Boost Your RADIO IQ

1980 EDITION $1.95
£1.25

Electronics Theory Handbook

by the Editors of ELEMENTARY ELECTRONICS

Using Solar Cells to Make Electricity

8 BASIC Computer Programs for Home & Office

Design your own Power Supply

How to:
- ✓ Tune up your Car
- ✓ Use Digital Multimeters
- ✓ Forecast SW Propagation

Complete Theory on: Dipoles, CRTs, Capacitance, Multivibrators, Crystals, Superhets, Computers and much, much more!

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A DAVIS PUBLICATION

Electronics Theory Handbook

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COMPUTER INSIGHTS

Acquaint yourself with how computers talk to each other as well as learn to use eight original BASIC programs.

COMMUNICATIONS CORNER

Discover how crystals and horizontal dipole antennas work and familiarize yourself with SW receivers and superhets.

INSIDE TEST EQUIPMENT

Two important pieces of test equipment are examined from the inside-out to reduce their inherent complexity.

APPLY YOURSELF

You too can become a mechanic or designer if you follow the step-by-step instructions in these articles.

THEORETICAL ELECTRONICS

Solar electricity is here now. The Theory Notebook is your reference to some common electronic components.

REGULAR DEPARTMENTS

Cover illustration by Ron McCarty

ISSN: 0270-501X

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New Products

Ballroom Lights

Edmund Scientific is now offering a Special Lighting Effects Kit which provides unique lighting effects at home for parties and fun.

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The Special kit includes three basic components: an 8-inch diameter, hand-made mirrored ball, a ceiling motor and a portable AC spotlight. Made up of hundreds of one-half inch square mirrors, the hand-made mirrored ball produces dazzling ballroom effects when rotated by the 4 rpm motor. The Special Home Lighting Effects Kit (Stock No. 72,524) at $99.95 plus $3.50 for packing and guaranteed delivery, can be obtained from Edmund Scientific Co., 7082 Edscorp Building, Barrington, NJ 08007.

Portable Digital Engine Analyzer Kit

Don't let the increasing price of gas get you down. Use the new Heathkit CM-1550 portable engine analyzer to pep up your car's engine for better mileage. The CM-

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1550 handles several tune-up measurements, including dwell for 4 through 8-cylinder engines, RPMs to 10,000 in two ranges, DC voltage to 200 volts in two ranges, resistance to 2 megohms in three ranges and direct current to 20 amperes. With the optional CMA-1550-1 Shunt Accessory, it will also measure starting current and battery charging/discharging current, up to 400 amperes. A large liquid crystal display shows all measurements. Power is supplied by a 9-volt battery (not included). The inductive pick-up for the RPM readings is attached to any spark plug wire. The Heathkit CM-1550 Portable Digital Engine Analyzer is mail order priced at $94.95, while the optional CMA-1550-1 400-Amp Shunt Accessory sells for $13.95, mail order plus shipping cost. For more information on the CM-1550 Engine Analyzer, send for a free catalog to Heath Company, Dept. 570-410, Benton Harbor, MI 49022.

Color Me Computer

A new low-cost, computer-operated color graphics generator/controller, is now in full production. Designed to generate color displays on either a TV set or monitor, the Electric Crayon, made by Percom, includes its own ROM operating system, EGOS, which accepts single-character commands directly from a parallel ASCII keyboard or program-generated commands from a computer. As shipped, the Electric Crayon interfaces a TRS-80 computer, but it may be easily adapted for interfacing to any computer. The system to be used principally for color graphics generation and

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control, but it is in fact a complete, self-contained control computer with provision for 1K-byte of on-board program RAM, and EPROM chip for extending EGOS and a second dual bidirectional 8-bit

New Products

port—over and above the dual I/O computer port—for peripherals. The Electric Crayon with the EGOS operating system, 1K-byte of refresh memory (character-store memory) and a comprehensive users manual which includes description and operating instructions, an assembly language listing of EGOS and listings of BASIC language demo programs sells for $249.95. Orders may be placed by calling Percom's toll-free order number 1-800/527-1592, or by writing to Percom Data Company, 211 N. Kirby, Garland, TX 75042.

Pocket Scanner

Weighing a mere 10 ounces and measuring just 2¾-in. wide by 1-in. thick, the new Bearcat Four-Six ThinScan pocket scanner is designed as a reliable, high performance scanner especially for the fireman, paramedic and other professionals on the move. The unit can receive any mix of six channels on four bands (high and low VHF, UHF and UHF "T" Public Service Bands). It scans the six

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crystal-controlled frequencies at the rate of fifteen channels per second and has built-in scan delay. Each channel has a lockout control and a Scan/Manual function switch which lets the user select and hold any of the six channels manually. The radio will operate from external power as well as from internal batteries. It also has provision for an optional external battery charger, earphone and external speaker. Bearcat Four-Six ThinScan pocket scanner sells for $179.95. Complete information on the new unit is available from Bearcat retailers or directly from Electra Company, P.O. Box 29243, Cumberland, IN 46229.

Universal Counter-Timer

Global Specialties Corporation's new Universal Counter-Timer, Model 5001, performs five functions: frequency counting, period and multiple-period averaging, time interval and multiple time interval averaging, frequency ratio and unit counting at a price of $360.00. As a frequency counter, the 5001 UCT provides a selection of four gate times—0.01, 0.1, 1.0 and 10 seconds—and an eight-digit display for a selectable resolution of 100 Hz, 10 Hz, 1 Hz or 0.1 Hz, respectively. In the period measurement mode, the 5001

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measures the time between successive selected edges at the "A" input. This measurement is taken over a range of 1, 10, 100, or 1000 cycles, and the average period-per-cycle is displayed. Maximum input frequency is 5 MHz. Time interval measurements are taken between the selected edge of the signal at the "A" input and the next selected edge occurring at the "B" input. The minimum measureable interval is 200 ns. The frequency ratio mode displays the number of cycles appearing at the "A" input during 1, 10, 100 or 1000 cycles at the "B" input. The unit counter displays the total number of rising edges appearing at the "A" input, incrementing continually until manually reset. For additional information or the name of the stocking GSC distributor most convenient to you, write to Global Specialties Corporation at 70 Fulton Terrace, New Haven, CT 06509.

Super-Grip Test Clip/IC Puller

AP Products has refined its basic design of a test clip to provide users with further benefits.

Designated Super Grip II, the new test clip features a narrower nose clearance, which easily attaches to high density boards. ICs with as little as 0.040-in. between opposing legs can now be readily

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tested. A new "duck bill" contour has been added to the contact tips for more secure contact with DIP ICs. Combined with AP's "contact comb" construction, the Super Grip II test clips claim to provide positive, reliable, no-shorting connections. And, offset pin rows make it easier to attach test probes. "Button heads" on the ends of the pins prevent probes from sliding off once they're in place. AP Super Grip II test clips are available in 8, 14, 16, 16 LSI, 18, 20, 22, 24, 28, 36, and 40 pin configurations. For more information, write to AP Products, 1359 West Jackson Street, Painesville, OH 44077.

Just Wrap Faster

O.K. Machine and Tool Corporation has announced "Just Wrap," a revolutionary wiring process and a series of tools that produce wire wrapped connections without prior stripping or slitting of the wire insulation. Designed to wrap on

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.025-in. (0.63 mm) sq. posts, each tool carries a 50-ft. (15 m) spool of 30 AWG (0.25 mm) wire. The tool will wire continuously through any number of pins (daisy chain). It is equipped with a handy built-in wire cutoff, and is equally suited for point-to-point wiring. Wire is available in 4 colors: blue, white, red and yellow. The JW-1 tool complete with 50-ft. spool of wire is priced at $14.95; refill spools are $2.98. Available from stock at your local distributor or directly from O.K. Machine and Tool Corporation, 3455 Conner Street, Bronx, NY 10475.

Gets the Angle

The DX-3 antenna directional indicator converts your HAM or CB

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antenna rotor control into an easy-to-read, digital readout system. Accurate to one degree, this low cost kit assembles in minutes, and installs with just three wires into Ham II, III, IV units without cabinet modifications. Easily adaptable to other systems too. It can also make an ideal workbench digital voltmeter. Only $39.95 U.S. money order directly from Monitor, Box 55, Agincourt, Ont., Canada M1S 3B4.

Tracking Baseballs

Midex's Sports Radar is a leisure-time product that may help improve the playing performance of both the professional and amateur

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athlete. The unit closely resembles the device that law enforcement officials use to trap speeding mo-

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New Products

torists. This product however, "traps"—records the speed of—tennis, golf, soccer and baseballs, hockey pucks and other identified flying objects such as downhill (ski) racers and radio-controlled model airplanes, slot-car racers and boats. It will time anything that moves, from 20 mph to 150 mph. The Sports Radar operates well below the FCC minimum power standards, thus does not need to be licensed. Operates on a 12-volt battery. The Sports Radar will be marketed nationwide through sporting goods and electronics stores at $149.95 (suggested retail). For more information, write to Solfan Systems, Inc., Midex Consumer Division, 665 Clyde Avenue, Mountain View, CA 94043.

Disguise Antenna has Preamplifier

A new 3-way antenna system that helps solve two of the concerns of the over-the-road motorist has been announced by The Antenna Specialists Company. First, the antenna disguises the

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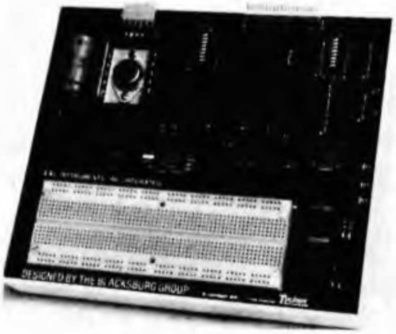
fact that a CB radio is in the vehicle, helping to prevent theft. It has no visible coil to show that it works on CB. It simply mounts in place of the standard AM/FM cowl mount antenna. Hidden couplers permit it to give excellent performance on CB as well as AM and FM broadcast reception. Second, the M-266 includes a solid-state amplifier to significantly boost FM signal reception. By providing up to 15 dB of signal boost it helps prevent noisy reception from distant FM stations and also reduces the "picket fencing" caused by rapidly changing signal strengths while highway driving. Power for the preamplifier is provided from the vehicles 12 volt electrical system. The suggested retail price is $49.95. Complete details are available by writing directly to The Antenna Specialists Company, 12435 Euclid Avenue, Cleveland, OH 41106.

TRS-80 Controller Interface Box

The IF-100 Interface Box, to provide buffered I/O connections to the TRS-80 computer for control, monitoring or testing of external devices and development and testing of I/O circuits, has been introduced by E&L Instruments, Inc. Self-powered, it plugs directly to the TRS-80 bus structure with a 40-pin cable (supplied separately), so the computer can be used for "real world" applications implemented by BASIC Level



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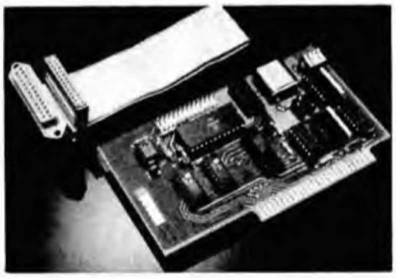
II software. The IF-100 comprises a power supply, logic probe for monitoring logic levels in I/O circuits, device and memory decoder section, bus buffer section, and control section with control signal buffering. An on-board SK-10 Solderless Breadboard Socket permits quick assembly of circuits, intermix of IC and discrete components, and immediate reuse of circuit elements. An experimentally-oriented manual is provided which is suitable for self-instruction by hobbyists. The IF-100 is available from distributor stock for either 115 or 230 VAC operation, in kit form or assembled and tested. Prices: IF-100 kit, $150; IF-100 assembled, $215; Interconnect cable, $25. Write to E&L Instruments, Inc., 61 First Street, Derby, CT 06418 for all the facts.

Serial Interface Card for Apple II

California Computer Systems 7710A Asynchronous Serial Interface is a plug-in card which enables the Apple II to communicate with all RS-232-C standard serial devices. The list of RS-232 compatible devices available is almost endless. Line, daisy, and matrix printers, intelligent and dumb terminals, keyboards, paper tape



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units, and other computers employ serial communications protocols which conform to the RS-232 standard. Features include fully selectable BAUD rates from 50-19,200 BAUD, 8 and 9-bit transmission, optional odd, even, or no parity. Software programmable interrupts, double buffered data I/O, full handshaking, and power-down ROM are included. The card is available in kit form ($99.95), software not included, or fully assembled and tested, ($159.95). Complete documentation is included. For more information, write to California Computer Systems, 250 Caribbean, Sunnyvale, CA 94086.

Digital Car Thermometer Kit

The new Heathkit CI-1525 Car Thermometer is said to keep track of temperatures inside and outside a vehicle, such as an RV, a camper, a motor home, or any vehicle or shack with a 12-volt DC, negative ground electrical system. The CI-1525's outdoor temperature sensor alerts the driver to freezing roads in winter or dangerously hot conditions in summer. According to Heath, the CI-1525 can even be used in a boat to indicate the surface temperature of the water. The 2½ digit blue-green fluorescent readout indicates temperatures between −20°F and +140°F or −30°C to +60°C. Either the indoor or outdoor reading can be chosen, or they can be automatically alter-

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nated. The new Heathkit CI-1525 Digital Car Thermometer is priced at $89.95, FOB Benton Harbor, MI. For a free catalog, with information on a complete line of automotive accessories and almost 400 other Heathkit products, write to Heath Company, Dept. 570-290, Benton Harbor, MI 49022.

CB Super Whip

A high-strength fiberglass whip that can bend 360-degrees to resist impact is the latest achievement from Avanti Research. The high performance antenna, called "The Skinny Stick," is 48-inches

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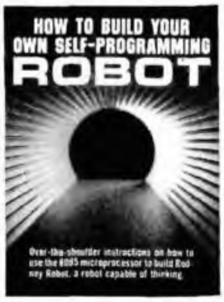
long and has a ¼-inch diameter. No wire tips to snag or bend, no windings to cut or unravel, plus pin tightening, are all featured on Skinny Stick. The foil band allows for precision tuning and is retunable, while the top-loaded coil gives the whip added punch and better reception. The whip fits standard 3/8-24 thread mounts; power capacity is 150-watts. For more information on The Skinny Stick, which is priced at $12.95, write to Avanti Research and Development, Inc., 340 Stewart Avenue, Addison, IL 60101. ■

BOOKMARK

It's a Book! Heath Continuing Education, a division of Heath Company, has introduced a new learn-at-home electronics program on phase-locked loops. Heath's Phase-Locked Loops program, EE-104, discusses the uses, designs and operation of PLLs widely used in television receivers, FM receivers, CB and 2 meter transceivers, industrial telemetry circuits and motor controls. Price is FOB Benton Harbor, MI. For further information on this and other advanced electronics programs, write for a free catalog to Heath Continuing Education, Dept. 350-160, Benton Harbor, MI 49022, or pick up a copy at the nearest Heathkit Electronic Center, or circle number 1 on the reader service card.

Loose-leaf binder
250 pages
$49.95

D2R2. Here's a fascinating and fantastic project in machine intelligence and robotics—a project an experimenter can carry as far as he wants, deciding just how advanced his robot will be! *How to Build Your Own Self-Programming Robot*, by David L. Heiserman, takes the reader through every step—every circuit, switch, program, and byte of memory. This is more than just a projects book, however; it's a straightforward how-to introduction to the sophisticated subject of robotics and machine intelligence, a practical guide that shows how to build a robot capable of learning how to adapt to changing circumstances in its environment. The unique little creature described in this book, named Rodney, can pick up signals and stimuli from his environment and develop perceptions just like humans and higher animals do. Yet Rodney is fully trainable, and his personality can be altered and molded by human intervention. All in all, Rodney is in a class by himself, and is a most remarkable and fascinating machine—he can program himself to deal with the problems of the moment, and devise theories for dealing with similar problems in the future. Yes Rodney is self-programming, and as a result no two Rodneys behave exactly the same way. In fact, if his self-generated memory is wiped out, he'll develop another one that's somehow different from the first. Published by Tab Books, Blue Ridge Summit, PA 17214. Circle number 61 on the reader service card.



Soft Cover
230 pages
$7.95

Latest CPU. *Programming the Z8000*, by Richard Mateosian, presents a comprehensive description of the Z8000—an advanced and sophisticated CPU. *Programming the Z8000* will be of special interest to all PDP-11 users and valuable to anyone interested in learning machine language programming. The text covers input / output techniques, Z8000 peripheral components, utility programming examples, Z8000 addressing modes, Z8000 hardware organization, and contains a complete instruction set. The book instructs the user, by example, how to write clear, well-organized programs. Published by Sybex, 2344 Sixth Street, Berkeley, CA 94710. Circle number 60 on the reader service card.

Soft cover
320 pages
$15.95

Look It Up! *Handbook of Electronic Formulas, Symbols and Definitions* by John R. Brand is an instant-access handbook providing thousands of electronic formulas, symbols, and definitions that relate to today's passive and active analog circuit technology. Its alphabetical format allows for instant location of information without searching through an index, saving the user hours of time and effort, the formulas are presented in linear form with sufficient parenthesis and brackets for direct use with any scientific calculator or computer program. Coverage of passive circuits extends from series circuit formulas to parallel and complex circuit formulas. Comprehensive information is presented on susceptance, bandwidth, capacitance, voltage, frequency, conductance, current inductance, power, Q factor, resistance, reactance, admittance, impedance, and much more. Greek letters that relate to electronics are defined, complete with sections on phase angles, wavelengths, ohms, and angular velocity. A handy appendix helps prevent laborious computations by listing ratios available from 5% component values. A virtual encyclopedia of useful data in a unique, "carry-around" volume, the Handbook will prove its value time and time again. Published by Van Nostrand Reinhold, 135 West 50th St., New York, NY 10020.

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Hard cover
368 pages
$15.95

Flippin' Good. *Computer Coin Games*, by Joe Weisbecker, is a brand new entry into the field of instructional books which employ games, illustrations and clever copy to teach readers of all ages about computers. Geared toward teachers for use as a supplement to other teaching materials and toward individuals who enjoy learning complicated concepts pain-

(Continued on page 102)

Get out of the rat race with your own TV or audio service business.

Start in your garage or basement and watch your business grow.

NRI will train you at home to service TV, audio equipment, video recorders, car stereo and more. Then show you how to run your own full- or part-time business.

Why stay stuck in a dead-end job when you can build your own future? You can learn to be a TV, audio and video technician right at home in your spare time. Get the training you need for a new career without quitting your job or traveling to and from night school. NRI makes it happen with exciting career training in TV and audio servicing.

Build TV, stereo, professional instruments

NRI training is practical training. Along with easy-to-digest theory in "bite-size" lessons, you get plenty of actual "hands-on" experience as you build our Master Course's big 25" computer-controlled color TV that lets you program a whole evening's entertainment, AM/FM solid-state stereo with speakers, transistorized volt-ohm meter, 5" triggered-sweep oscilloscope, TV color pattern generator, CMOS frequency counter, and perform meaningful experiments with them and the NRI Discovery Lab.®

Be an audio specialist servicing home and auto stereo.

Get into the booming video tape recorder market.

You get all this professional equipment, build this 25" (diagonal) computer-programmed TV as you learn.

Business training as well as technical training

Of course, NRI training gets you ready to enter this field at many levels. You can start by working for an established service company, a dealer, or a manufacturer. But you can start working for yourself, too. NRI lessons show you how to set up and run a full- or part-time business. You learn job costs and billing, even how to set up a complete accounting system. That's how complete the program is.

The pros select NRI training

More than a million students later, NRI is still first choice. A national survey (summary on request) shows that more than half of practicing TV technicians have had home study training, and among them, it's NRI 3 to 1 over any other school.

You can't beat the value. All in one course you get *both* color TV and audio training, *plus* video cassette and disc systems. Send for our free catalog to see it all.

Free catalog... No salesman will call.

Our big, 100-page catalog has all the facts. Descriptions of every course, each lesson and experiment, pictures and specifications of all the equipment you get. Send for it today, no salesman will ever bother you. If the postage-paid card has been removed, write to:

NRI Schools
McGraw-Hill Continuing Education Center
3939 Wisconsin Avenue
Washington, D.C. 20016

Ask Hank, He Knows!

Got a question or a problem with a project—ask Hank! Please remember that Hank's 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:

Hank Scott, Workshop Editor
ELECTRONICS THEORY HANDBOOK
380 Lexington Avenue
New York, NY 10017

Mr. Clean

I want to clean the rotary dial plate on my telephone—it's my telephone because I bought it myself. The phone company refuses to tell me how to remove the dial plate. Can you help?

—J.N., Freeport, IL

Look for a very small hole in the dial plate. It is usually located between the "9" and "0" finger holes. Rotate the dial clockwise as far as it will go. Hold the dial in this position and insert a "special tool" into the small tab-release hole and press down. A tab will release under the plate. Continue to rotate the dial plate until it is freed. To replace dial plate, position it over the opening with the last finger hole, which is the "0" position, in the number "9" position. Insert the plate into the opening and twist it in a counter-clockwise direction until it locks into the normal position. The special tool? Oh, send me $100 for one, or make it yourself by straightening one end of a wire paper clip.

It's All Over

In the Jan.-Feb. 1980 issue of Elementary Electronics you made reference to "remote control modules" to turn lights on and off. Also, reference was made to the BSR Control Unit. Where can I buy these modules and control unit?

—T.M., Raleigh, WV

The BSR Remote Control Units for lights and appliances along with the Control Unit can be purchased almost anywhere housewares are sold. I've seen them in the appliance sections of department stores, hardware stores, home improvement centers and in Radio Shack under a private label. The system is a real energy saver turning down lights and gadgets left on in remote corners of the home and workshop.

QSL Pyongyang

Where is "Radio Pyongyang"? I'd like to send them a reception report.

—L.S., Klamath Falls, OR

Radio Pyongyang is the official station of Democratic People's Republic of Korea (North Korea). Send mail to R. Pyongyang, Korean Central Broadcasting Committee, Pyongyang, Dem. Rep. of Korea. They send QSL's to qualified queries.

Lots of Tubes

I have hundreds and hundreds of old radio receiving tubes that date back to 1920 and '30, and they are in perfect condition. Could you tell me who might need these, I would be happy to sell some cheap?

—N.B., Rochester, NY

Okay, our readers now know! I suggest you mimeograph a list of tubes that you own and the price for each type. As readers respond, send them a list. Also, you may want to place an ad in our Classified Advertising section.

New Light on Laser

I'd like to do some Laser experimenting starting with building a low power unit that's safe to experiment with. Can you suggest a kit source?

—D.L., Amherst, NH

I scanned a catalog that you may want to see. Get a copy by writing directly to Information Unlimited, Amherst Professional Building, Box 716, Amherst, NH 03031. Tell 'em Hank Scott sent you!

Don't Do It

I have an old amplifier that operates on 240 volts at 50 cycles. How can I convert it to 120 volts at 60 cycles?

—J.L., Omaha, NE

There is really no practical way, other than buying a "US-grade amplifier." If you must—then look to replace the power supply section of the amplifier. Find out what the units DC requirements are and build in the power supply. This will mean the replacement of the power transformer. Ugh—a lot of work! And if it is too old, you may be throwing good money after bad!

Just Under CB

I hear broadcasters will be using 26 MHz (11-meters) in 1980. Why?

—E.N., Detroit, MI

Reception should be good during the daytime hours in North America all seasons for distances as great as half way around the world. During the summer months, reception should fall off permitting stations 1000 miles away to go right on through. However, 21 MHz will still be popular.

Too Basic

How do I change AC voltage to DC voltage?

—Z.H., Selma, NC

Some questions are better answered by research on your part. The question asked is so fundamental as to suggest that other basic concepts to electronics theory are not understood. I suggest you visit your local library and pick up a basic theory book on electronics. Also, the BOOKMARK column usually has some good suggestions. Look into it.

SCA Kit?

Where can I get an inexpensive SCA adapter kit for my FM radio?

—M.M., Hollis, NY

You can't. There are all sorts of regulations prohibiting marketing such a device to the general public. However, you can build your own SCA unit from parts listed in the plans given in the 1979 Edition of RADIO EXPERIMENTER. When built, use it only to entertain yourself and family. Do not use it in a restaurant, store or office, since you would be pirating a service. It could cost you a lot of money in law suits.

Quiet Band

Hank, I drove from Memphis, TN to Chicago, IL by car non-stop with two other drivers. We used CB to keep in touch with other drivers, but the band is dead. Is CB really dead?

—N.P., Memphis, TN

No way! That hopeless deluge of nonsense chatter is completely gone. I had the same experience driving to St. Louis from Washington, D.C. this past winter. When I was low on gas and called for assistance, one CBer got on my tail because he had a five gallon can in his pickup. Another CBer directed me to an open filling station. CBers are there, if you need them. The rachet jaws have virtually disappeared —which is better for CB.

Getting the Word

I want to add front panel nomenclature to my projects to give them a professional appearance. Where can I pick up the press-on letters?

—D.H., Corvallis, OR

Write directly to Circuit Specialists, 1344 No. Scottsdale, Rd., Tempe, AZ 85281, and ask for info on press-on letters. They sell word groups for Amateur Radio, test equipment, etc., in addition to the individual letters and numerals.

Lend a Hand

Antique Radio Services may be able to assist you in some services. Write to them briefly stating your need. Enclose a stamped, self-addressed envelope for their quick reply. Usually, help can be offered quickly at a reasonable fee. Write to Antique Radio Services, Att'n: Hartford Bertman, 646 Kenilworth Terrace, Kenilworth, IL 60043. In the meantime, see if you can assist your fellow readers below:

Δ Darnell Model 460 tube checker; needs new tube test data sheets and/or address

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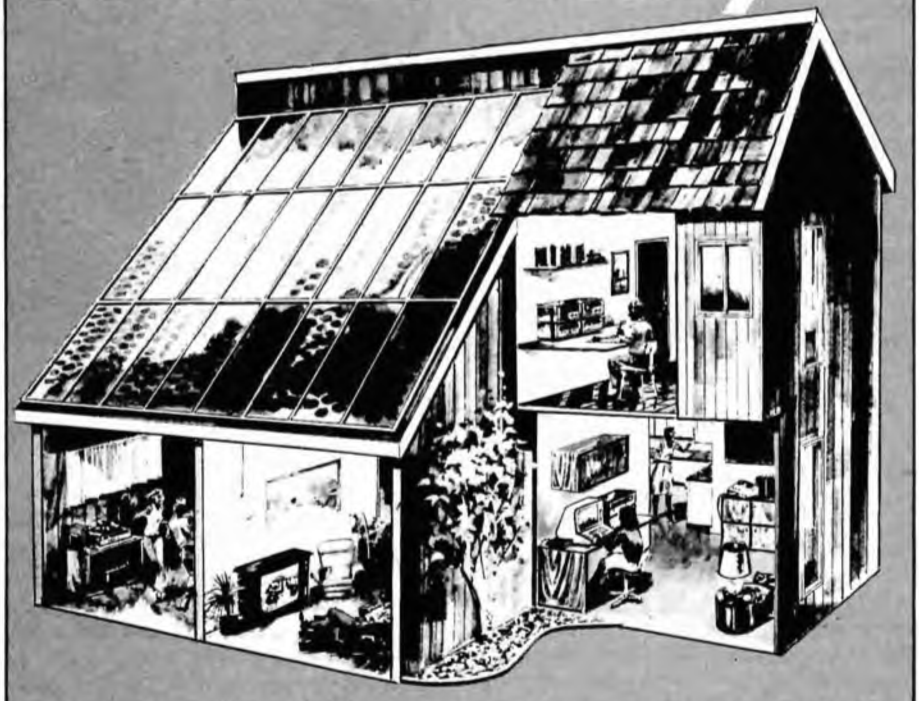
Electronics Theory Handbook

1980 EDITION

Solar Electricity



A look at its present use and how it works

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 electrictiy involve energy costs that are rising sharply. A hope of the U. S. Department of Energy is to reduce the cost of producing electricity with photovoltaics to 50 cents per peak watt by the mid-80's. 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 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.

Radio station WBNO, Bryan, Ohio is the first AM radio station to operate with a photovoltaic power system. This project is sponsored by the U.S. Dept. of Energy and managed by the MIT Lincoln Laboratory. The solar system has a 15 kilowatt peak rating, and delivers 128-volts DC to the station. Power is supplied by 800 photovoltaic modules employing 42 cells per module. This photovoltaic power system keeps 60 lead-acid cells. under charge.

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.

"Sun City." In another project sponsored by the U.S. Dept. of Energy, a small Papago Indian settlement has become the site of the world's first village powered by a photovoltaic power system. The village has a population of 95 and its location is 17 miles from the nearest available utility power. The solar array provides 3500 peak watts.

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 Fig. 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 Fig. 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.

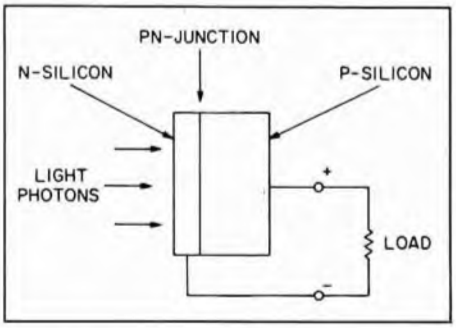


Fig. 1. A load connected between the N and P junctions will receive current flow when light photons hit the N junction.

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

Solar Electricity

cell voltage of 0.45-volts, there is maximum power delivered to the load. As shown in Fig. 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 Fig. 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 input:

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

Efficiency is important and determines the electrical power output that can be obtained for a cell of a given size. The

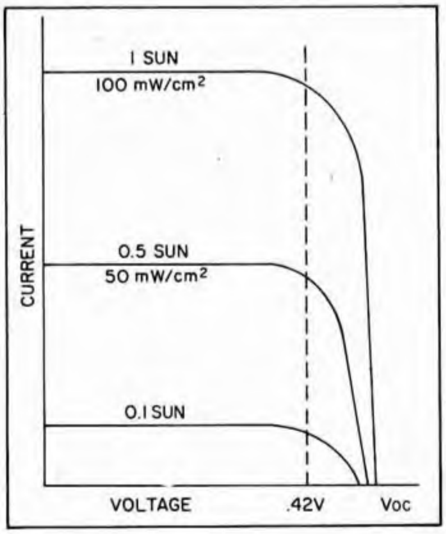


Fig. 2. Response of solar cell. Current is reduced in proportion to light intensity. One Sun yields 100 milliwatts maximum.

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 voltage 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

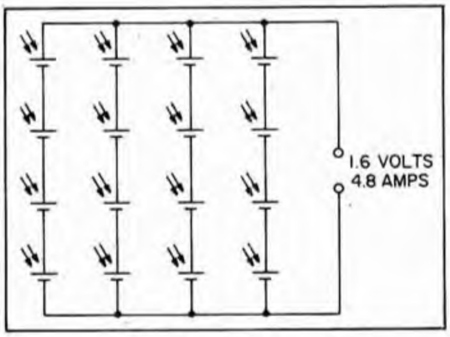


Fig. 3. Connecting solar cells in series increases voltage and in parallel increases current. Series/parallel steps up both.

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 x 0.4). Four, 1.2 ampere cells connected in parallel will result in a current capability of 4.8 amperes (4 x 1.2). If 16 of these 0.4-volt and 1.2 amperes cells are connected in series-parallel, as shown in Fig. 3, the output will be 1.6-volts with a current capability of 4.8 amperes.

Photovoltaic Solar Panels. A solar

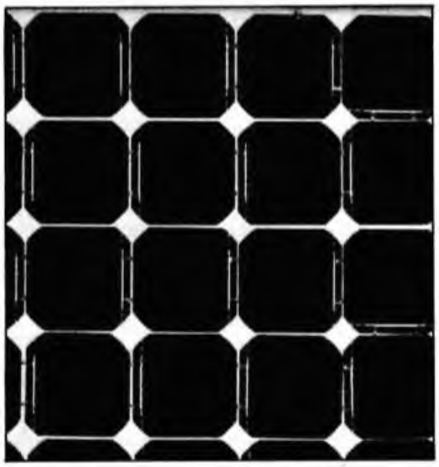
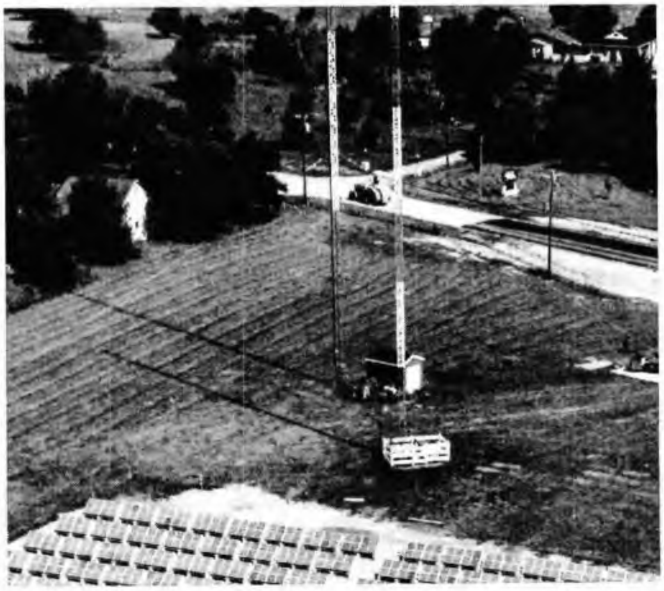


Fig. 4. Modern hi-density solar panel in frame. Model consists of sixty-four square cells producing up to 34 watts of power.

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 Fig. 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 Fig. 5. Based on the average insulation in the United States, the panel is capable of providing approximately 63 ampere-hours of electricity per week.

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 Fig. 6. In sunlight, the solar panel charges the bat-



The transmitter of AM radio station WBNO in Bryon, Ohio is said to be the first using photovoltaic power. An array 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.

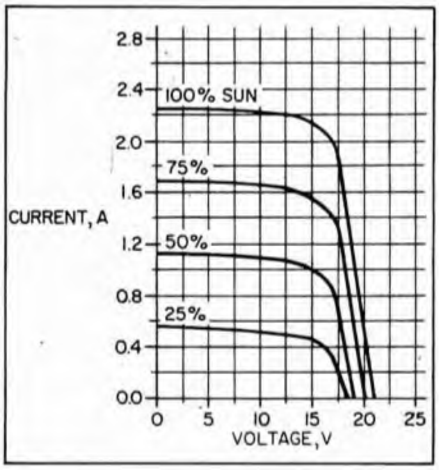


Fig. 5. A performance chart of the solar panel in Fig. 4. Note that voltage output remains at constant nominal 14-volts.

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

tery 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.

