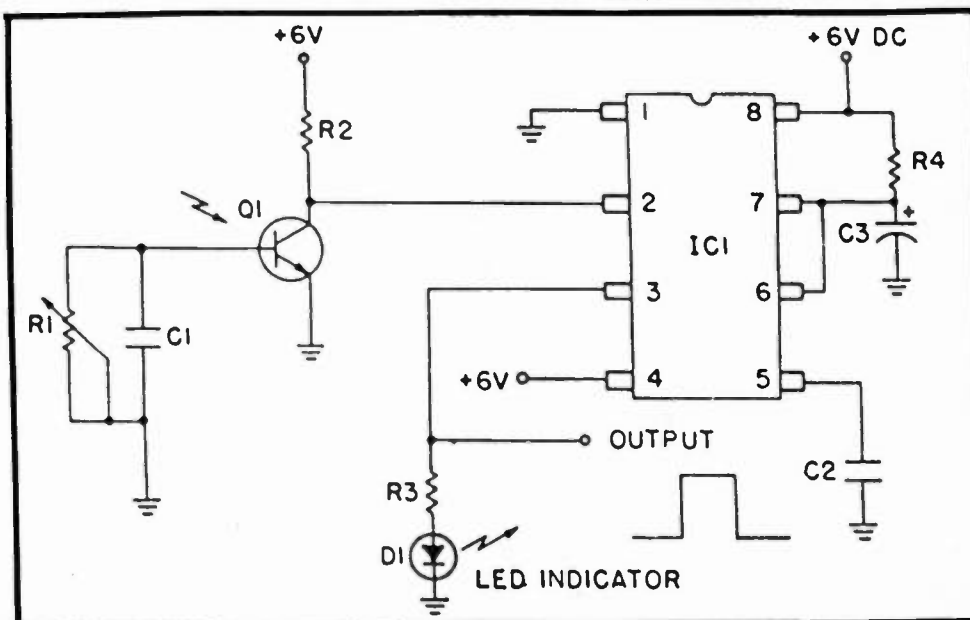


THE ROBOT EYE, TTL

A useful chip, at home with both TTL and CMOS logic, is the type 555 timer, which can be used both in the mono-stable and astable or free-running modes. In the mono-stable mode shown here, timing RC can run from 1000 ohms to over 1 megohm, and 0.001-uF to over 100-uF. A combination of 2.2-uF and 220K ohms gave a delay interval of about one second. The Robot Eye can thus extend from a tiny wink to an intent gaze!

PARTS LIST FOR THE ROBOT EYE, TTL

- C1, C2—0.1 uF ceramic capacitors, 15 VDC
- C3—2.2-uF electrolytic capacitor, 15 VDC
- D1—small LED
- IC1—555 timer
- Q1—FPT100 phototransistor or equivalent
- R1—250,000-ohm linear taper potentiometer
- R2—47,000-ohm, 1/2-watt resistor
- R3—470-ohm, 1/2-watt resistor
- R4—220,000-ohm, 1/2 watt resistor

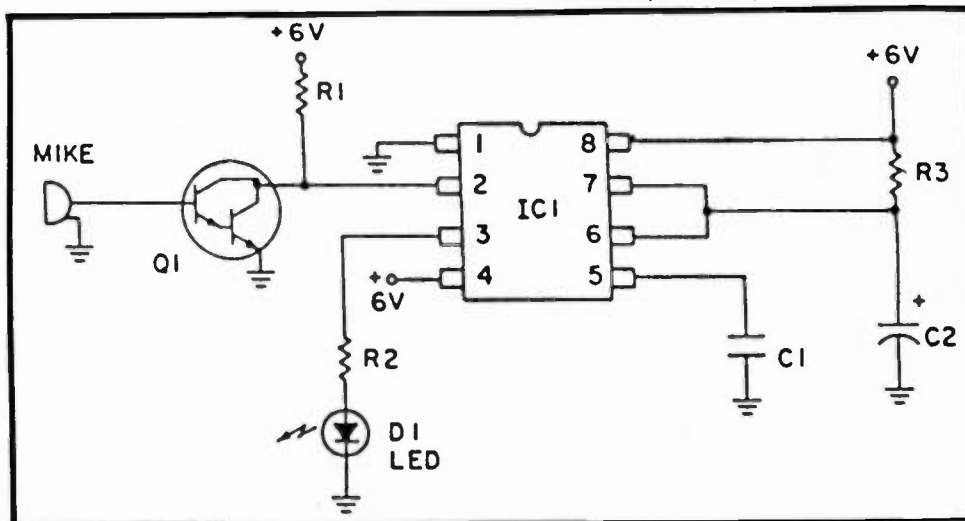


THE ROBOT EAR, TTL

The type 555 timer can not only see, but hear, as this sound pick-up circuit shows. It is most apt in picking up sudden sharp sounds. A type MPS A13 Darlington transistor provides gain to cause triggering action. With RC time constants of 4.7 or 5-uF and 220,000 ohms, the warning indicator LED will remain on for about two seconds.

PARTS LIST FOR THE ROBOT EAR, TTL

- C1—0.1-uF ceramic capacitor, 15 VDC
- C2—5-uF electrolytic capacitor, 15 VDC
- D1—small LED
- IC1—555 timer
- Q1—Motorola MPS-A13 Darlington transistor
- R1—47,000 to 100,000-ohm, 1/2-watt resistor
- R2—470-ohm, 1/2-watt resistor
- R3—220,000-ohm, 1/2-watt resistor



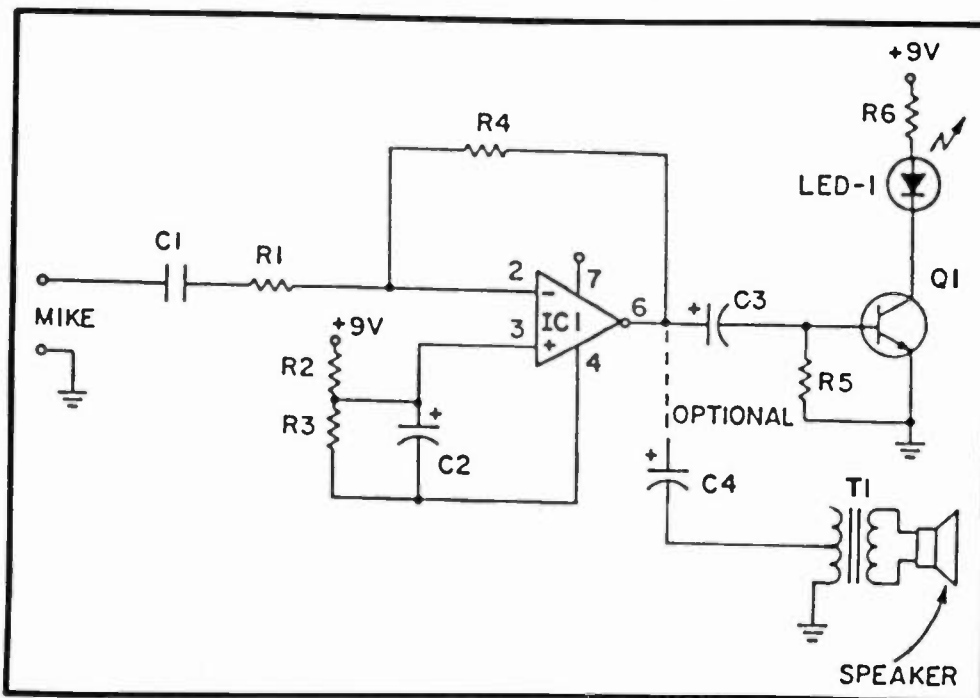
LED ADDS LUSTER

Through the addition of a transistor driver, a small LED indicator can give the visual state of an op amp, such as might be used to detect noise impulses, as in an alarm system. The 2N4401 NPN transistor provides plenty of power and gain for such an application. The method can be used both with and without an audio indicator, like a small loudspeaker, as well. You will have to experiment with the value of R1 to obtain triggering depending upon the impedance of the mike used.

PARTS LIST FOR LED ADDS LUSTER

C1—0.1-uF ceramic capacitor, 15 VDC

C2—10-uF electrolytic capacitor, 15 VDC
 C3—2.2-uF electrolytic capacitor, 15 VDC
 C4—50 to 100-uF electrolytic capacitor, 25 VDC
 IC1—741 op amp
 LED1—small LED
 Q1—2N4401 transistor
 R1—500 to 500,000-ohm, ½-watt resistor (see text)
 R2, R3—4,700-ohm, ½-watt resistors
 R4—500,000-ohm, ½-watt resistor
 R5—10,000 to 50,000-ohm, ½-watt resistor
 R6—100-ohm, ½-watt resistor
 SPKR—8-ohm PM type speaker
 T1—audio output transformer 1000-ohm center-tapped primary/8-ohm secondary (Radio Shack #273-1380 or equivalent)



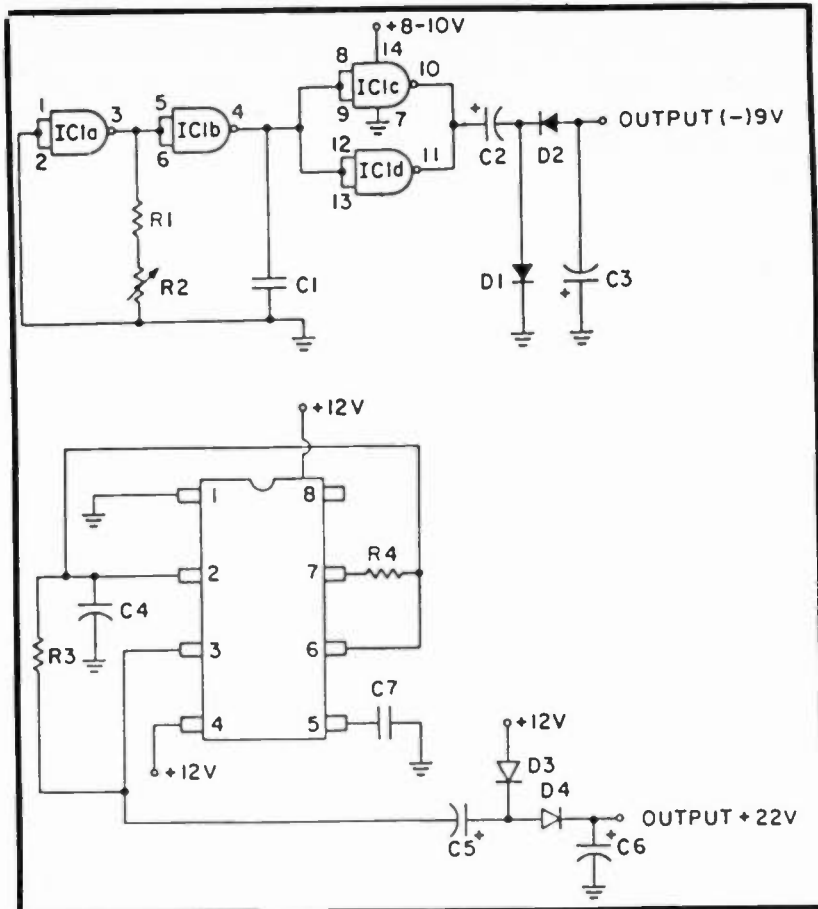
POSITIVE INTO NEGATIVE

Certain IC chips and other circuit elements often require small negative potentials of small current drain, necessitating the construction of bulky transformer-operated supplies. Operating at 1 KHz or higher frequency, the pulse generator shown below drives a voltage-doubler circuit furnishing a negative potential approaching that of the positive input supply. With a 10 volt input, an output of about -9 VDC was measured into a 20,000 ohm load. A voltage tripler or quadrupler circuit may also be employed for higher potentials (positive or negative) as well. For loads requiring up to 50 ma, the type 555 timer in astable mode is an ideal choice.

PARTS LIST FOR POSITIVE INTO NEGATIVE

C1—0.01 to 0.1-uF ceramic capacitor, 15 VDC
 C2, C5—10-uF electrolytic capacitors, 25 VDC
 C3—10 to 100-uF electrolytic capacitor, 25 VDC
 C4—0.001-uF ceramic capacitor, 15 VDC
 C6—25-uF electrolytic capacitor, 25 VDC
 C7—0.01-uF ceramic capacitor, 15 VDC
 D1 through D4—1N4001 diodes
 IC1—4011 quad NAND gate
 IC2—555 timer
 R1—500-ohm, ½-watt resistor
 R2—50,000-ohm linear-taper potentiometer
 R3—33,000-ohm, ½-watt resistor
 R4—4,700-ohm, ½-watt resistor

POSITIVE INTO NEGATIVE



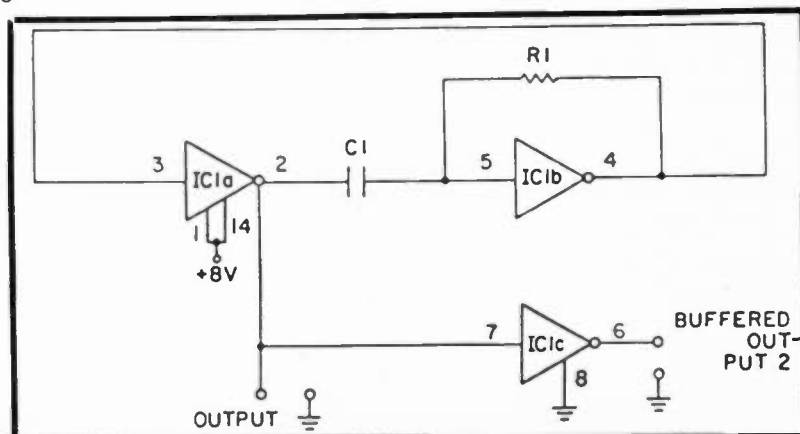
CMOS LOGIC-AL FOR RF

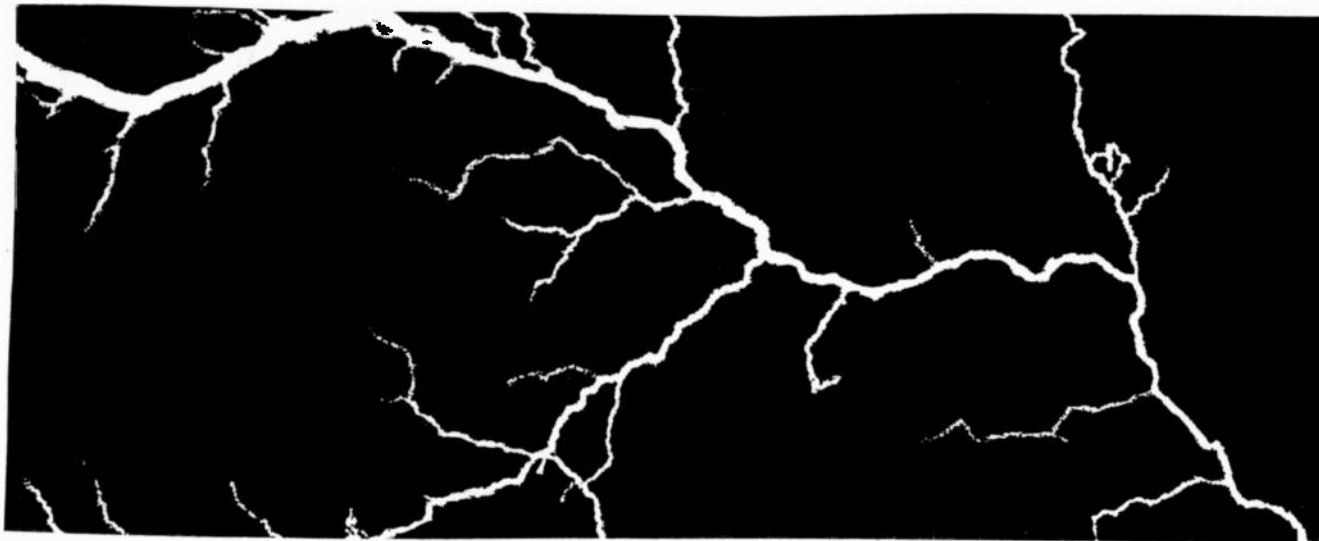
CMOS logic, of the 4000 Series, has sometimes been put down against TTL when speed is involved. However, the following circuit shows that oscillations of over 5 MHz are quite possible, and simple to obtain as well. With $C=27\text{-pF}$, the following frequencies were obtained with varying R . The output at pin 2 is sinusoidal, but the buffer shown (between pins 7 and 6) reduces frequency shifts from circuit loading.

PARTS LIST FOR CMOS LOGIC-AL FOR RF

C1—27-pF mica capacitor, 15 VDC
IC1—4009AE hex buffer
R1—see table

R1 (ohms)	freq. (MHz)
680	6.33
1,000	5.30
2,200	3.50
3,300	2.70
4,700	2.00
10,000	1.10





UNDERSTANDING ELECTRICITY

By Ron C. Johnson C.E.T.