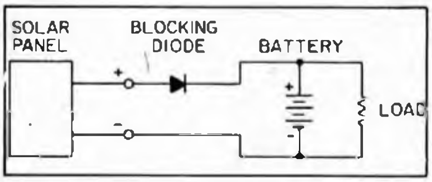


Fig. 6. Blocking diode prevents battery from discharging into solar panel when light is absent or at a very low level.

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:

$$\text{Transmit} = 1 \times 8 = 8 \text{ Ah}$$

$$\text{Receive} = 0.1 \times 16 = 1.6 \text{ Ah}$$

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 Iav 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.

Conclusion. In the next decade, the photovoltaic power supply will become increasingly popular. This is especially so in the field of radiocommunications and wherever low-powered electricity is required. Further along will be the high-powered systems now costly and experimental, but with a bright future in a world of renewable energy scarcity. ■

Inside Your Power Supply

☐ The catalog of a leading electronics supplier contained this glowing description: A superhet shortwave receiver covering the standard broadcast band through 20 Meters. Its cabinet was luxurious walnut, its audio output push-pull into a high-quality speaker. The set boasted low current drain and the latest circuitry. The price?—a mere $49.75.

The catalog was Allied Radio's and the date was 1932. The radio was a console meant for the living room, and it no doubt pulled in the A&P Gypsies with reasonable fidelity. The thing is, it required batteries for power.

Here's the battery complement for the handsome, but hungry, *Knight 8* vintage receiver: three 45-volt "B" batteries for tube plates; one 2-volt "A" cell for lighting filaments; one 22.5-volt "C" battery for biasing tube grids. This mountain of Evereadys cost $9.00, a rather steep tab even in the good old days. And they could have pooped out right in the middle of a Herbert Hoover speech.

Super Supplies. That danger is gone, thanks to power supplies. Now a receiver takes raw electricity from the utility company and converts it to filament, plate, or bias voltages. It does the same for transistorized circuits. Or it perhaps participates in the growing trend to 3-way operation, where you use the same device at home, in a car, or carry it as a portable. The supply not only powers the equipment in the home, it also recharges the portable batteries. Cost is low because AC power is priced about 7¢ per kilowatt hour—which means you can operate a plugged-in table radio for about 100 hours on a few pennies per day.

Though power supplies operate circuits of vastly different voltage and current requirements, the basic principles are the same. In most instances a supply accepts house current—usually 117 volts AC alternating at 60 Hz (cycles)—and performs the following steps.

- *Transforming Voltage.* The power company provides 117 volts for home outlets, but it's hardly the value that many electronic devices demand. The plates of receiving tubes require about 100 to 250 volts for operation, while transmitting tubes may need a "B+" several hundred volts higher. Transistors, on the other hand, usually function at less than 30 volts. So the first task of the supply is to transform voltage to the desired value. In many CB sets, for example, there's plate-voltage requirement of 250 and filament-voltage requirement of 12.6 VAC. The power transformer delivers these levels.

- *Changing AC to DC.* Furnishing correct voltage is not enough. Those voltages must often be DC—and the power company provides alternating current. So the second function of a supply is to *rectify*, or convert AC to DC. If a rectifier malfunctions in your radio you'll soon learn its function. The symptom is annoying hum in the speaker (caused by 60-Hz alternations in the audio). In a TV set, suffering rectifiers can put a thick, dark, "hum" bar across the screen.

- *Filtering.* Though rectifiers change AC to DC the product is far from suitable because it contains objectionable ripple. This will be attacked by the filter, which smooths the pulsations to pure DC.

The final step of the supply depends on the designer. He can add a *bleeder*, choose a *regulator*, or insert a *divider* at the output. We'll look at these extras, but first consider how the supply's basic parts operate.

The Transformer. In Fig. 1 is a typical power transformer that's been produced by the millions with only slight variations. As we'll see, the transformer acts to create a voltage change between its primary and various secondary windings. The trick's based on the turns-ratio between the various windings. If turns in the secondary number twice those of the primary, then output voltage doubles; if turns in the secondary are a fraction of those in the primary, then a stepdown in voltage occurs.

Thus, in Fig. 1, the rectifier filament, which operates at 5 volts, has few turns compared to the primary; the high-voltage winding at 500 volts, however, has about five times as many turns as the primary. The colors shown for the windings, incidentally, are standard and observed by many transformer manufacturers.

The *centertap* connection of a winding splits the voltage in half. In our example, the high-voltage secondary is capable of 500 volts across the full winding (red to red), but only 250 volts between the centertap (red/yellow) and either end. The most important job for a centertap occurs in a *full-wave* supply, as we'll see in a moment. Note that a protective fuse and a power switch are located in one primary lead of the transformer.

Rectification. The two filament voltages from our transformer (5.0 for the rectifier and 6.3 for other tubes) will need no further processing. AC can be applied directly for filament heating (or for lighting pilot lamps on the front panel). High voltage, however, must be converted to DC before powering tube plates or transistor collectors and drains.

A circuit for changing AC and DC is a *half-wave* rectifier, shown in Fig. 2. It's based on a diode's ability to conduct current in only one direction. The rectifier cathode boils off electrons (negative) which are attracted to the plate when the plate is driven positive by incoming AC.

When the next half-cycle of the AC appears, the plate is driven negative, so electrons are repelled at this time. The

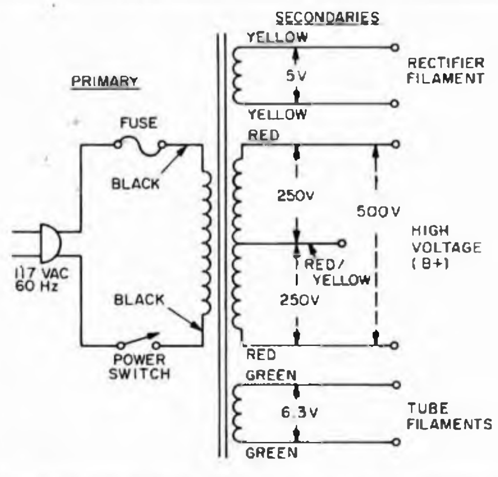


Fig. 1. Schematic of typical power transformer, showing voltages and EIA color-coding of transformer windings.

net result is shown in the output: a series of positive voltage pulses appearing at the load. (The dotted line shows where the negative side occurred.)

In practical circuits the half-wave rectifier is usually reserved for light-duty power supplies. It's inefficient because it fails to make use of AC voltage half the time (during the negative pulses). Secondly, those wide spaces between pulses are difficult to filter because of low ripple frequency. In a half-wave rectifier, the pulsations occur at 60 Hz, the same frequency as the applied line voltage. But don't underrate the half-wave supply because it's been used in just about every 4- or 5-tube table radio now playing. After all, its power requirements are low and the circuit is inexpensive to manufacture.

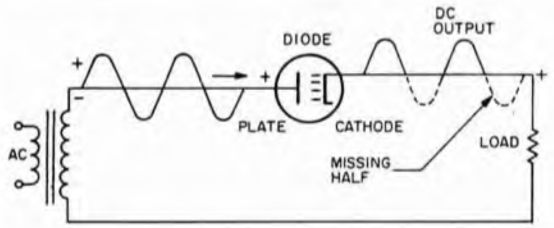


Fig. 2. Half-wave rectifier, showing how diode produces pulsating DC output by repelling electrons when plate is driven negative.

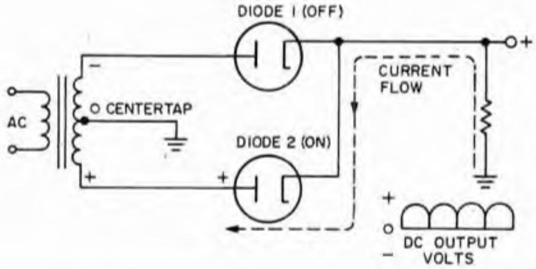


Fig. 3. Full-wave rectifier is a pair of diodes driven alternatively to take advantage of both halves of AC input voltage.

Full-Wave Supplies. Transmitters and higher-power equipment overcome the half-wave's shortcomings with the full-wave system. It's nothing more than a pair of diodes that are driven alternately so they consume every bit of AC input voltage. The key to full-wave operation is the centertap on the transformer's secondary winding. As applied AC appears across the complete winding, it makes the top end negative (as shown in Fig. 3) and the bottom end positive.

The centertap at this time establishes the zero voltage point because it's at the common, or grounded, side of the circuit. During the time the lower diode (No. 2) has a positive plate, it does the conducting. Next, the applied AC voltage reverses and makes the top diode plate (No. 1) positive so this tube now conducts.

This load-sharing combination of two diodes and a centertapped power transfomer not only improves efficiency, but doubles the ripple frequency. An input of 60 Hz emerges as 120 Hz in a full-wave arrangement because every half-cycle appears in the output. This reduces the pulsating effect (cycles are closer together) and the DC becomes easier to filter.

If you purchase a transformer, watch out for one pitfall. It may be rated, say, "250 volts CT" and appear to be suitable for a rig with a 250-volt plate supply. In a full-wave supply, however, the transformer voltage output would be only 125, since a centertap reduces the voltage of a winding by one half. This can be avoided by specifying a transformer that has 250 volts *each* side of centertap or, stated another way, "500 volts CT."

Solid-State Rectifiers. Tube rectifiers are still widely found in electronic equipment, but they're destined for the Smithsonian Institution. Solid-state equivalents are superior because they don't need filaments or heaters to accomplish the same rectifying action. They're several hundred times smaller and much cooler in operation. Instead of a huge 5U4 vacuum-tube rectifier in your TV set you're now more apt to find a pair of tiny silicon diodes.

Circuits using these semiconductors, though, are similar to those of vacuum tubes. As shown in Fig. 4, diodes can be used in equivalent half- and full-wave arrangements.

Unlike tubes, though, solid-state diodes rectify AC and DC by a semiconductor effect at the diode junction (a region between the anode and cathode). The action, in simplified fashion, occurs when "current carriers" in the material flow toward and away from the junction under the influence of applied AC. When few carriers appear at the junction, little current gets through the diode; conversely, when many carriers are in the area, they reduce the junction's opposition to current flow. Depending on the way the diode is connected in the circuit, it can recover either the positive or negative half of the AC.

Bridge Rectifiers. Another common arrangement is the full-wave bridge (Fig. 5). Though it uses four diodes, it offsets this disadvantage by an ability to produce the same output as a regular full-wave supply without a centertapped transformer. It accomplishes the feat by operating one pair of diodes during each half cycle. And as one diode pulls current out of the load, its partner pushes current into it.

The net effect is a total voltage across the load which is about equal to the applied AC. We've shown how it occurs for diodes 1 and 2 in the diagram (Fig. 5) but a comparable action occurs in the other diodes when the AC switches polarity.

Filtering. The next major section of the supply is the filter, which smooths out the ripple. Its two major components are often a *capacitor* and a *choke* which eliminate pulsations by dumping a small amount of current from the peak of each ripple into the "valleys" between them. The result, as shown in Fig. 6, is pure DC fit for a tube or transistor.

In operation, pulsating DC arrives at the filter choke, a coil of wire wound on a soft iron core. As the name implies, the choke attempts to oppose any change in current flow. The rippling part of the wave, therefore, encounters high reactance in the choke and fails to get through. This is aided by the filter capacitor which is charged by ripple voltage.

As the ripple falls (between pulses), the capacitor discharges part of its stored current into the "valley." Thus the combined effect of choke and ca-

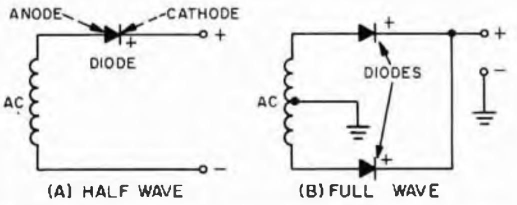


Fig. 4. Solid-state selenium or germanium diodes in similar half- and full-wave rectifier circuits are better than tubes since they don't need filaments or heaters for rectifying action.

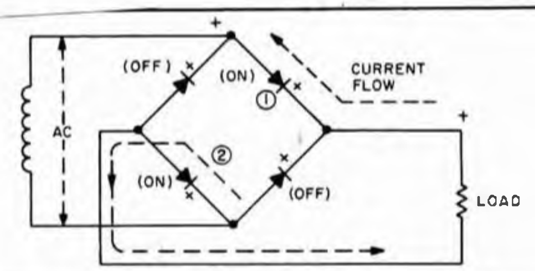


Fig. 5. Solid-state bridge rectifier provides full-wave rectification with center-tapped transformer by using four diodes.

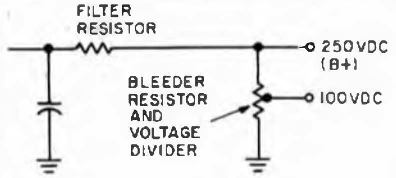


Fig. 7. Choke can be replaced by filter resistor. Also shown is bleeder resistor that serves both as output regulator as well as voltage divider.

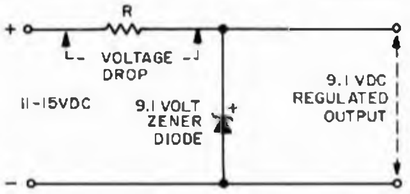


Fig. 8. For more efficient regulation than produced by bleeder resistor, zener diode shunted across DC output will hold voltage to specified limit.

pacitor results in smooth DC which can have ripple as low as a few percent of the total voltage.

You won't find the choke in some power supplies because it's an expensive item. Many designers eliminate it (especially in mass-produced equipment) by using a resistor instead, as shown in Fig. 7. The resistor does the job of filtering, but with one penalty: it reduces the amount of available voltage at the output. Yet, the loss can be tolerated in many circuits and filter resistors are common.

Another use for resistors in a supply is to serve as a *bleeder*, also shown in Fig. 7. In this function, it protects parts in the supply from possible damage due to sudden voltage surges when the supply is first turned *on*. Also, a bleeder helps stabilize voltage output when the load changes (as in a keyed ham transmitter) by always drawing some small degree of load current. Bleeders, too, are found in dangerous high-voltage circuits where they bleed-off the stored charge of filter capacitors that could deliver a lethal shock to a repairman (even after the equipment has been turned *off*.)

Note that a tap can be added to the bleeder to provide a second output voltage from the supply. Now the bleeder becomes a *voltage divider*. As such, it can supply the designer with multiple output voltages for operating various devices in a circuit.

Voltage Regulation. A ham who's received a "pink ticket" from the FCC for chirpy signals, a color TV that's gone fuzzy, a shortwave receiver that won't stay on frequency—all may suffer from a problem in voltage regulation. Line-voltage fluctuations or other electrical swings can cause poor, unstable operation. So the engineers have come up with methods for "stiffening" a power supply.

If, say, line voltage changes from 105 to 130, they design the circuit to operate at 100 volts. Whatever voltage arrives over the line is reduced to 100, and the surplus is dumped (usually in the form of heat). To perform this task, the regulator establishes a reference point, then regulates around it.

A common example is the zener diode found in the power supply of many CB transceivers. Since these rigs can operate from a car's battery or generator, supply voltage can swing from 11 to 15 volts. This could happen if you're standing for a traffic light, then pull away, causing a shift between car battery and generator. If the CB set is on at this time, receiver tuning could be thrown off because of large changes in local oscillator voltage.

A zener diode can compensate for the shift, as shown in Fig. 8. At first glance it appears as an ordinary diode connected backward. Since the cathode (upper) terminal is connected to the positive side of the supply, there's a "reverse bias" condition. A zener diode, however, "breaks down" (or "avalanches") whenever its rated (zener) voltage is exceeded. In our example, the zener is a 9.1-volt unit, so the diode conducts current as the supply voltage shifts from 11 to 15 VDC.

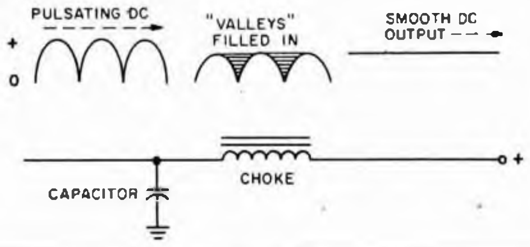
Yet we see 9.1 volts indicated at the output. Secret of the zener's ability to hold at 9.1 is that it detours part of the supply current as the voltage increases. Since a resistor is in series with that current flow, a voltage drop (as shown) appears across the resistor. Thus, any increase in supply voltage is dissipated across the resistor and effectively subtracted from the output. This automatic and continuous action occurs for any voltage above 9.1—the zener's nominal rating—so the output is said to be regulated.

Fusing Power Supplies. You can protect your power supply by installing a fuse or circuit breaker on the primary or secondary side of the transformer. A fused primary gives good overall protection but does not have the sensitivity needed for some circuits. By installing a fuse between the transformer's secondary center tap and ground you can improve fusing sensitivity. In solid state circuits the value of the fuse is all-important due to the low voltages involved, but since fuses do not react fast enough to save a transistor or IC chip you might have to resort to semiconductor protection such as using a zener diode.

More and Merrier. This barely brushes the subject of power supplies, since the variations are nearly endless. More than 20,000 volts for the picture tube of a color TV are derived from a special "flyback" transformer. It captures voltage from rapidly moving magnetic fields in the set's horizontal scanning section. An oscilloscope power supply contains strings of adjustable voltage dividers to move the pattern of light on the screen in any direction.

There are also high-current supplies with massive rectifiers for battery charging and super-smooth lab supplies for circuit design. But behind most of them are the simple principles which transform, rectify, filter, and regulate a voltage so it can do the job at hand. ■

Fig. 6. Curves depicts how reactance of choke and discharge of capacitor eliminates ripple and fills in valleys for smooth DC.



INSIDE TEST EQUIPMENT

In this section, ELECTRONICS THEORY HANDBOOK will describe the origins, theory and uses of two important pieces of test equipment, the Frequency Counter and the Digital Multimeter (DMM). Both have distinct advantages over their analog counterparts and are now used widely by technicians and hobbyists in virtually every area of electronics.

The Digital Multimeter

THIS HANDBOOK, ATTEMPTS to introduce its readers to new developments in instrumentation, will now discuss advances in the measurement of voltage, current, and resistance. In the past, measurement of these parameters have utilized analog devices; however, with the advent of large scale integration semiconductor chips, a new generation of digital sampling techniques has been developed that allows accuracy to laboratory standards with moderately priced equipment. Full appreciation of the flexibility and advantages of the newer digital devices is apparent when comparison is made with analog equipment.

The relationship between current and voltage for steady state linear direct current applications is called Ohm's Law. This "Law," the most basic concept of electronics, is written

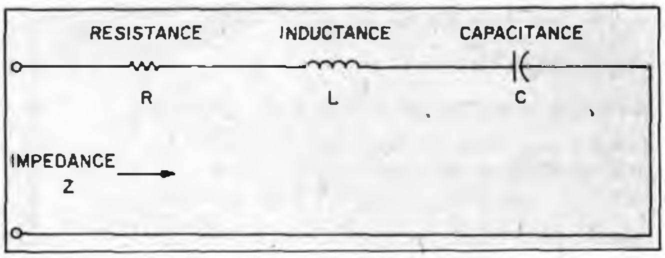
$$E = IR$$

The basic unit of voltage (E) or electromotive force is the volt. The basic unit of current (I) or time rate of change of charge is the ampere. Resistance (R) is measured in ohms.

IMPEDANCE

Things become more complex when steady state AC circuits are investigated. The units of voltage and current do not change; however, there is now a dynamic relationship between voltage and current which must take into consideration the phase angle between these two parameters. Simple DC resistance becomes a complex impedance. Impedance by definition is voltage divided by current and is the sum of the resistive

COMPONENTS AFFECTING IMPEDANCE

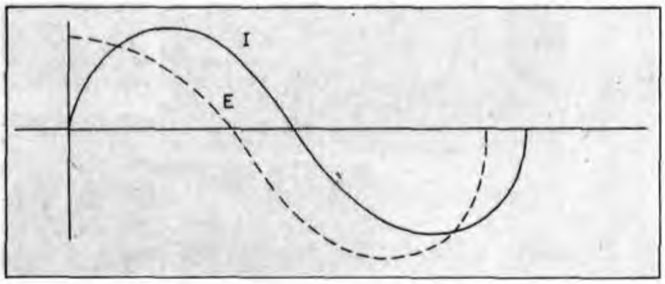


plus reactive components of the circuit. Coils and capacitors determine the magnitude of the reactance of a given circuit. It is beyond the scope of this article to deal in depth with the problem of complex impedance, but some knowledge is necessary for an understanding of voltage measurements.

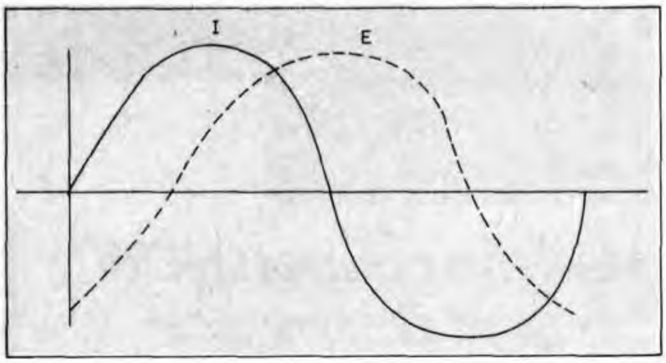
The DC resistance of an *ideal* capacitor is infinity. Actual capacitors have leakage dependent upon their composition, e.g. electrolytics will have much more leakage than ceramic or mica capacitors. An *ideal* inductor has zero resistance. Actual inductors have a series resistance which is a function of diameter, temperature, length, and composition of the wire used in their windings.

Under transient and AC conditions, the current flow in an inductor always *lags* the voltage flow, whereas the current in a capacitor always *leads* the voltage.

CAPACITOR CURRENT/VOLTAGE PHASING



INDUCTOR CURRENT/VOLTAGE PHASING



Any measurement of voltage under these conditions must take into consideration the changing nature of voltage and current flows and the impedance of the measuring device.

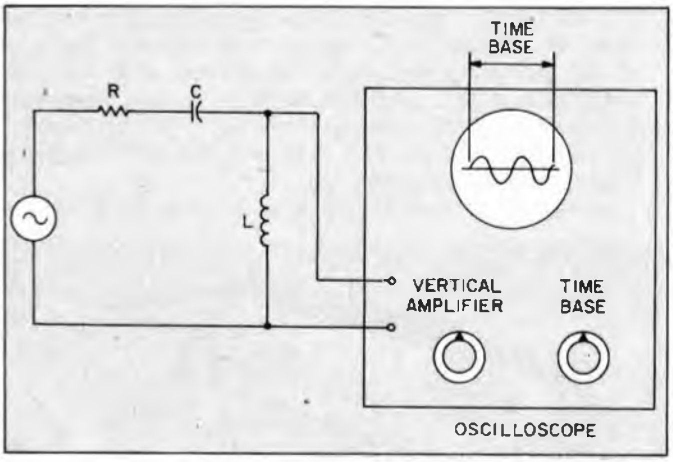
DESIGN CRITERIA

Certain criteria can be formulated concerning the equipment used to measure direct or alternating currents or voltages. First, the device should be accurate and capable of measuring both AC and DC currents or voltages. Second, linearity should be present over a wide range of readings. Third, the impedance of the device should be sufficiently high so as not to "load down" the circuit being measured. Fourth, measurements of resistance should be taken at low voltages so as not to alter the resistance of complex circuits that consist of active and passive elements. Last, the readings should be reproducible and not a function of the temperature, humidity, or the supply voltages necessary to power the measuring device.

THE STONE AGE

In the past, several methods were used to accomplish these goals. For AC, high frequency, and transient measurements, the oscilloscope provided the "gold standard" for a reproducible, high quality, high

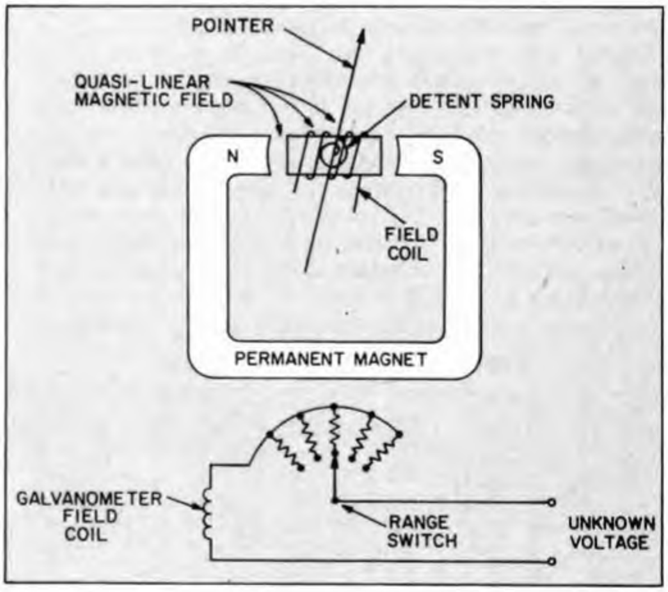
OSCILLOSCOPE MEASUREMENTS



impedance device that had reasonable linearity. If the device was well calibrated, and had gain stability, measurements to two significant figures could be made over a wide range of voltages and frequencies. By use of suitable coupling devices, measurements of current could also be made. With appropriate attenuators, an oscilloscope could be made to have an input impedance of 10-megohms which was sufficient for most circuits. The phase relationship between voltage and current was easily demonstrated using dual sweep or chopped-beam oscilloscopes. Difficulties were commonly encountered with DC and very high frequency AC measurements, and with obtaining an accurate time base for the horizontal sweep circuit. Finally, the oscilloscope was not portable and proved to be a fragile device that was tied to a service bench.

Most measurements of voltage, current, and resistance not done on an oscilloscope were obtained with portable devices using D'Arsonval galvanometers called "meters." These devices, like the oscilloscope, suffered from several major faults. First, because of distortion in the magnetic field, true linearity was never achieved over the entire range of readings. Second, accuracies of only two or perhaps three significant places were available. Third, as with the oscilloscope, under certain conditions parallax (difference in reading that is dependent on the position of the observer) was a major problem. Fourth, the basic resistance of the galvanometer was low, on the order of 20,000-40,000-ohms-per-volt for expensive equipment, and 5,000-10,000-ohms-per-volt for less costly gear. Impedances, when AC voltages were measured, were commensurately lower—on the order of 1,000-5,000

GALVANOMETER CONSTRUCTION



ohms. Lastly, the devices were basically fragile and easy to burn out. In spite of these shortcomings, the analog volt-ohmmeter was and is a popular, inexpensive device that sells for prices ranging from approximately $10 to $150, depending upon the accuracy, ranges, functions, and input resistance.

True laboratory standard accuracy—voltage readings to three and four significant places—could be obtained using D'Arsonval-type devices that operated over very narrow ranges and were used in bridge circuits that compared the unknown voltage to a known standard voltage. Unfortunately, this equipment was expensive, difficult to use, and not portable.

In another class of devices, the low basic input resistance of the galvanometer was improved by using vacuum tubes (VTVM) or semiconductor devices (eg, FET). Unfortunately, this was done at the expense of doubling the price of the equipment and adding the problem of gain stability and input offset voltages.

DIGITAL DESIGNS

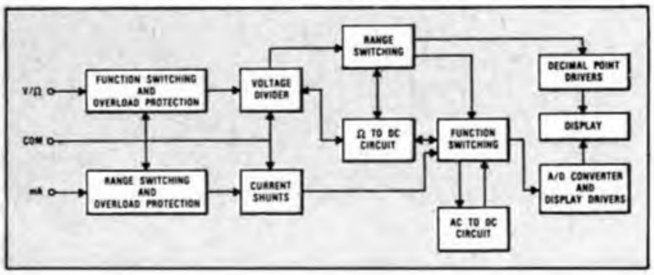
With the advent of large scale integrated circuits, an alternate means of measuring voltage, current, and resistance became available. This class of devices converted the analog signal, e.g. the current, voltage, or resistance, and displayed it in digital form. Higher accuracies were obtained by expanding the scale of measurement and eliminating meter reading errors—parallax and nonlinearity. Therefore an order of magnitude advantage was obtained. For example, if a high quality volt-ohmmeter had an accuracy to 1 percent of a given reading, similar quality digital devices could be made to read to 0.1 percent accuracy. Such an advantage is obvious when analyzing complex circuitry using semiconductor components. Furthermore, the ohmmeter function of these new generation digital

INSIDE TEST EQUIPMENT

devices uses very low currents when compared to the standard volt-ohmmeter. Lastly, the input impedance of these devices is in the 10-megohm range, shunted by a small capacitor of approximately 50 pF.

Digital volt-ohmmeters are only as good as their amplifier stability and linearity, internal voltage and time references, and method of eliminating offset voltages. Various schemes have been devised to provide automatic zeroing, programmable or long term stability, and minimal offset voltages. Input signals are converted into a scaled DC voltage, which is then transformed into a digital readout by integration, logic, and display circuits. DC voltages to be measured are applied across a voltage divider. A decade fraction of this voltage is selected by the range switch. The signal

TYPICAL FUNCTION DIAGRAM



is then passed into a DC voltmeter which consists of an automatic offset correction (auto zero) circuit, a dual slope integrator, and a digital processing and multiplexing device. The reference voltage is derived from a highly stable Zener diode.

AC MEASUREMENTS

AC voltages are measured in a similar manner, except a full wave bridge is used to yield a DC voltage equivalent to the RMS of the unknown AC signal. A high impedance buffer is used to isolate the bridge circuit. Resistance measurements are made by generating a precision known constant current which develops a DC voltage across the unknown resistor. The signal is then applied to the buffer amplifier and processed in a manner similar to the voltage measurements. Current measurements are made by passing the unknown current through a precision shunt-resistor which develops an AC or DC voltage proportional to the current in the shunt resistor. This voltage is again applied through the bridge (for AC currents), buffer, and integrator circuits. Various degrees of auto ranging are available depending upon the design and price of the instrument. This auto ranging refinement allows wide ranges of voltage to be measured with one setting of the range selector without internal overload. Some manufacturers offer a high/low ohm feature that permits in-circuit resistance measurements at voltage levels below the conduction threshold of semiconductor. The high ohm feature allows semiconductor junction tests by measurements of forward and reverse resistance ratios.

CIRCLE 1 ON READER SERVICE COUPON

Heath's IM-2212 digital multimeter offers auto-ranging, which selects the proper voltage, current, or resistance range for more convenient measurements. It weighs 8 lbs., less optional NiCads.

ACCURACY

As mentioned earlier, the specifications of digital multimeters are normally in the range of 0.5 percent of the reading, plus 0.1 percent of the range ± one count for DC voltages. A display reading of 1.00-volt DC from a low impedance source will have an uncertainty of ± 0.0035 volts; a truly amazing feat. Because of the sampling nature of the device and the auto ranging features, response time is usually less than 3 seconds to within stated accuracy. Settling time for the semi-ranging devices (100 percent overvoltage) is typically 1/2 of a second.

Optimal performance can be obtained by observing

CIRCLE 40 ON READER SERVICE COUPON

B&K Precision's model 2830 digital multimeter offers 4-place red LED readout, high/low resistance range selection, direct DC/AC current readout, a convertible carrying handle and desk prop.

a number of precautions when test measurements are made. Ground loops must be avoided since differences of ground potentials may set up loop currents and distort the measured value. Problems of this type can be almost completely eliminated by using battery operated equipment. Ground loops may be lessened by connecting the test source ground to true earth ground if possible. In floating DC or AC measurements, it is possible to introduce a common mode voltage by reactive coupling when the line cord is connected. Again, problems of this type can be almost entirely eliminated by using a battery operated meter. If only AC operation is available, this type of measurement should be made on the highest range possible consistent with usable measurement resolution. Most devices will handle up to a 100 percent full range overvoltage with meaningful readings.

CIRCLE 40
ON READER
SERVICE COUPON

An example of a handheld digital multimeter is B&K Precision's model 2815. The new LSI IC has built-in shielding against strong RF fields, making it a hot item with hams, CBers and radio techs.

The basic design features of the digital multimeter make it the ideal replacement for the existing analog multimeters and FET/VOMs or VTVMs. In addition to providing equivalent functions and range, the inherent accuracy and features of this type of instrument provide a significant margin of improved performance over comparably priced analog meters. Digital multimeters are priced from $60 to several hundred dollars and come in kit or assembled form. Outstanding examples of this type of instrument are the Heath model IM 2212 auto ranging digital multimeter kit, the B&K Precision 2830 3½ digit multimeter, and the new inexpensive Radio Shack model 22-197 hand-held liquid quartz 3½ digit display unit.

CONCLUSION

In summation, the proven stability of dual-slope integration combined with precision, ratio-trimmed resistor networks and advanced LSI technology has generated a series of digital multimeters that provide extreme versatility and accuracy at an affordable price. They have virtually made the hand-held galvanometer-based analog volt-ohmmeter obsolete. Their major drawback is in their time to settle on a given reading and the necessity of using sampling techniques. They are an exciting, accurate, and dependable way of making basic measurements of voltage, current, and resistance in modern electronic circuitry. ■

The Frequency Counter

THIRTY YEARS AGO FREQUENCY counters were large expensive devices reserved for colleges, the military service, and those repair facilities that had the funds to afford a counter. Most frequency measurements were done rather crudely with oscilloscopes using either Lissajous patterns or a calibrated time base sweep circuit. In any event exact frequency measurements were rarely available to the average experimenter. With the technological explosion promoted by the ever expanding consumer electronics market the need to accurately determine frequency has become apparent. Digital display of frequency or time which was once a rarity has now become commonplace.

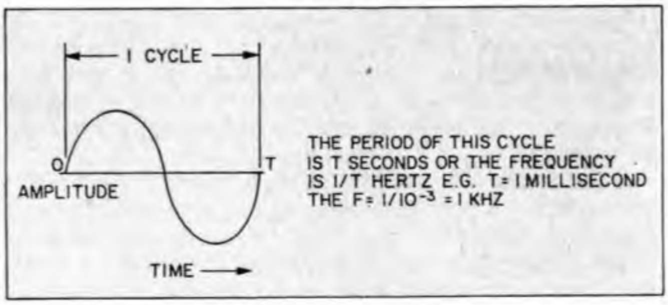
HOW THEY WORK

The unit of frequency measurement is the Hertz. Frequency also implies time since the Hertz by definition is a cycle per second. Therefore, the period of a given frequency is defined as the reciprocal of that frequency. This can best be visualized by examining this diagram.

The simplest serial counter is one made up of two bistable devices known as "flip flops". This two bit serial counter has four distinct states. It is important to note that this device counts in the binary number system. Adding an additional flip flop will yield 2^3, or eight states, and adding N flip flops serially will yield 2^N states. Unfortunately our number system uses the base ten, not the base two. For example, the number ten in our decimal system would be 1010 in the binary or base two system. Any base ten number has an equivalent "binary coded decimal" (BCD) number.

If a precise gate interval is used in conjunction with the counter just described, frequency could be determined from the number of cycles counted during the gate period. A gate period of one second would yield a frequency equal to the number of cycles counted during this gate period. Likewise, if the gate period was .1 second, then the frequency would be 10 times the number of counts. After counting the number of pulses or counts in a gate period, some method must be devised to display and store this information until the frequency is updated during the next counting period. The scheme

THE CYCLE

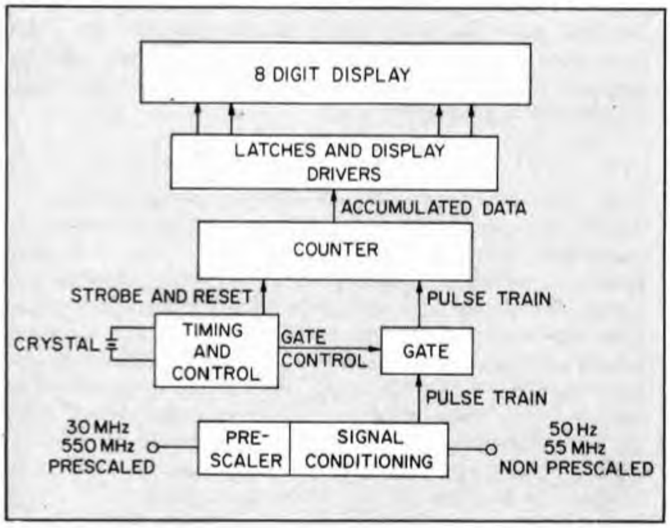


GLOSSARY OF TERMS

BCD	Binary Coded Decimal
CMOS	Complementary Metal Oxide Semiconductor
DTL	Diode Transistor Logic
FET	Field Effect Transistor
FF	Flip Flop or Bistable Multivibrators
LED	Light Emitting Diodes
LSI	Large Scale Integration
RTL	Resistor-Transistor Logic
SSI	Small Scale Integration
TTL	Transistor-Transistor Logic

INSIDE TEST EQUIPMENT

COUNTER BUILDING BLOCKS



then consists of a clock oscillator which generates the gate period, a decade counter, and latch and digit driver elements plus the actual digital display.

ACCURACY

The frequency counter's accuracy is a function of its time base stability (accuracy of the gate period), which is dependent on the quality of the quartz crystal. Most counters use either the readily-available color burst TV crystals (3.579545 megahertz) or other specially designed crystals in the 4 to 10 megahertz range. To achieve a 1 part per million accuracy in the count frequency requires that the crystal oscillator have no more than 1 part per million drift over the temperature range 20 to 40 degrees centigrade (ambient temperature). Stability is achieved by pre-aging this crystal.

In the past, discrete digital elements were required in the design of a frequency counter. These sub-units were formed of "small scale integration" (SSI) building blocks of individual "diode transistor logic" (DTL) or "transistor-transistor logic" (TTL) circuits. With the advent of "large scale integration" (LSI) circuitry, it is possible not only to include a decade counter and gate within a single chip but also to place the latch circuitry and "light emitting diode" (LED) segment drivers all in one module. A typical example of such an LSI chip is the 7208 manufactured by the Intersil Corp. The maximum signal frequency which a typical LSI decade counter chip can handle is between 6 and 7 megahertz. This device is not designed to handle sinusoidal inputs as are commonly encountered during servicing applications. Also, frequencies up to 600 megahertz are now in common use.

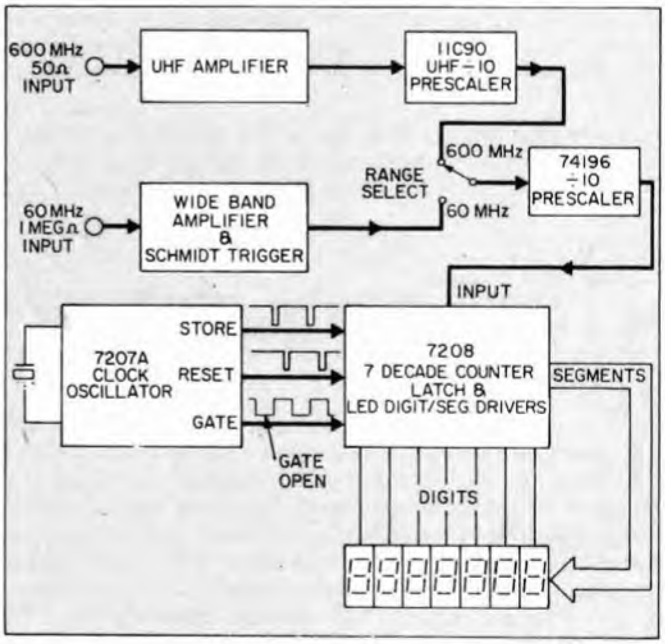
VERY HIGH FREQUENCIES

The usefulness of a given counter chip can be extended by prescalers. A prescaler is a BCD device which counts an input frequency and divides it or prescales it to a desired output frequency. For example, if a 60 megahertz signal is to be counted by a device whose maximum frequency is in the 6 megahertz range, then a divide-by-ten circuit is necessary for useful counts to appear. Prescalers usually are SSI devices which consist of a number of flip flops that divide the incoming frequency, "square it," and present a pulse for every tenth cycle of the original frequency. Extension of the frequency range to the 600 megahertz region can be obtained by coupling additional prescalers that are specifically designed to work at these frequencies. Useful input impedances and high sensitivities are obtained by placing amplifiers in front of the prescaler.

The input impedance of the wide-band mid-frequency amplifier is typically 1 megohm and obtained by bipolar "field effect transistors" (FET's). Amplification is then achieved by a broad band multi-stage receiver that commonly has a Schmidt trigger to "square up" the output.

The advantage of high input impedance in this frequency range is quite evident, since most harmonic oscillators will cease to operate or shift frequencies when loaded by a few thousand ohms. UHF prescalers have reasonable sensitivity without pre-amplification but again some means of impedance matching must be obtained. This is commonly done with a high frequency RF transistor and special UHF techniques to keep self inductance at a minimum and prevent possible attenuation. High input impedance in the UHF/VHF range is not desirable since the reactance of shunt capacitance is present in coaxial input cables, jacks, and various leads. Therefore, a nominal input impedance of 50 ohms is used for counting in the UHF/VHF range.

PRESCALER AMPLIFIERS

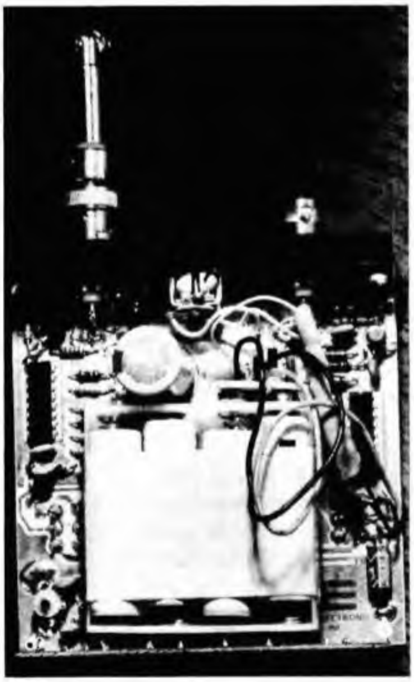


CHOOSING A COUNTER

Frequency counters are available both in kit and assembled forms and, depending on the price range, various options are available including initial zero suppression, gate indicators, AC and portable DC operation, attenuators, and temperature compensation of the crystal oscillator.

Any counter will perform properly when connected to the output of a pure sine wave signal generator. In many instances, however, frequency measurements must be made on complex electrical signals. In general, a signal may have an irregular wave shape containing noise and

The MAX 100 from Global Specialties Corp. is a portable eight digit counter for field or lab use. Range is 20 Hz to 100 MHz. Suggested retail is $149. Circle 64 on Readers Service Card.



The Optoelectronics Model 7000 is a very compact Frequency Counter kit with seven digits and a resolution of 10 Hertz up to 60 Megahertz. It covers up to 550 Megahertz. This photo shows the upper side of PC board, including the battery pack. A good amount of wiring mounts on the other side of the board too. Price is $99.95. For more information circle 68 on the Readers Service Card.

harmonics. It may also be combined with higher and/or lower frequency signals of reduced amplitude. When noise spikes and interference are present, the count may appear unstable and a significant amount of error can result. Noise or interference therefore can be seen by the counter as a signal and an erroneous reading may occur.

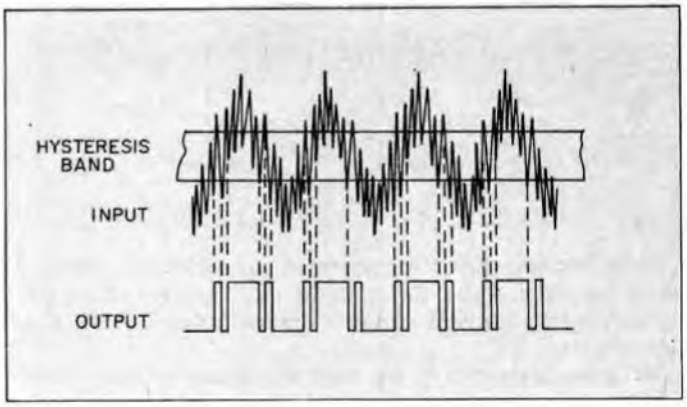
THE WRONG NUMBERS

Some inexpensive frequency counters have a remarkable tendency to display totally inaccurate counts that are both stable and reproducable. This condition can occur when the input signal level is just below the counter's sensitivity threshold. The counter's input amplifier tries to amplify and convert this low level signal into a countable square wave. Unfortunately there may be no indication when this condition occurs because the frequency displayed can be higher, lower, or fairly close to the actual frequency. Some high priced counters have a feature called clean drop-out, where all zeroes are displayed whenever the input signal is less than the counter's sensitivity threshold. Special precautions must therefore be taken when using inexpensive counters and measuring complex signals that are at or just above the threshold sensitivity. Accurate measurements can only be made with some knowledge of the counter's characteristics.

Most counters use Schmidt triggering circuits to "square up" input signals before counting takes place. Such a trigger has a hysteresis band between triggering points. Counter circuits usually trigger on the trailing edge of a square pulse.

Commonly used methods to prevent these problems consist of attenuation of the signal with significant noise, removal of dc components, increasing the signal to the counter when there is significant harmonic distortion, and eliminating ringing by the proper selection of a series damping resistor. Analyzing a few of these methods may prove useful in developing a practical approach to the problem of frequency measurement.

DERIVING SQUARE WAVES



COUPLING

Let us assume that we have a signal that has ringing. This ringing will cause false triggering at every crossing of the hysteresis band as shown.

A series damping resistor which acts as a low pass filter will effectively diminish the amplitude of the rining while leaving the basic frequency of the fundamental component unchanged.

The effect of such a series damping resistor can be analyzed as follows: for frequencies less than 60 megahertz, most counters have an input impedance of approximately one megohm and require a 10 millivolt signal for a consistent count.

The easiest method of coupling an unknown signal to the counter is by means of a short length coaxial cable. A 2½-foot length of coaxial cable has a shunting capacity of approximately 80 picofarads. The input capacitance of most counters is approximately 20 picofarads. Since these two capacitances are in parallel, the total capacitance seen by an external load is approximately 100 picofarads. A simple resistance in series with the coaxial cable will form a voltage divider. The voltage across the shunt capacitance would be equal to:

$$V_{counter} = V_{signal} / (R_{Damping} WC + 1) \text{ where } W = 2\pi f$$

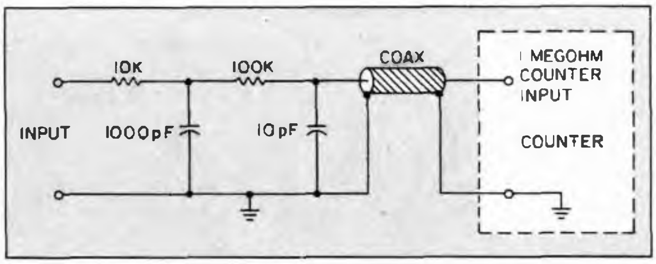
Maintaining a voltage of approximately 10 millivolts across the input of the counter will then require a damping resistance of the order of

$$R_{Damping} = V_{signal} / WC \times 10^2 \text{ if } V_{signal} >> 10^{-2} \text{ Volts}$$

A good compromise is to place a ten thousand ohm resistor in series with the coaxial cable for adequate damping of most signals.

When signals in the audio range are analyzed, a more elegant low pass filter should be placed in series with the probe. A two-stage filter with a 12 dB per octave final band pass attenuation is seen in the next figure.

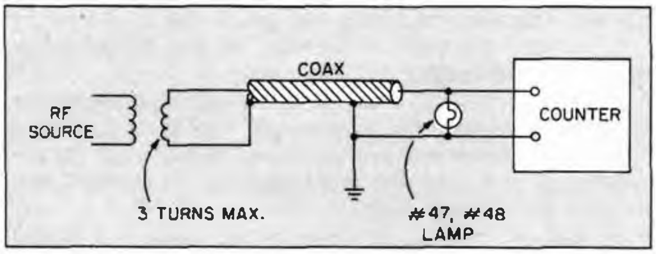
LOW PASS PROBE



Here, the two cut-off frequencies are arbitrarily chosen at 10 kilohertz and 100 kilohertz and may be changed by varying the resistor-capacitor combinations of (R_1, C_1) and (R_2, C_2).

RF measurements in the high frequency to ultra high frequency range can be accomplished either through use of small whips, "rubber duck" antennas, or more elaborate coupling techniques. Feed-through terminators such as the Heath SU 511500 or Hewlett-Packard 10100-C are specifically designed to couple a counter to an RF source. A home brew RF coupling technique is shown in the following diagram.

RF PROBE CIRCUIT



Three turns of number 18 gauge wire is fed by a suitable length of coaxial cable that is terminated in a number 47 lamp. This lamp will act as a 50 ohm termination for the coax. Such a scheme will work at the counter's one megohm or 50 ohm input impedance sources.

PUTTING THEM TO WORK

Now let's look at a couple of practical applications of frequency counter techniques. You are a licensed technician and a citizen's band transceiver is brought to you because of claimed frequency deviation from the desired channels. All frequencies have been found to be in error by the user. The frequency counter can make your trouble shooting much easier.

First, using an RF probe and having the transmitter keyed, the frequencies of the various channels can be measured. If an error exists and the channels are 10 kilohertz apart, then the problem is not in the dividing circuit of the phase lock loop circuitry but rather in one of the harmonic oscillators. On the other hand, if the frequencies are not ten kilohertz apart, the problem is in the phase lock loop circuitry.

The proper probe for measuring the frequency of an oscillator consists of a voltage divider formed of two capacitors. If one uses a high impedance probe directly, the oscillator may be loaded down and a false reading obtained. As we have discussed, 10 millivolts are required for accurate counting. Since the impedance of a 2½-foot long piece of 52-ohm coaxial cable combined with the input capacitance or shunting capacitance of the counter is a total of 100 picofarads, a 5 picofarad series capacitor will form a 1/20th voltage divider which should convert each volt of oscillator signal to a 50-millivolt signal across the input of the frequency counter.

If the problem is with the balanced mixer circuit, and the first IF frequency of the transceiver is known, the balanced mixer oscillator should be adjusted accurately to this frequency. If the problem is with the phase loop oscillator, then the reference oscillator should be checked and adjusted. By using these techniques, accurate frequency alignment can be made within 60 hertz with commonly available counters and 6 hertz in counters with temperature control units.

Another application would be to measure the frequency response of an audio amplifier. With a suitable low pass filter installed in series with the input probe, an inexpensive audio oscillator can be made of a pair of moderately priced operational amplifiers. The RC oscillator need not be calibrated since the frequency counter will serve as the reference for your measurements. A simple audio volt meter can then be used to measure the amplitude variation as a function of frequency. The frequency counter therefore has allowed an inexpensive device to become a very accurate frequency generator.

Similar technique can be used to calibrate AM and FM receivers. Low cost oscillators can be made from UHF and VHF transistors or TTL circuitry. The output of these inexpensive RF sources is then fed into the frequency counter and circuit to be aligned. The accuracy of these frequencies is determined by the accuracy of the frequency counter. IF and RF frequency circuits can be aligned by monitoring the AGC voltage, audio output, or signal strength on the output meter of the receiver. This technique can also be used to evaluate and adjust sonar, depth finders, and fish finders. From the above discussion, it is clear that any inexpensive signal generator becomes a precision piece of equipment when it is used in conjunction with a frequency counter.

Frequency counters may also be used as signal detectors. Present day state-of-the-art devices have sensitivities in the order of 10 millivolts for signals of from six hertz to sixty megahertz. Therefore, they may be used to detect strong sources of RF radiation, trouble shoot individual oscillators in a given complex piece of equipment, or even detect the source of unwanted, spurious, or parasitic oscillations.

Thus, it is clear that a modern portable inexpensive counter is an indispensable tool to anyone interested in electronics. Considering their capabilities, frequency counters are a splendid "buy" and in kit form within the pocket range of most hobbyists. They are accurate, stable, sensitive, and compact, and their number of uses are only limited to the imagination of their user. Creative designers and LSI circuitry have thus opened another door in the development of imaginative electronics. ■

ETH Guide to Using Tune-Up Instruments

Learn how to use the basic tools of the automotive tune up

When one hears the words "engine tune-up," they usually bring to mind an automotive service which can result in a bill approaching $100.00 or more. As a result, many of us are content to forget about this facet of automobile maintenance until we are forced to do something because the engine runs very poorly or not at all. The irony of this situation is that while the engine is in such bad condition, it's costing you money in excessive gasoline consumption. Automobile tune-ups are not complicated, and the investment in parts is so small that there really is no reason why anyone, especially anyone who has a serious interest in electronics, should drive a car that is badly in need of a tune-up. The purpose of this article is to discuss the elements which comprise an engine tune-up, and to discuss some of the various electronic instruments which are being used by both professional and amateur car mechanics alike.

If possible, you should refer to the automobile manufacturer's specifications and tune-up procedures as a supplement to the information provided by this article. At the very least, refer to the tune-up information which is contained on a decal and prominently displayed in the engine compartment of your car. This will give the proper specifications for ignition timing, spark plug gap, and idle speed adjustments.

Tachometer. The basic automobile tune-up instrument is a combination tachometer and dwell meter, which is commonly referred to as a "dwell/tach." This instrument is capable of measuring engine RPM, and in those cars which are not equipped with factory installed electronic ignition, point dwell. (More about dwell later). The more elaborate instruments also include additional functions, such as voltage measurements, resistance measurements, and current measurements. For a small additional cost, some instrument manufacturers have included an alternator test function which determines the condition of the alternator diodes by measuring the level of AC ripple voltage appearing on the alternator output terminal.

The tachometer section of the dwell tach measures engine RPM by responding to the pulses which appear at the distributor side of the ignition coil (negative terminal). This is the point where the sensing lead of the instrument is connected. Referring to Fig. 1, a typical schematic diagram of a conventional (non-electronic) automotive ignition system, note that each time the points open, the collapsing magnetic field of

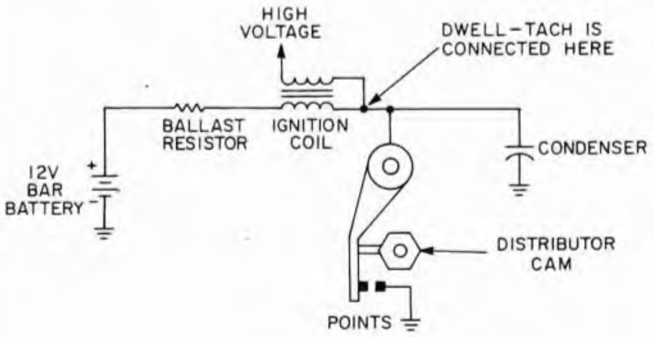


Fig. 1. A simplified schematic of an automotive ignition system using mechanical points (not electronic or "breakerless.")

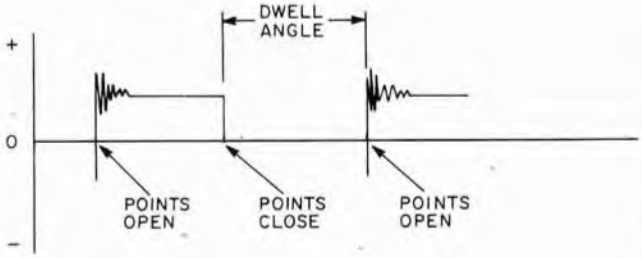


Fig. 2. This is a waveform representation of what occurs as points open and close. Dwell measurement is by averaging.

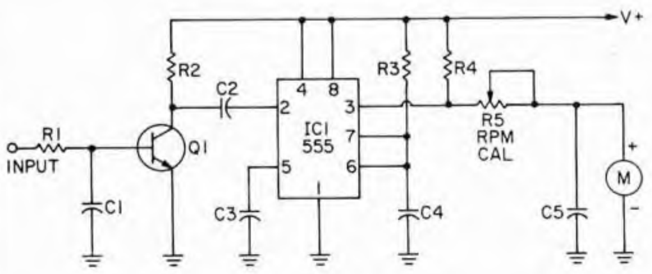


Fig. 3. This is a schematic of a simplified tachometer. It operates by counting pulses which appear at distributor side of coil.

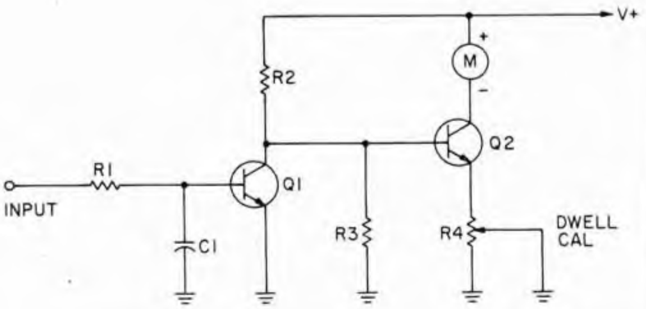


Fig. 4. This simplified dwell meter operates by reading voltage which is inversely proportional to that seen across the points.

the coil produces 20,000-volts or more at the secondary of the coil, and 100-volts or more at the primary. Fig. 2 illustrates the waveform appearing at the primary of the ignition coil, which is the voltage across the points. Since engine RPM is directly related to the number of pulses-per-second at the ignition coil, it can be seen that a simple frequency-to-voltage converter circuit can be used to measure engine RPM.

Fig. 3 is a typical schematic diagram of a tachometer circuit. Each time a pulse appears at the input to the circuit, Q1 conducts current and feeds a negative pulse to the trigger input of a one shot multivibrator, U1. The pulse duration of U1, about 4000 microseconds, is fixed. A resistor capacitor network, R5/C5, acts as a low pass filter to smooth the voltage pulses fed to the meter. The meter responds to the average of the voltage generated by U1, and is calibrated in RPM. Since the number of pulses-per-minute generated by 4, 6, and 8 cylinder engines is not the same, the meter circuit must incorporate a scale factor which automatically provides the correct RPM reading. This is the cylinder select switch which appears on tach's front panel.

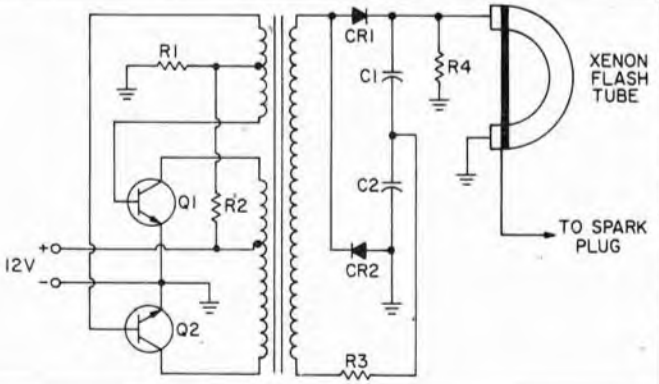
Electronic ignition systems provide a special test point which produces pulses for use with standard automotive tachometers. Refer to the service manual for your car, or ask your dealer for the location of the tachometer connection.

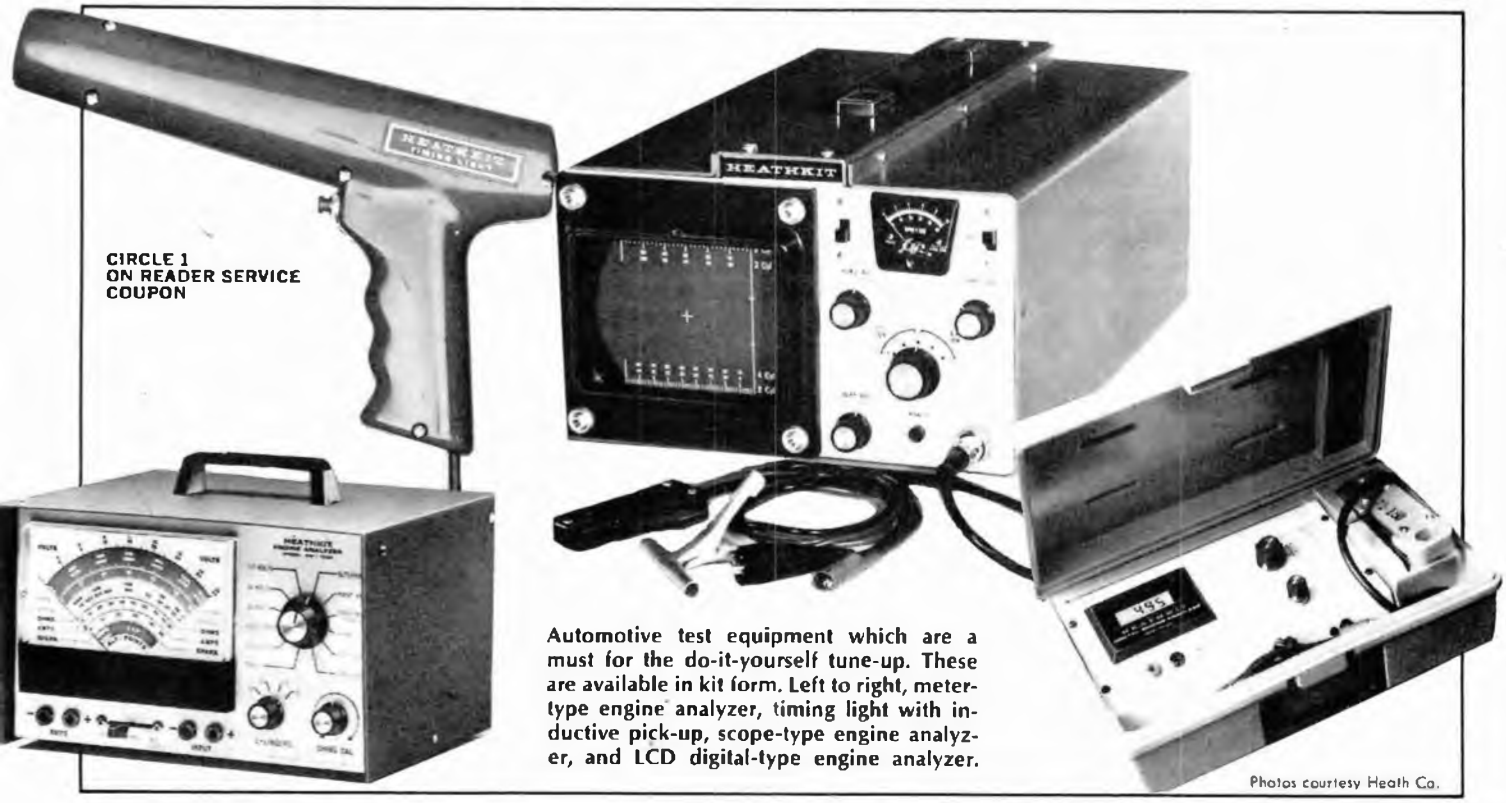
Dwell Meter. Point dwell is a measurement of the number of degrees that the ignition points in non-electronic systems remain closed during the rotation of the rotor in the distributor. This measurement is directly related to the point gap, and is a more accurate method of properly tuning an engine. This measurement is made at the same test point in the system as used for the tachometer connection. Factory installed electronic ignition systems have no points, and therefore no need for dwell measurement.

The number of degrees of point dwell depends on the number of cylinders in the engine. One full rotation of the distributor rotor is 360 degrees, and this is divided up in equal amounts for each cylinder. Thus, an eight cylinder engine can have a maximum point dwell of 45 degrees. 6 and 4 cylinder engines have maximum point dwell angles of 60 and 90 degrees respectively. Proper point dwell angle for these engines is usually slightly more than half the maximum. Typical dwell angles for 8, 6 and 4 cylinder engines would be 28, 36 and 56 degrees respectively.

The dwell meter measures dwell angle by producing a meter reading which is inversely proportional to the average voltage across the points. One such circuit that does this is shown in Fig. 4. The voltage appearing at the points is fed to the base of Q1, so that it is cut off when the points are closed, and saturated when the points are open. The collector of Q1 controls the base of Q2 which is connected as a constant current generator. Meter current is adjusted to full scale value (45, 60 or 90 degrees) by R4 when the sensing lead at the base of Q1 is shorted to ground, simulating closed points. As the points

Fig. 5. A timing light uses a DC-to-DC converter to obtain the necessary high voltage used to trigger the flash tube. Stroboscopic action freezes flywheel motion to observe camshaft/valve timing.





Automotive test equipment which are a must for the do-it-yourself tune-up. These are available in kit form. Left to right, meter-type engine analyzer, timing light with inductive pick-up, scope-type engine analyzer, and LCD digital-type engine analyzer.

Photos courtesy Heath Co.

Tune-Up

open and close at a rapid rate when the engine is in operation, the meter reading becomes the average of the two conditions and is the actual dwell angle of the points.

Timing Light. One final electronic instrument which is required for engine tune-up is the timing light. Quality timing lights are referred to as "power" timing lights, which means that the energy which fires the xenon flash tube is derived from a built-in power supply. Most units in use today use the car's 12-volt battery as the source of power. Refer to Fig. 5 which is a typical timing light schematic diagram. A DC to DC converter circuit charges two capacitors in a voltage doubler circuit to the high voltage (250 to 450-volts) necessary to fire the flash tube. The spark voltage generated by the car's ignition system provides the trigger which causes the flash tube to conduct, producing a burst of light perhaps 1/1000 second in duration. The car manufacturer has provided a timing mark on the flywheel of the engine, and a timing scale next to the flywheel. When spark plug number one fires, the stroboscopic action of the timing light enables the mechanic to visually determine if the flywheel is in the proper position. This shows engine timing.

The best timing lights on the market provide inductive coupling to the spark plug wire so that it is *not* necessary to insert an adapter in series with the distributor wire and number one spark plug. Spark plug wires must never be pierced to make a timing check. To do so will render the wire defective.

The Engine Tune-Up. In addition to making the electrical measurements described above when tuning up an engine, there are certain mechanical procedures which must be performed to do a complete job. These procedures should be performed before making any electrical measurements or adjustments.

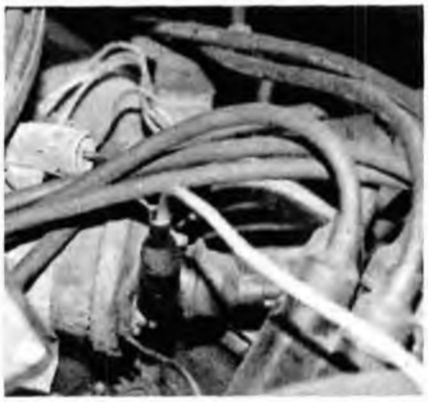
A complete and proper engine tune-up will include replacing spark plugs, ignition points, and condenser (if so equipped). In addition to these items,

Almost all pre-1975 Delco (GM) distributors have a window through which point gap (dwell) can be adjusted while engine is running. This saves the time needed to remove cap and rotor to reset gap.

the distributor cap, rotor, fuel filter, and PCV valve should be either replaced or examined to make certain that they are still in serviceable condition. The air filter and crankcase ventilation filter should also be cleaned or replaced as necessary. The last item on this list are the carburetor and choke linkages, which should be cleaned with a carburetor spray product made for the purpose. Once these procedures have been completed, you are ready to perform the instrument checkout.

The electrical checkout of the engine is made with the engine running and warm. On those cars which use ignition points, it will be necessary to set the point gap to the proper spacing so that the engine can be started. The only exception to this is on General Motors cars which use external adjustment Delco Remy distributors. Replacement points in these distributors usually are preset to such a gap that will permit the engine to be started without any prior adjustment.

A word of caution before making the instrument checkout of the engine: At no time should you permit your hands to come in contact with the metal portion of the test instrument's clip lead as you are connecting or removing it from the engine, if the engine is running. The test point may have sufficient high voltage to cause electrical shock. This may result in personal injury as you jerk your hand away. If in



The input lead to the Dwell/Tachometer is connected to the distributor side of the coil. You can find this terminal by tracing back the wire from the condenser to the coil. Clip on the lead at the coil terminal.

doubt, make your connections with the engine shut off.

Dwell Angle. The first measurement and adjustment to be made is dwell angle, which is necessary on all cars that have conventional (non-electronic) ignition systems. Attach the meter leads to the distributor side of the ignition coil and chassis, observing correct polarity. On negative ground automobile electrical systems (as in all American made cars), the positive lead of the meter is connected to the ignition coil. Follow the meter manufacturer's instructions for dwell measurement, and refer to the decal in the car engine compartment for the permissible range of dwell. If your measurement falls out of this range, the point gap will have to be decreased (for readings too low) or increased (for readings too high). On most General Motors cars,

With cap and rotor removed on this Delco distributor, the point gap adjusting screw can be seen. Lift the window in the distributor cap and you can turn this screw to perform point gap (dwell) adjustment.

This is a typical ignition tune-up kit for a 4-cylinder car. From left to right: distributor cap, rotor, spark plugs, points, and condenser.

this is a simple adjustment which can be made with an Allen wrench while the engine is running. On other cars you will have to stop the engine, remove the distributor cap, and reset the point gap making it greater or smaller as necessary. Recheck dwell angle with the instrument after readjustment of the point gap.

Timing. After the proper dwell angle has been attained, the ignition timing can be checked and set if necessary. Ignition timing should always be checked after changing ignition points or point gap since any change in dwell angle will cause a corresponding change in timing. Improper timing will affect gas mileage, engine power, and exhaust emissions levels.