PART II

Whether you are starting out in electronics, golf, playing the piano, or basket weaving the same principles apply: Get the basics down cold and you'll be off to a good start. From there you can work your way into the more complex stuff with a minimum of problems.

(That's what I did and today I'm an incredible basket weaver.)

So fasten your seat belts, grip your calculator firmly, and take a deep breath...

We now enter the land of mobile Ohm.

No doubt some of you have wondered why you would want to know about Ohm's Law anyway. Though the math is simple and you probably had no trouble with it, you may have been building projects for years and never needed to use it. Just the same, Ohm's Law will help in understanding the concepts to come later. Also you may be interested in designing some of your own projects in which case this will all be useful. Another electrical law we will talk about in this issue is called Kirchhoff's Voltage Law. Again, though basic and a bit math oriented, this is useful in understanding how circuits work.

PREFIX	SYMBOL	MULTIPLIER	EXPONENT
GIGA	G	1,000,000,000	10^9
MEGA	M	1,000,000	10^6
KILO	K	1,000	10^3
MILLI	M	.001	10^{-3}
MICRO	u	.000001	10^{-6}
NANO	n	.000000001	10^{-9}
PICO	p	.000000000001	10^{-12}

Figure 1. Prefixes for engineering notation

said in Part I that we would get into some circuits and some of the components used in them. First, though, we should establish a common numbering system and standard coding for resistors, capacitors and other components so that we are talking the same language later on.

COUNTING LIKE SCIENTISTS AND ENGINEERS:

In electronics, as we said previously, mathematics plays an important role in determining the quantities of various parameters. We talked about voltage, current, resistance and power to start with. These are all determined with math and can have values which range from extremely small to extremely large. In order to express these numbers without filling pages with zeros we use a system of numbering called "scientific notation."

In scientific notation we take a number like:

$$2,540,000 \text{ volts}$$

which is the same as:

$$2.54 \times 1,000,000 \text{ volts}$$

and express it as:

$$2.54 \times 10^6 \text{ volts}$$

For those of you not familiar with this notation, our goal is to make a shorter expression of the same number. 1,000,000 is the same as 10^6 . When we multiply it by 2.54 we end up with the original number.

Similarly we can express:

$$.0000001579 \text{ Amps as: } 1.579 \times 10^{-8} \text{ Amps}$$

An easy rule to remember is that when we convert a number to scientific notation, we count the number of decimal places we will move the decimal point and use that number as the exponent of ten. If we move the decimal to the left, (in a large number) the exponent is positive. If we move the decimal to the right, (in a small number) the exponent is negative.

That is scientific notation.

In engineering notation we shorten the number even further by using prefixes before the units we are expressing. The common prefixes which correspond to exponents of ten are given in Figure 1. Referring back to our examples, for the first one we can take the prefix "Mega" from the table (as it corresponds to 10^6) and we get:

$$2.54 \text{ Mega volts or: } 2.5 + \text{ Mv}$$

ELECTRICAL QUANTITY	SCIENTIFIC NOTATION	ENGINEERING UNITS
254,200,000 volts	2.542×10^8	254 Megavolts
.00276 Amps	2.76×10^{-3}	2.76 milliamps
8990 ohms	8.99×10^3	8.99 kilo ohms
750,000 watts	7.50×10^5	750 kilowatts
.00000477 Siemens	4.77×10^{-6}	4.77 microSiemens
.000000000012 Farads	1.2×10^{-11}	12 picoFarads

Figure 2. Table of electrical quantities with scientific notation and engineering units

COLOR	BAND #1 DIGIT 1	BAND #2 DIGIT 2	BAND #3 MULTIPLIER	BAND #4 TOLERANCE
BLACK	0	0	10^0	-
BROWN	1	1	10^1	1
RED	2	2	10^2	2
ORANGE	3	3	10^3	3
YELLOW	4	4	10^4	4
GREEN	5	5	10^5	-
BLUE	6	6	10^6	-
VIOLET	7	7	10^7	-
GREY	8	8	10^8	-
WHITE	9	9	10^9	-
GOLD	-	-	10^{-1}	5
SILVER	-	-	10^{-2}	10

Figure 3. The Resistor color code

In the second example we have an exponent of ten of -8 . From the table we can see that there is no prefix for 10^{-8} so we must move the decimal right one place so that we have 10^{-9} which has the prefix: "nano." This gives us:

15.79 nano Amps or: 15.79 nA

When converting to engineering notation the rule is that the first part of the number should be between 0 and 999. By choosing to place the decimal point so that the number falls in that range you can always find an exponent of ten for which there is a common prefix.

Probably most of you have encountered these systems of notation before but maybe you have not used them for a while. In Figure 2 a table of electrical quantities with their scientific and engineering notations has been set up. If you want practice in converting, just cover the middle and right columns with a piece of paper and do the conversions yourself. Then uncover the answers and see how you did. (Betcha nobody does them!)

Okay, now I have you all convinced that the rest of this is going to be pure math. Right? No. We'll try to keep it to a minimum. What we really need the

engineering notation for right now is to understand the resistor color code.

VIOLET AND THE BAD BOYS

Resistors (and less often, capacitors) use a code consisting of bands (or dots for caps) of color on the component to indicate the value of the component. We learned in Part I that resistors are the components which have the property of resistance built into them. Resistance is that property which opposes the flow of current in a circuit and is measured in ohms. The colored bands on a resistor give us the value of resistance and the tolerance of the resistor. The tolerance is an indication, in percent, of precisely how the resistor was manufactured. If it has a ten percent tolerance the actual value of the resistor will be within plus or minus ten percent of the value given by the colored bands on it.

Figure 3 shows a resistor, its bands, and the corresponding values of the color code.

The mnemonic used to remember the color code, (or at least the one that is printable) is:

Bad Boys Race Our Young Girls But Violet
Generally Wins. (Good Stuff!)

Figure 3 shows how the first letter of each word of the mnemonic represents a color and its value. Note that the first two bands give the first two digits, the third gives a multiplier, which corresponds to an exponent of ten, and the last band is the tolerance. If there is no fourth band the tolerance is assumed to be 20%.

Sometimes there are five bands on resistors. These are usually precision resistors and the extra band (the third one) is an extra digit to more precisely indicate the value of the resistor.

For those of you who want to practice determining values from the color code, Figure 4 gives several examples with their resistances. To practice just cover the right hand column while you figure out the answers and then check to see how you did.

ONWARD AND UPWARD

Let's get on with the good stuff.

One of the last things we did in Part I was set up a simple circuit with a battery, wire, and a lamp. We calculated how much current was flowing, whether it

COLOR CODE	EQUIVALENT RESISTANCE
RED, RED, ORANGE, GOLD	22 KOHM, 5%
GREEN, BLUE, GOLD, GOLD	5.6 OHMS, 5%
GREY, RED, RED, SILVER	8.2 KOHM, 10%
BROWN, BLACK, BROWN	100 OHMS, 20%
ORANGE, ORANGE, BLUE, GOLD	33 MEGOHMS, 5%
YELLOW, VIOLET, YELLOW, SILVER	470 KOHMS, 10%

Figure 4. Examples of the color code

was within the specs of the lamp, and how much power was being dissipated. That circuit was called a *series* circuit because everything was connected end to end. All the current in the circuit flowed through all the components. (Note that whenever we talk about current we say that it flows "through" a component or conductor.)

If all the current flows through all of the components, what would happen if the wire became disconnected from the battery or if the filament of the lamp burnt out? Obviously there would no longer be a path for current to flow and all of the current would stop. (Remember we must have a complete circuit or circle for current to flow in.) This is called an *open circuit*.

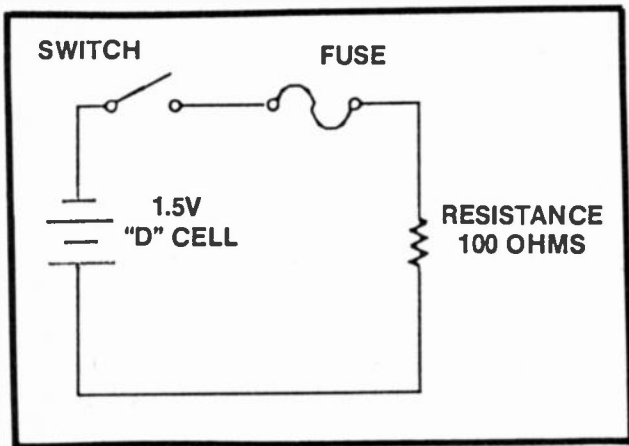


Figure 5. A Series circuit

In Figure 5 we have the same circuit but now we have added a switch and a fuse. Both of these are used to create open circuits. The switch is there so you can turn the lamp on and off by interrupting the flow of current to it. The fuse is a safety device. It is constructed in such a way that if the current exceeds its rated value the internal link will melt and create an open circuit so that current can no longer flow. When the circuit is originally designed we determine the maximum current we would ever want to flow and choose a fuse with a current rating slightly higher than that. If the current ever reaches that level the internal link melts and current stops.

KIRCHHOFF'S LAW: IT ALL ADDS UP TO NOTHING

Let's talk about voltage. In Part I we said that when voltage is supplied by a battery or other power source (called a voltage rise) we labelled it "E" and if we were talking about a voltage drop across a resistor or other device we labelled it "V." We also said that, according to Ohm's Law:

$$V = I \times R$$

or we could say the voltage drop across a resistor is equal to the resistance times the current through it.

If Ohm's Law is the most important, then the second most important concept in electricity is Kirchhoff's Voltage Law which states:

The sum of all the voltage rises and drops around a closed loop (circuit) will equal zero.

Don't be intimidated. This isn't Electricity 101. If you never remember the name Kirchhoff again it's really

not that important. The important thing is the concept.

If we look at our circuit in Figure 5, (with the switch closed) we see that the battery supplies 1.5 volts. That is a voltage rise. We calculated in Part I that the current in the circuit was .015 amperes. (15 mA according to engineering notation) If we use Ohm's Law to multiply the current through the resistor times the resistance we find that there is 1.5 volts dropped across the resistor. If we note the polarities of the battery and the voltage dropped across the resistor we will see that they are opposite or oppose each other. If we add them algebraically the sum is zero.

Kirchhoff would be proud of us.

This may not seem like it's very profound in a simple circuit but it comes in very handy a little later on. So let's look at another simple circuit.

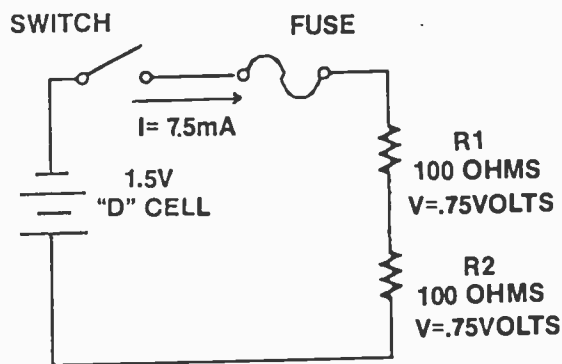


Figure 6. A Series circuit with two resistances

The circuit in Figure 6 is still a series circuit. How do we know? Because there is only one path for current and it flows through all of the circuit components. In this case, however, we have two resistances connected end to end. (Do you remember the old series Christmas tree lights? Because all the current flowed through all of the lamps, if one burnt out, creating an open circuit, they all went out.)

Let's consider what the relationships between voltage, current and resistance are in this circuit. Has the source voltage changed? No the battery is still a 1.5 volt cell. Has the circuit resistance changed? Yes, because now instead of one 100 ohm resistor we now have two. When two resistors are connected in series we can add their values to get the total resistance so:

$$R_T = 100 \text{ ohms} + 100 \text{ ohms} = 200 \text{ ohms}$$

If the resistance in the circuit has been doubled what will happen to the current? Right, it will be one-half what it was before because:

$$I = V / R = 1.5\text{v} / 200 \text{ ohms} = 7.5\text{mA}$$

Now if we work backwards and multiply the current (7.5mA) times each of the resistors (100 ohms) we find that each of them has .75 volts dropped across them. If we add those voltages up they will equal 1.5v which is the battery voltage. Again Kirchhoff would smile approvingly.

We call this circuit a *voltage divider* because the source voltage is divided between the two resistors. If the resistors were not the same values what would happen? A ratio of voltages would be dropped across them which would be proportional to the values of the

resistors. And the total of the two voltage drops would always equal the source voltage.

SPLITTING THE CURRENT

Before we wrap up Part II of this series, we have to take a look at parallel circuits. Just as the name implies, the resistors in a parallel circuit are arranged in a parallel configuration. (See Figure 7) Although you may not always see them drawn this way, if they are in parallel they can be redrawn so that they are parallel to each other because they will be connected together at both ends.

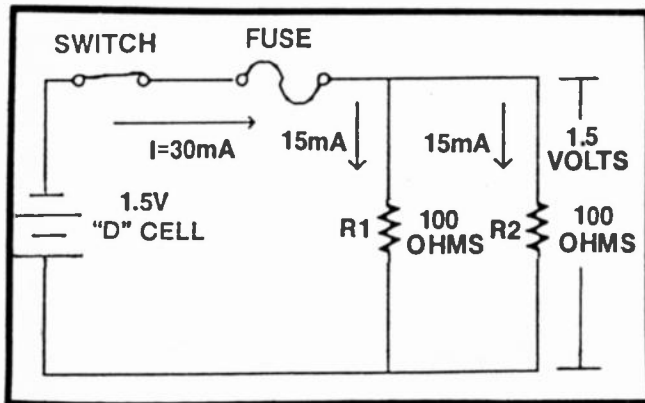


Figure 7. A Parallel circuit

In the circuit in Figure 7 we can see that current will be sourced from the battery and will flow through R_1 (which originally was the resistance of our lamp filament). Because R_1 is connected directly across the battery, which is still 1.5 volts, and R_1 is still 100 ohms, there should be:

$$I = V / R = 1.5v / 100 \text{ ohms} = 15\text{mAmps}$$

Okay, I hear all those "but"s. You're saying "Why doesn't the current split and some of it flow through

the other resistance?" Well, you are right. The current does split, but since R_2 is connected directly across R_1 , and therefore the same 1.5 volts is also across R_2 , there will also be 15 mAmps flowing through R_2 . If that is the case, then the battery must be sourcing both of those currents for a total of 30 mAmps.

If the battery is supplying 30 mAmps (15 mAmps to each resistor), then what will Ohm's Law tell us about the overall resistance of the circuit?

$$R_{\text{Total}} = V / I = 1.5v / 30\text{mA} = 50 \text{ ohms}$$

The total circuit resistance is 50 ohms, one half that of each resistor. So we now know that connecting resistors in parallel *reduces* the total resistance. (Remember that in series circuits the resistors added together give the sum of the resistors.) The simple way of determining the equivalent resistance of resistors in parallel is to use *conductance*.

Arghh! Not more terms!

Sorry, but this one is easy. Conductance (symbolized by G , with units, Siemens) is the reciprocal of resistance:

$$G = 1 / R$$

and conductances in parallel can be added together like resistances in series. After the total conductance is determined we can convert back to resistance by:

$$R = 1 / G$$

so for Figure 7:

$$G_T = 1/100 \text{ ohms} + 1/100 \text{ ohms} = 10\text{mS} + 10\text{mS} = 20\text{mS}$$

converting back:

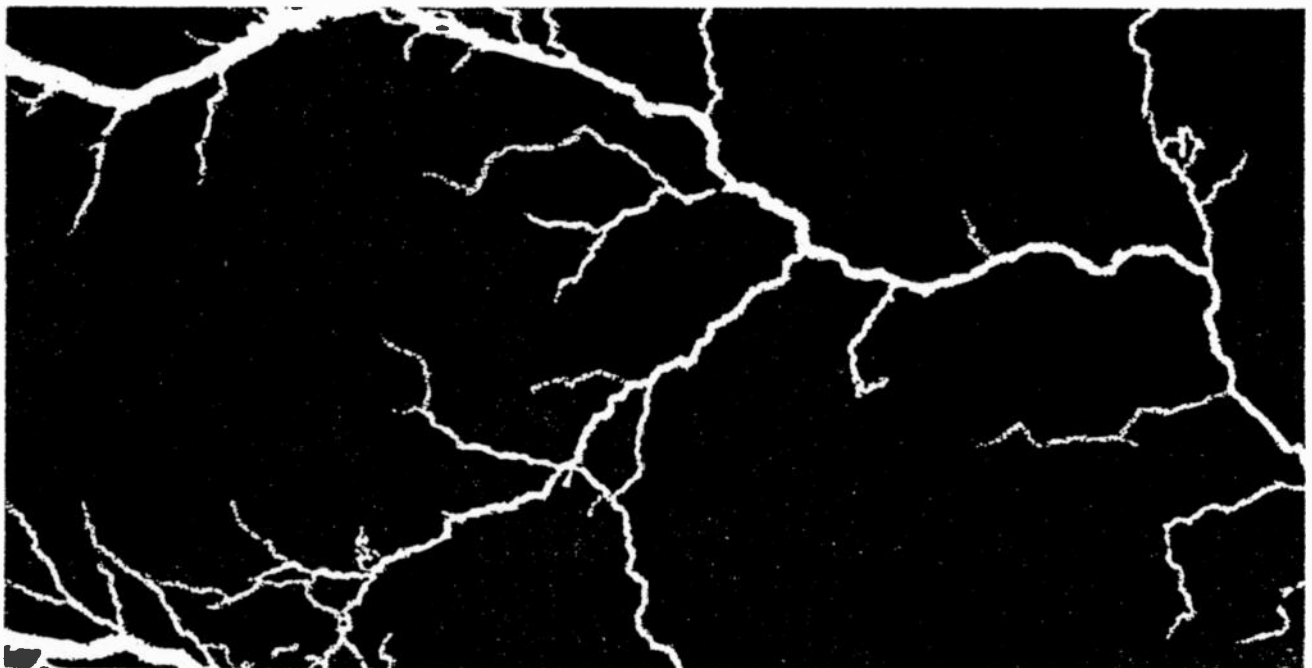
$$R_T = 1 / G = 1/20\text{mS} = 50 \text{ ohms}$$

And that's what we determined it was before.

Enough. We can only take so many thrills at one time.

In Part III we will look at series and parallel circuits together, short circuits, meters and how they are used, and tons of other good stuff.

Meanwhile, back to my basket weaving. ■



ANOTHER LOOK AT SOLAR ENERGY

Solar energy is an idea whose time has come. Solar energy is not only the energy of the future, it is the energy of now. It is the sun, our sun, one sun out of millions of suns, a sun 93 million miles away which always has powered the earth. All forms of life are dependent on the sun. Many millions of years ago, fossil fuels—coal, natural gas, petroleum—were created by chemical reactions stimulated by the sun. These fossil fuels are difficult to get to, imported at great expense, increasingly taxed, and just plain running out. Now, today, we are turning to the sun to provide for us the basic stuff of life, energy. The sun shines down at about 138 watts per hour per square foot of area on this planet. This energy is a gift, free, ours for the taking.

Some day we may have satellites revolving in space, collecting solar radiation before it is deflected by the atmosphere. These solar-absorbing extraplanetary devices may then radio signal the captured energy back to a welcoming mother earth.

A gleaming, glittering satellite wings effortlessly through the expanse of outer space performing a multitude of tasks. Meanwhile, a desert well pumps hundreds of gallons of water daily, changing an arid wasteland into an oasis. What do they have in common? They're both solar powered! Solar power by photovoltaic cells is a space-age technology which has come into its own on our planet.

Let's take a look at this workhorse of space, now established on terra firma, and see how it performs its magic.

Photoelectric Beginnings

We're not performing any new tricks here, just improving on some old ones. Although the photoelectric effect has been known for a century, it took the wizardry of solid state electronics to make it a practical reality. Many of the pioneers of electronics studied it, including such names as Davey and Edison. Albert Einstein gave it substance when he penned the photoelectric theory, for which he was awarded a Nobel Prize. Our first encounter with solar electricity came about thirty-five years ago, with the introduction of the selenium solar cell manufactured by International Rectifier, designated B2M. At the time, it was considered a breakthrough, in that it was within the budget of the hobbyist and relatively efficient in use.

It powered more than one home-built transistor radio, despite its minute power capacity of ½-volt at 1-milliampere. Thumbing through the pages of electronic periodicals of the time leads one to believe we were in a solar electricity boom, which was closer to the truth than many experimenters ever would have suspected.

Uncle Sam was also building solar powered projects. The race for space and the need to power earth orbiting satellites demanded a solar cell capable of supplying their needs in a hostile environment. Bell Laboratories obliged.

Bell, having just received the Nobel Prize for the invention of the transistor, was exploring the new technology of silicon semiconductors. Utilizing their vast knowledge of this budding science, they were able to produce the first silicon solar cell, the forerunner of today's photovoltaic cells.

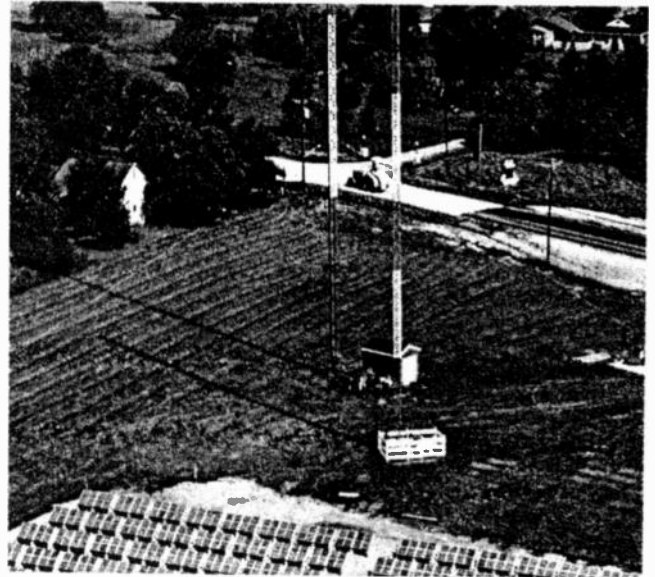
Well, the success of solar generators in space is apparent. As bigger, more efficient cells become available, and oil supplies dwindle, terrestrial solar technology will branch off by itself, conjuring up its own special magic.

Solar Cell Theory

The solar cell, or photovoltaic cell, makes a direct conversion from sunlight (solar energy) to electricity. No fossil fuel is required. Moreover, photovoltaics are safe and nonpolluting and are manufactured from materials in relatively abundant supply. Manufacturing costs are high, but declining steadily, while other methods of generating electricity involve energy costs that are rising sharply. Additionally, photovoltaics require no moving parts and minimal maintenance. Associated components have a long life and no waste products are generated.

Solar Radio

Photovoltaic supplies are used extensively in the radio-communication services, such as for repeater, relay and rebroadcast stations that must be mountain-top located or located at a remote site where there is no source of power. The two-way radio services in particular can now make use of repeater sites at high locations where there is no convenient power. Weak signals from mobiles can be picked up by the receiver and then retransmitted to obtain a



The transmitter of AM radio station WBNO in Bryon, Ohio is said to be the first using photovoltaic power. A combination of 800 modules, containing 33,600 cells produce 15 kilowatts peak and delivers 128 volts DC to the station. Sixty lead-acid cells are kept effectively charged by this system.

reliable coverage over a much larger area. High locations permit a greater separation between relay stations of a point-to-point system and more economical operation. TV and FM broadcast signals can be picked up and rebroadcast from high locations to obtain extended and better coverage into remote areas.

Marine beacons, buoys and other navigation equipment can be powered with solar cells and associated batteries. A number of railway signaling systems are now powered with photovoltaics.

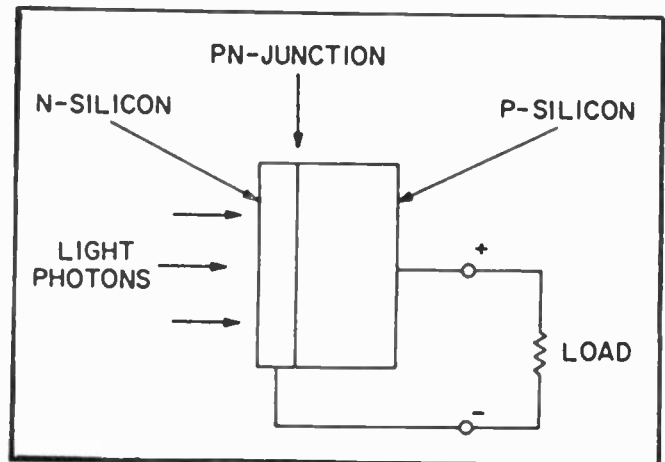


Figure 1. A load connected between the "N" and "P" junctions will receive current flow when light photons hit the "N" junction.

Basic Operation

The basic solar cell is a semiconductor diode. Most often, it is made of pure silicon properly doped to obtain a PN junction as seen in Figure 1. The N-type silicon is doped with phosphorus, while the P-type silicon is doped with boron. The N-silicon has free electrons while the P-silicon has free-moving positive

charges called holes. At the PN junction region, the charges neutralize and with no incident light, there is no charge motion.

The arrival of light-rays at the thin N-silicon layer permits a penetration of photons to the junction region. The light energy forces electrons out of the crystal structure. This motion of charges produces an output current when there is a load path connected between the positive P-silicon terminal and the negative N-silicon terminal. The current varies linearly with the amount of light striking the cell and the cross-sectional area of the cell. The absolute output current is also a function of the load resistance and the conversion efficiency of the cell.

If a solar cell is directed toward the sun at noon on a clear day, the energy striking that cell will be approximately 100 milliwatts per square centimeter. This results in maximum current as demonstrated by the top response curve of Figure 2. Note that a light level of 100 milliwatts per square centimeter is referred to as "1 sun." If the light level is reduced to 0.5 sun, corresponding to 50 milliwatts per square centimeter, the output current is halved.

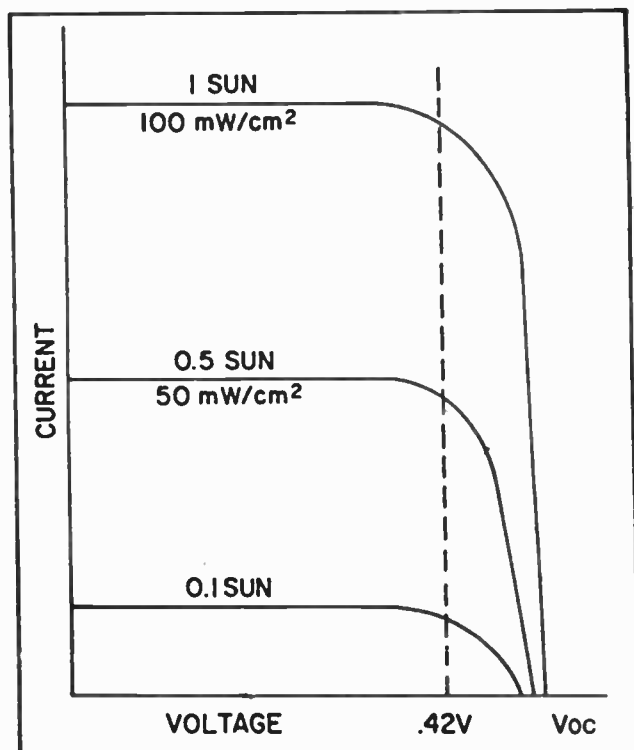


Figure 2. Response of a solar cell. Current is reduced in proportion to light intensity. One Sun yields 100 milliwatts maximum.

The open circuit voltage of a silicon cell is approximately 0.57-volts. This corresponds to zero output current. When the load connected to the cell is of a resistive value that results in a cell voltage of 0.45-volts, there is maximum power delivered to the load. As shown in Figure 2, almost maximum current flows. A reduction in the load resistance below this value results in very little change in current. In fact, the solar cell can be short-circuited and there will be no damage or significant increase in the load current. This condition too is shown in Figure 2, with the same

current present from right above the knee of the curve over to the zero voltage value.

In practice then, the voltage produced by a single silicon solar cell is between 0.4 and 0.45-volts. The size and shape of the cell has nothing to do with this value. The level of the output current as a function of a given light intensity is related directly to the cell area regardless of the shape of the cell, be it circular, semicircular, rectangular or any other configuration. Under the illumination of 1 sun, a typical 3-inch diameter solar cell will produce an output current of 1.2 amperes at a voltage of 0.45. A similar 2¼-inch diameter cell (about half of the area of the previous one) will provide an output current of 550 milliamperes.

The efficiency of a solar cell is the ratio of the electrical power output over the light power unit:

$$\% \text{ Efficiency} = \frac{\text{Power output}}{\text{Power Input}} \times 100$$

Efficiency is important and determines the electrical power output that can be obtained for a cell of a given size. The greater the efficiency, the more power that can be obtained with a solar panel of a given dimension. Typical efficiencies of modern silicon solar cells fall between ten and twelve percent.

Series and Parallel Connections

Higher voltages and higher current capability can be obtained with appropriate series and parallel connections of solar cells. The voltage is increased when cells are connected in series just as there is a voltage increase when batteries are connected in series. Also, there is a higher current capability when solar cells are connected in parallel just as the current capability is increased when batteries are connected in parallel. Four, 0.4-volt solar cells connected in series will provide an output voltage of 1.6-volts (4×0.4). Four, 1.2 ampere cells connected in parallel will result in a current capability of 4.8 amperes (4×1.2). If 16 of these 0.4-volt and 1.2 ampere cells are connected in series-parallel, as shown in Figure 3, the output will be 1.6-volts with a current capability of 4.8 amperes.

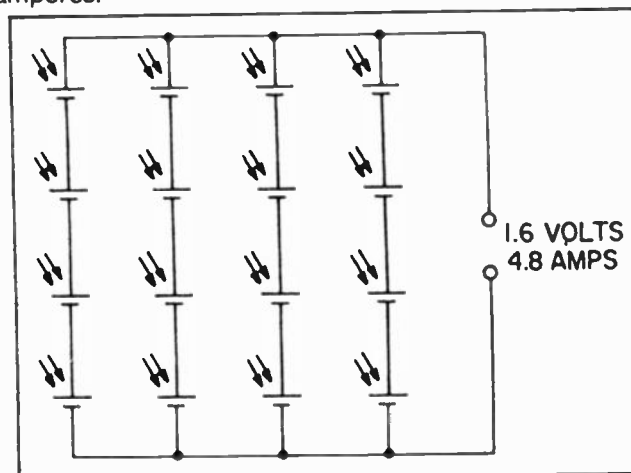


Figure 3. Connecting solar cells in series increases voltage and in parallel increases current. Series/parallel steps both up.

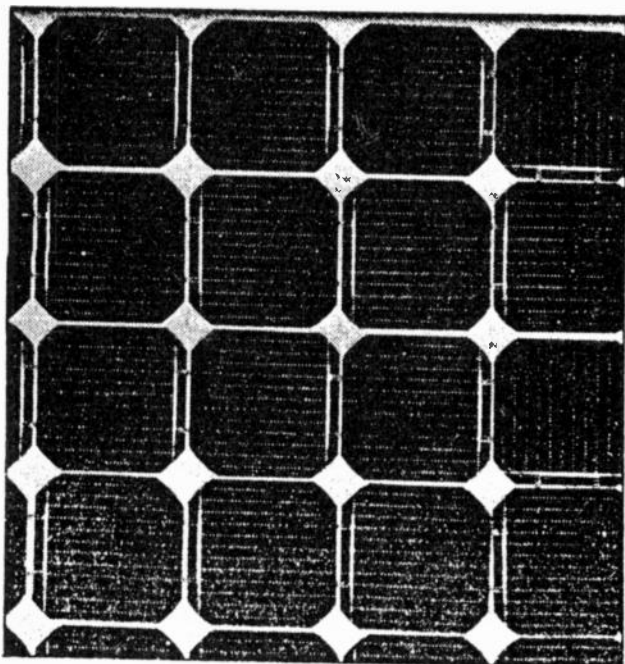


Figure 4. Modern hi-density solar panel in a frame. Model consists of sixty-four square cells, producing up to 34 watts of power.

Photovoltaic Solar Panels

A solar photovoltaic panel is the result when many solar cells are mounted in a series-parallel arrangement on a frame. Note that the solar panel of Figure 4 consists of 64 square cells. The Solarex HE-51 21-inch by 21-inch solar panel provides a peak power capability of 34 watts. Its rating is 2.1 amperes at 14-volts nominal. The response of the panel is shown in Figure 5. Based on the average insulation in the United States, the panel is capable of providing approximately 63 ampere-hours of electricity per week.