Before starting the engine, you can facilitate the timing measurement by cleaning the engine flywheel and locating the timing mark, which is usually a narrow groove impressed in the flywheel. If possible, apply a small quantity of white paint or chalk to this groove to make it more visible. You must also locate the vacuum advance mechanism which is located at the bottom of the distributor housing, and remove the vacuum advance hose which is connected to the mechanism. Plug the open end of the hose with a pencil. This procedure is necessary if the timing of an engine is to be made with the automatic vacuum advance disabled. Check to see whether or not your car requires this procedure.

Connect the timing light to the number one spark plug according to the directions provided by the timing light manufacturer. Connect the timing light power leads to the car battery, observing correct polarity. Check to make sure that no wires will be caught by the fan or other moving parts. Start the engine and measure the timing. Refer to the tune-up decal in the engine compartment, which should have an illustration of the timing scale for your particular engine. If the timing is out of spec, adjustment is made by loosening a clamp at the bottom of the distributor housing and rotating the unit to the correct spot. Tighten the clamp, and recheck the timing to make sure it did not change. Stop the engine and replace the vacuum hose if it was removed earlier.

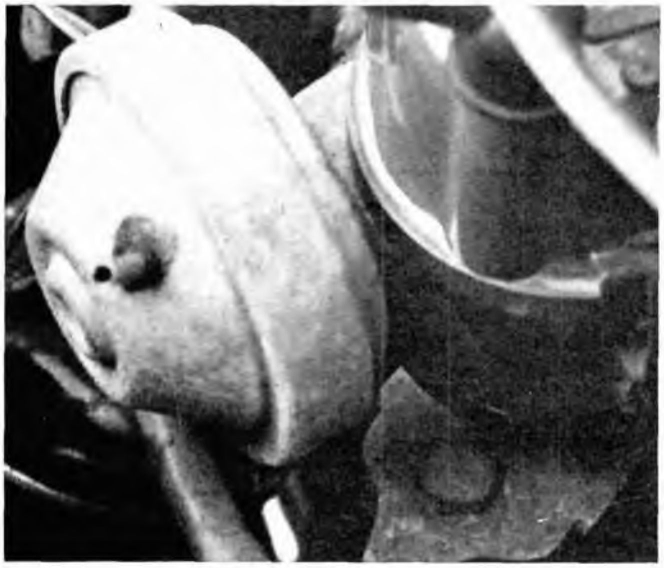
Carburetor Adjustments. All carburetors have some form of adjustment which controls engine idle speed. Single barrel carburetors have one adjustment for idle fuel mixture, and two and four barrel carburetors have two fuel mixture adjustment screws. These adjustments are performed with the aid of the tachometer, since engine RPM will vary as these adjustments are made. Since the order in which these adjustments are performed is important, the best practice would be to follow the vehicle manufacturer's sequence. Some tune-up decals in late model cars contain the proper adjustment sequence. The following procedure should prove satisfactory for most cars. Note: Some cars equipped with extensive emission control equipment have plastic caps covering the idle mixture screws, which limit the adjustment range of these screws. Under no circumstances should these caps be removed to set the mixture screws beyond the normal adjustment range. To do so may upset the engine exhaust emissions.

Allow the engine to reach normal operating temperature before adjusting the carburetor. Connect the tachometer to the ignition system according to the manufacturer's instructions so that the meter reads engine RPM. Follow the information provided on the tune-up decal as to whether the transmission should be in neutral or drive, and if the air conditioning or lights should be turned on. (Be sure to set the parking brake securely before placing the transmission in Drive!)

Adjust the idle mixture screw or screws for maximum engine RPM. Do this very carefully since only a small adjustment is usually necessary. Now adjust the engine idle speed adjustment to the engine RPM as specified on the tune-up decal. Very carefully turn the idle mixture screws clockwise to attain a 20 RPM drop in engine idle speed. Reset the idle speed adjustment for the recommended engine RPM.

The method just described is known as the "lean roll" method of setting the idle mixture. With this method, the vehicle exhaust emissions should be within specifications, and it avoids the necessity to use an exhaust gas analyzer for adjustment of the idle mixture.

If you have performed the various engine adjustments as specified, you should have an automobile that performs as well as it was designed. Keep a record of the date and speedometer mileage, so that you will be ready to perform the next tune-up when due. ■



Release the distributor clamp bolt at the base of the distributor to adjust timing. Some engines need to have their timing adjusted with the vacuum advance (round object mounted on the side of the distributor) connected, and some need it disconnected. Check in your owner's manual or with your dealer.

Use of the timing light allows you to freeze the action of the flywheel and read the timing adjustment. A decal under the hood will list number of degrees (either in BTDC or ATDC) to which pointer on the flywheel must point to on scale next to the flywheel. Timing is adjusted by rotating the distributor body.

A Guide to Propagation and

A look at ways to make the most of your DX hunting time in the shack
by Thomas R. Sundstrom

What's the band like? A knowledge of propagation is useful to the SWL and the radio amateur in hunting that elusive DX station. In a period of high solar activity—and 1980 is the peak in the 11-year sunspot cycle—band conditions can become quite variable. With a solar disruption on the sun's surface, blackouts of communication links on earth can disrupt radio worldwide.

The Old Method. The long range forecasts found in magazines, DX bulletins, and newsletters are estimates at best. With some variations, most are based upon projecting current activity against a 27-day solar cycle. For example, a solar flare that disrupts communications today will no doubt have some recurring effects in 27 days from now as the sun completes one revolution.

Long range forecasts are useful to do some long range planning, but current information is better. The National Bureau of Standards station, WWV, broadcasts propagation data at 18 minutes past each hour; the information is updated every six hours at 0000, 0600, 1200, and 1800 GMT.

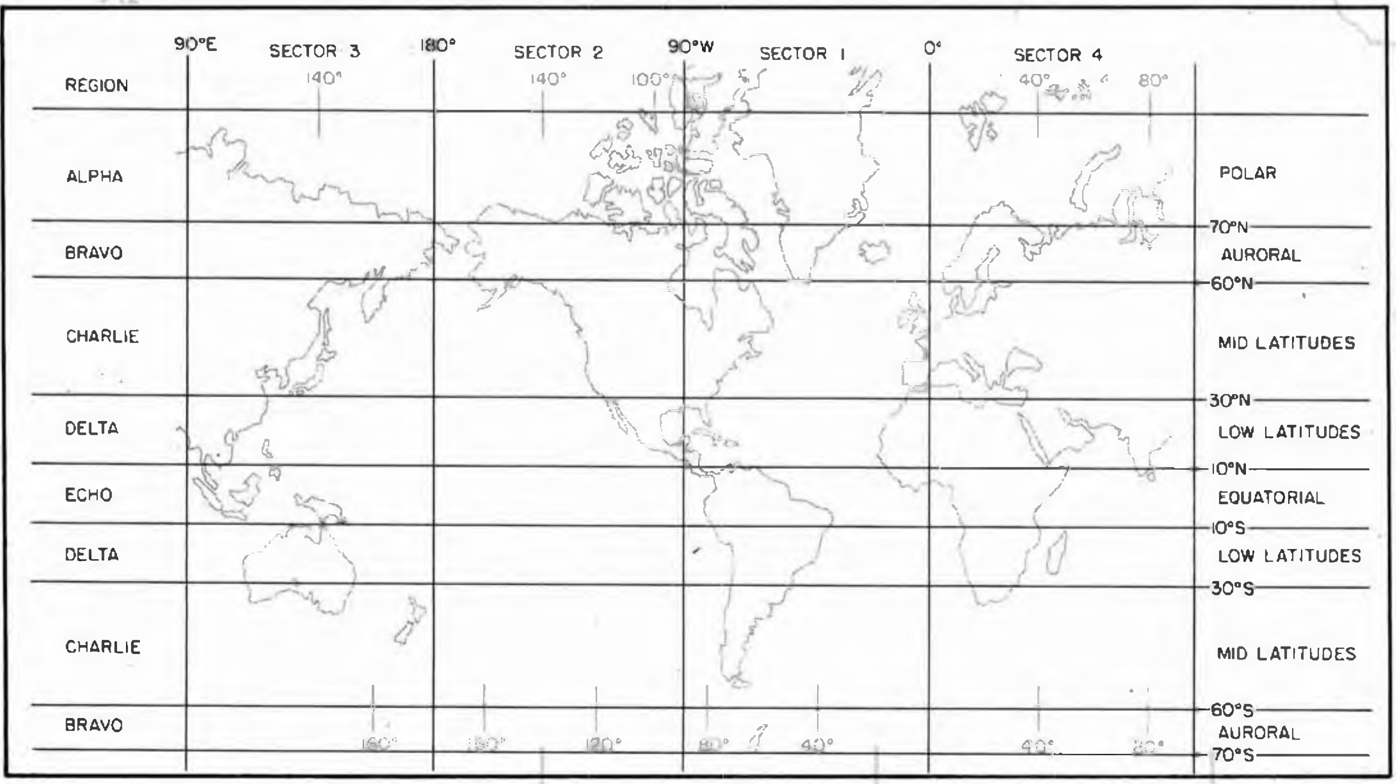
The first part of the WWV message contains a solar flux number (which is correlated to the sunspot number and the maximum useable frequency) and an "A" index (a daily measure of geomagnetic activity); these daily figures are changed at 1800 GMT. The "K" index is changed every six hours and is mathematically related to the "A" index. By tracking the daily flux and "A" over days and months, a relatively clear picture of the cyclical variations on a solar cycle can be seen; try graphing the data. A comparison of the latest "K" with a previous "K" or yesterday's "A" can tell you which way conditions are moving. (See the table.)

Ideally, a high solar flux number (to raise the MUF) and a low geomagnetic activity number (to minimize signal path absorption) should produce the best long-haul signal propagation on the higher bands.

The New Method. There is now a *second* propagation buleltin on the air. This one is aired by the United States Air Force and, like WWV, information is broadcast 24 hours a day, 7 days a week. Unlike WWV, however, the bulletin is aired twice an hour.

The USAF calls the broadcasts "Beer Can." The information is in coded form, and depends upon prior knowledge of the USAF operator to know what the predicted maximum useable frequency and optimum working frequency (90% of the MUF) were through previously supplied 30-day forecasts.

The "Beer Can" broadcasts occur at 15 and 45 minutes past the hour on 4590, 7540, and 13993 kHz on upper sideband (USB). The content of the bulletin is revised at 0000, 0600, 1200,



This mercator world projection shows the regions and sectors into which the Air Force has divided the world for purposes of the propagation forecasts. The phonetic sectors read downwards on the outside margins, the numerical regions read across the top.

Band Condition Reports

TABLE OF "A" AND "K" INDICES

A	K	Geomagnetic activity classification
0	0	Quiet
3	1	Quiet
7	2	Quiet
15	3	Unsettled
27	4	Active
48	5	Minor geomagnetic storm
80	6	Major geomagnetic storm
140	7	Major geomagnetic storm
240	8	Major geomagnetic storm
400	9	Major geomagnetic storm

The WWV propagation broadcasts include both the A and K indices for calculations of the relative levels of geomagnetic activity.

and 1800 Zulu. Station AGA3HQ (Scott AFB, IL) broadcasts first, followed a minute later by station AIR (Bolling AFB, MD).

As the general public doesn't have access to the USAF long range propagation forecasts, we can substitute the WWV data recorded over a period of days and months and draw approximations from the flux data.

"Beer Can" broadcasts are divided into three parts: the maximum useable frequency, solar anomalies, and other phenomena. See the table for a full breakdown on their contents.

Part I of the broadcast will always be aired. Either *regions* (defined by horizontal latitudes) or *sectors* (defined by horizontal latitudes *and* vertical longitudes) may be referenced. The grid system and boundaries are illustrated by the map in Fig. 1.

Parts II and III will only be aired on an *exception basis;* either regions or sectors may be referenced.

DECODING TABLE FOR "BEER CAN" MESSAGES

PART I	**THE MAXIMUM USEABLE FREQUENCY VALUE CODE**
Sierra	Path MUFs Normal
Tango	Path MUFs High to 25%
Uniform	Path MUFs High to 50%
Victor	Path MUFs High to 75%
Whiskey	Path MUFs Low to 10%
X-ray	Path MUFs Low to 25%
Yankee	Path MUFs Low to 50%
Zulu	Radio Blackout
PART II	**SOLAR ANOMALY STATUS CHART**
Hotel	Probable significant SID (sudden ionospheric disturbance) of up to 30 minutes duration in sector ____ starting ____ hours Zulu time.
India	Probable significant SID of up to 1 hour duration in sector ____ starting ____ hours Zulu time.
Juliett	Probable ionospheric storm/PCA (polar cap absorption) of under six hours duration in sector ____ starting ____ hours Zulu time.
Kilo	Probable significant ionospheric storm/PCA of over six hours duration in sector ____ starting ____ hours Zulu time.
PART III	**OTHER PHENOMENA CHART**
Oscar	Moderate intensity Sporadic E in sector ____ starting about ____ hours Zulu time.
Papa	Blanking Sporadic E in sector ____ starting about ____ hours Zulu time.
Quebec	Significant radio noise in sector ____ starting about ____ hours Zulu time.
Romeo	Significant fading occurring in sector ____ starting about ____ hours Zulu time.

This is the table used for decoding the phonetic symbols used in the Air Force's Beer Can propagation broadcasts. Each part has its own phonetic code alphabet characters.

An actual broadcast at 2015 GMT:

BEER CAN BEER CAN THIS IS AGA3HQ
ALPHA GOLF ALPHA THREE HOTEL QUEBEC
DO NOT ANSWER DO NOT ANSWER
ONE SIX ONE EIGHT ZERO ZERO ZULU BREAK BREAK
BRAVO THREE TANGO
QUEBEC ALPHA BRAVO ONE EIGHT
ROMEO ALPHA BRAVO ONE EIGHT
BREAK AGA3HQ OUT

Cracking the Code. Let's decode the message using Fig. 1 and the table. The message was prepared on June 16 (ONE SIX) at 1800 GMT (ONE EIGHT ZERO ZERO ZULU); note that the month is not given.

The signal path with a reflection point in the auroral zone over Siberia will handle frequencies up to 25 percent greater than the forcasted MUF; the rest of the world is "normal." The two part III messages indicate radio noise and signal fading worldwide (if just a sector or two were involved, a number of one, two, three, or four would have followed ALPHA or BRAVO) in the polar and auroral zones, commencing at 1800 GMT. Note that the last two numbers in the part II and III messages refer to the GMT hour.

This data, coupled with a solar flux that had been dropping for a couple of days (down to 161) and an "A" index of 18, would indicate no polar path signals and marginal and noisy signals from the middle and low latitudes.

Other examples to consider. if there is a part II message of HOTEL or INDIA, one would look for a JULIETT or KILO message in the next day or two. Coupled with that, VHF DXers of either the TV channels, the public service bands, or the 50 MHz amateur band, should be on the lookout for an OSCAR or PAPA message in sector CHARLIE ONE or CHARLIE TWO (for the United States and Canada).

A part II message of KILO CHARLIE ONE TWO THREE would decode to a probable ionospheric storm of more than 6 hours duration beginning at 2300 GMT in the sector over the east coast of the United States, the Atlantic, and extreme western Europe. That would be a good time for U.S. amateurs to start looking for DX out of South America, in a direction unaffected by the storm.

In conclusion, the "Beer Can" broadcasts can be very useful in short-run forecasting for the active DXer. The WWV data and the "Beer Can" data provide an instant picture of band conditions. Take a listen; it's a more efficient use of time than tuning randomly around the bands. ■

DESIGNING REGULATED POWER SUPPLIES

You don't have to have a degree to design the power supply you need

UP UNTIL A FEW YEARS AGO, the task of designing a regulated power supply was both complicated and time-consuming. As a result, the average experimenter either made do without regulation or copied someone else's circuit. Things have changed a lot since then. Now, even a beginner can design his own regulated supply using one of the integrated-circuit voltage regulators. No fancy oscilloscope is necessary; in fact, you don't even need a calculator. Simply by consulting the tables and graphs in this article, you can custom-design your own regulated supply in a matter of minutes.

The supplies to be covered here range in output from 5 to 18-volts at currents up to one-ampere. Both positive and negative outputs are possible. Let's start by examining the basic positive-regulator circuit shown in Figure 1. Voltage from transformer T1 is full-wave rectified by diodes D1 and D2, and smoothed by filter capacitor C1. Voltage regulator VR+ converts the unregulated DC across C1 into a regulated potential of the desired size at its output, pin 2. Capacitor C2 bypasses this output and thereby stabilizes the circuit and improves transient response. On the primary side of T1, fuse F1 protects the circuit should a malfunction cause excessive current to be drawn from the AC line.

Similar, But Not Equal. The similarity between the positive-supply circuit and the negative-supply circuit (Figure 2) is apparent. Note, however, that D1, D2, C1 and C2 are reversed in the negative circuit. Furthermore, the pin designations of negative regulator VR– are different from those of positive regulator VR+. For the positive regulator, pin 1 is the input, while pin 2 is the output, and pin 3 is ground. On the negative regulator, however, pin 1 is the ground connection. Pin 3 is now the input, and pin 2 remains as the output of the voltage regulator.

Both the positive and negative regulators are available in two case styles, a "T" package and a 'K' package; see the base pin diagram.

Regardless whether a regulator is positive or negative, the same pin-numbering scheme applies. Remember, however, that the numbers have different meanings for positive and negative regulators. For example, on the "T" package, pin 3 is always the middle pin. If the regulator is positive, the middle pin is ground. But if the regulator is negative, then the middle pin is its input.

In the design procedure to follow, the same tables and rules will be used to specify F1, T1, D1, D2, C1 and C2, whether a positive or negative supply is being built. This is certainly reasonable since the two circuits are so similar. However, the positive and negative supplies must use different types of regulator ICs, and these may not be interchanged. With all the preliminaries out of the way, let's get down to the basics of this easy seven-step method for designing the supplies.

Determine the Required Voltage. You have your choice of seven positive voltages and seven negative voltages, as shown in the middle column of Figure 6. Note that +10V has no negative counterpart. Be sure that you know the *maximum* current that your load can draw; it must be no more than one ampere. If you are powering a construction project or a kit, you should find a supply-current specification somewhere in the literature. If you have no idea as to how much current your intended load will draw, you can measure it directly. Connect the device you intend to power to a variable bench supply set to the desired voltage. Measure the current drain with an ammeter in series with one of the power leads.

Select a Transformer. Refer to Figure 6, and locate the desired output voltage in the middle column. For a positive supply, you will find the necessary transformer listed in the hight-hand column, and in the same row as your selected voltage. The proper transformer for a negative supply will be found in this same row, but in the column furthest to the left. The transformers are specified according to the RMS voltage from one end of the secondary to the other. Note that all secondaries must be center-tapped (CT). The transformers listed are standard, although they may not seem so if you are accustomed to the usual 6, 12, and 24-volt transformers that flood the hobby market. Finding a source is not hard; check the catalogs of any of the large electronics retailers. At least one transformer company, Signal, will sell you these transformers by direct mail-order. Before ordering, request a catalog and price list (Signal Transformer Co., 500 Bayview Ave., Inwood, N.Y. 11696).

You do have a little bit of leeway in the selection of a transformer, particularly at the higher voltages. If a 34-VCT transformer is called for, and you have on hand one that measures 32-VCT, go ahead and use it. Also, you could hook up the secondaries of two 12-volt transformers in series (and in the proper phase) to obtain the equivalent of a 24-VCT transformer.

In addition to the voltage, you must also specify your transformer's current rating. A convenient rule-of-thumb is to pick a transformer whose secondary-current rating is about 1.2 times the maximum current that is to be drawn from the supply. If you use a transformer whose current rating is too small, it will overheat. On the other hand, if you choose a transformer that can supply much more current than is necessary, it will be bulkier and more expensive than a transformer of the proper size.

Pick a Regulator. Here again, you should use Figure 6. Positive regulators can be found in the column just to the right of the "Output Voltage" column, and negative regulators are just to the left. As you can see, a positive regulator may be chosen from either of two IC families: The 7800 series, or the 340 series. Furthermore, each family comes in either the "T" package or the "K" package. Thus, when selecting a 6-volt positive regulator, you can pick from any of the following: 7806K, 7806T, 340K-6 or 340T-6. If you were looking for a negative 6-volt regulator, the 7900 and 320 families would offer the following candidates: 7906K, 7906T, 320K-6 or 320T-6. Actually, there is no significant distinction between the 7800 and 340 families, nor between the 7900 and 320 families. The "K" package, however, can facilitate high power more readily, so it might be preferred at the higher supply-current levels. On the other hand, the "T" package is probably preferrable if you intend to build your supply on a PC board.

At all but the smallest load currents, these voltage regulators will have to be heat-sinked. This will be covered in more detail later. When you buy a regulator, try to get a specification sheet, too. It will provide you with more complete information on your particular IC.

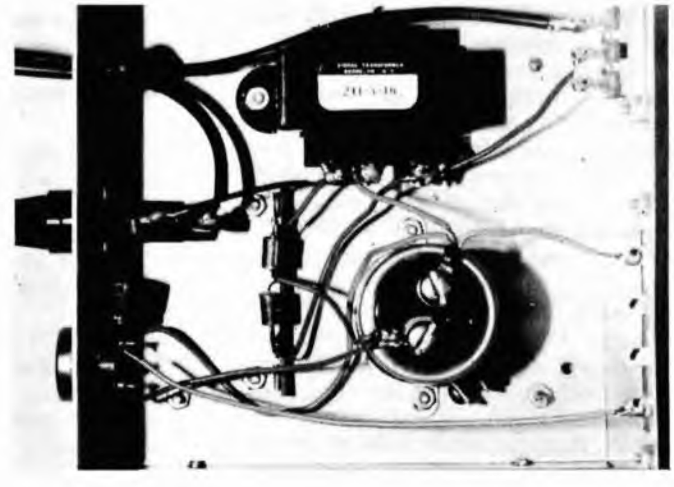
Choose Your Rectifier Diodes. The factors to be considered here are the diodes' voltage rating, average-current rating, and surge-current rating. Since the supply's load current is restricted to a maximum of one ampere, each diode must see an average current of less than half an ampere. Therefore, a rectifier diode with an average-current rating of one-ampere should suffice. A voltage rating of 100-PIV would be adequate, but it is even safer to use diodes with a 200-PIV rating. These will survive most power-line transients. The surge-current rating becomes an important consideration at the instant when the supply is turned on. At that moment, filter capacitor C1 is uncharged. Transformer T1 charges the capacitor with a current through one of the rectifier diodes. Since this current is limited primarily by the small resistance of the transformer's secondary, it is very large. When all of the above factors are taken into account, the 1N4003 emerges as a good rectifier with transformers of 28-VCT or less. Its higher-voltage cousins, the 1N4004 and 1N4005, also will work well. For transformers of 34-VCT to 48-VCT, use a 1N5402 rectifier or a higher-voltage relative (1N5403), etc.). The 1N5402 is a 3-ampere diode that will handle higher surges than the 1N4003. Both rectifier types are readily available from many suppliers, including Radio Shack.

Specifying Capacitor C2. This is easy, since anything greater than 25-μF will be fine. The capacitor's voltage rating should be from 1.5 to 2-times the output voltage of the supply you are building. If a capacitor with too small a working voltage is used, it will not last long. Conversely, using a capacitor with a working voltage greater than twice the supply voltage is wasteful of space and money.

Selecting Filter Capacitor C1. First, determine this component's working-voltage rating from the chart. A range of satisfactory working voltages will be found opposite the transformer voltage that you selected in step 2. Use a filter capacitor with a voltage rating as high as possible within the recommended range of working voltages.

The minimum capacitance of C1, in microfarads, can be found from the graph. Locate your supply's maximum current drain (see step 1) on the x-axis of the graph. Project a line upward to strike the one line (out of the three in the graph) that is appropriate to the transformer voltage being used. The y-value at the point of intersection is the minimum capacitance necessary. Use a standard electrolytic capacitor that is greater than or equal to the value determined from the graph.

In most cases, you can afford to be generous with capacitance. A larger capacitor will have less ripple voltage across it. As a result, it will heat less and last longer. So, when a low-current supply demands only 200-μF, you can



Here's the interior of our "typical" 5-volt power supply. Unless you're the type who likes to dress up all of your projects, these types of power supplies can be assembled in any handy chassis. There's almost never any cause to worry about ventilation, as many of the regulator chips can handle their full-rated loads without even heatsinking!

DESIGNING SUPPLIES

use 500-μF if you like. But when the capacitor must have a high working voltage (50 to 75-volts), extra microfarads come in a bigger package and at a higher price. Therefore, you may not wish to be so generous.

In order to locate a suitable electrolytic capacitor, consult the catalog of a large mail-order supplier, such as Allied or Burstein-Applebee. You will find some electrolytics listed as "computer-grade." These cost a little more, but they last longer in heavy-duty service. Whether or not the extra cost is warranted is a decision that is up to you.

Finding the Right Fuse. The fuse rating table will be of assistance here. Locate the row corresponding to the transformer being used, and the column appropriate to the maximum expected load current. Check the zone in which the row/column intersection lies for the proper fuse rating. Be certain to buy a slow-blow (3AG) fuse, since this type is less prone to blow on the current surge at turn-on.

Now, let's consider a practical design example. Suppose that a 15-volt, 350-milliamp, positive supply is required. The table indicates that a 40-VCT transformer will be needed. Estimate the transformer's current rating: 350 x 1.2 = 420. A look through a transformer catalog reveals the nearest commercially available unit to be 40-VCT @ 500 milliamps.

Referring once more to the table, let's choose a 7815K regulator IC.

Since a 40-VCT transformer is being used, 1N5402 rectifier-diodes are a good choice.

For capacitor C2, let's use a 100-μF unit with a standard working voltage of 35-volts. Because the voltage rating is about twice the supply's output voltage, this is a safe selection.

Figure 4 reveals that filter capacitor C1's working voltage should lie between 40 and 60-volts. Turning to Figure 5, and using line "B," we find the minimum capacitance to be about 750-μF. The nearest commercial unit turns out to be 1000-μF @ 50 volts. You can use more capacitance if desired.

Finally, Figure 3 indicates that a ¼-amp, slow-blow fuse is appropriate for this particular combination of transformer voltage and maximum load current.

Now that you know how to design your supply, let's talk about how to build it. Most manufacturers recommend that a voltage regulator be mounted fairly close to C1. This means 3-inches or less of interconnecting wire. Likewise, C2 should be mounted close by—right on the pins of the regulator, if possible.

Rectifiers D1 and D2 are cooled by heat conduction through the two mounting leads. To assist conduction, mount these rectifiers with short leads. If the rectifier is mounted on a terminal strip, then the lugs of the strip will act to sink some heat. Printed-circuit mounting requires the use of large pads and thick connecting traces to draw heat away from the rectifier's leads.

Be sure that there is adequate air flow around the components of the supply in order to prevent overheating. This applies particularly to the higher-current supplies.

Short, heavy wires should be used for interconnecting components. Again, this is most important for high-current

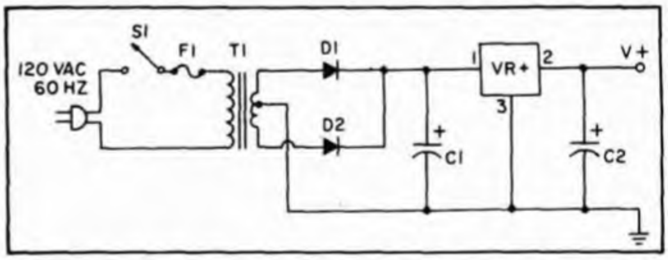


Fig. 1. Here is the schematic for the typical positive - regulated supply. Note the pin connections on the voltage regulator chip.

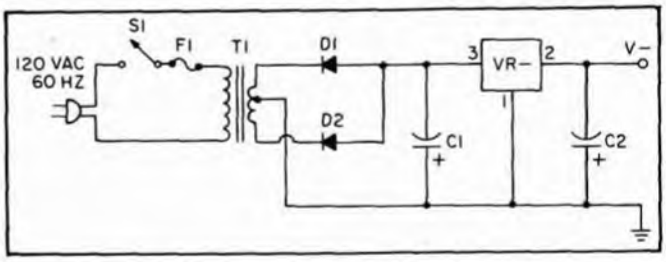


Fig. 2. The negative supply is almost identical to positive, with the exception of the reversals of the diodes and the pinouts of the regulator.

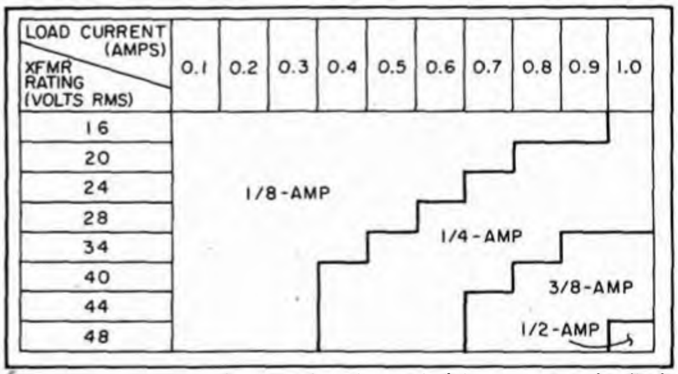
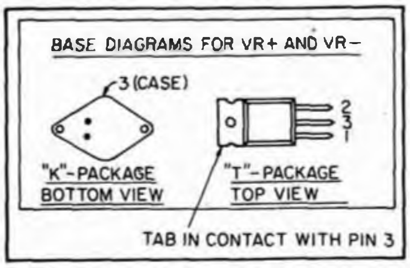


Fig. 3. To calculate what size fuse is needed for your supply, find your transformer's output rating in the vertical column, and your regulator's rating at top. Draw a line out to the center of the chart from each box. Where they meet is the fuse rating in amps.



Above are the pin diagrams for both the "T" and "K" package regulators. Note difference between pos. and neg.

TRANSFORMER RATING (RMS VOLTS)	WORKING VOLTAGE OF C1 (VOLTS DC)
16	16−25
20	25−35
24	25−35
28	30−40
34	35−50
40	40−60
44	50−75
48	50−75

Fig. 4. Simply look across from left to right in order to determine what the working voltage of C1 will need to be.

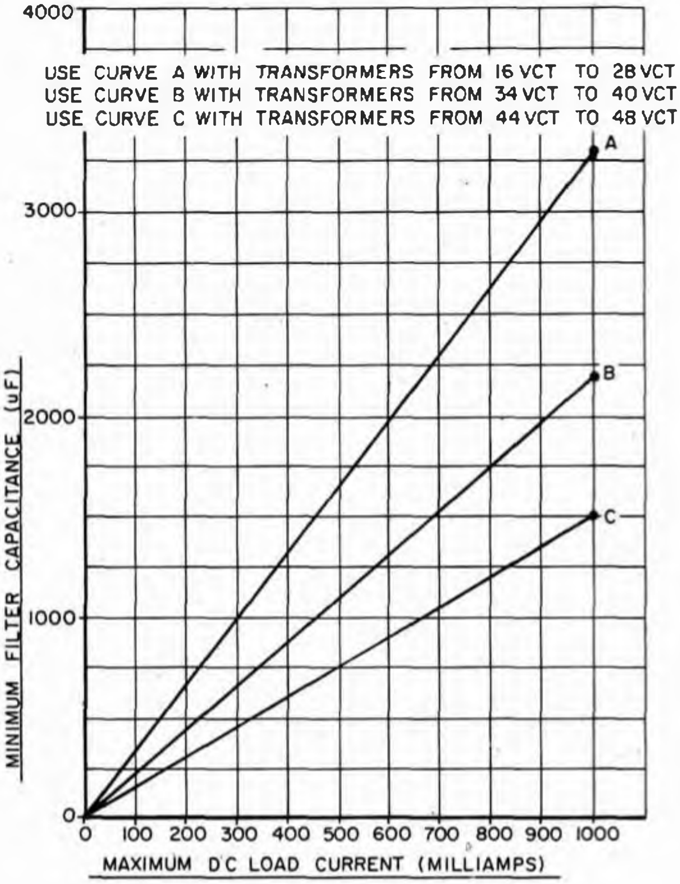


Fig. 5. After consulting fig. 4 for the voltage rating, use this graph to determine the correct capacitance for capacitor C1.

NEGATIVE SUPPLIES			POSITIVE SUPPLIES	
TRANSFORMER (RMS VOLTS)	REGULATOR	OUTPUT VOLTAGE	REGULATOR	TRANSFORMER (RMS VOLTS)
16 ct	7905/320-5	5	7805/340-5	20 ct
20 ct	7906/320-6	6	7806/340-6	20 ct
24 ct	7908/320-8	8	7808/340-8	24 ct
24 ct	7909/320-9	9	NOT AVAILABLE	
NOT AVAILABLE		10	7810/340-10	28 ct
34 ct	7912/320-12	12	7812/340-12	34 ct
40 ct	7915/320-15	15	7815/340-15	40 ct
44 ct	7918/320-18	18	7818/340-18	48 ct

Fig. 6. Here's a listing of the most commonly used transformer and regulator combinations for both positive and negative.

supplies, which should be wired with #16 or #18 stranded wire. Those wires connecting the load to the supply should be as short as possible for the best regulation.

In most instances, voltage-regulator ICs will need to be heat-sinked. There just fine. However, there is an even better, cheaper way to heat-sink a regulator IC: Assuming that the supply will be mounted in an aluminum case, simply attach the regulator to the case. Remove all paint from the area where the IC is to be mounted, and then bolt the regulator to the chassis. Silicone grease between the chassis and the regulator will improve the heat transfer.

If, as is generally the case, the chassis is to be at ground potential, then positive regulators may be mounted directly to the chassis with no difficulty. Negative regulators, however, pose a problem because the mounting flange on both the "T" and "K" packages is connected to the in-

If, as is generally the case, the chassis is to be at ground potential, then positive regulators may be mounted directly to the chassis with no difficulty. Negative regulators, however, pose a problem because the mounting flange on both the "T" and "K" packages is connected to the in-put, not ground. The solution here is to use mica insulating wafers, coated with silicone grease, between the IC and the chassis. Heat will still be effectively transferred, but the mounting flange will be electrically insulated from the chassis.

Once your supply is finished, check it out before permanently wiring it to a load. You will need a dummy resistor to test the supply. Its resistance should be equal to the supply's output voltage divided by the maximum expected output current, in amperes. For the supply that was designed in this article, that amounts to 15/35, or about 43-ohms. The resistance should have a power rating of about two-times the product of output voltage and maximum current. Again, for the supply that was designed here, this comes to 2 x 15 x .35, or about ten-watts. Usually, you can build up such a dummy resistance from series and parallel combinations of lower-wattage resistors.

Connect the dummy resistance across the supply's output terminals, and then connect a voltmeter across the dummy resistance. Turn on the supply. Your

This is a prototype power supply with a "K" package regulator mounted on rear of chassis for heatsinking. Make sure case connection agrees with ground!

meter should indicate the desired output voltage. After a few minutes, *carefully* feel the regulator IC's flange. It should be no hotter than hot tap water. If touching the regulator case is painful, use a larger heat-sink to cool it down.

If, at the end of ten minutes, your supply is still putting out full voltage, and the regulator is not uncomfortably warm, you can turn the supply off. Disconnect the dummy resistance and voltmeter, wire the supply up to its load, and start pumping out those happy amps. ■

Solid State Multivibrators

By any other name there are still three basic types

☐ When the conversation turns from the Mets to multivibrators, you may hear all manner of strange words bandied about. Flip-flop, one-shot, astable, and bistable roll off the tongue of the all-knowing. And don't be too surprised if you hear the words free-running, single-step, and monostable—to name just a few—at your next electrified cocktail party. What do all these terms mean? Are there really so many different kinds of multivibrators? And, for that matter, of what use is a multivibrator for the experimenter?

The main job of a multivibrator is to generate square waves and pulses. Period. That's all!

A square wave is often used as a test signal for audio amplifiers to reveal frequency-response problems. In other applications, multivibrators generate short time constant pulses—only a few microseconds in duration. These mini pulses synchronize, or steady, the picture on our TV screens.

Longer pulses—those which are several seconds in duration—control the exposure time of photographic enlargers. Slow multivibrators can also drive the flashing warning lights seen by motorists as they approach roadside hazards. And, in the radio amateur's shack, faster multivibrators running at audio rates train the ham's eye and ear as he works with his code practice oscillator. Or, the same MV, as the multivibrator is also called, doubles duty as an audio signal source. The list could go on and on.

The uses of multivibrators grow daily, limited only by the ingenuity of those who understand their working principles.

The imposing list of names in the first paragraph creates the impression that there must be almost a dozen different types of multivibrators. Fortunately, this is not so! There are only three basic types. The long list of names merely shows the existence of more than one name for the same type of multivibrator.

The Circuit With an Alias. The three basic types of multivibrators are the *free-running* multivibrator, the *one-shot* multivibrator, and the *flip-flop*. With these three basic circuit types under your belt, you can whip up any of the jobs a multivibrator is capable of doing.

The free-running multivibrator is probably the type most familiar to the experimenter. It is very likely that the square wave generator or oscilloscope on his workbench has a free-running multivibrator buried somewhere in the instrument's circuit. The outstanding characteristic of the free-running multivibrator—and the one from which it earns its name—is that it runs freely. As long as a power supply is connected to it, the free-running MV enthusiastically pumps out a never-ending stream of square waves. This feature consistently earns the title of the Most Popular Circuit whenever John Q. Electronicsbuff needs square waves. See Fig. 1.

In contrast to the free-running MV, the one-shot multivibrator is a very reluctant beast. If fed DC from a power supply, it does not react by joyously bubbling forth a stream of square waves like its enthusiastic free-running cousin. Instead, it sits there, doing nothing.

And, it will continue to sit there unless kicked in the right place by an externally generated pulse, called a trigger pulse.

Under this urging, it reluctantly makes one and only one pulse, and then lapses back into its former sullen condition. Until, of course, it's kicked by another trigger. It derives its name—one shot—from the fact that it gives only one pulse in response to a trigger. See Fig. 2.

Flip Out Forget-me-not. The third type of multivibrator, the flip-flop, is a forgetful fellow. It, like the one-shot, gives no output pulse unless urged by a trigger pulse. But its response to a trigger is quite different. It starts out to produce a pulse, but forgets to end it, unless told to do so by another trigger pulse. Strangely enough, this forgetfulness can be turned into a memory. The flip-flop is the heart of the register system of large computers. See Fig. 3.

How can this be? Because, as Fig. 4 shows, the flip-flop can remember forever (or, at least, until the power is turned off) that a trigger pulse has been applied to it. Using this single basic capability, the registers of giant computers can be constructed.

Some Basic Building Blocks. Circuit diagrams for these three basic multivibrators are surprisingly similar. They're all built from the same basic building blocks. These building blocks are shown in Fig. 5.

The free-running multivibrator combines these basic building blocks. The

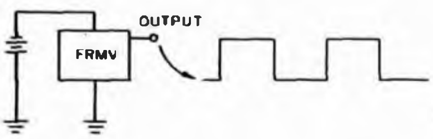
Fig. 1


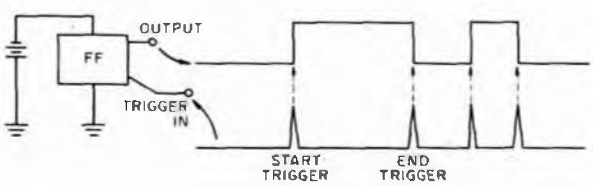
Fig. 3


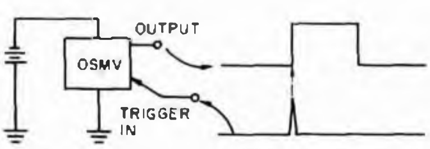
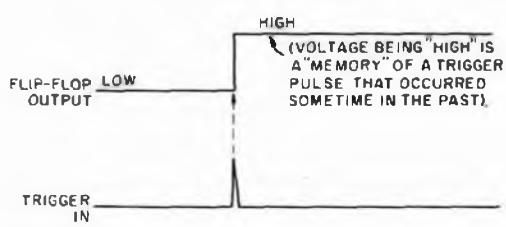
Fig. 2


Fig. 4


component values shown in Fig. 6 will make a free-running multivibrator which runs at 440 Hz. Musicologists know that frequency as A above middle C on the piano.

To double that frequency, cut the values of both coupling capacitors in half; to triple it, cut them to one third the value shown, and so on. To hear the square wave, place an ordinary 2,000-ohm headset across either 1,500-ohm collector load resistor. To see the square wave, connect an oscilloscope to the point marked "output."

The one-shot multivibrator is very similar. It is built from pieces stolen from the free-running multivibrator as shown in Fig. 7 by replacing one of the coupling capacitors with a coupling resistor, and one of the "on" amplifiers with an "off" amplifier.

The values shown produce a pulse two seconds long. To double the pulse length, double the capacitor's value; to triple it, triple the capacitor's value, and so on. To hear the pulse, place an ordinary 2,000-ohm headset across either 1,500-ohm resistor.

Momentarily touch the point marked "trigger in" to the the power supply. A click will be heard in the headphones as the one-shot begins its solitary pulse. Two seconds later, a second click will be heard as the one-shot ends its pulse. (The actual time may be longer, because large-value capacitors sometimes have twice the capacity on their case.)

To see the pulse, connect a voltmeter to the point marked "output." It will indicate –9 volts. Trigger the one-shot as above, by touching "trigger in" to the power supply. The voltmeter's needle will drop to zero volts, remain there for two seconds, and then pop up to 9 volts again.

To change the one-shot schematic to a flip-flop schematic; both pulse amplifiers must be of the biased-off type, and both coupling elements must be resistors. See Fig. 8. To see the action of this circuit, connect a voltmeter to output #1 or output #2—whichever of the two causes the voltmeter to register –9 volts. Leaving the voltmeter connected, short the output to ground. The voltmeter reading will drop to zero, of course, because there is a dead short right across its terminals. But, the surprising thing is that the reading will stay at zero after the short is removed.

Next, short the other output to ground. The voltmeter reading will rise to –9 volts, and stay there after the short is removed, showing that the flip-flop can remember an occurrence (like shorting one output) even after the occurrence is ended.

Kicked by a Trigger Pulse. Of course, shorting an output to stimulate the flip-flop into action is not the same as running it from a trigger. Triggering circuitry can be added to the basic flip-flop as shown in Fig. 9.

So, in spite of the abundance of names, there are only three basic types of multivibrators. Call the MV what you will, but the application of these three types reach through to almost every project the electronics hobbyist is likely to conjure up on his workbench. ■

Fig. 5

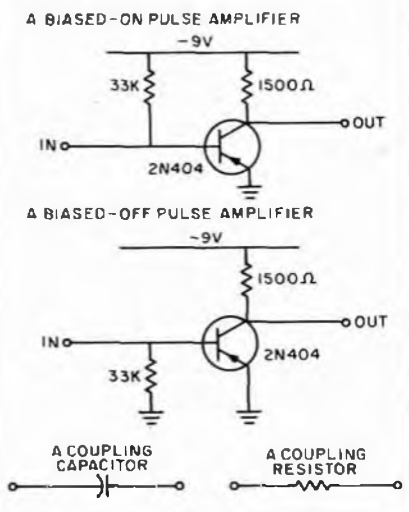


Fig. 6

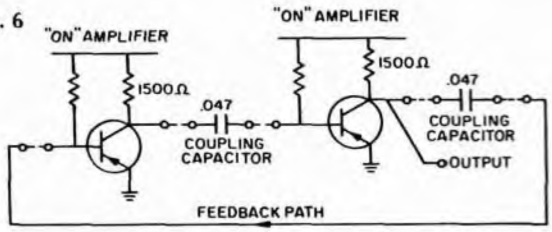


Fig. 7

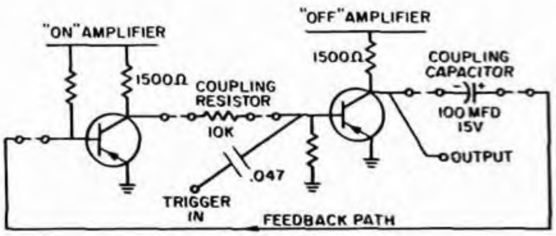


Fig. 8

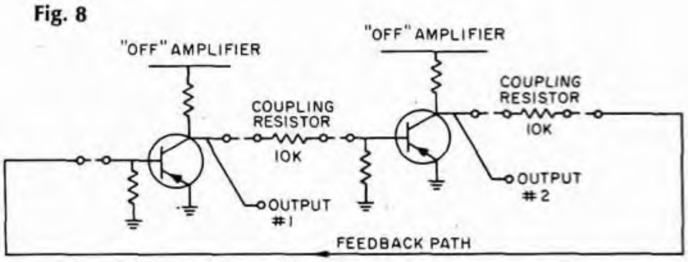
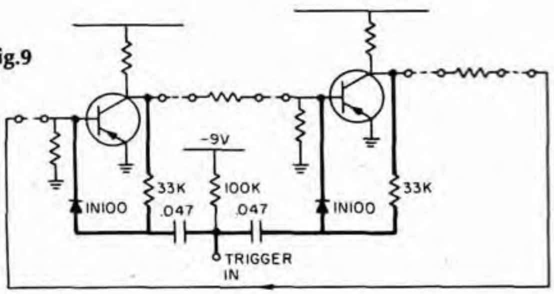


Fig.9



Cut the Cost of TV Repairs

What to do before you call a service technician

☐ Every professional television technician knows that a certain percentage of his service calls are going to be "nuisance calls." There won't be any *real* trouble with the TV set. It will be the simple things: set not plugged in, antenna lead-in unhooked, controls not set properly, and so on. The technicians call these "nuisance" calls because they really are to him. He doesn't like to have to charge you for a service call, but he has to; it costs him money to make it.

If you know how your TV set works, and how to check for the simple things, you can save yourself a lot of time and money. So we'll tell you about all of the nuisance-things, and how to find them yourself. It's easy. We will also tell you how to know when you *should* call a technician; you'll see, hear, and *smell* things that mean trouble. Besides these, we'll tell you several things that you should *not* do, to keep from doing further damage to the TV set. This will be confined to tube and hybrid type TV sets, for the solid-state TV sets can't be serviced by anyone but a pro. However, a whole lot of these tests will apply to all types.

Using the Controls. A lot of this will deal with the various controls on the TV set. We'll tell you how to check these controls for proper operation. You can use these tests to tell whether the set is working or not. In many cases, these controls will have been set wrongly, either by accident or by someone who didn't know how to set them. (Small-type kid brothers are very good at this; for the women's libbers, so are small-type kid sisters!) So we'll tell you how to set them. If you know what each of these controls is supposed to do, you can tell whether the trouble is a simple misadjustment or some real problem in the set. We'll also tell you about the ones you must *not* adjust. Fiddling with these can mean that you will have to have a service call. There are also some conditions that mean "turn it off quick." If the set is left on when these things happen, it can cause more damage, and make the bill higher. We'll get to these later on.

Power. If the complaint is, "The set doesn't light up at all," the first thing to check is the AC line cord. Be sure it's plugged in. Cleaning around the back of the set can accidentally pull the line plug. If the screen of the set doesn't light up, check to see that the pilot light (if any) is on. If it isn't this could mean that there is no power at all getting to the set. Peep in through the holes in the back cover and see if the tubes are lighting up. If they are, but the pilot light isn't on, the pilot light is burned out.

No Light on Screen. If the pilot light is on, but you have no light on the screen, you are getting power to the set. Check the brightness control. Someone may have turned it down too far. If you hear the sound, but the screen doesn't light, this could mean that the brightness control is turned off, or somethings more serious. Here is one of the main "no-nos." If you can get sound, but the screen refuses to light up at all, turn it off *quick*. Leaving a TV set on in this condition can cause quite a bit of extra damage to tubes and parts, in certain conditions. There is one thing you can check: Look on the back of the set for a small red shaft coming out of the chassis, usually near the place where the line cord goes in. This is the circuit breaker. Push this in, and see if this brings back the light on the screen. If so, and it stays on, OK. However, if you push this and the set lights up but goes out in about one minute or less, *don't* push it again. You have some kind of short-circuit in the set, and it will need a service call. Repeated setting of the breaker can cause more unnecessary damage.

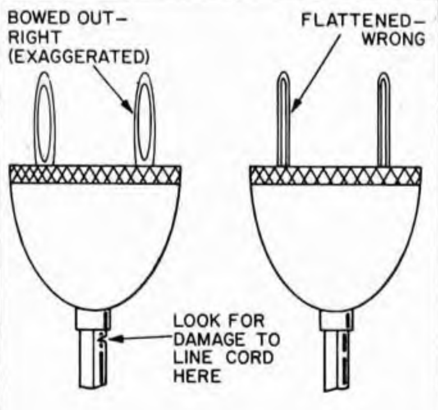


Fig. 1. Prongs of the line plug should have "spring" to make good contact. If they don't, bend them apart with a knife blade.

TV Set Goes Off and On. If the picture, sound, and pilot light go off and on at irregular intervals, check the line cord and the AC outlet. If everything quits at the same time, this is a very good suspect. Hold the plug in the outlet with one hand and move the line cord back and forth with the other. If this makes the set cut in and out, the wires are probably broken inside the insulation. Get a new plug, and cut the line cord at a point about 3 inches from the original plug. Most of these breaks will be right at the point where the wire goes into the plug. Check the other end of the line cord, too. If the break is at the point where the line cord goes into the set, you'll have to have a technician replace it. The "interlock" plug on the set end is molded on the cord and can't be replaced.

There is one other common cause for this. Check to see if the plug fits tightly into the outlet. When you push it in, you should feel a good deal of friction. If it slips in easily it can fall out just as easily. Check the prongs of the plug. Many of these are "doubled" to give a spring action to make good contact. If they're flattened out, push the tip of a knife blade between them, to give them more "spring." Fig. 1 shows how to do this. If the plug is still very loose in the outlet after you do this, the outlet itself is worn out and will have to be replaced. Try the plug of a lamp in the same outlet to find out if it will light up.

Check that Line Cord! While you're working on the line cord, check its condition *very* carefully. You've probably heard of the alarming number of "fires caused by TV sets" in the media. This is exaggerated very badly, but it *is* quite possible for a bad line cord to cause a fire. These are almost always near curtains and other flammable materials, so if they should short, it's easy to start a fire. This is due to deterioration of the insulation of the cord. Pull the plug, and look it over very carefully.

The insulation should be smooth and "live." Bend the cord sharply between your fingers, and check it right at the bend. It the insulation has aged, you'll see fine cracks, or perhaps even breaks, exposing the wires. A line cord which has these conditions must be replaced at once. *Don't* tape it up and leave it; get a new one. Fig. 2 shows how this looks.

Bad Pictures. Now let's look at some of the troubles that you can have. If you do have a picture and sound, but they're not as good as they should be there are several simple things which can cause this. There are several of these which can fake troubles inside the set, and cause you to call a technician. Let's find out about the ones you can check out easily.

One of these is too much snow in the picture. The sound may be all right, or it may have a blowing or roaring sound if the picture is very weak. This can be caused by trouble in the TV antenna or the lead-in. Whether you have an outside antenna, rabbit-ears, or a cable, check the connections on the back of the set. The lead-in connects to two small screws on an insulating panel, usually near the top of the set. If one of the wires is off, you'll get snow. Be sure that the wires are tightly held under the screws. If you have one of the "quick disconnect" antenna connectors, called "clothespins," be sure that this hasn't slipped off. The screws should be loosened about two turns so the clothespin can get a grip on them. Most sets now have two sets of antenna connectors, one for VHF and the other for UHF. If the antenna lead-in is fastened to the UHF terminals, and your stations are all VHF, you'll get very bad pictures.

If you have an outside antenna, the lead-in may have broken on one side, due to the constant flexing from the wind. The lead-in is usually a flat ribbon type of wire called "300-ohm twin-lead." It is quite possible for one side of this wire to break, inside the insulation. The fastest way to check this is with an ohmmeter. Take the lead-in off the TV set, and check between the two wires. This should be a complete DC circuit, from one wire up through the antenna and back down the other. You should see about 5-6 ohms in the average lead-in antenna combination. For the rabbit-ears antennas, you may see continuity from one side of the lead-in to the other, or you may not. If you don't, check from each wire to one arm of the antenna; one wire will go to each one.

If you do find the lead-in open, you'll have to lower the antenna and put on a new lead-in. The plastic insulation of the lead-in will deteriorate after a few years of sunlight, and a new line will often improve reception noticeably. Most antennas can be lowered without too much trouble, or reached from a

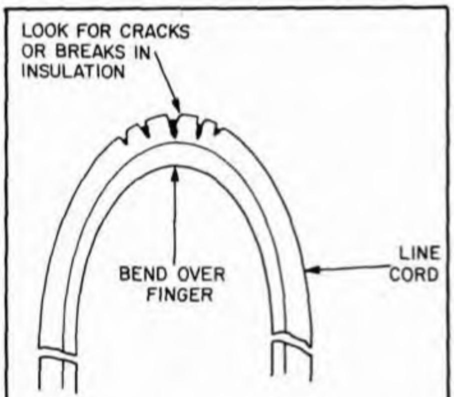


Fig. 2. Bend the line cord sharply between your fingers and look for cracks in the insulation. Don't forget to pull the line plug!

ladder. You should have a lightning arrester installed right at the place where the lead-in goes into the house. Take the lead-in off this and check it. If it has been hit by lightning, the arrester itself may be damaged, and shorting out. You should read a completely open circuit across the two terminals of the arrester.

The final test for antenna trouble is to try another TV set on it. If this set too shows too much snow, then you can be pretty sure that the antenna itself is the problem. If the test set shows a good clean picture, then it's time to take the first one to a shop; it has a weak tube or some kind of trouble in the tuner. Make all of the other tests first, of course.

Scrambled Pictures. If you can see that there is a good strong picture signal present, but it's what many people call "scrambled," you have a "sync problem." Every TV set has two controls to hold the picture in place, or "in synchronization" (and from now on it's "sync" for short). Strangely enough, we call these the "hold" controls. One holds the picture vertically, and the other horizontally. In the older sets, these controls will be at the bottom of the front panel; in portables, they may be on the side; and in some sets, on the back apron of the chassis (Fig. 3). They'll be marked "H(orizontal) Hold" or "V(ertical) Hold."

The Vertical Hold Control. The best way of learning how these controls work is to try them out on a set that is in good shape. The vertical hold control, turned one way, should make the picture roll downward. At first, it'll roll slowly, and as you turn the control farther, it'll go faster. Turn the control back to the center, and stop the picture. Now go the other way. Normally, turning this way, the picture should stay locked in until you reach a certain point, and then break out, going upward pretty fast. Technicians usually say "rolling" for a picture moving down, and "flipping" for one that's moving up. Remember how these control-reactions work; we're going to use them in a minute.

If the vertical hold control is turned away too far in either direction, the picture may be moving so fast that you can see two pictures at once; there will usually be quite a lot of flickering. Now check: Move the hold control very *slowly* from one end to the other. At some point near the center of rotation, the picture should slow down, then stop and lock, if the set is working all right. Now, here are a few abnormal reactions that mean you must call a technician: One, if you can not make the picture even slow down in its rolling or flipping by turning the vertical hold control. Two, if you can make the picture stop, but it will not lock; it floats up and down. Try this before sending the set to the shop: Roll the picture down very slowly by setting the vertical hold control. Watch the horizontal black bar across the picture. This is the "vertical blanking bar" between each picture. When this bar reaches a point about 2 inches from the bottom of the screen, the picture should suddenly "snap" into hold, even if only for a second. However, if the bar floats smoothly on down without even pausing, or if you can turn the vertical hold control in the other direction and make the picture move *up* very slowly, you have a sync problem. This means a trip to the shop.

Here are a couple of no-nos: On the back of the set you will see two controls marked "V Size" (or "V Height") and "Vert Lin"(earity). Leave these alone. If you get these adjusted so that the picture is *stretched* too far, you can cause a fake sync problem, and an unnecessary trip to the shop.

The Horizontal Hold. Now we come to the control which will show a different reaction. When the picture is rolling vertically, it's easy to see that there is a picture there. However, if the picture is out of sync horizontally, you get an entirely different pattern. Remember that the picture is still being scanned vertically. So if the horizontal hold is out of adjustment, you won't be able to see a picture at all, rather a pattern which is a series of slanting lines. (The fact that there *are* thick, black lines on the screen shows that you *do* have a picture, but it's out of sync horizontally. For color TV's, color sync is lost too.) These lines may slant from upper right to lower left, or upper left to lower right, depending on which way the horizontal sync is off. If you have only 2 or 3 horizontal lines, you may be able to see a distorted picture in there. This means that the horizontal hold control isn't too far off. However, if you see 8 or 10 slanting lines, the hold control is quite a bit off the right setting. The more lines you see, the farther it's off, and the less they'll slant. In some cases they may even look as if they are actually horizontal, but they're not.

To clear this up, turn the horizontal hold control very slowly, watching the screen. If the horizontal hold control is on the back of the set, prop up a mirror in front of the set so that you can check the screen. When you move the hold control, you'll see the lines change. If you get *more* and thinner lines, you're turning the wrong way. Back up, and you'll see the lines get thicker, more slanting, and fewer. This is right. Keep on turning slowly and you should find a point where the picture will straighten up and lock in.

Now, turn the horizontal hold control just a little bit more. To check for correct operation of this control, turn the channel selector to another station, or to a dead channel, then back to one with a picture. If you have it set just right, the picture will snap in, firmly locked. If you see it break up into slanting lines for a second or two and then lock in, it's not quite right yet. Adjust the horizontal hold control just a little bit and repeat the channel-change test. If it's worse this time, you went the wrong way. Turn it just a wee bit in the other direction and repeat. Keep on until you see the picture snap in, tightly locked.

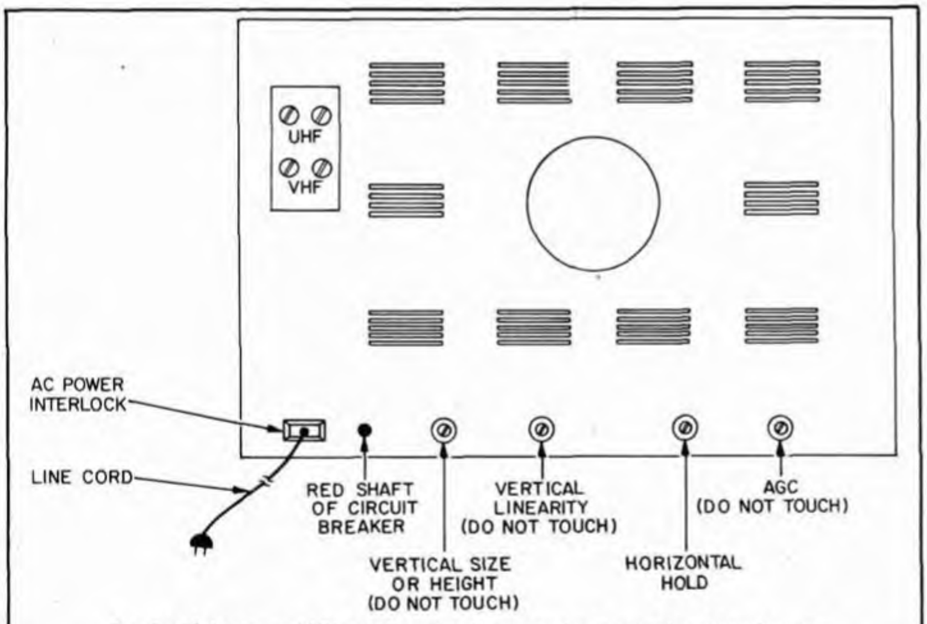


Fig. 3. Back view of TV set showing those controls you should not move.

Finding Troubles. Now then: If you can't get the picture to lock in by adjusting the horizontal hold control, but it "sits up" for a split second and then falls out slanting the other way, there is trouble in the set. In a lot of these, if you carefully "fiddle" the horizontal hold control, you can make the picture straighten up; it will float off sidewise, or fall out of sync again whenever there is a change in the program. This means a trip to the TV shop. All horizontal hold controls should have a "hold range" of about one half of a turn at least before the picture starts to be unstable.

There are two common types of horizontal hold controls. One is a variable resistor like a volume control. These will have a range rotation of about 320 degrees. Normally, you won't be able to get the picture very far out of sync with this type. The other type is actually the adjustable core of a coil. (The horizontal oscillator coil.) This type *should* have a special knob with an "ear" on it, so that it can't be turned more than 320 degrees. However, if this knob has been pulled *out* too far, or if the ear is broken off, this type can be adjusted far from the correct frequency. In tube-type TV sets, this normally doesn't do any damage unless it's screwed out so far that the oscillator stops. If this happens, the screen will go dark. If it does, turn the set off instantly. You can damage up to three expensive tubes by leaving the set on in this condition. Turn the horizontal hold control several turns in the opposite direction, and turn the set on again. If the screen does not light within 30-45 seconds, turn it off again fast. When this has happened, you'll see a great many very thin lines; always turn the control toward the point where the lines get fewer and thicker.

Turning a horizontal hold control way off frequency, in many solid-state sets, can cause damage to quite a few transistors. This can happen quite rapidly, so always be sure that you do have light on the screen; if it goes out, turn the set off as fast as possible.

Here is a final hint for color TV sets, especially some of the older types. If you have a problem with intermittent loss of the color, and you also see some horizontal instability, try adjusting the horizontal hold control *just a little bit*. If this control is set "right at the edge" of its holding range, this can cause the color to drop out now and then. You'll often see color drop out just a little before the picture itself falls out of horizontal sync.

Just the Beginning. So there you are. These are the normal reactions of the hold controls. If you have trouble, the first thing to do is check these to see if they are reacting the way they ought to. In a great many cases, you'll find that this is all that you need. ■

Tube faults represent at least 70% of all service calls. Unplug set and allow to cool down. Check tubes at your nearest parts store or where they have a free tube tester. It can save you time and money before you call in service.

COMPUTER READOUT

Computer Graphics

One picture is worth a thousand bytes

THE CRT TERMINAL is well known to computer enthusiasts as a fast and economical means of communicating with their machine. Mostly, the terminal accepts and displays information in the form of letters and numbers which are translated into ASCII (American Standard Code for Information Interchange) that the machine understands.

But the CRT screen, which is also used in television, is capable of displaying more than just alphanumeric information. Many home computers are supplied with a built-in graphics capability and many more have accessories available with which graphics can be added by the owner.

TV/CRT. How does the CRT terminal display information, and how can it be made to do all the spectacular graphics that are becoming increasingly common in today's home computers? The cathode ray tube in a computer terminal is no different than the one in a TV set, so theoretically it should be able to display the same sort of picture information as a TV. In fact, many CRT displays are converted television receivers, and some personal computers output a video signal which can be sent via an RF modulator directly into the home TV set.

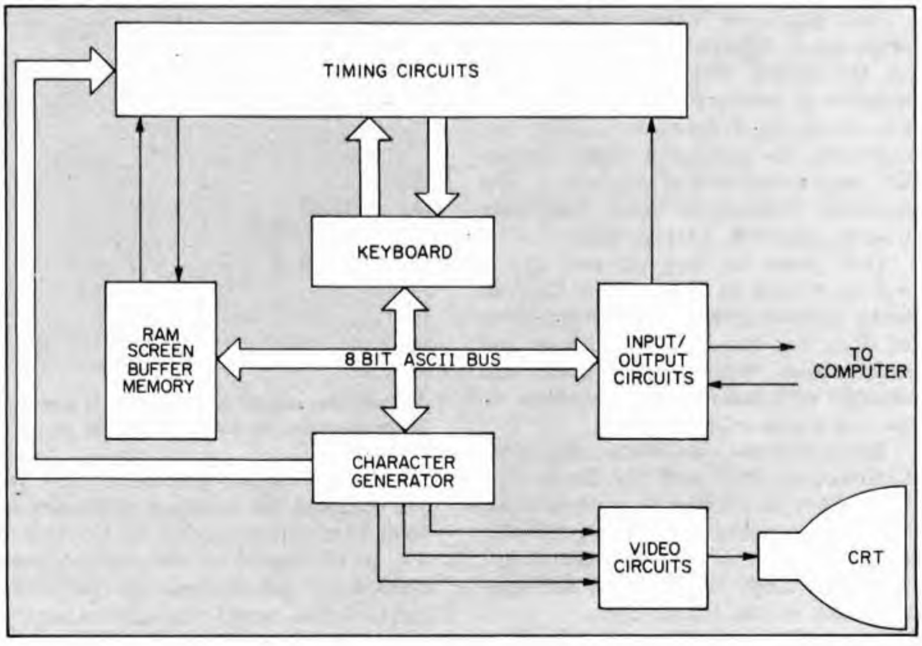
An electron beam is swept back and forth across the screen from top to bottom in just the same way as in a TV. Many displays meant especially for computers increase the sweep frequencies to give the display a greater "bandwidth," enabling them to display more information, but the principles are exactly the same. This means a CRT terminal requires vertical and horizontal sweep circuits just like a television.

It also means that a video signal is required to deliver information to the display. The video signal is usually supplied by a circuit board inside the terminal, but in some cases it is generated by a video display board connected to the computer's bus.

In either case, the similarity to television ends here. When we get to the point of modulating, superimposing information onto that video signal, we enter a totally digital world. In television, the strength of the electron beam varies continuously as it sweeps across the screen giving black, white, and varying shades of grey. In color TV it's three electron beams for red, green, and blue. But in a computer display, that beam is either on or off; there are no shades of grey.

If we assume that our video circuits are exactly the same as a television set, we will have 525 scan lines per frame. What the computer does is supply information to turn the beam on and off at selected times so it will paint letters, numbers, or pictures on the screen. And that's really all there is to understanding computer graphics.

Screen Buffer. I'm kidding, of course, but in a sense it is true. The CRT displays information, and any information it does display must be in the computer's memory in binary form. The memory where alphanumeric and graphic information is stored is called the *screen buffer*, or sometimes the *graphics buffer*. A buffer is any distinct area of computer memory which is set aside for a specific purpose, in this case, the storage of display information. Most terminals today are at least par-



This block diagram shows the specialized circuitry used for graphics generation. Note the screen buffer; this stores the contents of the screen while allowing local updates.

tially "intelligent," which means they have a memory area for storing display information that is separate from the computer's main memory.

As it sweeps the electron beam across the screen, the terminal repeatedly looks at the information in the screen buffer to know what it is to display, when to turn the beam on and off. If the information in memory changes, the display on the screen will change the next time the terminal looks at that location.

In order to understand how all the stuff the computer has to display is organized, we have to think of the screen as a matrix with X and Y axes. If you are thinking of buying a terminal, this will be an important concept to know. You will want to know how much information your terminal will be able to display at any one time.

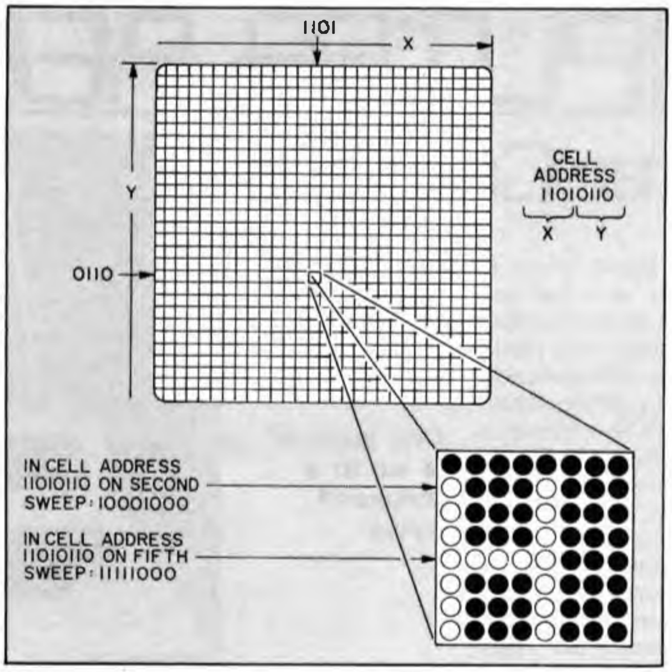
For displaying text, 24 lines of 80 characters each is considered a good size. But terminals with 16 lines of 64 characters, 16 lines of 32 characters, and so on are also available with corresponding differences in price.

Resolution. When evaluating the graphics capability of a terminal, the matrix will refer to its *resolution*, that is, how many individual zones the screen is divided into which can be individually turned on and off. For home computers, a relatively high resolution screen may have something like 192 by 256, or 49,152 individual "cells" or "pixels," whereas a lower resolution display may have something like 48 by 100, or 4800 points. As we shall soon see, there doesn't have to be a location in memory for every point on the screen. One location can tell the terminal to turn on a certain area of the CRT display screen.

On a low-resolution display, the figures will look angular and blocky, while a high-resolution display will show finer detail and smoother curves. Of course, a high resolution display will require more memory for its screen buffer and will cost more than low resolution, and for color graphics, even more memory space is required.