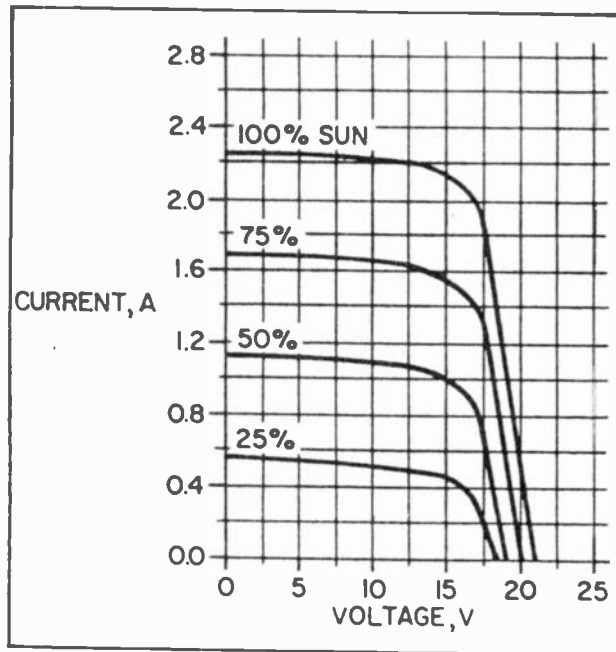


Figure 5. A performance chart of the solar panel in figure 4. Note that the voltage output remains at a constant nominal 14 volts.

When a higher voltage is desired, panels can be connected in series just as individual solar cells. For example, two such panels in series would provide an output of 28-volts. Two of them connected in parallel would provide a current capability of 4.2 amperes.

Complete Power Supply

A complete solar power supply, including battery and load, is shown in Figure 6. In sunlight, the solar panel charges the battery through a blocking diode. The load is connected across the battery. In darkness and at low light levels, the battery supplies the necessary energy to the load on a continuous basis. Theoretically, the solar panel must be capable of supplying at least the same number of ampere-hours to the battery as the load demands from the battery. Of course, in practice, system losses and other variables require that the solar panel and battery capabilities be greater than the actual load demand.

The blocking diode is an important part of the charging system. In darkness and low illumination, the battery voltage could exceed the solar panel voltage. Without the diode in the circuit, the battery would then discharge into the solar source. Under the condition of high battery voltage and low charge voltage, the diode is reverse-biased. Consequently, the anode becomes more negative than the cathode and the discharge path into the panel from the battery is opened.

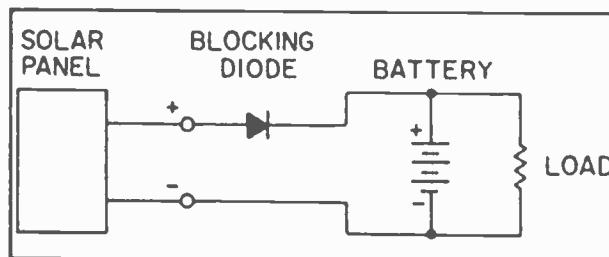


Figure 6. Blocking diode prevents the battery from discharging into the solar panel when light is absent or at a very low level.

The solar panel must supply the total power required by the load. This it must do when sunlight is available. The battery function is to smooth out the power delivered to the load as the sunlight varies, and to supply power when the light level is low.

An additional factor that must be known is the number of peak sun-hours per day for a mounting site. This information is available from appropriate charts and tables. Peak sun-hours in the southwest, for example, would be greater than along the east coast. Consequently, the ampere-hour capability would require more solar panels at a mounting site in the east as compared to one in the southwest. The average peak sun hours and the daily load in ampere-hours can be used to determine the total current in amperes that must be supplied by the solar system according to the following relationship:

$$\text{Amps} = \frac{\text{Ampere-hours per day}}{\text{Peak sun hours}}$$

As a safety margin, the amperes required should be a figure which is at least 20% greater than the above

calculation. The capacity of the battery is usually made substantially greater than the above ampere-hour figure. Thus the battery should be capable of supplying the necessary power for an extended period of time, perhaps a week, assuming that illumination at the site could be low because of poor weather conditions extending over such a period of time.

A Typical Example

Assume that a radio transceiver was to be powered by a solar panel. On transmit, the current demand is 1 ampere; on receive, 0.1 ampere. Over a period of a day (24 hours) the intermittent operation of the transmitter involves a total time period of 8 hours. The receiver is in operation for the remainder of the 24 hour period. Consequently, the ampere-hours (Ah) drawn by the transmitter and receiver are:

$$\begin{aligned} \text{Transmit} &= 1 \times 8 = 8 \text{ Ah} \\ \text{Receive} &= 0.1 \times 16 = 1.6 \text{ Ah} \end{aligned}$$

The total demand is 9.6 ampere-hours (8 + 1.6).

Assume at the site of the solar panel there are an average of 4 peak sun hours. Consequently, the current (I) that must be made available by the solar power system becomes:

$$I = \frac{\text{Ampere-hours}}{\text{Peak Sun Hours}}$$

$$I = \frac{9.6}{4}$$

$$I = 2.4 \text{ Amperes}$$

Allowing a 25% safety factor, the solar system should be capable of delivering an average current I_{av} of:

$$\text{Average Current} = 2.4 + (0.25 \times 2.4)$$

$$I_{av} = 3 \text{ amperes}$$

If the transceiver operates at 12 volts, the rating of the solar panel should be about 14-volts at 3 amperes.

In this arrangement, on an average basis, the ampere-hours delivered by the solar panel would be 12 (3 × 4), while the average demand of the transceiver would be 9.6 ampere-hours.

A solar cell consists of two types of silicon semiconductor material separated by a junction. Half the solar cell is made up of material designated type N. This semiconductor material tends to attract and hold electrons. The other half of the cell contains type P material, which has a surplus of electrons and is willing to give them over to the N substance. More on this later.

Think of the silicon atom as having four protuberances. It is the atom's nature to want to hook up with other silicon atoms, rather than having its appendages flapping idly. These "arms" of the silicon atom are in reality electrons surrounding the silicon nucleus. The electrons don't swarm about the

nucleus, as often depicted; instead, each electron occupies an energy shell. The closer to the atom's core the electron is located, the lower its energy and the more stable it is.

Each shell will accommodate a specific number of electrons, and each oscillates at its respective energy level. Atoms like the feeling of being complete. Should any shell lack the correct number of electrons, the atom is said to have a valence—a desire to complete the defective shell. The atoms at the junction, all having the exact number of electrons vibrating in each of its shells, are content to remain.

It's within this junction region that the sun will perform its magic.

This stable group of electrons in the junction remains at rest unless disturbed. Should an energy packet of sunlight (a photon) invade this clique, it's quite possible that it will be absorbed by one of the atoms. This boosts one of the electrons to a higher energy level or to a different, more remote shell. When this occurs, the electrons have a tendency to wander off, becoming lost.

These wayward electrons are attracted to their electron-hungry neighbors and collect in the N material. Here other free agents bustle about, satisfying the atom's needs. The now deficient atom is bumped from the junction and migrates toward its P type cousin.

This state of events creates tension between the two factions. So much tension, in fact, that the dislodged electrons will do almost anything to get back to the warmth and security of the junction. But the laws of quantum, like a traffic cop, only allow for a one way trip. But there is a back door!

If a conductor is connected from the N to the P materials, it forms a tunnel for the electrons. The free electrons, accumulated in the N material, flee through the conductor.

Since the pumped-up electron contains more energy than necessary to occupy its former position (shell), it can afford to be wasteful in its journey. Traveling through the conductor it meets certain amounts of resistance, from bumping into electrons and the like. This energy is released and can be put to useful work. It is current flow.

Once reunited with an atom, the happy couple try returning to that harmonious section, the junction.

Some Technical Considerations

What we've created is a wafer of silicon possessing a difference of potential (voltage). Theoretically, the voltage is 650 millivolts; in reality it doesn't exist. There are a number of reasons for this shortcoming voltage shortfall.

Let's return to the junction group. This lethargic group rests secure, with all shells occupied. But suppose an agitator were to disrupt their tranquility, something that would stir up a ruckus and send the atoms hurrying about. The "arms" (valence electrons) are now in a more excited state—a higher shell level—and tend to lose their grip on neighboring atoms, which are also rushing about busily.

However, the inciter doesn't arouse the electrons sufficiently to escape...just enough to create mass

confusion; an arriving photon will be absorbed, as before. But instead of rushing to the N territory, there's a good chance the chaos will cause it to stumble to the opposite side—where it combines with migrating holes. The same is true for the holes, which mistakenly travel to the N section. Therefore, no current flow is generated by these backward electrons in transit.

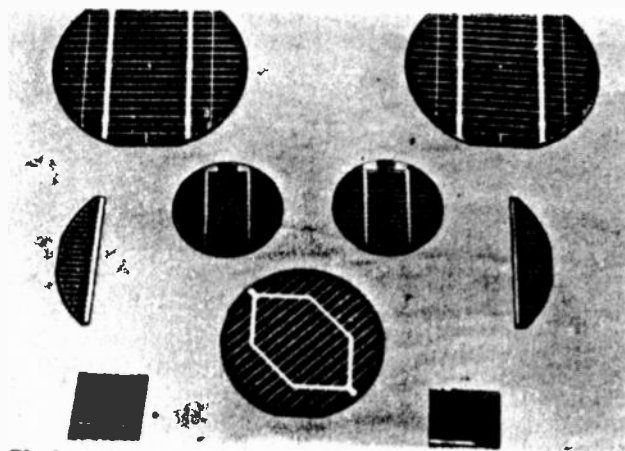
This isn't true of all the atoms, but it does occur often enough to reduce the electrons available for useful work. The more excited the crowd becomes, the more likely it'll happen.

What could possibly cause this? Heat. Thermal agitation can and does disrupt the atoms orderly state, creating enough havoc to reduce efficiency.

Impurities (other than those purposely introduced) can also add to the reluctance of electrons to flow. Some atoms are more aggressive than others—in fact, some are downright explosive when it comes to matching-up with other atoms. Tenacious atoms, accidentally entering into the affair, grab the free electrons—never to release them. Hydrogen is such a culprit, as is oxygen.

It goes without saying that the more electrons dislodged and put to work for a given light level, the greater the efficiency of the unit. More electrons, more current produced.

With all these considerations, 460 millivolts is considered a practical figure per cell, with the open circuit voltage somewhat higher. Attempts are being made to increase this potential, thereby increasing efficiency.



Photovoltaic cell varieties. The larger discs are high output cells, the smaller discs and crescents have a lower output. Rectangles are highly sophisticated cells destined for use in space exploration.

Silicon Into Photocells

Now that you have a fair understanding of the internal workings, let's journey with a slab of silicon, observing its metamorphosis from sand to photon converter. A solar cell begins life as a silicate—much like common sand—not yet converting its energy into electrons.

The silicon is refined (with a purity exceeding 99.99%), by being placed in a crucible and melted. A small amount of boron is added. Boron is an atom with five electrons in its outer shell, thus making it a donor (P type) substance; it will supply the free electrons.

A small, perfectly formed crystal, called a seed, is touched to the molten surface. The solution is held at its melting temperature of 1,420 degrees centigrade, controlled to within 2 degrees. The seed is rotated, inducing a counter rotation in the liquid. Individual atoms begin depositing on the seed, aligning themselves into a perfectly structured crystal, using the seed as a pattern.

Once the ingot is finished, it's clamped into a saw, an abrasive cutter designed to slice the cylinder into wafers. Resembling a bread slicing machine, its multiple blades grind away, producing all wafers simultaneously. Unfortunately, this is an extremely wasteful process, rendering three-fourths of the crystal to dust.

Wafers 3 inches across and 16 mils thick reveal the shape of the completed cell. Sometimes the edges are cut, producing a square or rectangular unit. A freshly sliced disc carries saw blade marks on the surface. To remove the marks, the slab is subjected to chemical processing. A sodium hydroxide—the same as household lye—bath etches the blank to a smooth finish. The cell is now ready for processing.

The disc is submersed into a much weaker 2% sodium hydroxide solution for approximately 30 minutes. This diluted bath doesn't etch the wafer's thickness as previously, but removes material from between the crystal structure. This characteristic of silicon leaves a plane of tetrahedrons. Incoming light is reflected off the sides of the pyramids, ricocheting its way to the junction. The tetrahedron allows the light to enter the cell, but reflects very little, thus eliminating the need for an anti-reflective coating. A sulfuric acid rinse neutralizes the alkaline etchant and cleanses the wafer. This process creates the type P semiconductor part of the cell.

The N type semiconductor is created through a diffusion process. Cells are placed in a quartz tube and the system purged with nitrogen. The temperature is raised to 850 degrees centigrade, and a measured amount of gaseous phosphorus acid is injected into the chamber. The phosphorous atoms disassociate and actually force themselves into the surface structure, displacing silicon atoms. With only three valence electrons, it produces the holes.

The junction is formed at the same time. It's within these seven angstroms the elite society will set up housekeeping; the remaining wafer thickness is largely for physical support. (An angstrom is equal to 10^{-4} microns. A micron is one-millionth of a meter!)

Two discs are placed back to back during the procedure. This avoids forming a junction on both sides of one cell.

Our silicon slab is now a bona fide photovoltaic cell. All that's necessary is to remove the free electrons and put them to work. The front surface, the one sporting the junction, is printed with a network of thin lines, all interconnecting with one another.

Here the manufacturer must make a compromise. The grid can be silk-screened, a simple process producing thick heavy lines, or extremely thin lines can be made by vacuum depositing metal through a mask. Obviously, the wider grid lines block photons from reaching the junction, while the thinner vacuum

formed lines require a larger equipment investment and higher manufacturing cost to produce.

This is a tough decision, because the grid lines must be of sufficient quantity—giving the electrons a short path to travel (or else they get chummy and combine with an atom). This means the more numerous the lines, the more photons that are blocked.

The exception is space-destined cells. Here efficiency is paramount and cost secondary. There's another variation in aerospace solar cells—wafer thickness. Weight is critical in space vehicles, so the silicon is only about 4 to 6 mils thick, making them extremely fragile. A conductive coating is applied to the back to complete the circuit.



This water pump, miles from a power source, draws its electrical power from a bank of solar cells. Similar pumps could transform arid deserts into arable, productive farmland.

Solar Cells Galore

Silicon solar cells are the most popular and least expensive. That's not to say nothing's new under the sun—there's plenty happening!

Silicon cells suffer two drawbacks: high cost/power ratio (watts per dollar) and mediocre efficiency. Research is traveling a variety of routes seeking a solution to this.

The efficiency of a typical silicon unit is around 11%. If this percentage were raised, the price per watt could be reduced. But atoms, are very selective about the kind of photons they'll absorb. Silicon has a preference for long, low energy wavelengths. This affinity for light in the red to infrared spectrum limits the theoretical efficiency to under 20%. Gallium arsenide, on the other hand, prefers high energy, high frequency photons.

Gallium arsenide technology is newer and not as well developed as silicon, but it promises greater rewards. Cell efficiency presently exceeds 20%—a sizable difference. On a one-to-one basis, it would require about twice the surface area of silicon to equal the power of gallium. Manufacturers are striving for 30% conversion, a figure they say is already within reach.

Let's examine a gallium arsenide solar generator. Again we have two semiconductor materials—a substrate of N doped GaAs (the chemical shorthand for gallium arsenide) and P type GaAs—with the junction sandwiched between.

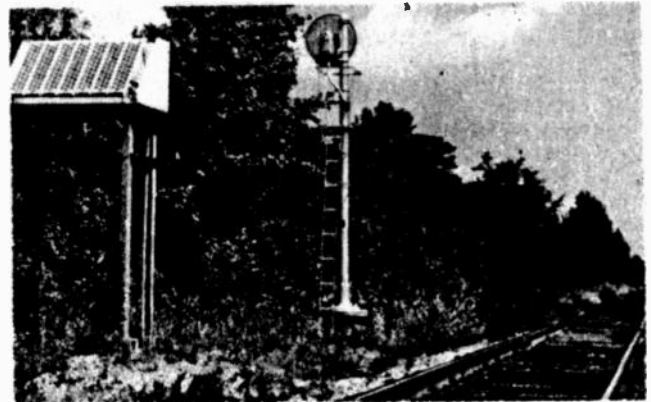
An overcoat of aluminum gallium arsenide (A1GaAs) about 10 microns thick is vacuum

deposited over the P type semiconductor, forming one electrical contact. Photons pass through the A1GaAs and strike the junction region, dislodging electrons. The free electrons collect in the N type material, where they are removed and allowed to flow. An approach to increasing the efficiency of A1GaAs is to stack them with silicon cells. An A1GaAs cell is placed on top of a silicon unit. The entering sunlight strikes the GaAs junction, which promptly absorbs the high frequency photons; the low energy wavelengths pass through and are absorbed by the silicon wafer. The overall performance 11% silicon and 17% GaAs approaches the 30% mark. Not a bad gain in efficiency.

Another way to enhance cell output is multiplying the available light; this is usually accomplished by focusing the sun's radiation with parabolic reflectors. A concentration of 20 suns isn't uncommon, with technology sending that figure soaring up to 1000! The cells are specially manufactured to be mounted onto a heatsink. The grid lines are thinner and more numerous, since they have to handle more electrons. It's sort of like adding freeways to eliminate traffic congestion.

Gallium arsenide cells are specially suited for concentrator setups. They'll operate at 200 degrees centigrade with no heatsink and little loss of efficiency. An equivalent silicon unit drops appreciably above 50 degrees centigrade. By water cooling the A1GaAs cell and concentrating the light to 1000 suns, a single cell 1/3-inch in diameter is capable of producing 10 watts of power!

Of course, this system must be able to track the sun as it journeys across the heavens, but considering the gains it's well worth it. Tracking capability in any solar collector will increase its performance by 40%.



Solar power can eliminate the need for constant battery recharging in remote installations such as this railroad signal. A trickle charge can be maintained, thereby allowing the signal to function with minimum attention.

Bargain Cells

Some researchers are taking the opposite road: reducing manufacturing cost and settling for less efficiency. The cost of growing and cutting crystal igots is astronomical in comparison to subsequent steps, since over half is lost to dust. Let's look at one manufacturer's solution.

First, a ceramic substrate is coated with carbon.

This enables the molten silicon to adhere. The substrate is dipped and the resulting silicon layer exhibits a grain structure which is larger than the thickness of the layer. But, unlike the pyramids of the crystal, it appears that whiskers are growing on the surface when viewed under a microscope. These whiskers add to the surface area available to light.

The ceramic backing is laced with slots, permitting access to the reverse side of the semiconductor. The semiconductor is now processed in the usual manner previously described.

An advantage of this process is its ability to be manufactured in long strips. The strip is passed over molten silicon, a procedure similar to flow soldering. This greatly reduces the silicon loss, cutting costs. The process is also easily adapted to automated assembly and manufacture.

There are numerous approaches, using a variety of materials—including plastics and removable backing. The silicon doping impurities also vary widely with application.

Here's an interesting approach. Two strands of silicon are touched to the surface of molten silicon. Capillary action sucks up the liquid, filling the gap, which can be as wide as 40 mm. This does away with the need for support backing, since it's rigid enough.

Still others are trying the thin film approach. Here we have low cost and low efficiency (5%)—hopefully these drawbacks will be offset by improved cost effectiveness. The candidate here is cadmium sulfide

coupled with copper sulfide on thin film.

P doped copper sulfide is applied to an aluminum backing, sprayed or dipped. To this a thin layer of N type cadmium sulfide is vacuum deposited—about 20 microns—forming the junction. Since the thicknesses involved are on the order of microns, very little material is used (and consequently little is wasted). A transparent conductive grid is applied over the N material and protected by a Mylar covering.

The material cost is low, as is the number of manufacturing steps involved. But such a design must maintain a greater surface area.

Another approach incorporates liquid as the energy converter. Dust-sized particles of silicon are placed in transparent capillary tubes, which are filled with an electrolytic generating fluid.

Sunlight striking the silicon generates electricity, which in turn breaks the electrolyte down to its components, probably something like hydrogen bromide and water.

The decomposed matter is transferred to a fuel cell (presumably with a pumping system) where, upon recombination, electricity is generated. More than likely, the fuel cell is similar in design to the type developed for the Apollo missions. The electrolyte is then recycled.

And so it goes with solar technology. It would appear that, while progress is slow, there are some bright spots on the horizon. ■



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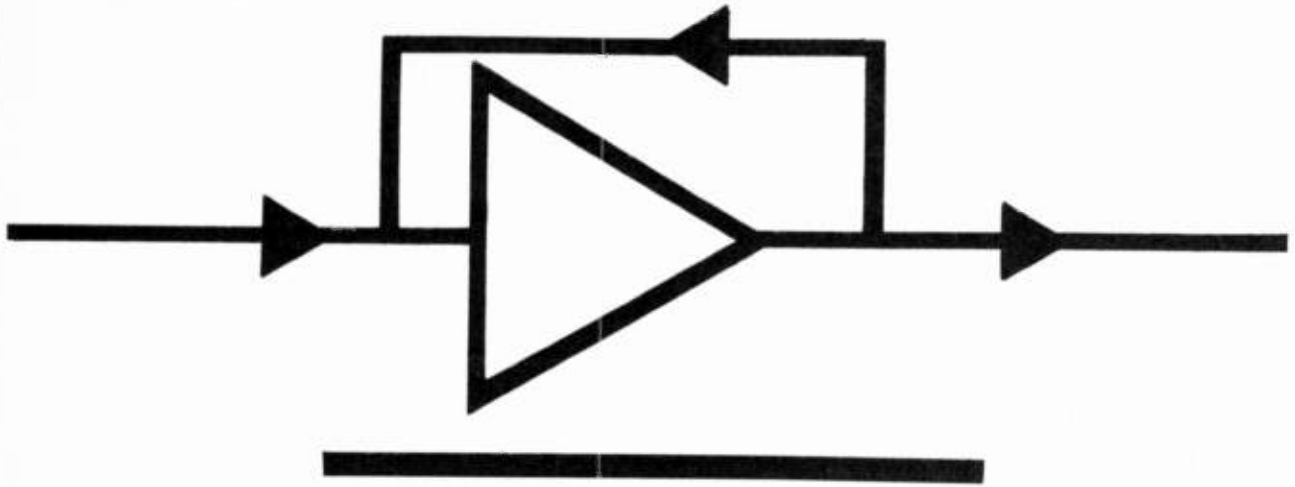
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IC TESTBENCH



Integrated Circuits, digital and linear, are where it is at; that is, the state-of-the-art in electronics technology. For the newcomer to this fascinating area of electronics, we have tried to select a representative cross-section of the digital and linear integrated circuits available on the market, and design construction projects around them that not only entertain, but educate as well.

In truth, there is no easy way to learn electronic theory, at least in a manner that will prepare the individual to cope effectively with the influx of technical applications that are now reaching the home, the car, and your place of business. For those with no prior experience in the construction of electronic projects, we strongly suggest that you begin with some of the Transistor projects found elsewhere (Circuit Fragments) in this magazine. By beginning with these simpler projects, where construction technique is less critical, you will learn, by necessity, the basics of component arrangement, lead trimming or lead dress as it is properly called, and the difficult art of translating those funny lines and squiggles on a schematic diagram into a working piece of electronic equipment.

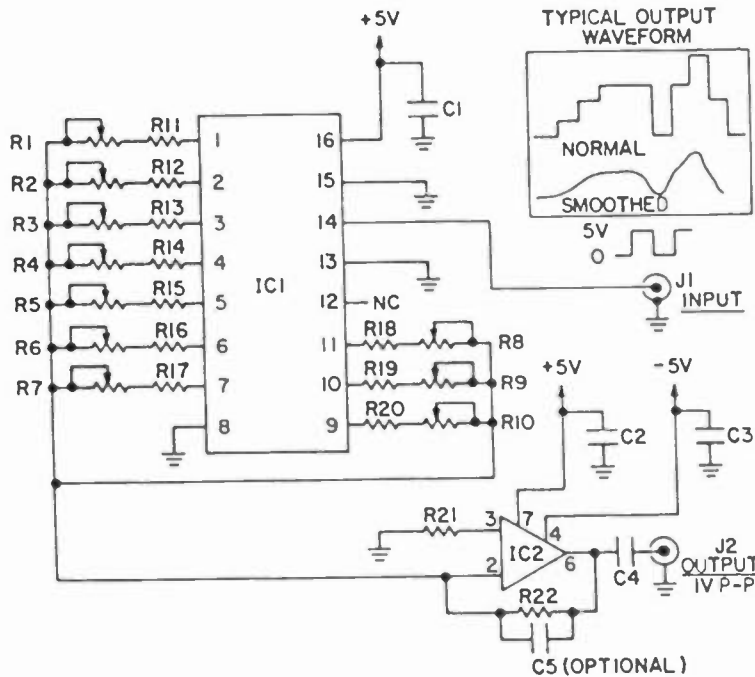
For those of you who have had experience in building transistor projects before, the word is caution. Integrated Circuits are extremely sensitive devices and require very special handling.

THE WAVESHAPER



This little circuit illustrates the principle behind multi-kilobuck laboratory-style waveform synthesizers as well as some of the more advanced music synthesizers. Into J1 you should feed a square-wave signal swinging from ground to almost 5-volts. The input signal's frequency should be ten times that of the desired output. Adjusting potentiometers R1 through R10 will enable you to literally design the shape of the output waveform. If you can get hold of

an oscilloscope, use it to observe the effect of R1 through R10 on the output. At the same time, feed the output to an audio amp so that you can hear the changes in timbre that occur as the waveshape is altered. Capacitor C5 can be used to smooth out the chunky shape of the output. With a 10kHz input, start with a value of 0.1uF for C5 and experiment. Make sure at least one potentiometer is set to maximum resistance and that at least one is set to minimum. This guarantees a full 1-volt peak-to-peak output.



NOTE: OUTPUT FREQUENCY = INPUT FREQUENCY ÷ 10

PARTS LIST FOR THE WAVESHAPER

C1, C2, C3—0.01- μ F ceramic disc capacitor, 35 VDC
 C4—0.5- μ F mylar capacitor, 35 VDC
 C5—see text
 IC1—4017 CMOS decade counter
 IC2—741 op amp

J1, J2—phono jack
 R1 through R10—2-megohm linear-taper potentiometer
 R11 through R20—68K-ohm $\frac{1}{2}$ -watt resistor, 10%
 R21, R22—15K-ohm $\frac{1}{2}$ -watt resistor, 10%

A SWITCH WITH A MEMORY

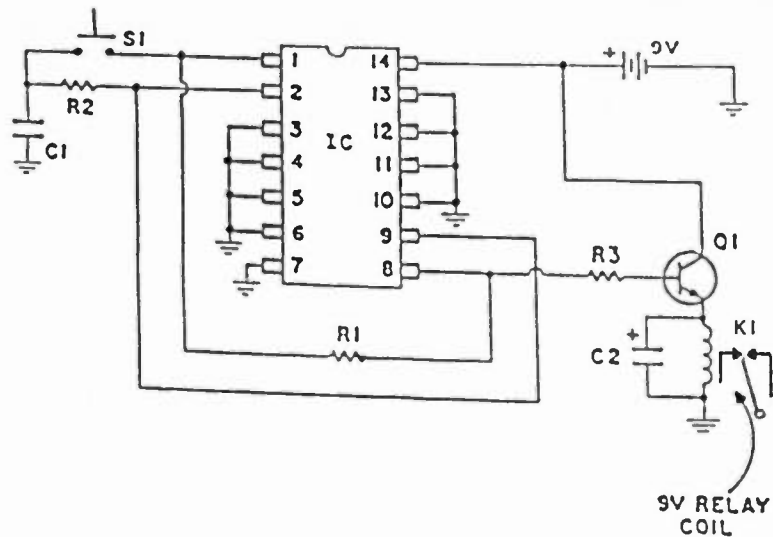


Here is a switch with unlimited uses. When momentary contact switch S1 is pressed, the relay will be energized. Press S1 again and the relay will be de-energized. In other words, this circuit remembers what state it was in even after S1 is released. This type of circuit can be very handy around the house. All unused pins should be grounded.

PARTS LIST FOR SWITCH WITH A MEMORY

C1—0.1- μ F ceramic disc capacitor, 15 VDC
 C2—1- μ F electrolytic capacitor, 15 VDC
 IC1—4069 hex inverter
 K1—Relay 6-9 VDC, 500 ohm coil, Radio Shack #275-005
 Q1—2N4401
 R1, R3—10,000-ohm, $\frac{1}{2}$ -watt resistor
 R2—91,000-ohm, $\frac{1}{2}$ -watt resistor
 S1—SPST momentary-contact pushbutton switch

SWITCH WITH A MEMORY



CODE PRACTICE OSCILLATOR

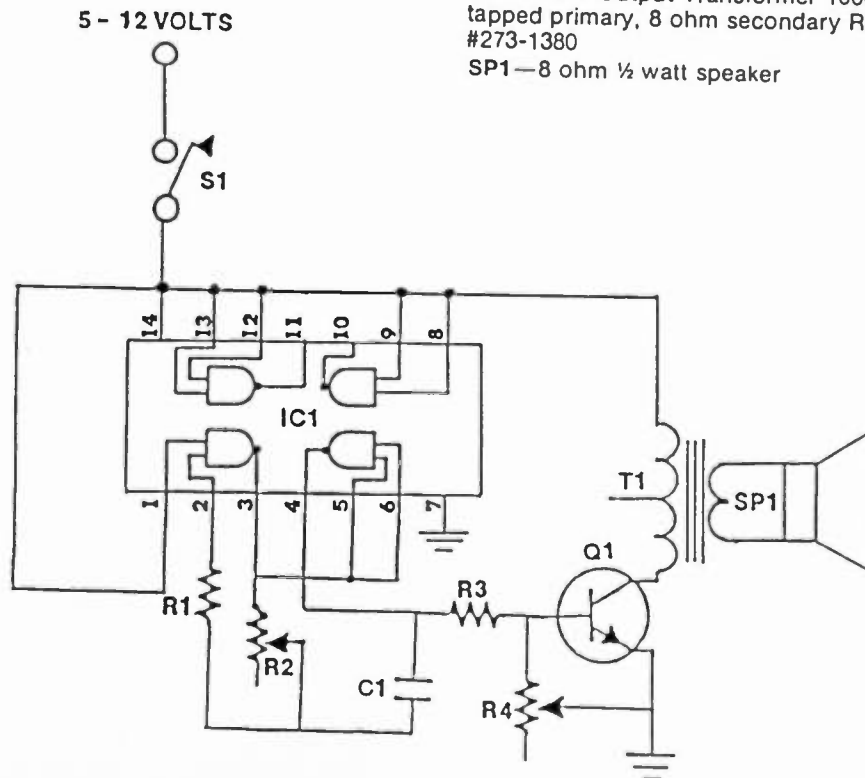


If you are an Amateur Radio Operator or just want to learn Morse Code, a code practice oscillator can be an invaluable tool. The code practice oscillator is simple to build, requires only a few parts, and operates over a wide voltage range.

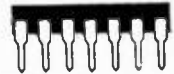
Two of the gates of the 4011 Quad NAND Gate are used to make a simple oscillator, whose frequency can be changed by adjusting R2. R4 is used to control the volume of the oscillator and Q1 drives speaker SP1.

PARTS LIST FOR CODE PRACTICE OSCILLATOR

- C1—.001uf Capacitor
- IC1—4011 CMOS Quad 2-Input NAND Gate
- R1—1,500,000 ohm, ¼ Watt Resistor
- R2—1,000,000 or 2,000,000 ohm Potentiometer
- R3—10,000 ohm ¼ Watt Resistor
- R4—5000 ohm Audio Taper Potentiometer
- Q1—2N3903 NPN Transistor or Equivalent
- S1—Code Practice Key
- T1—Audio Output Transformer 1000 ohm center tapped primary, 8 ohm secondary Radio Shack #273-1380
- SP1—8 ohm ½ watt speaker



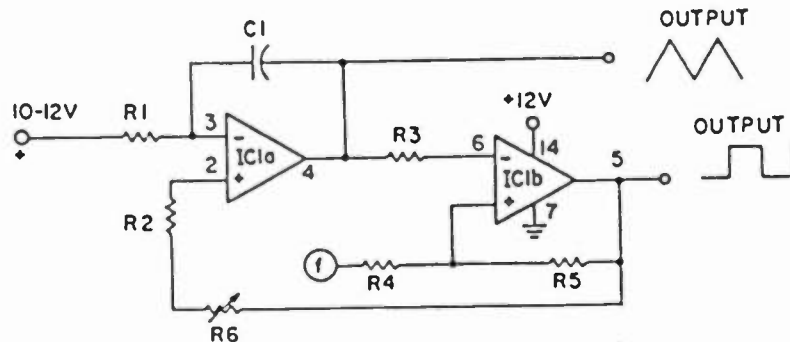
DOUBLE FEATURE



The versatile quad op amp LM-3900 (or MC-3401) can easily be persuaded to deliver two different waveforms from two of its sections, reserving the other two for mixing or amplification purposes. Section one is an integrator, furnishing a fine triangular waveform, the other unit supplies a square wave signal. Adjusting R6 varies both frequency and duty-cycle (symmetry) of the two waveforms. AC1 value of .001 uF will give a frequency of about 1 kHz while .01 uF will be close to 100 Hz.