The method mentioned above of turning on a certain area of dots on the screen, such an area is referred to as a *dot matrix*. By using dot matrix, a computer terminal can generate a given set of letter and number characters. It can also generate a set of graphics characters and thereby save on the amount of memory it needs for fairly high resolution graphics. Here's how it works:

Characters. Inside the terminal, there



A video terminal screen is divided into thousands of cells which are in turn divided into dots. A cell is called a character matrix. The one illustrated here is an '8-by-8' matrix. The matrix, which is identified by an address, is scanned eight times, once for each row of dots.

is a special IC called the *character generator*. Actually, it is a ROM, or Read Only Memory, which contains codes for a given set of characters that the terminal is able to display. A dot matrix with a character in it is shown in Figure 2 along with the binary codes that turn on the proper dots.

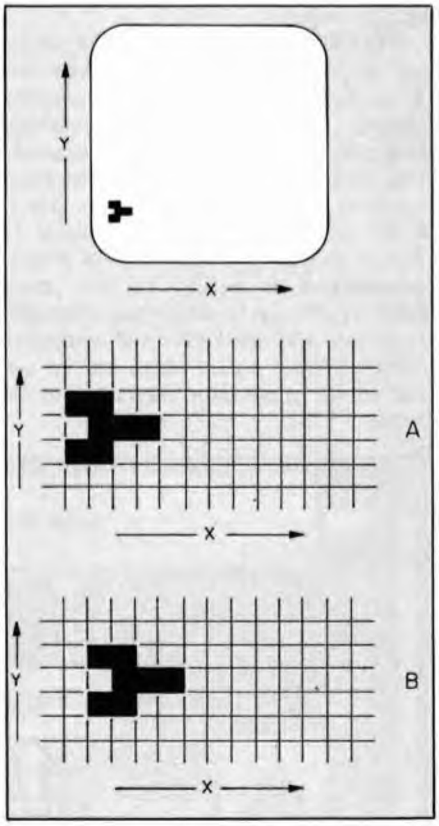
Obviously, the electron beam can only write one row of a character on each sweep. Now remember, each cell location corresponds to an address in the screen buffer. If that cell is 8 lines high, the terminal looks at its address for 8 sweeps of the electron beam before going on to the next row.

Our good old character generator sends out 8 different bytes for each cell on the screen. They go to the same location in memory because the beam has to go by 8 times to display one character. So to paint a single character, our terminal has looked at one memory location 8 times, but each time its contents were updated.

O.K. that's all very detailed and it will do simply to think of the CRT as being capable of showing distinct areas of dots that can be on or off in any combination. We can make letters and number with them as just described or we can create odd shapes.

Some personal computers, such as the Commodore PET and the Exidy Sorcerer, have an additional graphics mode where by pressing a shift key, the user can type a set of graphics characters, which are really just different dot combinations in the CRT's cells.

Saves Memory. There is always a tradeoff for this method. We get better graphics than if we only had the option



A computer moves a rocket across a screen by turning on the neighboring set of cells.

of turning whole cells on or off. We can combine the graphics characters to form lines and curves at dot resolution, but we're limited to the combinations defined on our system. On the other hand, we've saved valuable memory which would have been required to give us control over every single dot.

But enough of electronics. Let's proceed to some concepts of how we use and program computer graphics. We'll assume for our purposes that our graphics system is one that does not use the special graphics characters described above, but is one with moderate, say 100 by 200, resolution.

There are a number of graphics languages and programs written in them on the market. There are also a number of versions of BASIC which have been modified to include commands for the control of the graphics. They all have two things in common: they must be able to turn a given cell on the screen on or off, and they must provide a means of referring to each cell by location.

Graphics in BASIC. Now comes the fun part. To demonstrate how a graphics capability can work, we will use two hypothetical commands built into BASIC to draw a simple picture of a spaceship and then "fly" it across the screen. The commands are ON(X,Y) and OFF(X,Y) where X and Y stand for the screen coordinates of the cell location. ON and OFF simply means that that location is lit (ON) or not lit (OFF).

The first thing we do is turn on the cells we wish to represent our spaceship in its starting position. We have to name each cell in terms of its X and Y coordinates and tell the computer to turn it on. The computer then tells the CRT terminal to turn on the locations in its screen buffer that will light the corresponding areas on the screen.

We then see displayed on the left side of the screen our little spaceship. How do we make it fly? Simple. We tell the computer to turn off the leftmost cell in each row of our picture (that is, of our spaceship) and turn on the next cell to the right. When it has done this the spaceship will appear to have moved one increment to the right.

This is because when the terminal scans its screen buffer it will now see that the cells we want turned on have all shifted one place to the right. If we repeat this process by successively adding 1 to the X coordinates of those cells we want lit, our spaceship will appear to move across the screen.

We can control the speed of the spaceship by having the computer wait some fractions of a second before changing the contents of the screen buffer. Since the CRT displays 30 frames per second, the same as a television, motion can be very rapid and smooth, or very slow.

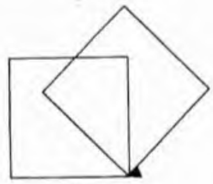
Lines and Curves. In the same way we can draw a line or a curve on the screen by turning on cells or dots in succession and leaving them on. Some graphics systems allow you to specify a direction in degrees from a starting point and the number of "steps" you want your line to take. In this way, pictures and geometric figures can be formed conveniently.

One graphics system uses the concept of the *naki.* The naki is a little mouse or turtle which can move in specified directions on the screen. It can be told to move leaving a "trail" or line, or to move without drawing a line. For instance, the following short program would draw a square with its sides the length N.

```
10 INPUT N
20 DRAW
30 AHEAD
40 RIGHT 90
50 GO TO 30
60 END
```

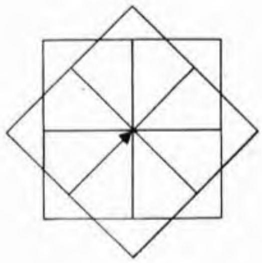
Very complex figures can be drawn by modifying and combining these simple commands, and by utilizing the computer's ability to repeat operations many times. In the case above, the computer would go on drawing the same square until it was turned off.

If at one point, we added a command that added 45 degrees to the naki's direction, the second time around the figure would look like this:



Some home computers provide for control of their graphics by means of a joystick. This consists of two potentiometers which represent the X and Y axes. The computer reads the different voltages output by different positions of the potentiometers. These are then

And after 6 times, like this:



referenced to the locations in the screen buffer memory which are loaded (turned on or off) with whatever information the program dictates.

Computer graphics is an exciting way to present information and it is appearing with increasing frequency as an integral part of home computer systems. One of the best comments on the value of graphics for conveying information is the name of a San Francisco Bay Area graphics consulting firm which calls itself "1K Graphics." . . . because a picture is worth a thousand words. ■

COMPUTER READOUT

How Computers Communicate

☐ MOST PEOPLE WHO HAVE begun investigating the world of computers are probably familiar with the most common means of communicating with the machine—the keyboard terminal. This type of input/output, or I/O, device reads the different keystrokes typed by the operator and converts each into a distinct pattern of 1's and 0's which are then transmitted to the computer through one of its I/O *ports.* A port is simply a location (sometimes a memory address) where the CPU looks for incoming information from the terminal and to which it transfers data to be read by the terminal.

For the computer to receive meaningful data from a keyboard terminal, the operator must first formulate it in terms of the alphanumeric characters available on the keyboard and the computer must be programmed to interpret the symbols sent to it. This works quite well for a great many applications, but what if we want the computer to do something that requires so much constant input that the task of formulating it and typing it in all the time would be too dull and repetitive for a human to put up with all the time?

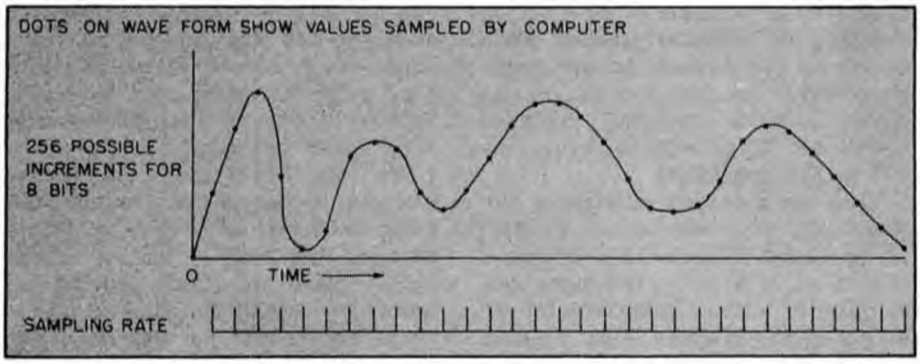
Computer Control. Let us take for an example, the task of reading—and later controlling—the temperature in some device. While that job could be done by a simple thermostat, we will see that using a computer will enable us to expand incredibly the possibilities for using the temperature data it reads.

The first problem is to get the information into the machine. We could have an operator read a thermometer and type the readings in via the keyboard, but he would soon get frustrated, especially if we wanted readings every half second or so. With the computer, we can do it automatically. This whole subject of automatic data gathering and external control is called *process* control. It is simply obtaining information from the real world, processing that information according to a program in the computer's memory and performing operations based on that information.

This means that an incredible variety of specialized I/O devices and programs must be devised and tailored to the specific application. These can range from sensors of all kinds to stepper motors, valves and electric trains. We will now look at some of the general methods that are used to interface a computer to the outside world.

Analog to Digital. Since the real world does not normally present convenient digital data, some method must be found to translate *analog* signals into digital data. The general device for doing this is called an analog to digital, or A/D converter. An analog signal such as an audio wave, has constantly changing values so the best a digital device can hope to do is to *sample* positions of the wave and to approximate its shape in the form of digital information. Given the speeds at which computers operate, this can be done with surprising accuracy.

Let us look at the wave form shown here. It is applied as a continuously varying voltage to the input of the A/D converter which is at one of the computer's input ports. The computer then reads the instantaneous value at regular intervals and accepts the digital value through its port. It can thus form an approximation of the wave form. The greater the frequency of this *sampling rate*, the more accurate the digital approximation will be.



A computer can represent a wave form by sampling the level of the wave at a given point in time. The computer can interpolate the wave in between the points. The audio industry is just starting to use this same technique to make master recordings at the studio. The record albums that are produced are clearer and have more range than analog recordings.

Each sample that is read by the computer represents the value of the analog signal at a given point of time. For an eight-bit A/D converter, this value can be resolved into 256 increments ($2^8 = 256$). For example, it would be possible for such a device to measure a range of temperatures from 0 degrees to 100 degrees Celsius to an accuracy of better than 0.4 degrees Celsius! This accuracy can be enhanced by more complex (and more expensive) 10- or 16-bit converters.

The opposite of A/D conversion, digital to analog conversion, is also done, often on the same circuit board known, naturally, as an ADAC. Here, the digital information is output at a specific rate to a network of resistors, filters and op amps to produce an analog signal. The most sophisticated D/A converters are used in computer music applications where the highest quality complex waveforms are essential.

One inexpensive example of these principles, now available to hobbyists, is the Data-Bag™ speech processor made by Mimic Electronics (P.O. Box 921, Acton, MA 01720). This device allows the user to digitally record his voice in the computer's memory and then play it back by having the computer output those memory contents through the D/A section of the Data-Bag to a speaker. In all this there is a tradeoff the user must be aware of. The faster the sampling rate, and hence the more accurate the representation of the wave form, the more information must be stored—and the more memory must be taken up with stored data.

Of course, most real world applications are concerned with more than just inputting and outputting the same information. The real power of the computer, after all, is to process the information and make decisions based on it. And the true purpose of real-world connections is to enable the computer to act independently on those decisions. In this context, then, they are merely the things which implement the end results of the processing which is the computer's main task.

Control. By outputting analog signals, the machine could be used to control conventional analog devices. Let us take a look at our example of temperature control. The A/D coverter, under software control, samples and presents temperature readings to the computer which reads and compares this data with its program information. If the temperature is outside the specified parameters, the computer outputs a digital value to the D/A converter which applies the proper analog voltage to the motorized temperature control until the readings again satisfy the limits in the program.

Well, we certainly don't have to invest in a computer simply to use it as a thermostat! As I said and will emphasize again, the power of the computer lies in its speed and its ability to analyze large amounts of data and make decisions based upon it. So let us set our machine a somewhat more challenging task.

Multiple Data. We have a chemical process in which the computer must simultaneously monitor several thermometers, flow meters and pH meters, control various valves and temperature controls, and, in addition, prepare a human-report on materials used, temperature variations and the like. In addition, it must be alert for critical conditions (or combinations of conditions) and sound an alarm, and shut down operations if necessary. It should be apparent that the main problem here is not so much in the various on-off or analog devices at the machine's ports, but more in the considerations put into the software program.

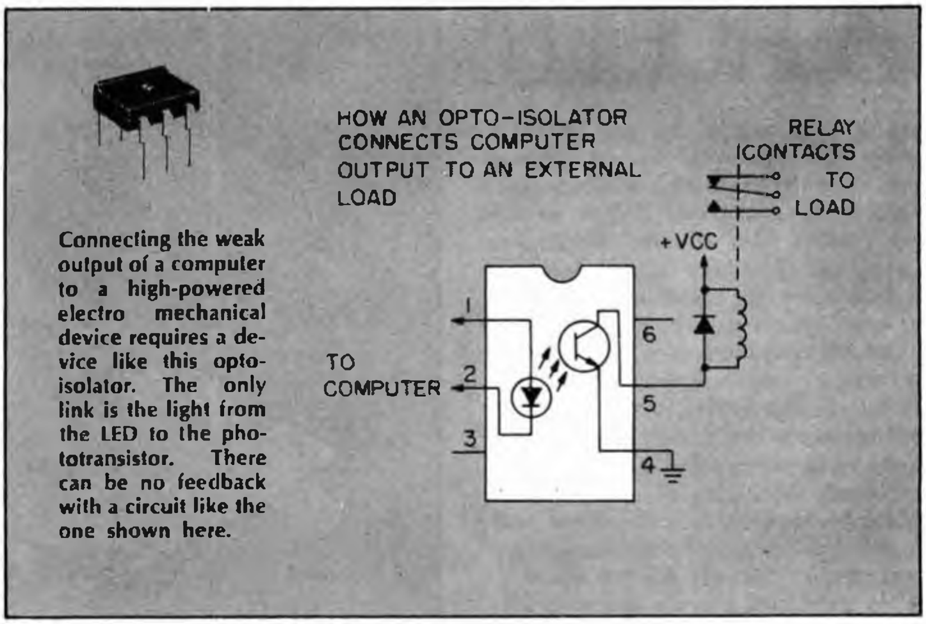
Having the computer monitor many different inputs simultaneously is accomplished with an analog multiplexer.

A typical such device can monitor 16 channels by rapidly scanning the inputs. In much the same way, an automobile distributor can service 8 different spark plugs seemingly at the same time.

Parts of the computer's program can then store the different values in memory locations alloted to the different input channels. This information can then be manipulated analysed and output in whatever manner the programmer thinks best.

There are two more devices that are very important in process control applications. The first is the *real time clock*. Since all computer functions are controlled by various timing circuits in "clocked logic" there is a central timing reference in the form of a crystal oscillator known as the system clock. It's typical frequencies in home computers are between 2 and 4 MHZ. Since a crystal controlled clock is extremely accurate. divider circuits can be added to give the system an internal source of time reference calibrated in hours, minutes, seconds and fractions of seconds. The computer can then be programmed to refer to this time standard in order to time and delay the external processes it is controlling.

The other important device is one which enables the computer to turn on and off high voltage or high power devices safely. Obviously, the low voltage levels present at a computer's output port are not capable of controlling large devices by themselves. One solution is to use them to turn relays on and off which in turn controls the devices that do the actual work. The problem with relays and transistor switches is that there is danger of high voltage getting back into the computer and destroying components. The solution for simple on-off functions is to isolate the voltage with an *opto-isolator*. As the diagram shows, this is a device consisting of a photo transistor and an LED. The LED is connected to the computer output and is totally electrically isolated from the phototransistor. The phototransistor is turned on by the light emitted when the LED is on. It can thus be used to turn on any type of relay or other device while protecting the computer circuits from dangerous voltage.



Connecting the weak output of a computer to a high-powered electro mechanical device requires a device like this opto-isolator. The only link is the light from the LED to the phototransistor. There can be no feedback with a circuit like the one shown here.

This is the type of device we would use to sound alarms and activate sprinkler systems if our computer detected dangerous conditions, in our chemical process. Of course, with the computer in charge of things that should not happen.

If it did, the operators could use the computer to analyse the recorded data and the records of its control functions to generate a report on the entire process. This report could then be printed out in an orderly format for the chemists to look at and make decisions as to what program changes would be necessary in the process control to make sure such a disaster did not reoccur.

And that brings us back to the point I have been emphasizing. The program control and analysis of the data are the crucial aspects. The external devices must sense accurately and carry out the machine's orders exactly. But the whole system is still merely a tool which is used to extend the power of the human mind in the same way the lever extends the power of the human muscle. ■

COMPUTER READOUT

Operating Systems

EVENTUALLY, EVERY ENTERPRISING computerist, if he has been using cassette storage for any length of time, will look at the system he started out with and begin dreaming of upgrading it to do even more wondrous things. Visions of printers, X-Y plotters, color graphics, and controlling external devices will dance in the heads of those who have become relatively competent at programming and operating their basic systems.

Disk Drives. One of the first and most popular upgrades to a personal computer is, of course, the addition of a floppy disk drive. It is also one of the most dramatic. A disk system really makes a computer come alive and seem more "magical" after those interminable waits for a program to load from cassette. It also makes the system a serious contender for use as a business tool.

The big advantage of a disk system is the increased storage obtained and the speed with which stored programs and data can be read and utilized. We hear much about single and double density, access time, formats, etc, that is, the physical capacity of the disk itself. But one major consideration is often neglected. It takes a very sophisticated computer program, that is, software, to even begin to use the capabilities of a floppy disk system.

Operating Systems. Such a program, called an *operating system*, is far beyond the abilities of most home computer users to write and is therefore usually supplied by the manufacturer or by an independent software house. Anyone who is contemplating upgrading his system to include floppy disks should look well to the type of operating sysem that will be available to him. Also, by examining what an operating system is and what it does, we will get a better idea of some of the true potentials of today's microcomputers.

Essentially, the operating system is a program which supervises and coordinates the operation of all the various programs and peripheral devices (printers, disk drives, terminals, etc.) operating on the computer sysem. It keeps track of the order in which things are done, the names of different programs in memory, their locations, and it allows the user to tailor the system's operation to opimally suit his needs.

To understand how the operating system does this, we will need to use the concepts of "devices" and "files." A device can be any peripheral device connected to the computer: a CRT terminal, a printer, a disk drive, and X-Y plotter, etc. The operating system communicates with and uses these devices by means of special sub-programs known as *device drivers*.

Different peripherals require different software routines to drive them and an operating system may not have drivers for all possible devices. Nonetheless, a set of such routines is essential if the computer is to communicate with external contraptions, be they teletypewriters or robot arms. The ambitious programmer who wishes to run some exotic gizmo with his computer usually has to deal himself with writing the software to run it as well as building the hardware. A good operating system, though, will provide an easy method for the user to add device drivers of his own making.

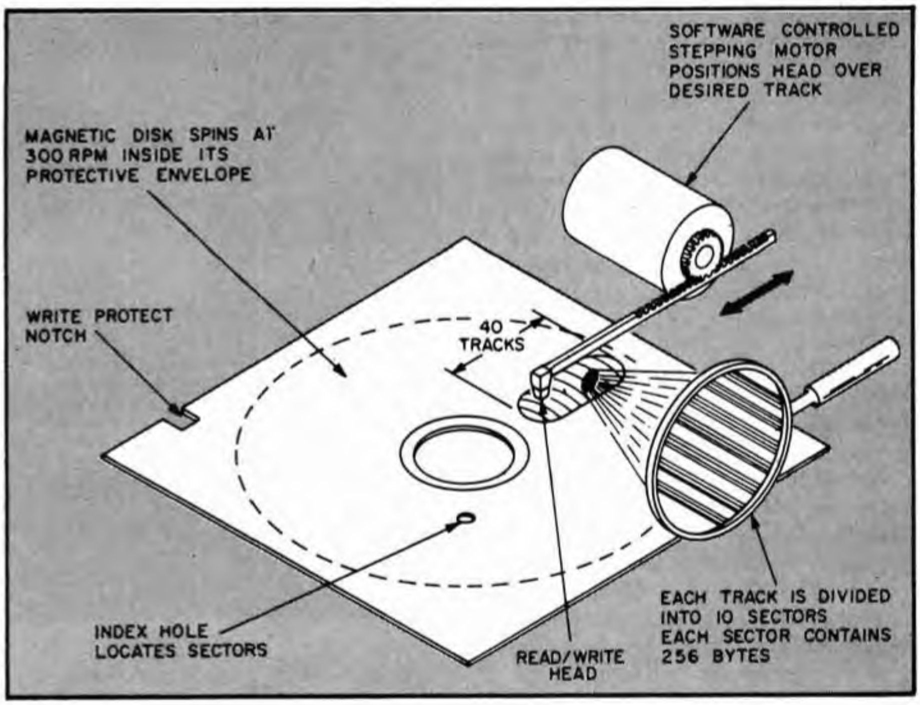
Files. The concept of a "file" is a little more complicated. To explain it, we will use the example of the floppy disk. The floppy disk is both a "device" which requires its own device driver, and a gigantic "file" itself. It is the place where all the other blocks of data and programs, or "files" are kept.

In fact, you can think of the disk drive, the device, as the filing cabinet, the physical storage unit. All the pieces of paper and records in the filing cabinet, then, correspond to the data blocks or files, recorded on the disk. The way the data is stored on the disk is illustrated in the accompanying diagram.

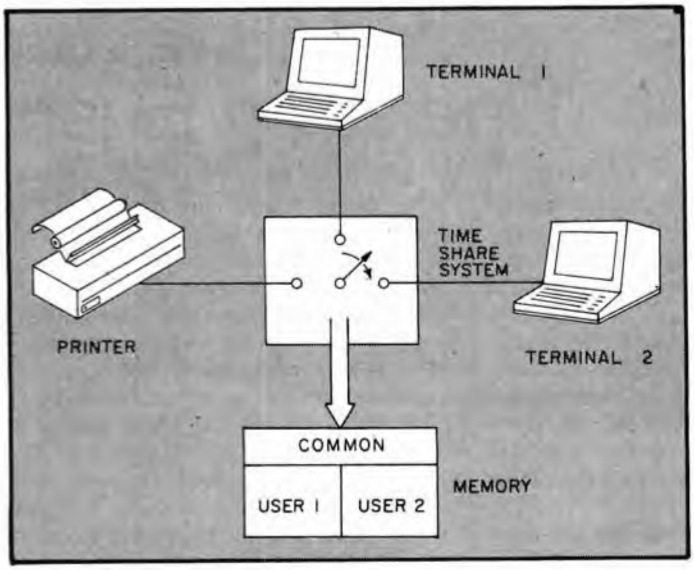
The floppy disk is a circular piece of material much like magnetic recording tape. It rotates inside a protective envelope under the read/write head of the disk drive. The disk is divided into a number of concentric tracks, and each track into a number of sectors. A sector is the smallest unit of information the disk can access at one time. In a typical home computer diskette, each sector contains 256 bytes and each track contains ten sectors. On a diskette with 40 tracks, that adds up to over 102,000 bytes of storage!

With the disk rotating continuously under it, the read/write head moves quickly in and out until it has found the track requested by the computer. It then waits over that track until the proper sector comes around. At that point the head "taps" the disk and either reads data from it into the computer or writes data onto the disk.

File Finder. The job of the operating system in all of this is to keep track of where all the things are on the disk so they can be found when requested by a program. The operating system acts much the same as a poor, harassed file clerk who is constantly asked to fetch and file records. To ease its task, it generally uses part of the disk to establish a *directory* for itself. The directory



There are many different sizes and types of floppy disks but they all look much like the one in this diagram. The disk tracks are not visible lines but rather sectors of a single magnetic coating. The read/write head is positioned by a stepping motor. Some systems have read/write heads for both sides of the disk. Index hole marks the first sector.



In a time sharing system various terminals, printers and other "slow" peripherals share the use of a single computer to enable more efficient use of the machine. This requires a special operating system to keep the different inputs and programs sorted.

is a little reference file the operating system uses to tell itself where everything is stored on the disk.

The name of each file (a file can consist of as many sectors as necessary, all grouped under one name) is chosen by the user and generally means something in English, such as STARTRK or BIOTHM. The operating system reads the file name when it is entered on the terminal, then looks it up on the disk directory. From the directory it finds out what track and sector it must go to to find the beginning of the file. We might also liken this process to finding a book in the library. First we go to the card catalog (the disk directory) and find out what aisle and shelf (track and sector) the book is on, then we go get the book.

So far, we have seen the actions of the operating system with the main means of mass storage, the disk drive. Let us now explore some of the things that are made possible by a typical microcomputer operating system. Not all the methods described here work for all operating systems because the approach of different authors varies. The general concepts, however, apply to all operating systems.

One major thing we can do with an operating system is take a file and transfer it from one device to another, or copy it from one disk to another. Many operating systems contain a program called PIP (Peripheral Interchange Program), which simply copies a file from one device to another. Using this program, a businessman can record the status of his inventory or reciepts on a disk kept outside his shop and update that backup disk, say, every week. Thus, if anything should happen to his daily working disk, he only has to go back one week in his paper records to get things straightened out. A better idea is to update the backup disk daily—with PIP it only takes a few seconds.

An operating system increases in versatility if it is able to treat certain peripheral *devices* as if they were *files*. In that way it can use them as sources of data to be copied to a corresponding file on the disk and later used by a program. For instance, if a program is monitoring a temperature at some peripheral, that information can be read as a file by the operating system and stored as a file on the disk. It can later be read as a file from the disk and copied as a file to a printer or used as a data file by another program.

With various peripheral devices connected to the computer (CRT, printer, disk, etc.) the operating system must always be aware of which one is really running the show, that is, which terminal is allowed to give commands to the operating system, tell it to shut up, power down, or fetch a file. This terminal is known as the *console terminal*.

In most cases, the console terminal is the CRT terminal since many printers don't even have keyboards. It is, however possible to have more than one console terminal and more than one user program working on the same computer system at the same time. This is done by means of a method called *time sharing*, and it is one of the most powerful features available on today's computers.

Thumb Twiddling. Peripheral devices, especially those with mechanical parts, are terribly slow when compared to the speed of a microprocessor CPU. While the printer is busy printing the letter "G," the CPU is spending most of its time twiddling its electronic thumbs waiting until the printer is ready for it to send the next character to be printed.

A time sharing system makes use of these idle moments by paying attention to other console terminals. To do this, it "polls" them one after another in much the same way an automobile distributer services spark plugs in rapid succession. The operating system also has to assign certain portions of memory to each user and keep track of who is where and when.

In addition, the system must keep track of priorities: if two terminals are ready for its attention at the same time, it must decide "who's on first." Thus, in a time sharing computer, our operating system not only plays the role of file clerk and scheduler, but, it seems, that of diplomat.

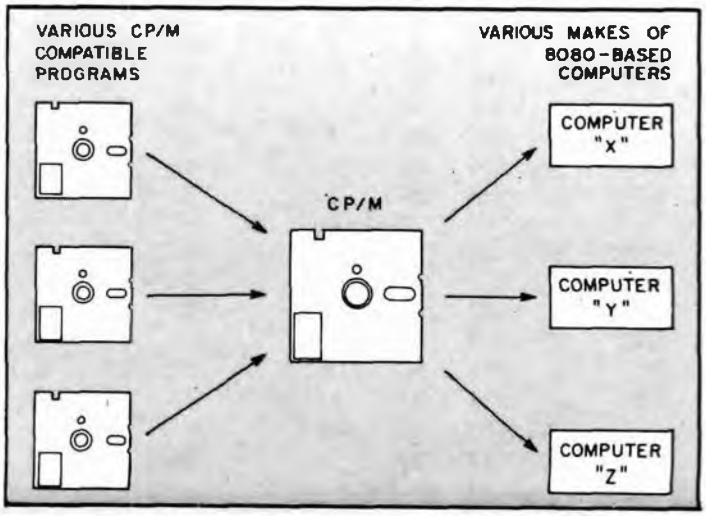
Time shared systems on microcomputers seem to be *the* coming thing for small to medium sized businesses. Studies have shown that what a small businessman needs is a system with four terminals or less which sells for under $10,000. And manufacturers are currently falling all over each other trying to meet that need.

A typical such system might be found in a parts store where inventory control is critical. One terminal might be out at the counter or in the shipping area. Sales and shipments are entered here and the computer then automatically subtracts the parts from the inventory file and adds the sale amount to the ledger file.

Back in the warehouse, there could be a terminal where incoming parts would be entered and added to the inventory file. Meanwhile, in the office, inventory reporting and bookkeeping could be done using both fiiles with a third terminal along with a printer. And all this could be (and *is* being) done by a single computer with the necessary memory, disk space, and an efficient operating system.

One thing must be noted, though. There is a distinct difference between the operating system and the various programs and computer languages which do the actual programs and calculations that the user finds useful. The operating system actually just does the housekeeping. But it represents something more, something very important.

The operating system provides a software *interface* between a computer language like BASIC or a large application program like "General Ledger" and the piece of hardware that is the actual computer. So we often speak of a language or a program that will run *under* a certain operating system. That means, no matter what sort of funny piece of hardware it may be, if a certain operating system has been adapted to run on it, any piece of software written to run



The CP/M operating system can be modified slightly to run on any 8080-based microcomputer. Applications programs can then be written to conform to CP/M's requirements rather than those of the computer. Thus, any computer running CP/M can use any of the thousands of independently produced programs written to run under that operating system.

READOUT

on that machine also.

D.O.S. A number of manufacturers have produced Disk Operating Systems to run on their machines. Processor Technology has PTDOS, Heathkit has HDOS, Cromemco has CDOS, etc. There is also a very popular operating system which has been modified to fit a wide variety of computers. It is called CP/M and was produced by Digital Research (P.O. Box 579, Pacific Grove, CA 93950). The reason CP/M (for Control Program/Micro) is so popular is that it has been adapted to run on a number of different machines.

Programs written by many independent software companies need then only be written in such a way that they run under CP/M and they can then be used on any computer that has a CP/M and they can then be used on any computer that has a CP/M operating system. This is a big incentive for independent producers of software to get busy and write programs that are CP/M compatible because they know they will find a large market.

Having more software available in turn makes the computer more versatile for the user, and increases its value to him. Expanding a personal computer from a hobby to a serious tool for business or career still represents a sizeable investment. The add-ons are themselves expensive, but the user should look beyond that to the features of the operating system he will be using—both at what he can do with the system itself and how much more of the world of micro-computer software it will open up to him. ■

ASCII CODES

Decimal to Octal to Hex to ASCII Conversion

DEC	OCT	HEX	ASCII	DEC	OCT	HEX	ASCII	DEC	OCT	HEX	ASCII	DEC	OCT	HEX	ASCII
0	000	00	NUL	32	040	20	SPACE	64	100	40	@	96	140	60	'
1	001	01	SOH	33	041	21	!	65	101	41	A	97	141	61	a
2	002	02	STX	34	042	22	"	66	102	42	B	98	142	62	b
3	003	03	ETX	35	043	23	#	67	103	43	C	99	143	63	c
4	004	04	EOT	36	044	24	$	68	104	44	D	100	144	64	d
5	005	05	ENQ	37	045	25	%	69	105	45	E	101	145	65	e
6	006	06	ACK	38	046	26	&	70	106	46	F	102	146	66	f
7	007	07	BEL	39	047	27	'	71	107	47	G	103	147	67	g
8	010	08	BS	40	050	28	(	72	110	48	H	104	150	68	h
9	011	09	HT	41	051	29	)	73	111	49	I	105	151	69	i
10	012	0A	LF	42	052	2A	•	74	112	4A	J	106	152	6A	j
11	013	0B	VT	43	053	2B	+	75	113	4B	K	107	153	6B	k
12	014	0C	FF	44	054	2C	'	76	114	4C	L	108	154	6C	l
13	015	0D	CR	45	055	2D	—	77	115	4D	M	109	155	6D	m
14	016	0E	SO	46	056	2E	PERIOD	78	116	4E	N	110	156	6E	n
15	017	0F	SI	47	057	2F	/	79	117	4F	O	111	157	6F	o
16	020	10	DLE	48	060	30	0	80	120	50	P	112	160	70	p
17	021	11	DC1	49	061	31	1	81	121	51	Q	113	161	71	q
18	022	12	DC2	50	062	32	2	82	122	52	R	114	162	72	r
19	023	13	DC3	51	063	33	3	83	123	53	S	115	163	73	s
20	024	14	DC4	52	064	34	4	84	124	54	T	116	164	74	t
21	025	15	NAK	53	065	35	5	85	125	55	U	117	165	75	u
22	026	16	SYN	54	066	36	6	86	126	56	V	118	166	76	v
23	027	17	ETB	55	067	37	7	87	127	57	W	119	167	77	w
24	030	18	CAN	56	070	38	8	88	130	58	X	120	170	78	x
25	031	19	EM	57	071	39	9	89	131	59	Y	121	171	79	y
26	032	1A	SUB	58	072	3A	:	90	132	5A	Z	122	172	7A	z
27	033	1B	ESC	59	073	3B	;	91	133	5B	I	123	173	7B	≤
28	034	1C	FS	60	074	3C	<	92	134	5C	[	124	174	7C	I
29	035	1D	GS	61	075	3D	=	93	135	5D	]	125	175	7D	≥
30	036	1E	RS	62	076	3E	>	94	136	5E	◇	126	176	7E	÷
31	037	1F	US	63	077	3F	?	95	137	5F	—	127	177	7F	DELETE

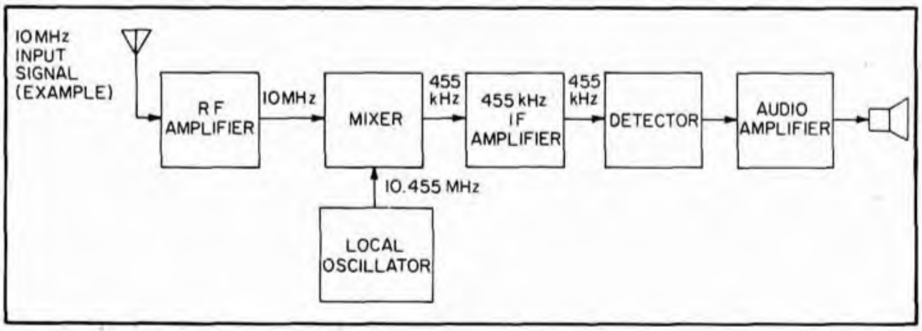
A Short Course in Understanding Shortwave Receivers

A guide to understanding and interpreting the specifications of modern shortwave receivers

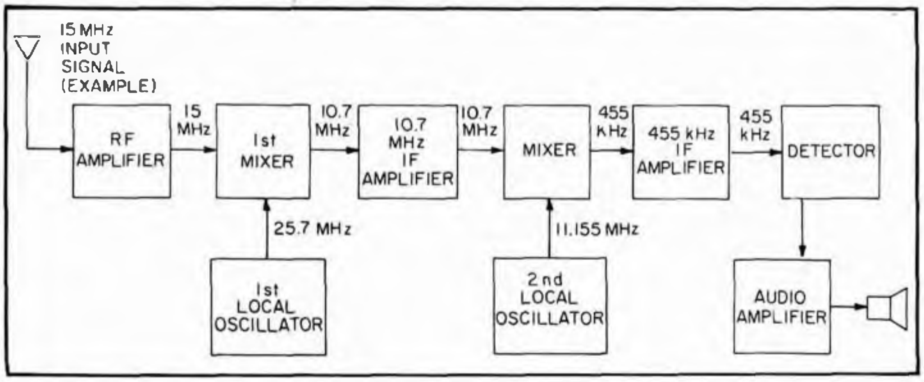
CIRCLE 32 ON READER SERVICE COUPON

WHAT DO SHORTWAVE RECEIVERS and automobiles have in common? They both come in many shapes, sizes, and price ranges. You can buy an economy price leader, a luxury model with lots of chrome trim, or even an exotic high-performance model. For the beginner, or even the experienced DXer, the question of which receiver to buy is often a difficult one. Most of us have a limited budget, so we can't order the $4000 receiver that the government may choose, but we do want to buy as much receiver as our funds allow. We will attempt to simplify that task by providing a basic explanation of common receiver features, specifications and designs. Finally, we will offer hints on how to get the best buy on a receiver and whether you should select a new or used model.