PARTS LIST FOR DOUBLE FEATURE

- C1—.001 or .01-uF ceramic capacitor
- IC1—LM-3900 or MC-3401 op amp
- R1, R4—1,000,000-ohm, ½-watt resistor
- R2, R3—100,000-ohm, ½-watt resistor
- R5—120,000-ohm, ½-watt resistor
- R6—500,000-ohm, linear-taper potentiometer

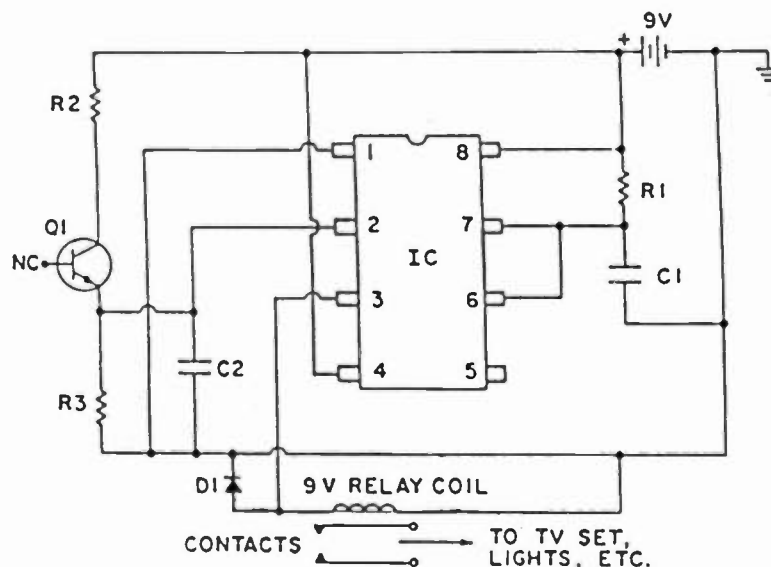


AUTOMATIC TURNOFF



This circuit can save you steps, time, and electricity. When you leave a room and turn out the lights, for example, this circuit will sense that the lights are off and will activate the relay coil. Use it to turn off the TV, hi-fi, or another light in another room

without bothering with extra house wiring. Or you can use the circuit to help keep burglars away. With Q1 sitting at the window, it will turn on house lights when the sun goes down. R1 and C1 keep the relay in operation for a minimum of one-half second to avoid bouncing of the relay contacts.



PARTS LIST FOR AUTOMATIC TURN-OFF

- C1, C2—.01uF ceramic disc capacitor
- D1—1N914 or 1N4148
- IC1—555 timer
- Q1— NPN phototransistor FPT 100 or Equivalent.

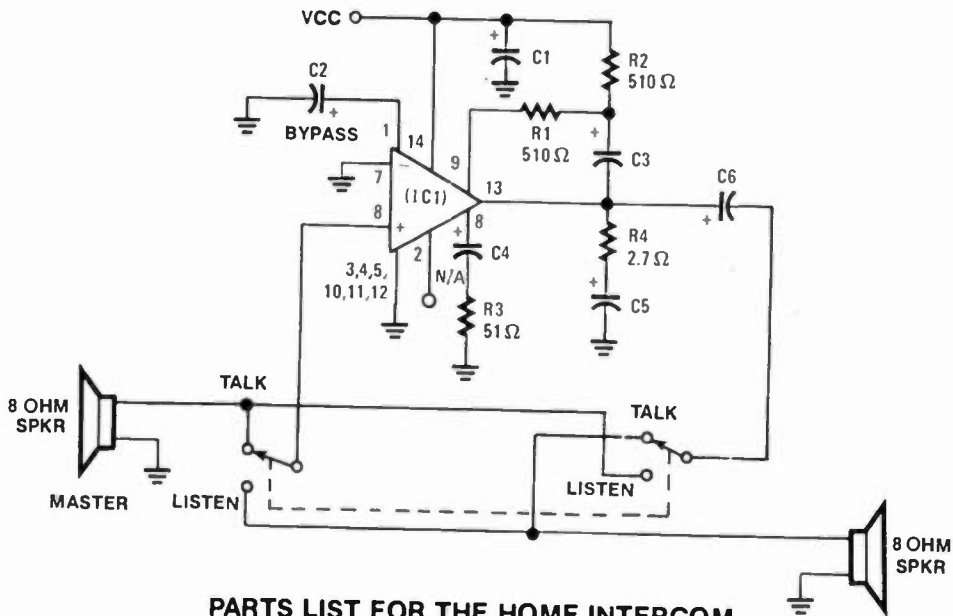
- R1—4,700,000 ohm, ¼ watt resistor
- R2, R3—1,000,000 ohm, ¼ watt resistor
- Relay—6-9 VDC coil with switch contacts rated at 120 VAC/2 amp

HOME INTERCOM SYSTEM



This circuit requires a little more than average skill in construction. Therefore, it is advisable that the experimenter or hobbyist have some experience with integrated circuits and/or solid state devices before

attempting construction of this circuit. A breadboard is recommended for the final construction as a permanent device for home use. IC's are extremely sensitive so proceed with caution.



PARTS LIST FOR THE HOME INTERCOM SYSTEM

- | | |
|----------------------------|---|
| C1—.1Mfd disc capacitor | IC1—#388 1.5W Audio Power Amp |
| C2—Any available capacitor | R1, R2—510 ohm resistors |
| C3—4.7Mfd disc capacitor | R3—51 ohm resistor |
| C4—25Mfd disc capacitor | R4—2.7 ohm resistor |
| C5—.05Mfd disc capacitor | S1, S2—SPDT single pole/double throw switches |
| C6—100Mfd disc capacitor | Vcc—see instructions for Max. Vcc on IC package |
| | Misc—two 8 ohm speakers |

MAG TAPE AMP



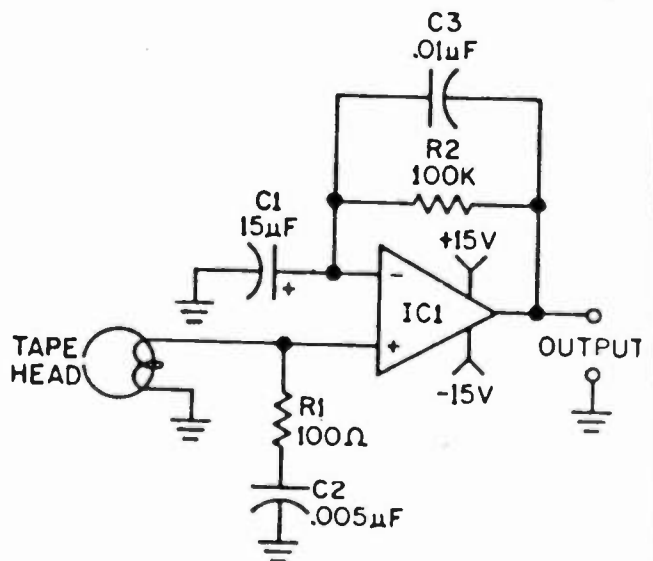
From time to time surplus dealers offer complete tape or cassette mechanisms—everything ready-to-go except for the electronics, and at rock-bottom prices of \$10, \$15 or \$20. Often, all the mechanism needs is this equalized tape head preamplifier.

Though the power supply is rated at ± 15 VDC, almost optimum results will be obtained with supply voltages as low as ± 7 VDC. Two ordinary 9-volt transistor radio batteries will power the preamp for many hours.

As with all these projects, the 741IC is internally compensated and no special wiring practices are needed; the preamp can be built in just about any enclosure.

PARTS LIST FOR MAG TAPE AMP

- | |
|---|
| C1—22- μ F electrolytic capacitor, 25-VDC or better |
| C2—0.005- μ F disc capacitor, 25 VDC or better |
| C3—0.01- μ F capacitor, 25-VDC or better |
| IC1—Type 741 opamp |
| R1—100-ohms, $\frac{1}{2}$ -watt resistor |
| R2—100,000-ohms, $\frac{1}{2}$ -watt resistor |



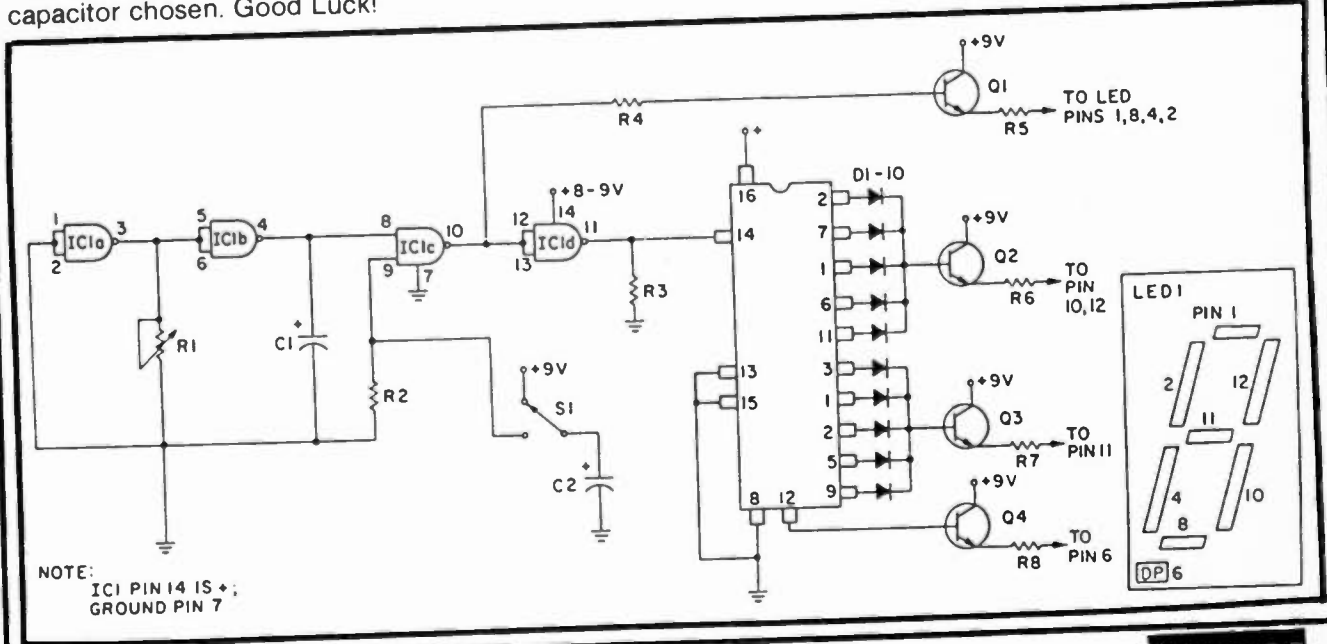
EVEN ODDS



The continued versatility of the 4017 counter and DL-750 digital display is demonstrated in this Odd-Even or Coin Toss simulator. As an added feature, the decimal point of the display is illuminated for an Odd or Even "Low Count," 0, 1, 2, 3, or 4 count from the counter. Even numbered counts (0 is considered even, for the sake of symmetry) cause the display to present an E, while odd-numbered counts result in a 0. Segments A, D, E and F are common to both 0 and E, but they are driven by the clock along with B, C, and G to stimulate all the segments into "random" motion. Holding down the pushbutton, causes C to discharge through R, giving an uncertainty period of five or seven seconds, depending upon the size of the capacitor chosen. Good Luck!

PARTS LIST FOR EVEN ODDS

- C1—0.47 to 2.2- μ F electrolytic capacitor, 15 VDC
- C2—50 to 100- μ F electrolytic capacitor, 15 VDC
- D1 through D10—1N4148 diodes
- IC1—4017 decade counter
- Q1 through Q4—2N4401 transistors
- LED 1—DL-750 7-segment common cathode display or equivalent
- R1—500,000-ohm, $\frac{1}{2}$ -watt resistor
- R2—100,000-ohm, $\frac{1}{2}$ -watt resistor
- R3—1,000-ohm, $\frac{1}{2}$ -watt resistor
- R4—560-ohm, $\frac{1}{2}$ -watt resistor
- R5, R6, R7, R8—1,000-ohm, $\frac{1}{2}$ -watt resistors
- S1—SPDT momentary-contact pushbutton switch



PROGRAMMED MUSIC

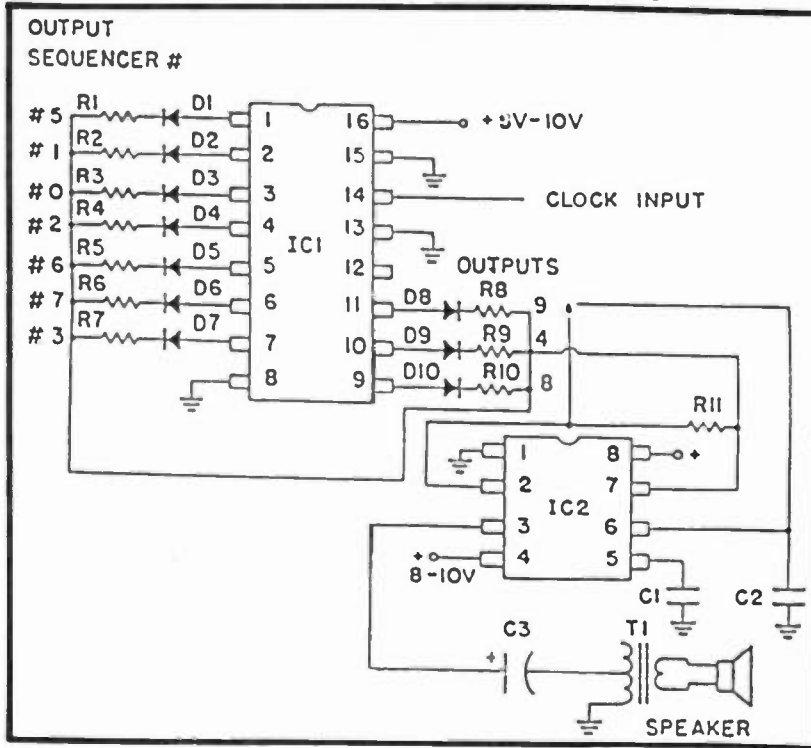


"Music" may be a little optimistic, but sequential tones are entirely possible with this circuit, and with a little experience, simple but recognizable themes can be produced. The system combines the 4017 decimal decoder counter with the 555 timer in astable oscillation. As the counter steps through its ten outputs, a different frequency-determining resistor (R1-10, which may range from 1K-100K) is activated, through an isolation diode. The input clock frequency may be 1 and 5 Hz; use slower tempos for chime-like notes for an electronic door-bell. Notes may be made longer by giving succeeding steps, like 5 and 6, the same value tuning resistors. Rhythm may be accomplished by skipping one or more outputs. For very short themes, the next stage can be made to reset the counter. Composition, anyone?

PARTS LIST FOR PROGRAMMED MUSIC

- C1, C2—0.1- μ F ceramic capacitors, 15 VDC
- C3—1,000- μ F electrolytic capacitor, 25 VDC
- D1 through D10—1N4148 diodes
- IC1—4017 decade counter
- IC2—555 timer
- R1 through R10—1,000 to 100,000-ohm, $\frac{1}{2}$ -watt resistors (see text)
- R11—4,700-ohm, $\frac{1}{2}$ -watt resistor
- SPKR—8-ohm PM type speaker
- T1—audio output transformer 1000-ohm center-tapped primary/8-ohm secondary (Radio Shack #273-1380 or equivalent)

PROGRAMMED MUSIC



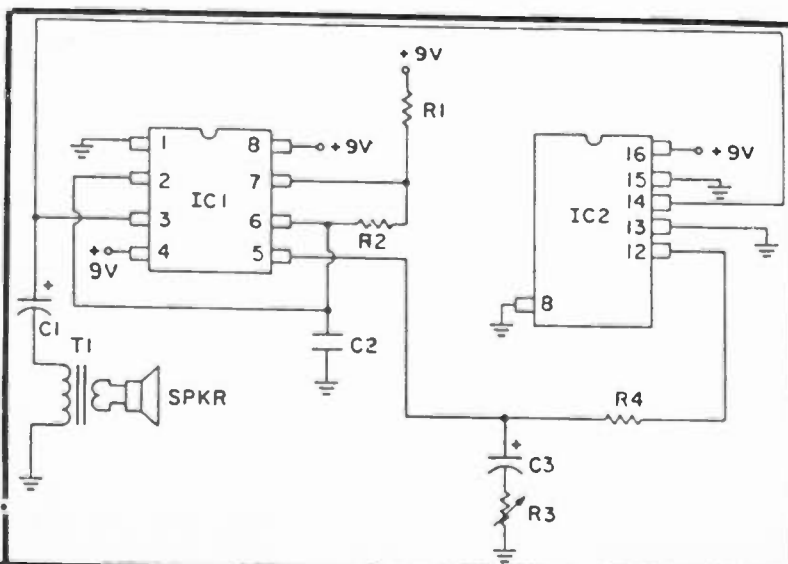
TWO TONE ALARM



When this circuit is triggered into action, it is hard to ignore for very long! A 555 timer is operated in the astable free-running mode, with its output powering both a loudspeaker and clocking a 4017 counter. Pin 12 of the counter provides a high-low output which changes with every five input pulses counted. This output is applied via a resistor of from 2.2K to 10K ohms to pin 5, the modulated input of the timer. This produces a strident warble that calls immediate attention. More mellow, but interesting, tones can be obtained with the addition of the RC filter shown.

PARTS LIST FOR TWO TONE ALARM

- C1—100-μF electrolytic capacitor, 25 VDC
- C2—0.1-μF ceramic capacitor, 15 VDC
- C3—1-μF electrolytic capacitor, 25 VDC
- IC1—555 timer
- IC2—4017 decade counter
- R1, R2—4,700-ohm, ½-watt resistors
- R3—10,000-ohm linear-taper potentiometer
- R4—2,200 to 10,000-ohm, ½-watt resistor (see text)
- SPKR—8-ohm PM type speaker
- T1—audio output transformer 1000-ohm center-tapped primary/8-ohm secondary (Radio Shack #273-1380 or equivalent)



SOLID STATE UPDATE

Each month, the manufacturers of solid state components release literally hundreds of new devices. While we cannot report on all of these, we do intend to feature some of these devices that are most likely to interest our readers. For further information on any of these solid-state components, write directly to the manufacturers. They can provide you with data sheets and application notes at no charge.

SEMICONDUCTOR DATABASE

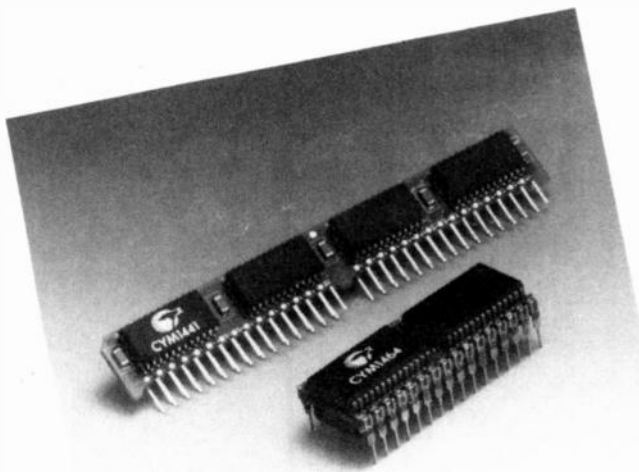
Each year, semiconductor manufacturers introduce thousands of new devices—so many, in fact, that it's next to impossible for the average person to keep abreast of things. To give users a fighting chance, Motorola now offers a new version of its Data Disk, called the **Motorola Electronic Selection Guide**. This floppy-resident database allows designers to rapidly search Motorola's entire line of semiconductors and select the best device for their application. The Motorola Data Disk provides information on over 13,000 Motorola ICs and components in 124 product categories, and also cross-references 25,000 competitive devices. The Data Disk provides a fast, easy alternative to the printed selection guide. All searches are performed in under one second, and no user manual is required. To receive your free disk, write **Motorola Data Disk, Literature Distribution Center, POB 20924, Phoenix, AZ, 85063**. Specify IBM format (DK101/D) or Macintosh format (DK201/D).



TWO-AND FOUR-MEGABIT STATIC RAMS

They say you can never be too thin or too rich; to that dubious wisdom, we'd like to add that you can never have too much memory in your computer system, because no matter how much you've got, you'll soon fill it up. Those of you who use computers know what we mean.

Here's good news for all the memory-hungry system designers and computer users out there. Cypress Semiconductor now offers a 45-ns, 512K×8 CMOS static RAM (SRAM) in a 32-pin DIP package that is twice as fast as competitive versions of this device. Cypress also offers a 25-ns, 256K×8 CMOS SRAM module in a 60-pin vertical ZIP package. Both the CYM1464 (512K×8) and CYM1441 (256K×8) SRAM modules are targeted at high-performance, high-density applications such as high-end PCs, workstations, cache memories, digital signal processors, and simulators. Contact **Cypress Semiconductor, 3901 N. First St., San Jose, CA, 95134**.



LOW-POWER DUAL OP AMP

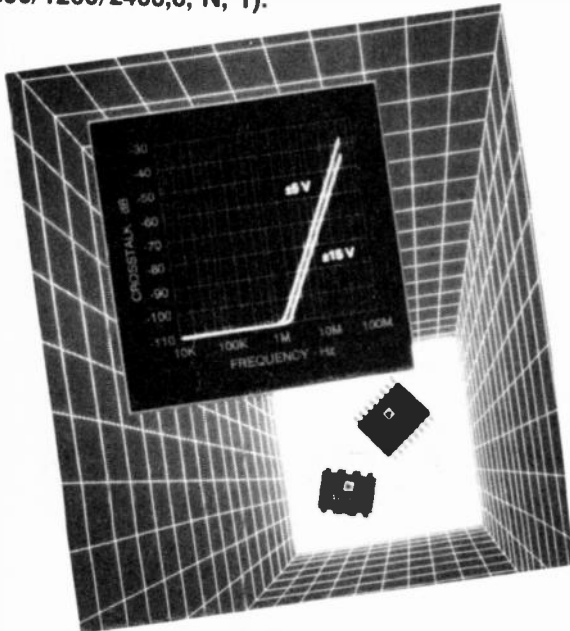
From Burr-Brown comes news of a new dual precision op amp, the OPA1013, suitable for applications demanding low-power and/or single-supply operation. It is intended for portable and battery-operated applications in medical and scientific instrumentation, test and measurement equipment, and industrial control. The OPA1013 is fully specified for operation at both $+5V$ and $\pm 15V$. When the device is operated from a single supply, the input common-mode range includes ground, and the output can swing to within 15 mV of ground. Quiescent current is a low 0.5 mA maximum per amp. The OPA1013 is unity-gain stable and requires no additional circuitry for overload protection. Independent biasing networks ensure freedom from interaction between the two op amps even when the inputs are overdriven in comparator applications. Contact **Burr-Brown Corp., P.O. Box 11400, Tucson, AZ, 85734. Or use their bulletin board service at 602-741-3978 (300/1200/2400,8, N, 1).**



DUAL HIGH-SPEED OP AMP

The AD827 from Analog Devices is a low-cost, general-purpose, dual, 50-MHz unity-gain bandwidth op amp. The device remains stable when driving any capacitive load, and features 85 dB of channel separation between the two amplifiers. Close matching between the two channels means that the AD827 will be well-suited to multi-channel video applications. Other important specifications include a high 300 V/ μs slew rate and 120-ns settling time (to 0.1%).

The AD827's superior DC performance makes it suitable for buffering fast 8- and 10-bit analog-to-digital converters. With $\pm 5V$ supplies, the AD827 has 2 mV of maximum offset voltage (guaranteed) and a typical open-loop gain of 3,500 with a 500-ohm load. With $\pm 15V$ supplies, the open-loop gain increases to 5,500 with a 1,000-ohm load, and the maximum input offset voltage is 4 mV. Data sheets are available from **Analog Devices Literature Center, 70 Shawmut Rd., Canton, MA, 02021.**

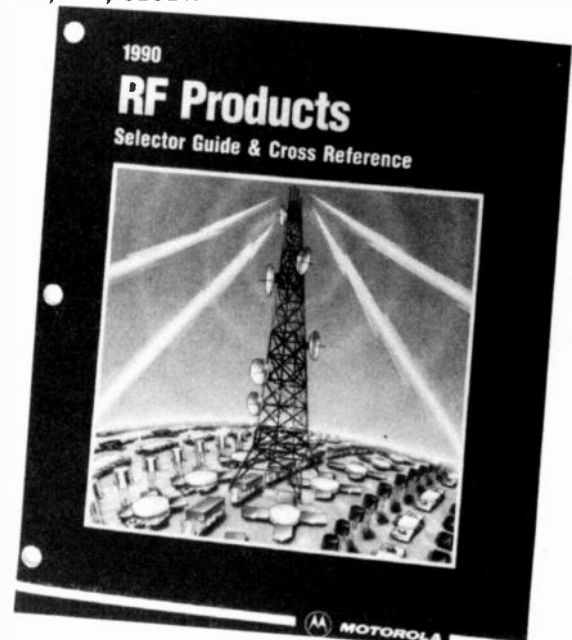


RF DEVICE SELECTION GUIDE

Motorola has announced the availability of its latest RF Selector Guide (SG46/D, Rev. 7). This new version represents the latest and most complete listing of standard semiconductor devices offered by the RF Products Division of Motorola Semiconductor, and includes 75 new products.

A key feature of this new Selector Guide is the updated cross-reference, which is the most extensive RF transistor cross-reference available in the industry today. The new Selector Guide lists data for all the RF products manufactured by Motorola, including power FETs, power bipolar transistors, small-signal transistors, and modules.

This 82-page reference booklet should be a welcome addition to the bookshelf of anyone interested in RF devices, and that includes radio amateurs, service personnel, and design engineers. A **free copy of SG46/D is available from Motorola Literature Distribution Center, POB 20924, Phoenix, AZ, 85063.**

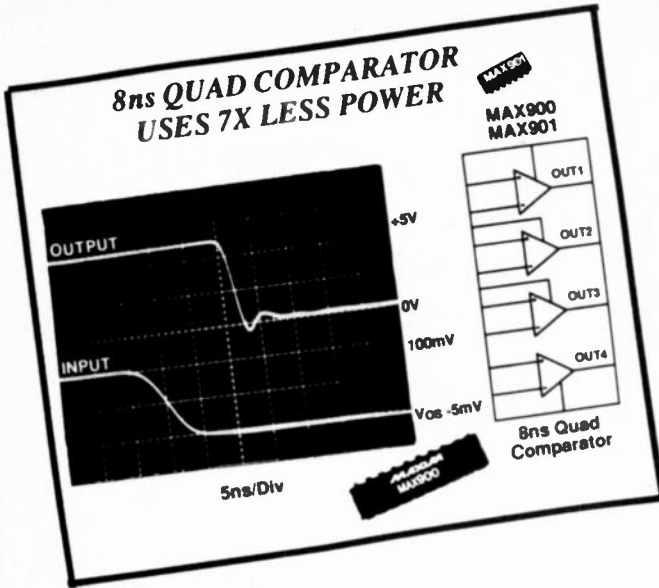


LOW-POWER QUAD COMPARATORS

Maxim Integrated Products' new MAX900 and MAX901 high-speed quad TTL comparators save board space and consume less than one-seventh the power of equivalent single- and dual-comparator combinations. Propagation delays are 8 ns, and power consumption is only 18 mW per comparator.

The MAX900 and MAX901 feature differential inputs and TTL-compatible outputs with internal active pullups. They can be powered from separate analog and digital supplies, or from a single +5-volt supply. These comparators will accept input signals that swing to ground in single-supply applications.

Typical uses for the MAX900 and MAX901 include threshold detectors, high-speed analog-to-digital and voltage-to-frequency converters, line receivers, and high-speed data sampling. The MAX900 provides a latch-enable function; the MAX901 does not. Contact **Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA, 94086.**

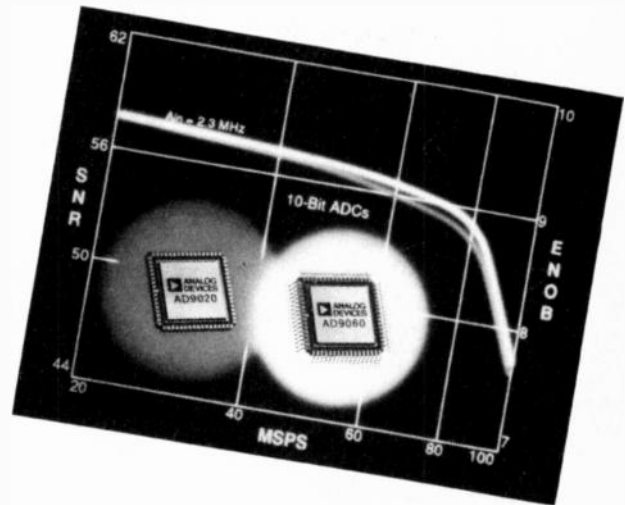


HIGH-SPEED A/D CONVERTERS

Analog Devices' new high-speed ECL-compatible AD9060, the industry's fastest 10-bit analog-to-digital converter (ADC), guarantees encoding rates up to 75 million samples per second (MSPS). Its TTL-compatible counterpart, the AD9020, provides encoding rates as high as 60 MSPS.

The analog input voltage is established by a pair of external reference voltages, nominally $\pm 1.75V$. The typical analog input bandwidth is 175 MHz. Maximum input bias current is 1 mA. The AD9020 requires a $\pm 5V$ supply, while the AD9060 requires $+5/-5.2V$.

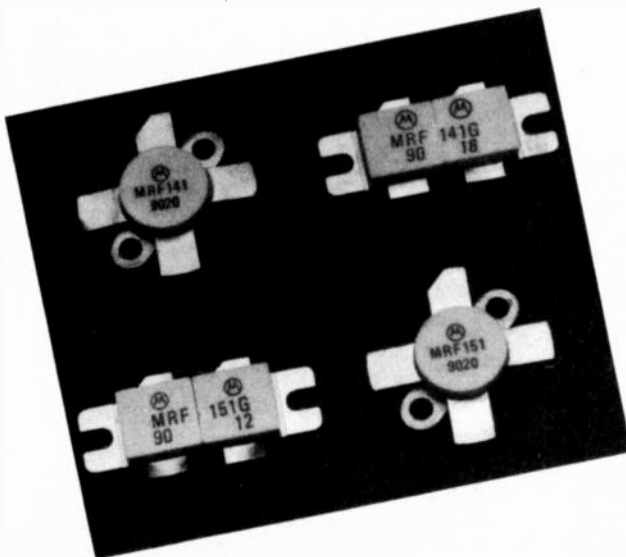
These two new analog-to-digital converters are well-suited to such applications as high-speed instrumentation, professional video, medical imaging, spectrum analysis, and radar. Track-and-hold circuitry and external trimming are not required to achieve rated performance. Contact **Analog Devices Literature Center, 70 Shawmut Rd., Canton, MA, 02021.**



RF POWER MOSFETS

Good news for hams and anyone else interested in high-power, high-frequency amplification: Motorola has added four high-power, high-gain power MOSFET transistors to its line of second-generation RF power FETs. The 28-volt MRF141 and 50-volt MRF151 are N-channel, enhancement-mode FETs characterized to 175 MHz, with output powers of 150 watts and typical gains (at 30 MHz) of 22 dB. The MRF141G and MRF151G are "Gemini" push-pull package versions, each using two die, and specified at 175 MHz to deliver 300 watts with typical gains of 14 and 16 dB, respectively.

These high-performance RF power MOSFETs will find use whenever high power and high gain are required over wide bandwidths. Typical applications include broadband power amplifiers up to 175 MHz, solid-state transmitters for FM broadcast, TV transmitters and translators. For data contact **Motorola Literature Distribution Center, POB 20924, Phoenix, AZ 85063.**



CONSTRUCTION QUICKIE

CURIOSITY DETECTOR

by Hugh Gordon

This interesting little circuit challenges a basic human characteristic...curiosity. "junk box." The enclosure can be metal or plastic and

To activate the circuit, simply, point the "Detector" at the person to be challenged and press S1. A loud, raspy tone will be emitted from the speaker as long as S1 is depressed. Most victims will respond, questioning the source of the sound. The rest we leave to the builders' imagination.

S1 should be placed on the back or bottom of the enclosure so that it cannot be seen when you press it. The variable resistor is optional and can be placed anywhere on the enclosure. It is used to readjust the basic "Detector" so that it can pick up other subjects.