The "Inside" Story. The modern shortwave receiver has a great deal in common with an ordinary superheterodyne AM broadcast radio. As in any "superhet" receiver, the signal tuned in by the user is converted to a new frequency, called an intermediate or IF frequency. After amplification, the signal may be converted to a second IF frequency (such a receiver would be called a dual-conversion receiver) or it could be directly demodulated by the detector into an audio signal. A number of elaborate shortwave receivers feature triple-conversion designs. In such a design, the input signal is converted three times (three IF frequencies) before it's converted to audio. We'll talk more about IF amplifier circuitry later.



A single conversion receiver combines the incoming signal with the local oscillator's signal, to create a 455 kHz IF signal which can then be converted into an audio signal.



The dual conversion receiver features greater selectivity by narrowing the frequency width of the incoming signal in the second mixing stage, keeping out unwanted signals.

Most shortwave receivers fall into two categories—general coverage and limited coverage models. General coverage receivers are so named because they cover a general, or wide range of frequencies and are designed for a general purpose rather than a special application. It is common for a general coverage receiver to tune from the broadcast band through 30 MHz. Some receivers of this type also cover longwave frequencies (below the broadcast band) and the FM broadcast band.

Limited coverage receivers, such as ham band-only or shortwave broadcast band-only, do not offer the continuous tuning capability of general coverage receivers, but instead concentrate on a limited number of small frequency ranges or bands. There are many instances where a general coverage receiver may be a preferred choice to a limited coverage receiver. If on the other hand, you are hoping to make the grade as a ham and are not interested in foreign broadcast DX, it would be wise to examine ham band-only receivers.

Understanding Specifications. In order to compare one receiver against another, it's a good idea to have an understanding of the specifications used to describe the performance characteristics of each. Before we take a closer look at specifications, here's one caveat: As the audio industry discovered some years ago, the stating of specifications can be an exercise in a game called "specsmanship." In that game, manufacturers attempt to show that their receivers perform better than competitors' units by stating specifications in the most complimentary terms possible. Much of this problem has been routed from the audio field, but the communications receiver field is fair game. In most cases, there is no need for a manufacturer to actually lie about specs, because he could present data in a manner that makes clear comparisons virtually impossible. So, when you compare "similar" specifications, you may be comparing apples to oranges.

Signal-to-Noise Ratio. The first spec that we will dig into is signal-to-noise ratio. For a clear picture of this concept, imagine that you are using a shortwave receiver and have just tuned in a distant-sounding signal that is strong enough for you to understand what the announcer is saying, though weak enough that you also hear a background rushing noise. If the signal carrying the announcer's voice becomes stronger, the background noise drops lower. If the signal becomes weaker, the background noise grows stronger. The difference between the amount of signal you hear and the background noise is called a signal-to-noise ratio (abbreviated S/N). As with many other ratios found in electronics, signal-to-noise ratios are expressed in dB units. For instance, if the audio signal heard from the receiver is 10 dB stronger than the background noise, we say the received signal has a 10 dB S/N ratio. Every receiver has its own ultimate S/N ratio; that is, a point at which further increases in signal strength will no longer affect the difference between background noise and signal. In practice, this ratio is quite great and is seldom found on a specification sheet. S/N ratio specifications are based on the noise generated within a receiver and provide no indication as to how the recever will perform with added atmospheric or local man-made noise. Our understanding of S/N ratios will help us to interpret sensitivity specifications, which are commonly found on even the most basic specification sheets.

Impedance. Before we move on to sensitivity, we must also discuss input impedance. Input impedance simply describes what antenna impedance the receiver will perform most efficiently with. Every antenna has a "characteristic impedance;" for a receiver to make the most of the signal captured by the antenna, its input impedance should be close to that of the antenna. Some receivers feature a so-called *antenna tuner*, or *trimmer* which helps to match the input of the receiver to a wide range of antennas by correcting impedance mismatches at different frequencies. Some receivers offer two antenna input terminals, one optimized for 50 to 75-ohms and the second for 300-ohm line. As with the S/N ratio specification, an understanding of input impedance will help us to compare sensitivity specifications.

Sensitivity. Sensitivity is probably the specification that SWLs are most accustomed to using for receiver evaluations. Generally, sensitivity is expressed in microvolts (abbreviated μV), with smaller numbers representing better sensitivity. What is often overlooked however, is that the mere statement of a microvolt sensitivity number is meaningless. In addition to the microvolt number, a signal-to-noise ratio, an input impedance and a frequency range should be stated. In addition, a complete specification sheet would also list sensitivity for each mode of operation (such as AM, CW, SSB, etc.) provided by the receiver.

CIRCLE 78 ON READER SERVICE COUPON

Panasonic's RF-2200 is an excellent example of a portable, general coverage SW receiver. The front end is a dual conversion type.

So what exactly does a sensitivity spec mean? When it is stated that a receiver has an AM sensitivity of 2 μV for a 10 dB S/N ratio at 50-ohms, it means that a received signal developed across the 50-ohm input of the receiver must be at least 2 μV in strength to produce a signal that is 10 dB stronger than the background noise. Because sensitivity may vary with frequency, the specification should identify what frequency bands the sensitivity figure relates to. If the frequency range is not specified, the sensitivity shown may be the best sensitivity of the receiver on its most sensitive band, meaning that other bands may offer considerably less performance. Worse yet, if the S/N ratio is not stated, it is impossible to know whether a 2 μV signal will produce a 10 dB S/N or an audio signal that is of such poor quality that all the listener could do is detect its presence.

Selectivity. The ability of a receiver to select one signal and separate it from other signals on nearby frequencies is called selectivity. Selectivity is closely related to another specification called bandwidth. Bandwidth and selectivity are expressed in dB units. Both selectivity and bandwidth are actually indicated in the standard selectivity specification for a receiver.

The bandwidth of a receiver reveals how wide of a signal can be passed by the IF stages with a maximum signal loss of -6 dB at its limits. For example, a 10 kHz bandwidth indicates that at plus-or-minus ($\pm$) 5 kHz off of the center frequency that the receiver is

Yaesu's highly popular "Frog-7" receiver covers 500 kHz thru 29.9 MHz, and features a phased-locked loop (PLL) for superior frequency stability.

CIRCLE 81 ON READER SERVICE COUPON

The NRD-505 by JRC (and available from Gilfer Associates), has digital readout for pinpoint tuning, and a CMOS memory for programming your favorite frequencies.

CIRCLE 47 ON READER SERVICE COUPON

tuned to, the signal strength reduction will be –6 dB. A 10 kHz bandwidth is wide enough to allow a broadcast music signal to be received with "high-fidelity" quality. This bandwidth would be too wide for serious DX listening on the crowded shortwave bands, however. As a result, it is the generally accepted practice to sacrifice some fidelity and use a narrower bandwidth to better separate one signal from others close-by. A 4-to-6 kHz bandwidth is acceptable for AM modulated signals; about 2 kHz for single-sideband (SSB) signals, and 150 Hz for CW (Morse code) signals. Some DXers prefer even narrower bandwidths. They are satisfied to listen to a somewhat distorted sounding signal, because it permits higher selectivity and more rejection of interference from signals on adjacent frequencies.

Now back to understanding selectivity. Two receivers may have exactly the same bandwidth, but very different selectivity characteristics. By examining at what frequency a signal will be reduced in strength (attenuated) by –60 dB at the bandwidth "skirts," we can learn the selectivity of the receiver. For example, a receiver selectivity specification may read: 6 kHz at –6 dB and 20 kHz at –60 dB. If you were using this receiver to listen to a signal on 14.250 MHz, and a second station was operating on 14.240 MHz (or 14.260 MHz), the second station would be reduced in strength by –60 dB relative to the desired signal. This specification does not however reveal what the bandwidth would be at –20 dB or –40 dB. That information can be obtained only by looking at a graphic illustration of the selectivity curves of the receiver (see illustration).

The bandwidth and stability of a modern receiver is determined by the IF amplifier circuitry design. While older shortwave receivers obtained high selectivity by adding many hand-tuned IF transformers, modern receivers use "selectivity blocks." Such selectivity blocks are usually ceramic, or mechanical filters. Ceramic filters are most common. IF filters never require re-alignment, so maintenance costs are reduced. Filters also reduce labor costs for the manufacturer and thus reduce the net price of a receiver to the consumer.

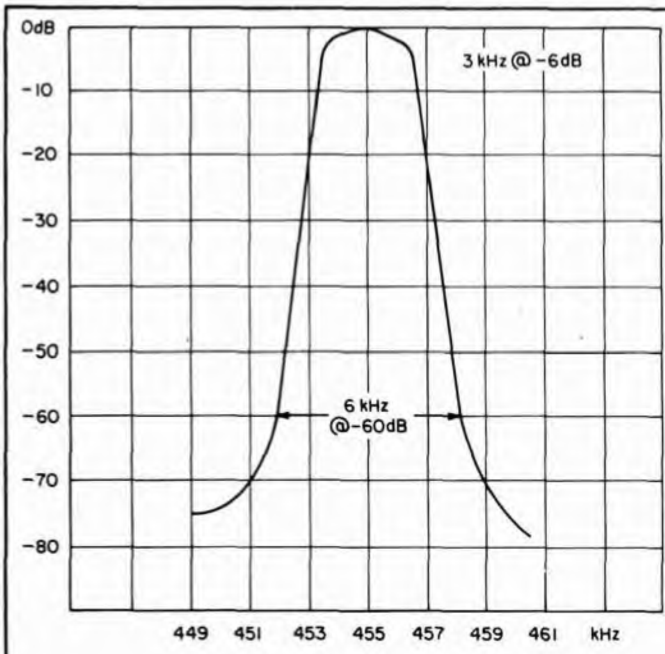
By building two or three filters into a receiver, the manufacturer can offer the receiver user a choice of broad and narrow selectivity positions for voice signals, and an additional very narrow position for CW reception.

Stability. Stability is one of the least talked-about specifications, and, with selectivity, is a key characteristic that separates expensive receivers from modestly-priced ones. The stability of a receiver reveals how well its local oscillator will maintain a constant frequency without drifting off the original setting. When stability is specified, the numbers usually indicate only electrical stability —that is, how much drift will occur over a given period of time because of changes in the electrical properties of components as their temperature changes. A warm-up period (before measurement is made) is also often stated. Mechanical stability, though seldom described, is also significant. If a receiver is gently bumped and the received frequency changes, mechanical stability is probably poor for that reciever. Likewise, if modest hand pressure is placed on the case, the frequency should not noticeably change.

Image Rejection. Image Rejection is still another of the specs that separate better receivers from their lesser counterparts. Image rejection is the ability of a receiver to reject an undesired "ghost" signal that is produced by the heterodyne (mixing) characteristics of every superheterodyne receiver. The image signal is separated from its true frequency by twice the first IF frequency of the receiver. Whether it appears above or below the true position of the signal, depends on whether a higher or lower local oscillator frequency is used. In some receivers (particulary ham band-only models), the local oscillator may be set above the tuned frequency on a few bands and below on others.

Let's look at one example of an image: Using a receiver with a 455 kHz first IF frequency (a common frequency), a strong signal transmitting on 18 MHz might also be observed with weaker strength at 18.910 MHz (18 MHz + (455 kHz × 2). Many better-quality receivers offer image rejection in excess of 60 dB (again a higher number indicates better performance).

To help achieve better image rejection, an ever-growing number of



RECEIVER BANDWIDTH IS 3kHz AND -60dB POINTS OCCUR AT A 6kHz BANDWIDTH.

The graph at left shows a typical bandpass response curve. Signals coming through at 455 kHz have 0 dB attenuation, but the attenuation rate increases sharply as the frequency moves up or down from the 455 kHz center bandpass frequency. The more sophisticated receivers have an adjustable bandwidth.

Shortwave receivers are designed with dual conversion designs having a high first IF frequency of anywhere from 10 to 90 MHz. On dual-conversion receivers, the second IF frequency is usually the standard 455 kHz. (It is at 455 kHz that the selectivity of the receiver is built in.)

Feature Hunting. Most shortwave receivers have a certain number of features and controls in common. Among these are AF gain (volume) control, RF gain control, bandswitch, mode switch, tuning (often including fine tuning or "bandspread"), relative signal strength meter, headphone jack and built-in speaker. Other desirable "extras" include selectable IF bandwidth, digital frequency readout, selectable sidebands (USB or LSB), tunable preselector, noise limiter, noise blanker, antenna trimmer, tunable notch filter, variable AGC (automatic gain control) response, and AC or battery power.

Which Receiver to Buy? Remember our opening analogy about receivers and automobiles? Well, just as there is no one "right car" for everyone, there is also no one "right receiver" for everyone. Based on your own intended use and future use for the receiver, there are many elements worth reviewing. Consider where the receiver will be used (battery power capability needed?), how much it will be used, what you plan to listen to (ham band only or general coverage?); and of course, your budget. If you plan to be only an occasional listener, it is doubtful that you would benefit greatly by purchasing an expensive receiver. The complexity of some elaborate receivers may actually become a deterrent to the casual listener who cannot devote sufficient time to understanding the capabilities and operation of the receiver.

New or Used? There are no tires to kick or *Consumer Reports* "frequency of repair" records to compare, but you can still find a good buy on a used receiver. If you have less than $150 to spend on a general coverage receiver or less than $225 for a ham band-only receiver, you *should* consider buying a used receiver. "What to look for when buying a used receiver" opens up a lot of territory—enough for a complete article on that subject alone. In short form, here are some hints:

Talk to other SWLs and hams. Ask about which receivers in your price range are most desirable. DX club bulletins are another good source.

High performance does not come cheaply. The McKay/Dymek DR 33C pictured here, and little brother DR 22C are not aimed at the budget-minded. These are professional-quality communications receivers, whose performance justifies price tags and looks.

CIRCLE 69 ON READER SERVICE COUPON

CIRCLE 81 ON READER SERVICE COUPON

Big brother to the FRG-7 is the FRG-7000, which features digital readout, and digital frequency programming to save you time.

Compare prices. Watch prices in classified ads (i.e., *QST* magazine), at hamfests, and at used equipment dealers. Amateur Electronic Supply (4828 West Fond du Lac Avenue, Milwaukee, WI 53216) offers a free listing of their extensive inventory of used equipment.

Dig deeper. Many manufacturers of older receivers are no longer in business, and replacement parts and proper repair service may be hard to come by.

Tubes? If you're interested in a tube-type receiver, be sure that it uses miniature tubes and not the older octal types.

Examine. Watch for damaged moving parts, such as rotary switches, variable capacitors and tuning-dial mechanisms. These parts may be difficult or impossible to obtain as replacements. Many odd frequency IF transformers are also difficult to find.

Stop. Avoid receivers that, when new, sold for under $100. There's a fine line between a good bargain on a cheaper rig, and throwing out money on a receiver that simply wasn't designed to do the kind of job you need for accurate monitoring. Spending a little now may save a lot more money on down the line.

The dealer connection. If you're not technically sharp (or you don't have a good friend who is), buy from a reputable dealer rather than an individual. You may pay more, but many headaches and dollars could be saved in the long run.

Beyond these steps, the same rules considered for any other used purchase apply. Be very sure you know what you're buying, what condition it's in, and what it's really worth. If you still have doubts, stick to new equipment.

What's New? General coverage receivers are making a comeback and many manufacturers are jumping on the bandwagon. Such manufacturers as Panasonic, Radio Shack, Sony, Sanyo, Standard, and Yaesu offer good-performing receivers in the $150 to $500 price-range. One popular Panasonic receiver, the RF-2200, sells for around $175 and offers 10 kHz shortwave dial calibration, and dual-conversion design. Five years ago, a general coverage receiver with equal accuracy and features would have cost at least several hundred dollars more.

The popular Yaesu FRG-7 and similar receivers from Radio Shack and Standard, use a frequency-synthesized design that results in excellent electrical stability. These receivers also offer a good range of features and good sensitivity. Beyond these units, there are a number of receivers at almost all price and performance levels. These include the McKay/Dymek DR-22C at $995, the (Gilfer) JRC NRD-505 at $2275, the (Rohde & Schwarz) Communications Products Corporation HF-1030 at $4500, and still others beyond!

Summary. Before you buy a receiver, be sure you understand all of the relevant specs and features. Spend a little time and decide what kind of receiver best fits your personal needs and budget, then spend more time comparing available receivers. Don't forget to ask about warranties. They typically range from 90-days to 2-years, and unlike car warranties, won't run out at 12,000 miles. Talk to other SWLs or read their comments on receivers in DX club bulletins. Word about an unsatisfactory receiver spreads even faster than word about a good one. Finally, there's no substitute for that test drive. If at all possible, try out the receiver you intend to buy, before you buy it. All in all, selecting the right receiver is almost as much of an adventure as using it. As an added dividend, careful receiver selection will add to your listening enjoyment for years to come. ■

IT'S SIMPLY BASIC

Once you have mastered the BASICs, why not try your hand at these programs for business and pleasure? All of them are in BASIC and can be used in various microcomputers with little or no program modification. A super-sophisticated system isn't needed either; memory requirements for these programs start at 4K RAM, and most can be loaded on cassettes.

by Larry Friedman, WB2AHN

Checkfile —Computerized banking at home

CHECKFILE is a program that will keep track of your checks so you can instantly retrieve information; for example, if the IRS asks you to substantiate your charity deductions, you can quickly get a list of all checks issued to charities without the time-consuming bother of inspecting each and every check you wrote during the tax year. Another example? The tax man says you didn't pay the real estate tax on your home. Simply enter TAX and the computer will give the check numbers for each tax payment.

Checkfile will search the data file by CATEGORY (examples shown above), MONTH, or LISTALL (this command prints a list of all checks entered into the file). To use the CATEGORY or MONTH command, type in the command and, after hitting C/R (carriage return), enter the name of the category or month for which you want a listing of the checks.

The program can store up to 100 checks; however, if your computer has the capacity for more than 100, you can modify line 120 to accommodate as many checks as desired. It is also limited to 25 categories (that is, not more than 25 categories, such as the ones shown in the first paragraph, can be displayed by the computer). However, the limit of 25 was set only for convenience, and you can set any limit for the number of categories by modifying line 115. Lines 650-690 provide a list of all categories, by printing the first check from each category. Without this feature, each category might be printed many times.

To start a file for entering checks, type NEW FILE when you're in the COMMAND mode. You may exit the NEW FILE mode by entering C/R when you are asked to enter the PAYEE's name. The OLD FILE command is used to add new checks to an old file. NEW FILE is located at lines 800-850, while OLD FILE uses the same lines, prefaced by lines 1000-1010.

To save this program on a Heathkit H-8 computer system with a tape recorder, type DUMP "CHECK." If you wish to save the variables along with the program, type FDUMP "CHECK." If you are using another computer system, or a different storage device, you may have to write a subroutine into the program to save the variables. ■

```
100 REM *
101 REM *             "CHECKFILE"
102 REM *
103 REM *          BY LARRY FRIEDMAN
104 REM *        WRITTEN FOR HEATH H-8
105 REM *    EX- BASIC VERSION 10.02.01.1
106 REM *
107 REM *
115 DIM J$(25)
120 DIM P$(100),C2(100),D2(100),M$(100),T$(100)
130 LINE INPUT "ENTER COMMAND ?";C$
140 IF C$="LISTALL" THEN 200
150 IF C$="MONTH" THEN 400
160 IF C$="CATEGORY" THEN 600
170 IF C$="NEW FILE" THEN 800
180 IF C$="OLD FILE" THEN 1000
185 IF C$="STOP" THEN END
190 PRINT "SORRY, THAT COMMAND DOES NOT EXIST. PLEASE RE-ENTER"
195 GOTO 130
200 FOR R=1 TO 5:PRINT :NEXT R
210 PRINT TAB(15);"LISTING OF ALL CHECKES"
215 PRINT
220 PRINT "PAYEE","CHECK #","AMOUNT ($$)","CATEGORY"
225 FOR R=1 TO 100
230 IF P$(R)="" THEN 370
235 PRINT P$(R),C2(R),D2(R),T$(R)
240 NEXT R
370 FOR R=1 TO 5:PRINT :NEXT R
375 GOTO 130
400 LINE INPUT "ENTER MONTH FOR FILE SEARCH ?";M$
405 FOR R=1 TO 5:PRINT :NEXT R
410 PRINT "PAYEE","CHECK #","AMOUNT ($$)","CATEGORY"
415 FOR R=1 TO 100
420 IF M$<>M$(R) THEN 430
425 PRINT P$(R),C2(R),D2(R),T$(R)
430 IF P$(R)="" THEN 440
435 NEXT R
440 FOR R=1 TO 5:PRINT :NEXT R
445 GOTO 130
600 GOSUB 650
604 LINE INPUT "ENTER CATEGORY FOR FILE SEARCH ?";T$
605 FOR R=1 TO 5:PRINT :NEXT R
610 PRINT "PAYEE","CHECK #","AMOUNT ($$)"
615 FOR R=1 TO 100
620 IF T$<>T$(R) THEN 635
625 PRINT P$(R),C2(R),D2(R)
630 IF P$(R)="" THEN 640
635 NEXT R
640 FOR R=1 TO 5:PRINT :NEXT R
645 GOTO 130
650 E=1
655 FOR R=1 TO 100
660 FOR X=1 TO E
665 IF J$(X)=T$(R) THEN 685
670 NEXT X
675 PRINT T$(R)
678 J$(E)=T$(R)
680 E=E+1
685 NEXT R
690 PRINT :RETURN
800 I=1
801 PRINT "ENTER PAYEE, CHECK #, AMOUNT, MONTH, AND CATEGORY"
802 PRINT "ENTER ON SEPERATE LINES, USING C/R BETWEEN ENTRIES"
805 PRINT "(HIT C/R FOR PAYEE TO RETURN TO COMMAND MODE)"
810 FOR R=I TO 100
812 REM INPUTS MUST BE ON SEPERATE LINES BECAUSE OF LINE INPUT.
813 LINE INPUT "PAYEE                    *";P$(R)
814 IF P$(R)="" THEN 835
815 INPUT "CHECK #              *";C2(R)
816 INPUT "AMOUNT (IN $$)       *";D2(R)
818 LINE INPUT "MONTH                    *";M$(R)
820 LINE INPUT "CATEGORY                 *";T$(R)
822 PRINT
830 NEXT R
835 PRINT
850 GOTO 130
1000 FOR I=1 TO 100
1005 IF P$(I)="" THEN 810
1010 NEXT I
9999 END
```

```
SAMPLE RUN OF "CHECKFILE" BY LARRY FRIEDMAN

>RUN
ENTER COMMAND ?NEW FILE
ENTER PAYEE, CHECK #, AMOUNT, MONTH, AND CATEGORY
ENTER ON SEPERATE LINES, USING C/R BETWEEN ENTRIES
(HIT C/R FOR PAYEE TO RETURN TO COMMAND MODE)
PAYEE           ?I.R.S.
CHECK #         ?25
AMOUNT (IN $$)  ?435.85
MONTH           ?APRIL
CATEGORY        ?INCOME TAX

PAYEE           ?NAACP
CHECK #         ?26
AMOUNT (IN $$)  ?100
MONTH           ?MAY
CATEGORY        ?CHARITY

PAYEE           ?RED CROSS
CHECK #         ?27
AMOUNT (IN $$)  ?100
MONTH           ?JUNE
CATEGORY        ?CHARITY

PAYEE           ?

ENTER COMMAND ?LISTALL

                LISTING OF ALL CHECKES

PAYEE        CHECK #     AMOUNT ($$)    CATEGORY
I.R.S.        25          435.85        INCOME TAX
NAACP         26          100           CHARITY
RED CROSS     27          100           CHARITY

ENTER COMMAND ?CATEGORY
INCOME TAX
CHARITY
ENTER CATEGORY FOR FILE SEARCH ?CHARITY

PAYEE        CHECK #     AMOUNT ($$)
NAACP         26          100
RED CROSS     27          100
ENTER COMMAND ?MONTH
ENTER MONTH FOR FILE SEARCH ?MAY
PAYEE        CHECK #     AMOUNT ($$)    CATEGORY
NAACP         26          100           CHARITY

ENTER COMMAND ?OLD FILE
PAYEE           ?JOE SMITH
CHECK #         ?27
AMOUNT (IN $$)  ?1000
MONTH           ?JULY
CATEGORY        ?USED CAR

PAYEE           ?

ENTER COMMAND ?LISTALL
                LISTING OF ALL CHECKES

PAYEE        CHECK #     AMOUNT ($$)    CATEGORY
I.R.S.        25          435.85        INCOME TAX
NAACP         26          100           CHARITY
RED CROSS     27          100           CHARITY
JOE SMITH     27          1000          USED CAR

ENTER COMMAND ?STOP

END AT LINE  185
>
```

Graph —Utilize the full graphic capability of your computer

GRAPH IS DESIGNED TO graphically display data using the Radio Shack TRS-80 Level II BASIC and graphics functions. The graph can have up to 10 vertical units (used for number values, ie. 10, 20, 30 . . . 100) and 12 horizontal units. After the graph has been printed, changes can be made in the data, and a new graph can be printed if desired.

A statement frequently seen in this program is the PRINT@ statement. This instructs the computer to print information at a given point on the screen instead of simply printing it on the bottom of the screen. This statement is necessary for graphics use to allow for graphs of different sizes. For example, line 680 states: PRINT@128 +(H*2.5),G$. This tells the computer to print G$ 2 lines from the top, and

```
100 REM
110 REM     "GRAPH"
120 REM     BY LARRY FRIEDMAN
130 REM
140 REM
150 REM     USES TRS-80 LEVEL 2 BASIC
160 REM     THIS PROGRAM USES TRS-80 GRAPHICS TO GIVE A
170 REM     VISUAL DISPLAY OF DATA. AFTER DATA HAS BEEN
180 REM     ENTERED AND THE GRAPH HAS BEEN PRINTED, THE
190 REM     DATA CAN BE ALTERED AND A NEW GRAPH WILL BE
200 REM     PRINTED.
210 REM
220 REM     THE PROGRAM'S CAPACITY IS 12 HORIZONTAL COORDINATES
230 REM     AND 10 VERTICAL COORDINATES. INDIVIDUAL HORIZONTAL
240 REM     ENTRIES SHOULDN'T EXCEED 4 CHARACTERS. THE LARGEST
250 REM     VERTICAL COORDINATES SHOULDN'T EXCEED 10,000.
260 REM
270 DIM N$(12),V(12)
280 CLS
290 INPUT "ENTER NAME FOR VERTICAL UNITS (7 CHAR MAX) ";G$
300 INPUT "ENTER NUMBER OF VERTICAL UNITS ";V
310 IF V>10 GOTO 300
320 INPUT "ENTER MAXIMUM VERTICAL VALUE ";M
330 IF M/V=INT(M/V) THEN 370
340 PRINT "MAX VERTICAL VALUE MUST BE DIVISIBLE"
350 PRINT "BY NUMBER OF VERTICAL UNITS"
360 GOTO 320
370 INPUT "ENTER NAME FOR HORIZONTAL UNITS ";H$
380 INPUT "ENTER NUMBER OF HORIZONTAL UNITS ";H
390 IF H>12 THEN 380
400 PRINT "ENTER NAMES OF HORIZONTAL UNITS (3 CHAR. MAX.) AND VALUES"
410 FOR I=1 TO H
420 INPUT N$(I),V(I)
430 IF V(I)>M THEN 400
440 IF V(I)<0 THEN 400
450 NEXT I
460 INPUT "ENTER NAME OF GRAPH";G$
470 REM PRINT GRAPH ON SCREEN
480 CLS
490 Z=0
500 FOR I=M TO 0 STEP- M/V
510 Z=Z+1
520 PRINT@(Z+2)*64,I
530 NEXT I
540 C=(Z+3)*64+5
550 FOR I=1 TO H
560 PRINT@C,N$(I)
570 C=C+5
580 NEXT I
590 FOR I=1 TO H
600 REM DETERMINE Y-AXIS FOR GRAPHIC DISPLAY.
610 A=V*3
620 B=(V(I)/M)*(V*3)
630 Y=A-B
640 Y=Y+10
650 X=2+(I*10)
660 SET (X,Y)
670 NEXT I
680 PRINT@128+(H*2.5),G$
690 PRINT@(Z+4)*64+(H*2.5),H$
700 PRINT@(Z+4)*64,G$
710 PRINT@0,"CHANGE (Y/N) ?";
720 INPUT Y$
730 IF Y$="Y" GOTO 790
740 PRINT @0,"HIT 'Q' TO ERASE GRAPHIC DISPLAY";
750 INPUT Q$
760 CLS
770 STOP
780 REM CHANGE DATA FOR HORIZ. COORDINATE AND PRINT NEW GRAPH.
790 PRINT@0,"NAME OF HORIZ. UNIT";
800 INPUT N$
810 FOR I=1 TO H
820 IF N$=N$(I) THEN 870
830 NEXT I
840 PRINT@0,"   NAME NOT IN CHART.    "
850 FOR R=1 TO 300:NEXT R
860 GOTO 790
870 PRINT@0,"ENTER NEW VALUE FOR ";N$;
880 INPUT V(I)
890 CLS
900 GOTO 490
999 END
```

half the width of the graph to the right. The TRS-80 screen is divided into 1023 characters, and the PRINT@ command can be used to print characters at any one of these.

Subscripted variables are also used in this program to allow for storage of data anywhere on the graph by entering new data for a subscripted variable. Subscripted variables are necessary in a graphics program when all the data is to be entered before printing.

This program can be used for loading variable electronic values for an equation, such as plotting voltage levels for a given current rating. It can also be used for business to indicate things such as unit price for an item (see sample run). Since data can be changed after the graph has been printed, the program can be used to make long-range predictions. ■

```
SAMPLE RUN OF "GRAPH"

ENTER NAME FOR VERTICAL UNITS (7 CHAR MAX) ? DOLLARS
ENTER NUMBER OF VERTICAL UNITS ? 4
ENTER MAXIMUM VERTICAL VALUE ? 80
ENTER NAME FOR HORIZONTAL UNITS ? YEAR
ENTER NUMBER OF HORIZONTAL UNITS ? 8
ENTER NAMES OF HORIZONTAL UNITS (3 CHAR. MAX.) AND VALUES
? '70,65
? '71,75
? '72,80
? '73,55
? '74,50
? '75,30
? '76,25
? '77,45
ENTER NAME OF GRAPH? UNIT PRICE
```

Music Library—This low-memory inventory keeps track of your music

MANY OF US COMPUTER HOBBYISTS can't afford the amount of memory normally required by a disk inventory program. But, if we eliminate both selective error correction and deletion of unwanted data, we sharply reduce the amount of RAM required.

In fact, *Music Library* requires only enough RAM to process six data variables and the error correction loop. The whole *bit* (pun intended), including the program itself, can be shoehorned into 4K of RAM.

Music Library will keep track of your records and tapes, and allow you to easily locate a long-lost treasure. Designed for SWTPCo version 2.0 BASIC in conjunction with the basic PerCom LFD-400 disk system, *Music Library* will run in about 4K of memory, and one single diskette will accommodate about 7000 individual entries, or in excess of 2300 complete entries consisting of artist, album (or tape) and song. The exact number will be determined by the length of each individual entry.

Updating. Once you have selected the starting disk sector (line 0115), the program will automatically and continuously write your data entries onto the disk. This is accomplished at line 1080. The UPDATE command automatically locates the end of your previous data and simply adds on the new data without requiring any additional memory in the computer. This is because the program does not use an array table (large list of variables, which takes large quantities of RAM).