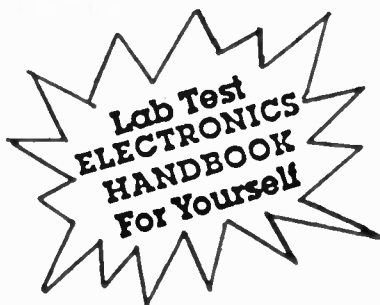
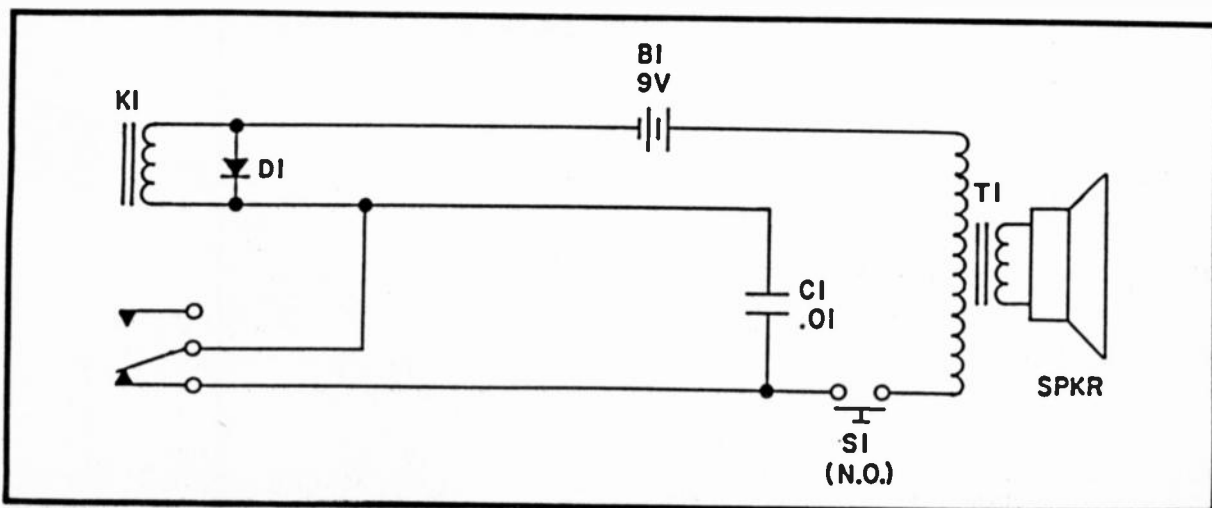
Construction is simple and cost is kept to a minimum

limited only by the builders imagination. ■

PARTS LIST

- SPKR1—Any small 8 ohm speaker
- T1—Any small audio transformer
- S1—Normally open momentary-on switch
- C1—.01 mF capacitor
- D1—Any small signal diode
- K1—5-12 Volt relay
- B1—9 Volt battery

SPKR1



ELECTRONICS HANDBOOK v 10

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THE CATALOG CORNER

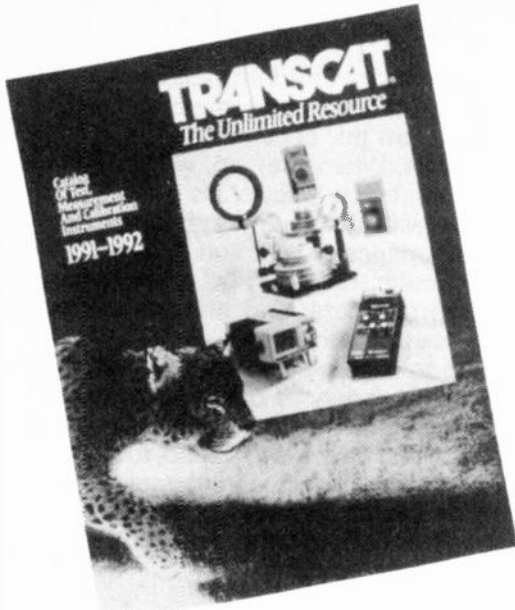
If you live in a relatively remote area that doesn't have ready sources for electronic parts, you can send away to numerous supply houses, who have good catalogs of electronic parts and assemblies...many of them real bargains.

Following are several catalogs that we have recently received in the mail, with brief descriptions and comments. Most of these suppliers send out new catalogs every four to six months, with many of the items repeated and new ones added, plus some new "specials"...usually on the first couple pages and the last few pages of each issue.

INFORMATION UNLIMITED

"The complete Catalog of Amazing and Fascinating Devices" is the name of the new catalog from Information Unlimited, and after looking over the contents, we think that's a pretty fair assessment. The company offers a wide variety of electronic gear—some of it high-tech, some of it off-the-wall, all of it intriguing. Plans, parts, kits, and assembled units are available. Looking for a laser? They've got them, in all shapes and sizes. How about a Tesla coil, a plasma discharge globe, or a magnetic cannon? They have them, too. Private-eye types will love the wireless microphones, tracking devices, bug detectors, and voice scramblers—devices so small that they'll hardly make a bulge in your trenchcoat pocket. Finally, if hostile aliens ever set up shop in your attic, you can blast 'em back to their own foul planet with one of Info Unlimited's stun guns. Get all the facts by sending \$1.00 to Information Unlimited, P.O. Box 716, Amherst, NH, 03031.





CONTACT EAST

Contact East's new 147-page full-color catalog contains all the test gear and tools necessary for the assembly, maintenance, and repair of electronic equipment. Test gear includes DMMs from Fluke, B&K, Soar, Beckman, Mercer, Tektronix, Triplett, and Exttech; scopes from Hameg, Tektronix, Hitachi, Beckman, and B&K; AC-power analyzers from Amprobe and BMI; datacom testers from Datatran and IQ Technologies; and PROM programmers from Data I/O and Logical Devices.

Their tool lineup includes screwdrivers, nutdrivers, wrenches, tweezers, pliers, cutters, strippers, crimpers, power tools, knives, files, saws, wire-wrap guns, soldering stations, solder pots, static-protection devices, cabinets, workbenches, PC board shears, heat guns, adhesive guns, and cleaning supplies from all the top manufacturers. If you want tool kits, Contact East offers 27 different kits, all reasonably priced. To get your catalog, write to **Contact East, 335 Willow St. South, North Andover, MA, 01845.**



TRANSCAT INSTRUMENTS

All of the major electronics retailers have a section of their catalogs devoted to test instruments, since these items are always in demand. But how many instruments can you fit into 25 pages or so? Not many at all, and that's why we were delighted to receive the new catalog from Transcat Instruments. This 480-page behemoth is just chock full of interesting test gear. Of course they've got the standard items like oscilloscopes, multimeters, logic probes, function generators, power supplies, digital capacitance meters, and frequency counters from such manufacturers as Fluke, Beckman, Simpson, B&K, Soar, Ballantine Labs, Hitachi, Leader, OK Industries, VIZ, Kenwood, Non-Linear Systems, Tegam, and Valhalla. But they've also got exotic, offbeat test gear like digital thickness gauges, vibration meters, leak detectors, electronic stethoscopes, gas monitors, dew-point indicators, open-stream velocity meters, and noise dosimeters. Whew! Write to **Transcat, P.O. Box D-1, Rochester, NY, 14606.**



C&H SALES CO.

Drop into C&H Sales in Pasadena any day of the week, and chances are you'll find yourself rubbing shoulders with scientists and engineers from nearby Cal-Tech and the Jet Propulsion Laboratory. It's not the ambiance of the place that attracts these guys; it's the bargain-priced electronic components. For those of us who can't make it out to Pasadena, the next best thing is to have a copy of the C&H Sales catalog on hand. Most of the material sold by C&H falls into the category of new surplus, and the selection is enormous. Consider the following partial list of items: motors, accelerometers, transducers, wave guides, solenoids, timers, hand tools, optics, meters, valves, synchros, semiconductors, magnets, differentials, gyros, pressure gauges, and relays. Prices are great. For example, Swiss-made Erem pliers, which list for over \$50, are just \$10.95. You can get a free copy of this great catalog by writing to **C&H Sales, P.O. Box 5356, Pasadena, CA, 91117-9988.**



JAMECO ELECTRONICS

A lot of readers have a terrible time trying to find integrated circuits and other semiconductors for their projects. We know this because they write to us with their complaints. When they do, we refer them to a company like Jameco Electronics.

Jameco's latest catalog is only about 75 pages long, but in those pages you'll find several thousand integrated circuits: CMOS, TTL, op amps, memory chips, microprocessors, and discrete semiconductors like transistors and FETs.

In addition to its huge stock of solid-state devices, Jameco offers a variety of passive components like resistors, capacitors, switches, and pots. DMMs and other forms of test gear are included, too. Finally, like many other parts suppliers, Jameco sells economical PC clones in kit form. To get your copy of the Jameco catalog, write to **Jameco Electronics, 1355 Shoreway Rd., Belmont, CA, 94002.**

ROLYN OPTICS

The new 127-page catalog from Roly Optics is a treasure trove of precision optical components that will be a welcome addition to the data library of the advanced experimenter as well as the professional engineer. Whether you're planning to build a telescope, an enlarger, a microscope, a copier, a spectroscope, or some other optical instrument, you can find all the parts you'll need in this catalog.

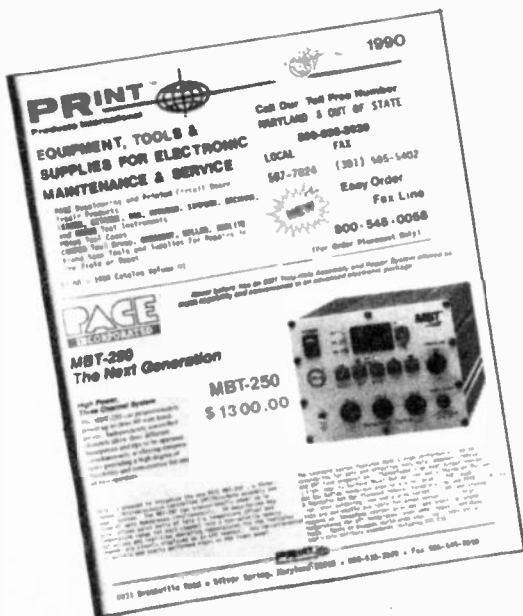
Roly sells simple and compound lenses of all kinds, prisms, beamsplitters, glass blanks, fused silica and sapphire windows, precision first-surface mirrors in a variety of shapes, optical filters, polarizers, reticles, precision pinholes and slits, compound eyepieces, focusing tubes, iris diaphragms, x-y tables, laser-beam expanders, mirror and lens mounts, and optical tools. Bear in mind that these are precision devices, and they are priced accordingly, i.e., they're not cheap. **Roly Optics Co., 706 Arrow Grand Circle, Covina, CA, 91722.**



PRODUCTS INTERNATIONAL

Lots of companies sell electronic test equipment, but most expect you to pay the full retail price; discounts are virtually unheard of. Therefore, it was a surprise to us when we received the new Products International catalog and found that almost every piece of test gear was being sold at discount prices. The typical discount seems to be about 10-15%, which means that you could end up saving hundreds of dollars in your next scope, counter, or EPROM programmer.

Products International is an authorized distributor for such test equipment manufacturers as Simpson, B&K Precision, Beckman, Hitachi, Kenwood, Leader, Fluke, Carlo Gavazzi, EKO, A.W. Sperry, Hameg, Systron Donner, VIZ, and American Reliance. As you can see, their product line is truly international, and it includes scopes, DMMs, frequency counters, signal generators, power supplies, and more. Write to **Products International, 8931 Brookville Rd., Silver Spring, MD, 20910.**



TIME MOTION TOOLS

Regardless of whether you are involved in electronics professionally or just as a hobbyist, you soon learn the value of good tools. With the right tools, your work is accomplished quickly, cleanly, and professionally; without them, the job seems to take forever, and the results are often disappointing. Finding the kind of tools you need can be a tricky business. Of course you can obtain some of the tools you need from the local hardware or department store, but you won't find everything there. The special tools necessary for electronic assembly and repair can only be purchased from a tool specialist—for example, Time Motion Tools, which puts out a full-color catalog featuring hundreds of time-saving tools for the engineer, technician, and hobbyist. They have hand tools like screwdrivers, nut drivers, crimpers, pliers, and wrenches. And they've got power tools like drills, heat guns, and wire-wrap guns. To get your catalog, write to **Time Motion Tools, 410 S. Douglas St., El Segundo, CA, 90245.**



MICRO-MARK

Although the Micro-Mark name is apparently well known among model builders, we never heard of the company until a sharp-eyed, helpful reader brought it to our attention. Micro-Mark proclaims itself the "small tool specialist," and the company's catalog makes good on that claim. What an extraordinary assortment of small hand and power tools. Ever hear of a polypus? Probably not, unless you happen to be an ear surgeon. The polypus looks like a bent pair of scissors, about 5 inches long, with minuscule crocodile jaws at the end of a slender metal stalk. It's obviously intended for surgical manipulation within the ear canal, but it strikes us as a useful device for handling small electronic components, too. Micro-Mark also carries small power drills, push drills, and table saws which should be ideal for PCB work. A free copy of this fine catalog is available from **Micro-Mark, 340 Snyder Ave., Berkeley Heights, NJ, 07922.**



SPECIALIZED PRODUCTS CO.

Tools, tool kits, and electronic test instruments are the featured items in the new catalog from Specialized Products Co. Tools run the gamut from screw-drivers to soldering irons, wrenches to wire-wrap guns. The one thing that all these tools have in common is that they are useful in electronic assembly and repair work. You can select individual tools or, if you like, buy a custom-configured tool kit complete with an attractive carrying case. The company offers kits for such specialized repair fields as data communications, computer maintenance, and telephone installation. General-purpose kits are available, too. Prices are reasonable, and service is prompt. (We've purchased many tools from Specialized Products, by the way, so we're speaking from experience.) You can get a free copy of the latest catalog simply by writing to **Specialized Products Co., 3131 Premier Dr., Irving, Texas, 75063.**



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CONSTRUCTION QUICKIE

INSTRUMENTATION AMPLIFIER

By Bill Axsen

PARTS LIST FOR INSTRUMENTATION AMPLIFIER

This is really a chop amp instrumentation amplifier. It is a differential amplifier that can amplify DC signals in the microvolt range and is accurate to plus or minus 1 microvolt. It has a gain of 1000 and the potentiometer, R1, can be used to zero the amplifier. Decoupling capacitors must be used with this circuit to ensure stable operation. This amplifier has been used to amplify various transducer voltages, such as thermocouples and strain gages.

Semiconductors:

IC1—LTC1052CN8 (Linear Technology, Chopper Stabilized Amplifier)

Resistors:

R1—1 Kiloohm (¼ watt, 1%)

R2—1 Megohm (¼ watt, 1%)

R3—10 Megohms (¼ watt, 5%)

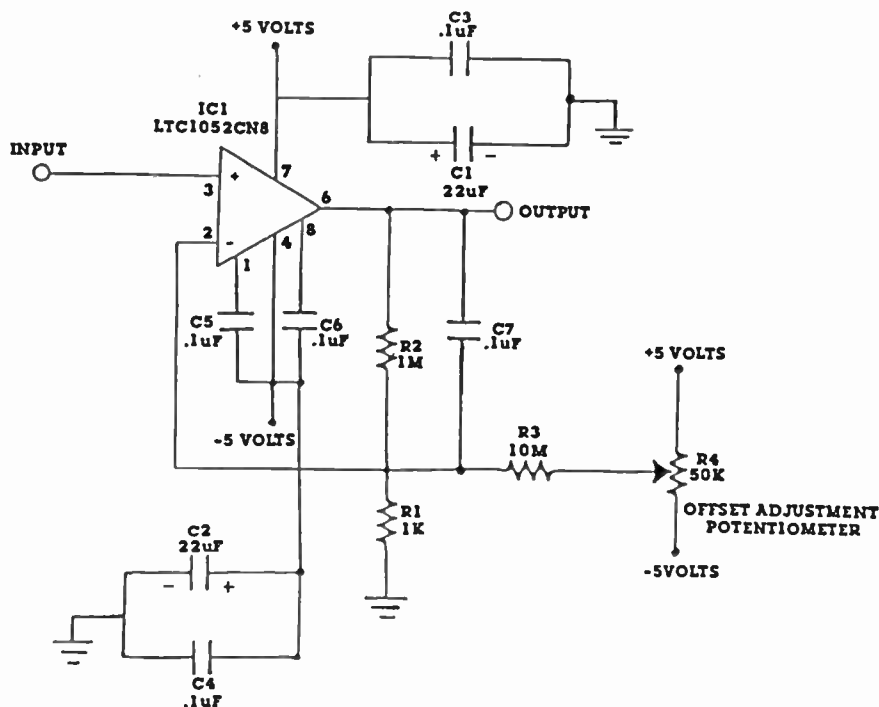
R4—50 Kiloohms (15 turn Pot)

Capacitors:

C1, C2—22µF, 16WVDC, Tantalum

C3, C4—.1µF Ceramic

C5, C6, C7—.1µF Metal Film (Radio Shack #272-1053)



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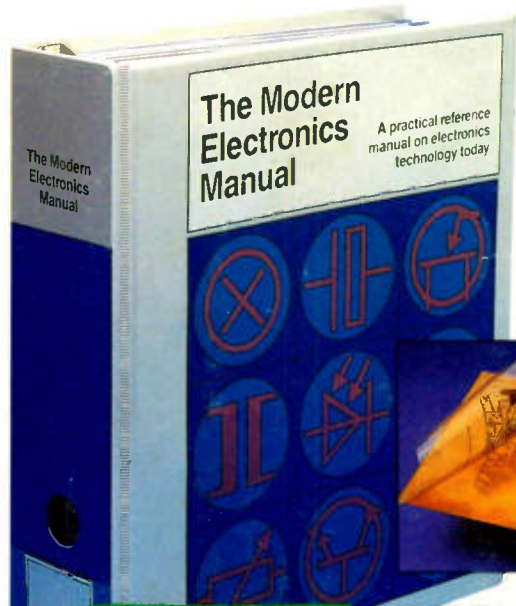
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