To keep the program reasonably short it does not provide for removal of an entry (this requires a considerable amount of RAM). But, it does have ERROR CORRECTION should you make a mistake while entering data. The ERROR CORRECTION system is intermingled with the start mode (lines 1000-1090). It is somewhat unusual in that it employs the "negative reaction" technique, meaning it won't write to the disk until you confirm there is no

```
0100 REM "MUSIC LIBRARY" BY LARRY FRIEDMAN
0101 REM
0102 REM
0103 REM WRITTEN FOR SWTP 8K BASIC VERSION 2.0,
0104 REM AND PERCOM LFD-400 DISK SYSTEM
0105 REM ****************************************
0110 INPUT "NEED INSTRUCTIONS? (Y/N) ",I$:IF I$="Y" THEN 210
0115 INPUT "SECTOR START",C
0117 REM #10 DENOTES THE FILE NAME USED FOR THE PERCOM DISK SYSTEM
0120 OPEN #10,C
0130 DATA START,ARTIST,ALBUM,SONG,LIST,UPDATE
0140 RESTORE #10
0150 PRINT :INPUT "COMMAND",C$:RESTORE
0155 IF C$="EXIT" CLOSE#10:END
0160 FOR X=1 TO 6
0170 READ L$
0180 IF L$=C$ THEN 200
0190 NEXT X
0195 PRINT "ILLEGAL COMMAND":GOTO 150
0200 ON X GOTO 1000,2000,3000,4000,5000,6000
0210 PRINT :PRINT
0220 PRINT "COMMAND              FUNCTION"
0230 PRINT "-------              ---------"
0240 PRINT "START                TO ENTER INITIAL DATA ENTRIES"
0250 PRINT "ARTIST               TO LOCATE ALBUM AND SONG BY ARTIST"
0260 PRINT "ALBUM                TO LOCATE ARTIST BY ALBUM"
0270 PRINT "SONG                 TO LOCATE ARTIST AND ALBUM BY SONG"
0280 PRINT "LIST                 FOR COMPLETE LISTING OF ALL FILES"
0290 PRINT "UPDATE               TO ADD TO LIST  (SEE 'START')"
0300 PRINT "EXIT                 TO LEAVE PROGRAM"
0310 GOTO 115
1000 PRINT :PRINT "ENTER ARTIST, ALBUM, AND SONG."
1010 PRINT "TYPE 'LEAVE' TO EXIT 'START' MODE"
1015 RESTORE #10
1020 PRINT
1030 PRINT :INPUT "ARTIST",A$:IF A$="LEAVE" P=6:GOTO 1080
1035 IF A$<>"ERROR" THEN 1075
1036  D$=""
1037 GOTO 1030
1040 INPUT "ALBUM",B$
1050 INPUT "SONG",C$
1055 REM D$, E$, AND F$ ARE USED FOR ERROR CORRECTION LOOPING
1060  D$=A$:E$=B$:F$=C$
1070 GOTO 1030
1075 IF D$="" THEN 1040
1080 PRINT #10;D$;E$;F$:IF P=6 P=0:GOTO 150
1090 GOTO 1040
2000 INPUT "NAME OF ARTIST",N$:X=0
2010 RESTORE #10
2020 READ #10,A$,B$,C$\2070
2030 IF A$=N$ X=1:GOTO 2050
2040 GOTO 2020
2050 IF B$="" THEN 2055
2052 PRINT "ALBUM: ";B$
2055 IF C$="" THEN 2060
2057 PRINT "SONG: ";C$
2060 GOTO 2020
2070 IF X=1 THEN 150
2080 PRINT "NO ARTIST LISTED UNDER NAME: ";N$:GOTO 150
3000 INPUT "ALBUM NAME ",N$:Y=0
3010 RESTORE #10
3020 READ #10,A$,B$,C$\3070
3030 IF B$=N$ Y=1:GOTO 3050
3040 GOTO 3020
3050 IF A$="" THEN 3060
3055 PRINT "ARTIST: ";A$
3060 GOTO 3020
3070 IF Y=1 THEN 150
3080 PRINT "NO ALBUM LISTED UNDER NAME: ";N$:GOTO 150
4000 INPUT "SONG",N$:Z=0
4010 RESTORE #10
4020 READ #10,A$,B$,C$\4070
4030 IF C$=N$ Z=1:GOTO 4050
4040 GOTO 4020
4050 IF A$="" THEN 4055
4052 PRINT "ARTIST: ";A$
4055 IF B$="" THEN 4060
4057 PRINT "ALBUM: ";B$
4060 GOTO 4020
4070 IF Z=1 THEN 150
4080 PRINT "NO SONG UNDER NAME: ",N$:GOTO 150
5000 RESTORE #10
5020 PRINT "ARTIST";TAB(18);"ALBUM";TAB(36);"SONG"
5030 READ #10,A$,B$,C$\150
5040 PRINT A$;TAB(18);B$;TAB(36);C$
5050 GOTO 5030
6000 READ #10,A$,B$,C$\1020
6010 GOTO 6000
9999 END
```

IT'S SIMPLY BASIC

error *by not* typing the word "error." (Yes, it is difficult to follow on the first five read-throughs.)

On a program run the computer will only output the information that it has, it won't fill with blank spaces by attempting to print information it doesn't have stored on the disk. (See lines 2050, 2055).

If you utilize this program on a different computer system make certain the fundamental BASIC "conditional GoTo command" (IF-THEN) is tailored for your system. For example, in line 4030 the statement reads IF C$=N$ Z=1. Your computer might require the statement to read IF C$=N$ THEN Z=1. (This byte-saving type of statement has been used throughout the program. Multiple statement lines have also been used to save RAM.)

The program can be easily modified to personalize the system for your particular needs. ■

Audio Designer —Keeps audio programs handy

WHILE A COMPUTER is capable of storing and processing almost endless amounts of data, it is also extremely efficient when you must make many calculations using the same formula, or information.

This rapid processing, combined with continuous printed output of the calculations, is used in *Audio Designer*, a program intended expressly for the audio experimenter and hobbyist. It is particularly handy when plotting amplifier input sensitivity and output power charts or curves, or when designing or calculating filters, the effects of capacitance versus resistance when plotting frequency cutoffs, etc.

The program features continuous recycling. Once a reference value for a problem is entered, the computer automatically prints the solution when an

```
100 REM
110 REM      "AUDIO DESIGNER"
115 REM      BY LARRY FRIEDMAN
120 REM      WRITTEN FOR TRS-80
130 REM      LEVEL 2 BASIC
135 REM
140 REM NOTE: ON SOME TRS-80 COMPUTERS
141 REM A BRACKET ([) IS PRINTED
142 REM INSTEAD OF AN UP-ARROW TO
143 REM SHOW EXPONENTIATION.
144 REM
145 REM THIS PROGRAM IS WRITTEN FOR
146 REM 40 CHARACTER LINES. IT CAN
147 REM BE EXTENDED TO 72 CHAR. IF
148 REM DESIRED
160 REM
165 CLS
170 INPUT "NEED A FORMULA CHART(Y/N)";Y$
180 IF Y$="N" THEN 400
190 PRINT:PRINT
200 PRINT "1.  DECIBELS (FOR VOLTAGE)"
210 PRINT "    DB = 20*LOG(E1/E2)"
215 PRINT
220 PRINT "2.  DECIBELS (FOR POWER)"
230 PRINT "    DB = 10*LOG(P1/P2)"
235 PRINT
240 PRINT "3.  CAP. REACTANCE"
242 PRINT "    (ENTER C IN MFD)"
250 PRINT "    X(C) = 1/(6.28*F*C*10[-6)"
270 PRINT
400 PRINT "ENTER NUMBER OF DESIRED"
405 INPUT "FORMULA  (1, 2, OR 3)";R
410 ON R GOTO 1000,2000,3000
1000 PRINT "DECIBEL FORMULA"
1005 PRINT "(FOR VOLTAGE)"
1010 INPUT "E1 = ";E1
1020 INPUT "E2 = ";E2
1030 IF E1=0 THEN 1200
1035 PRINT "E2";TAB(10);"DECIBELS"
1040 INPUT E2
1050 D=20 * LOG(E1/E2)/ LOG(10)
1060 PRINT " ";E2;TAB(10);D
1070 GOTO 1040
1200 PRINT "E1";TAB(10);"DECIBELS"
1210 INPUT E1
1220 D=20 * LOG(E1/E2)/ LOG(10)
1230 PRINT " ";E1;TAB(10);D
1240 GOTO 1210
2000 PRINT "DECIBEL FORMULA (FOR POWER)"
2005 PRINT "ENTER KNOWN POWER"
2010 INPUT "P1 = ";P1
2020 INPUT "P2 = ";P2
2030 IF P1=0 THEN 2200
2035 PRINT "P2";TAB(10);"DECIBELS"
2040 INPUT P2
2050 D=10 * LOG(P1/P2)/ LOG(10)
2060 PRINT " ";P2;TAB(10);D
2070 GOTO 2040
2200 PRINT "P1";TAB(10);"DECIBELS"
2210 INPUT P1
2220 D=10 * LOG(P1/P2)/ LOG(10)
2230 PRINT " ";P1;TAB(10);D
2240 GOTO 2210
3000 PRINT "CAP. REACTANCE FORMULA --"
3005 PRINT "DO YOU WANT TO"
3010 INPUT "SOLVE FOR X(C), F, OR C";Y$
3020 IF Y$="F" THEN 3200
3030 IF Y$="C" THEN 3400
3040 REM SOLVING FOR X(C)
3045 INPUT "F (IN HERTZ) = ";F
3047 INPUT "C (IN MFD) = ";C
3050 IF C=0 THEN 3100
3055 PRINT " F";TAB(10);"OHMS (X(C))"
3060 INPUT F
3070 X=1/(6.28*F*C*10[-6)
3080 PRINT F;TAB(10);X
3090 GOTO 3060
3100 PRINT " C";TAB(10);"OHMS (X(C))"
3110 INPUT C
3120 X=1/(6.28*F*C*10[-6)
3130 PRINT C;TAB(10);X
3140 GOTO 3110
3200 INPUT "X(C) = ";X
3210 INPUT "C (IN MFD) = ";C
3220 IF X=0 THEN 3300
3221 PRINT " C";TAB(10);"FREQUENCY"
3222 INPUT C
3225 F=1/(6.28*X*C*10[-6)
3230 PRINT C;TAB(10);F
3240 GOTO 3222
3300 PRINT " X(C)";TAB(10);"FREQUENCY"
3310 INPUT X
3320 F=1/(6.28*X*C*10[-6)
3330 PRINT X;TAB(10);F
3340 GOTO 3310
3400 INPUT "X(C) = ";X
3410 INPUT "F (IN HERTZ) = ";F
3420 IF X=0 THEN 3500
3430 PRINT " F ";TAB(10);
3435 PRINT "CAPACITY (IN MFD)"
3440 INPUT F
3450 C=1/(6.28*F*X*10[-6)
3460 PRINT F;TAB(10);C
3470 GOTO 3440
3500 PRINT " X(C)";TAB(10);
3505 PPINT "CAPACITY (IN MFD)"
3510 INPUT X
3520 C=1/(6.28*F*X*10[-6)
3530 PRINT X;TAB(10);C
3540 GOTO 3510
9999 END
```

SAMPLE RUNS OF "AUDIO DESIGNER"

```
>RUN
NEED A FORMULA CHART(Y/N)? Y

1.  DECIBELS (FOR VOLTAGE)
    DB = 20*LOG(E1/E2)

2.  DECIBELS (FOR POWER)
    DB = 10*LOG(P1/P2)

3.  CAP. REACTANCE
    (ENTER C IN MFD)
    X(C) = 1/(6.28*F*C*10[-6)

ENTER NUMBER OF DESIRED
FORMULA  (1, 2, OR 3)? 1
DECIBEL FORMULA
(FOR VOLTAGE)
E1 = ?
E2 = ? 200
E1        DECIBELS
? 100
  100          -6.0206
? 400
  400           6.0206
?
BREAK IN 1210
READY
>RUN
NEED A FORMULA CHART(Y/N)? N
ENTER NUMBER OF DESIRED
FORMULA  (1, 2, OR 3)? 3
CAP. REACTANCE FORMULA --
DO YOU WANT TO
SOLVE FOR X(C), F, OR C? X(C)
F (IN HERTZ) = ? 1000
C (IN MFD) = ?
 C        OHMS (X(C))
? .001
 1E-03             159236
? .002
 2E-03             79617.8
? .0005
 5E-04             318471
?
BREAK IN 3110
READY
>RUN
NEED A FORMULA CHART(Y/N)? N
ENTER NUMBER OF DESIRED
FORMULA  (1, 2, OR 3)? 3
CAP. REACTANCE FORMULA --
DO YOU WANT TO
SOLVE FOR X(C), F, OR C? F
X(C) = ? 159235
C (IN MFD) = ?
 C        FREQUENCY
? .001
 1E-03             1000
? .002
 2E-03             500.002
? .005
 5E-03             200.001
?
BREAK IN 3222
READY
>
```

unknown value is entered, and it is immediately ready for another unknown.

Block Construction. The program uses "block construction," so it can be easily modified to do other calculations. For example, if you want to calculate for L, or XL (inductance and inductive reactance) simply tack it on the end of the program as "block 4000," or "the 4000 series." Also, be sure to change line 410 to accommodate the added programming blocks, and include, at line 250, updated instructions.

Audio Designer was written for the Radio Shack TRS-80 with Level II BASIC. Take extra careful note that some TRS-80's print the exponentiation up-arrow (↑) as a bracket ([). The fact that a bracket is shown does not mean there is a print or programming error. The result during a program run is exponentiation regardless which symbol is shown.

Also, the TRS-80 tends to show three or more decimal place numbers in scientific notation.

To exit the program, type BREAK on the TRS-80. Other computers will require their normal interrupt statements, such as CONTROL-C. ■

Inventory—Keep track of stock and supplies

WHILE MASS DATA STORAGE is easily accomplished using a cassette recorder, it often takes so long to find and/or load a program or data that the whole thing isn't worth the effort. A set of index cards can often be handled faster than a personal computer with a cassette storage system.

For fast mass data handling a disc system is an absolute *must have.* Problem is, a disc system generally chews up a lot of memory just to operate the disc; usually about $250 worth of memory in addition to the cost of the disc system. But a disc system such as the PerCom LFD-400 (for the SWTP 6800 computer) requires no extra memory assigned exclusively for the disc, and is an ideal low-cost means for the hobbyist to attain mass storage at reasonable cost.

A Disk Delight. To show the convenience of a budget disk system *Inventory* was designed especially for a

```
0001 REM "INVENTORY" BY LARRY FRIEDMAN
0002 REM PROGRAM USES SWTP 6800 BASIC VERSION 2.0 AND
0003 REM PERCOM SINGLE-DRIVE LFD-400 DISK SYSTEM
0004 REM
0005 INPUT "DO YOU WANT A LIST OF COMMANDS  (Y/N)",A$
0006 IF A$="N" THEN 100
0007 PRINT
0008 PRINT "START              TO ENTER INITIAL ITEM ENTRIES"
0009 PRINT "UPDATE             TO UPDATE THE FILE WITH NEW ITEMS"
0010 PRINT "SEARCH             TO FIND AN ITEM IN THE FILE"
0011 PRINT "CATALOG            PRINTS ENTIRE CONTENTS OF FILE"
0012 PRINT "DELETE LINES       FOR MULTIPLE DELETIONS OF ITEMS"
0013 PRINT "QUANTITY           FOR FINDING QUANTITY OF AN ITEM"
0014 PRINT "DELETE             FOR DELETION OF A PARTICULAR ITEM"
0015 PRINT "LOCATION CHANGE    TO CHANGE THE LOCATION OF AN ITEM"
0016 PRINT "QUANTITY CHANGE    TO CHANGE THE QUANTITY OF AN ITEM"
0017 PRINT "LOCATION FIND      LISTS ITEMS IN SPECIFIED LOCATION"
0018 PRINT "END                TO CLOSE FILE AND EXIT FROM PROGRAM"
0100 DIM I$(75),S$(75),Q(75)
0110 INPUT "SECTOR START",A
0120 OPEN #10,A
0130 FOR N=1 TO 75
0140 READ #10,I$(N),S$(N),Q(N)\160
0150 NEXT N
0160 PRINT
0170 DATA START,UPDATE,SEARCH,CATALOG,DELETE LINES,QUANTITY
0180 DATA DELETE,LOCATION CHANGE,LOCATION FIND,QUANTITY CHANGE,END
0190 PRINT :PRINT:INPUT "COMMAND>",C$
0195 PRINT
0200 RESTORE
0210 FOR X=1 TO 11
0220 READ D$
0230 IF D$=C$ THEN 270
0240 NEXT X
0250 PRINT "SORRY, ";C$;" ISN'T A VALID COMMAND."
0260 GOTO 190
0270 ON X GOTO 1000,2000,3000,4000,5000,6002,7000,8000,9000,9250,9500
1000 PRINT "START FILE ENTRIES"
1010 PRINT "ENTER ITEM, LOCATION, & QUANTITY (SEPARATED BY COMMAS)"
1020 PRINT
1030  V=1
1040 FOR X=V TO 75
1045 PRINT "# ";X;
1047 INPUT I$(X),S$(X),Q(X)
1050 IF I$(X)="STOP" THEN 190
1070 NEXT X
1080 GOTO 190
2000 PRINT "UPDATE FILE ENTRIES"
2010 FOR X=1 TO 75
2020 IF I$(X)="STOP" THEN 2060
2030 NEXT X
2040 PRINT "SORRY, FILE IS FULL"
2050 GOTO 190
2060  V=X
2070 GOTO 1040
3000 INPUT "ITEM>",I$
3010 FOR X=1 TO 75
3020 IF I$=I$(X) THEN 3060
3030 NEXT X
3040 PRINT "ITEM NOT FOUND IN FILE"
3050 GOTO 190
3060 PRINT "ITEM ";I$(X);" FOUND IN LOCATION: ";S$(X)
3070 GOTO 190
4000 IF I$(1)="" PRINT "NO ITEMS IN LIST.":GOTO 190
4001  Q=0
4005 PRINT "ITEM";TAB(20);"LOCATION";TAB(40);"QUANTITY"
4010 FOR X=1 TO 75
4015  Q=Q+1
4020 IF I$(X)="STOP" THEN 4050
4025 IF I$(X)="" Q=Q-1 :GOTO4040
4030 PRINT I$(X);TAB(20);S$(X);TAB(40);Q(X)
4040 NEXT X
4050 PRINT :PRINT TAB(20);Q-1;" ITEMS IN CATALOG"
4060 GOTO 190
5000 PRINT "HIT RETURN TO ADVANCE ITEM, D TO DELETE ITEM"
5010 PRINT "OR T TO TERMINATE DELETE LINE FUNCTION"
5020 PRINT
5030 FOR X=1 TO 75
5035 IF I$(X)="" THEN 5120
5036 IF I$(X)="STOP" THEN 190
5040 PRINT I$(X);
5050 INPUT A$
5060 IF A$="T" THEN 190
5070 IF A$="" THEN 5120
5080 IF A$="D" THEN 5110
5090 PRINT "ENTER D,T, OR HIT RETURN"
5100 GOTO 5050
5110  I$(X)="":S$(X)="":Q(X)=0
5120 NEXT X
5130 GOTO 190
6000 INPUT "ITEM>",I$
6010 FOR X=1 TO 75
6020 IF I$(X)=I$ THEN 6060
6030 NEXT X
6040 PRINT "ITEM NOT FOUND IN LIST"
6050 GOTO 190
6060 PRINT "ITEM ";I$;" QUANTITY: ";Q(X)
6070 GOTO 190
7000 INPUT "ITEM>",I$
7010 FOR X=1 TO 75
7020 IF I$=I$(X) THEN 7060
7030 NEXT X
7040 PRINT "ITEM NOT FOUND IN LIST"
7050 GOTO 190
7060  I$(X)="":S$(X)="":Q(X)=0
7070 GOTO 190
8000 INPUT "ITEM>",I$
8010 FOR X=1 TO 75
8020 IF I$=I$(X) THEN 8060
8030 NEXT X
8040 PRINT "ITEM NOT FOUND IN LIST"
8050 GOTO 190
8060 PRINT S$(X)
8070 INPUT "NEW LOCATION>",S$(X)
8080 GOTO 190
9000 INPUT "LOCATION>",S$
9005  Z=0
9010 FOR X=1 TO 75
9020 IF S$=S$(X) PRINT I$(X):Z=Z+1
9030 NEXT X
9040 IF Z=0 PRINT "NO ITEMS IN THAT LOCATION."
9050 GOTO 190
9250 INPUT "ITEM>",I$
9260 FOR X=1 TO 75
9270 IF I$=I$(X) THEN 9310
9280 NEXT X
9290 PRINT "ITEM NOT FOUND IN LIST"
9300 GOTO 190
9310 PRINT "QUANTITY = ";Q(X)
9320 INPUT "CHANGE>",C
9340  Q(X)=Q(X)+C
9350 GOTO 190
9500 INPUT "ENTER SECTOR FOR DUMP",A
9501 CLOSE #10
9502 OPEN #10,A
9503 FOR X=1 TO 75
9510 IF I$(X)="" THEN 9700
9520 PRINT #10,I$(X);S$(X);Q(X)
9530 NEXT X
9700 CLOSE #10
9710 PRINT "NEXT AVAILABLE SECTOR = ";SCTR
9999 END
```

```
SAMPLE RUN OF "INVENTORY"


READY
#RUN
DO YOU WANT A LIST OF COMMANDS  (Y/N)? Y

START            TO ENTER INITIAL ITEM ENTRIES
UPDATE           TO UPDATE THE FILE WITH NEW ITEMS
SEARCH           TO FIND AN ITEM IN THE FILE
CATALOG          PRINTS ENTIRE CONTENTS OF FILE
DELETE LINES     FOR MULTIPLE DELETIONS OF ITEMS
QUANTITY         FOR FINDING QUANTITY OF AN ITEM
DELETE           FOR DELETION OF A PARTICULAR ITEM
LOCATION CHANGE  TO CHANGE THE LOCATION OF AN ITEM
QUANTITY CHANGE  TO CHANGE THE QUANTITY OF AN ITEM
LOCATION FIND    LISTS ITEMS IN SPECIFIED LOCATION
END              TO CLOSE FILE AND EXIT FROM PROGRAM
SECTOR START? 1100


COMMAND>? START

START FILE ENTRIES
ENTER ITEM, LOCATION, & QUANTITY (SEPARATED BY COMMAS)

# 1 ? RESISTORS,BOX 8,56
# 2 ? CAPACITORS,UNDER BENCH,82
# 3 ? SCREWS,BOX 11,200
# 4 ? TRANSISTORS,BOX 8,11
# 5 ? ROUND STAPLE GUN,GARAGE,1
# 6 ? DIODES,BOX 11,32
# 7 ? STOP,,0


COMMAND>? CATALOG

ITEM              LOCATION        QUANTITY
RESISTORS         BOX 8           56
CAPACITORS        UNDER BENCH     82
SCREWS            BOX 11          200
TRANSISTORS       BOX 6           11
ROUND STAPLE GUN  GARAGE          1
DIODES            BOX 11          32
                  6  ITEMS IN CATALOG


COMMAND>? UPDATE

UPDATE FILE ENTRIES
# 7 ? NAILS,BOX 4,60
# 8 ? SOLDERING IRON,ON TOP OF WORKBENCH,1
# 9 ? STOP,,0


COMMAND>? SEARCH

ITEM>? TRANSISTORS
ITEM TRANSISTORS FOUND IN LOCATION: BOX 8


COMMAND>? QUANTITY

ITEM>? RESISTORS
ITEM RESISTORS QUANTITY: 56


COMMAND>? DELETE

ITEM>? SCREWS


COMMAND>? DELETE LINES

HIT RETURN TO ADVANCE ITEM, D TO DELETE ITEM
OR T TO TERMINATE DELETE LINE FUNCTION

RESISTORS?
CAPACITORS?
TRANSISTORS? D
ROUND STAPLE GUN?
DIODES? D
NAILS?
SOLDERING IRON? T


COMMAND>? CATALOG

ITEM              LOCATION              QUANTITY
RESISTORS         BOX 8                 56
CAPACITORS        UNDER BENCH           62
ROUND STAPLE GUN  GARAGE                1
NAILS             BOX 4                 60
SOLDERING IRON    ON TOP OF WORKBENCH   1
                  5  ITEMS IN CATALOG


COMMAND>? END

ENTER SECTOR FOR DUMP? 1125
NEXT AVAILABLE SECTOR = 1126

READY
```

SWTP 6800 with the basic PerCom LFD-400, using the optional PerCom patch for the numbered files. The BASIC used was SWTP Version 2.0.

Inventory will keep track of up to 75 items per file. Simply use additional files for additional items. The functions given in lines 0008 to 0018 are self-explanatory. If you don't understand some of them simply load the program, put about five items into the inventory, and then experiment with the different commands.

Take care that you use a reverse slash in line 0140; don't substitute a division symbol ("/"). The reverse slash is PerCom's command to send the program to the specified line after the data is read/written. Also, make certain you use a sector number that hasn't been used (line 0110).

Note. This program handles up to 75 items because we assume a hobbyist's computer with a disc system will have 20K of memory. If you have more memory you can increase the number of items per file.

If we had two disc systems with random files we could easily handle hundreds of items, but another disc and support memory for random files is very expensive. The basic PerCom LFD-400 disc system with single drive, and 20k memory in the computer, requires specific files per 75 items.

Inventory can be easily modified to serve specific needs. For example, you can have it store four, five, or more entries per catalog item. Essentially, it is a "universal program" for a budget disc system such as the Percom LFD-400, one that does not require additional memory solely for the DOS (disc operating system). ■

Horse Race—Kentucky Derby on your video screen

THIS PROGRAM, *Horse Race*, is designed to let you simulate an actual horse race on the Radio Shack TRS-80 with Level II BASIC. The program will randomly select odds for each of five horses, and the player bets on one of them. Using the Radio Shack graphics, the computer will print the horse race on the screen. The horses are represented by graphic blocks, and will appear to move across the screen at a speed relative to their odds.

Horse Race uses a random number generator (see line 460) to determine the odds for each horse. Horses are given odds between three-to-one and five-to-one, and the chances of their winning and the amount you will win depends on their odds. For example, a horse with the odds three-to-one has a 1/3 chance of winning (relative to the other horses), and the player would win three times what he bet. On the other hand, a horse with the odds five-to-one would have only a 1/5 chance of winning, but the player would receive 5 times what he bet if he wins.

Although the program can be used by as many people as desired, it is designed to keep track of the winnings for only one player. Line 970 determines if the player has won, while line 1000 determines how much he has won.

The program uses a data statement to store the names of the five horses. This data statement is at line 220, and you can change the names of the horses to your liking by simply typing in your own names instead of the ones used in this listing. Keep in mind that you also must correct lines 310-350 if you want to change the horses' names.

The program has been designed to run on all TRS-80 Level II systems; the memory allocations for subscripted variables and the amount of program memory used have been held to a minimum. If you want to add different features to this program (for example, have "win," "place," and "show" instead of simply having "win"), feel free to do so. However, we have kept extra features to a bare minimum to allow the users with less memory to fit this program. ■

```
100 REM          "HORSE RACE"
110 REM        BY LARRY FRIEDMAN
120 REM
130 REM
140 P(1)=P(2)=P(3)=P(4)=P(5)=0
150 DATA 10,16,22,28,34
160 FOR I=1 TO 5:READ D(I):NEXT I
170 T1=0
180 RANDOM
190 DIM A$(5)
200 R=0
210 REM LINE 170 CONTAINS THE NAMES OF THE FIVE HORSES
220 DATA SWIFT SAM,PIZZA SLICE,TELETYPE,ARIES,CEASAR
230 FOR I=1 TO 5
240 READ A$(I)
250 NEXT I
260 INPUT "IS THIS FOR ONE PLAYER? (Y/N)";U$
270 INPUT "ENTER PAYOUT PERCENTAGE (FROM .01 TO 1.00)";P
280 CLS
290 PRINT@337,"WELCOME TO FRIEDMAN RACE TRACK"
300 PRINT@462,"TODAY'S COMPETITORS ARE (BY HORSE):"
310 PRINT@595,"(A) SWIFT SAM"
320 PRINT@659,"(B) PIZZA SLICE"
330 PRINT@723,"(C) TELETYPE"
340 PRINT@787,"(D) ARIES"
350 PRINT@851,"(E) CEASAR"
360 FOR I=1 TO 1300:NEXT I
370 FOR D=1 TO 1000:NEXT D:CLS
380 FOR I=1 TO 5:P(I)=0:NEXT I
390 IF U$="N" THEN 420
400 IF M<=0 THEN PRINT "YOU OWE THE COMPUTER ";-M
410 IF M>0 THEN PRINT "THE COMPUTER OWES YOU ";M
420 R=R+1
430 PRINT@212,"RACE NUMBER ";R
440 FOR I=1 TO 5
450 REM R(I) DETERMINES THE ODDS FOR EACH HORSE
460 R(I)=RND(3)+2
470 NEXT I
480 PRINT@320,"HORSE","ODDS"
490 FOR I=1 TO 5
500 PRINT A$(I),R(I);"-1"
510 NEXT I
520 PRINT@896,"ENTER HORSE'S NAME AND BET";
530 INPUT N$,B
540 P2=1
550 FOR I=1 TO 5
560 IF N$=A$(I) THEN 590
570 NEXT I
580 GOTO 520
590 FOR I=1 TO 500:NEXT I
600 CLS
610 Y1=1
620 A=1
630 FOR I=192 TO 704 STEP 128
640 PRINT@I,A$(A)
650 A=A+1
660 REM PRINT HORSE TRACK ON SCREEN
670 NEXT I
680 FOR X=36 TO 37
690 FOR Y=0 TO 127
700 SET (Y,X):NEXT Y:NEXT X
710 FOR Y=9 TO 36
720 FOR X=29 TO 30
730 SET (X,Y):NEXT:NEXT
740 FOR Y=9 TO 36
750 FOR X=125 TO 127
760 SET (X,Y):NEXT:NEXT
770 PRINT@116,"FINISH LINE"
780 FOR I=1 TO 5
790 R1(I)=RND(R(I))+1
800 NEXT I
810 FOR I=1 TO 5
820 REM P(I) DETERMINES HOW FARR THE HORSE WILL MOVE
830 P(I)=P(I)+(12/R1(I))
840 IF P(I)>100 THEN P(I)=100:F$(I)="WINNER"
850 NEXT I
860 FOR I=1 TO 5
870 IF P2=1 THEN P(I)=P(I)+3
880 SET (P(I)+27,D(I))
890 IF F$(I)="WINNER" THEN 950
900 RESET (K(I)+27,F(I))
910 K(I)=P(I):F(I)=D(I)
920 NEXT I
930 P2=0
940 GOTO 780
950 PRINT@916,"WINNER IS ";A$(I)"
960 F$(I)=""
970 IF N$<>A$(I) THEN 1040
980 PRINT@788, " YOU WIN ";(P*B*R(I))
990 REM COMPUTE  WINNINGS
1000 M=M+P*B*R(I)
1010 PRINT@960,"HIT RETURN TO START NEW RACE";
1020 INPUT R$
1030 GOTO 370
1040 PRINT@788," YOU LOSE ";B
1050 M=M-B
1060 PRINT@960,"HIT RETURN TO START NEW RACE";
1070 INPUT R$
1080 GOTO 370
9999 END
```

Jackpot—Program your own computer casino

HERE'S A PROGRAM to add excitement to a rainy day, liven up any party or perhaps raise a little money for a local charity at a Las Vegas Nite.

JACKPOT is a game where the player gambles a quarter in the hopes of winning some money by having the computer randomly (at line 440) select a winning combination of 3 objects out of a possible 7. If the computer picks three of the same object (apple, cherry, etc.), 2 of the same object on the first 2 wheels, or 2 cherries for the last 2 wheels, the player wins. The payout depends on what the winning combination is, and how much money the house has. In this version, designed for home enjoyment, the payout percentages are high. The computer starts by taking 60% of the money for the house, and from the remaining amount comes the payout. However, I strongly recommend that you don't try to use this program to make money without changing the payout percentage. This is controlled at line 610. It reads: 610 P1 = B*.40. If you want to make more money for the house, change that .40 to a .25 or .30. (The figure represents the payout percentage by the house.)

This program uses the AND statement (see line 490 for example) which is a logical command. It's used in IF-THENs and, translated, means: IF A AND B ARE TRUE THEN XX (where XX is some function for the computer to do). Examine lines 180-250 carefully; they are provided to allow each wheel to have different odds for each object. For example, there is only one ORANGE on the first wheel, while there are 2 on the second and third wheels. The odds for the payouts are computed at lines 530, 540-580, and 600. You can change them if you

IT'S SIMPLY BASIC

```
LIST

100 REM  *
101 REM  *                    "JACKPOT"
102 REM  *
103 REM  *                BY LARRY FRIEDMAN
104 REM  *               WRITTEN FOR HEATH H-8
105 REM  *           EX. BASIC VERSION 10.02.01
106 REM  *
107 REM  *
108 REM  * THIS VERSION OF BASIC HAS SUPPRESSED TRAILING DECIMAL
109 REM  * ZEROES; THEREFORE  $1.50 IS INDICATED AS $1.5
110 DIM R$(7),P$(3),W(3,9),C(3)
120 P=0:B=20:Y=0
130 DATA "JACKPOT","CHERRY","LEMON","ORANGE"
140 DATA "APPLE","PEAR","PEACH"
150 FOR R=1 TO  7
160 READ R$(R)
170 NEXT R
180 DATA 1,2,2,3,3,4,5,5,5
190 DATA 1,2,3,3,4,4,5,5,5
200 DATA 1,2,3,4,4,5,5,6,7
210 FOR X=1 TO 3
220 FOR Y=1 TO 9
230 READ W(X,Y)
240 NEXT Y
250 NEXT X
260 LINE INPUT "NEED INSTRUCTIONS (Y/N) ?";I$
270 IF I$="N" THEN 365
280 PRINT "JACKPOT - A SIMULATED SLOT"
290 PRINT "MACHINE. EACH PLAY IS $.25"
300 PRINT "PAYOFFS ARE FOR 3 OF A KIND,"
305 PRINT "2 OF A KIND ON THE FIRST 2 WHEELS,"
307 PRINT "OR CHERRIES FOR THE LAST 2 WHEELS."
310 PRINT "THE OBJECTS ARE: JACKPOT, CHERRY"
320 PRINT "LEMON, ORANGE,APPLE, PEAR, PEACH."
330 PRINT
365 IF D<0 THEN PRINT "YOU OWE THE HOUSE $";D*-1
370 IF D>=0 THEN PRINT "THE HOUSE OWES YOU $";D
380 IF I$="QUIT" THEN I$="":GOTO 810
390 PRINT :LINE INPUT "PLAY OR QUIT  (P/Q)  ?";G$
400 IF G$="Q" THEN 800
410 PRINT "THE LEVER HAS BEEN PULLED!"
420 D=D-.25:B=B+.25
430 FOR R=1 TO 3
440 C(R)=INT(RND(1)*9)+1
450 PRINT R$(W(R,C(R)));"    ";
460 P$(R)=R$(W(R,C(R)))
470 NEXT R
480 PRINT
490 IF P$(1)=P$(2) AND P$(1)<>P$(3) THEN 530
500 IF P$(1)=P$(2) AND P$(2)=P$(3) THEN 540
510 IF P$(2)="CHERRY" AND P$(3)="CHERRY" THEN 600
520 PRINT "YOU LOSE!!!":GOTO 365
530 I=.1:GOTO 610
540 IF P$(1)="JACKPOT" THEN I=.75
550 IF P$(1)="CHERRY" THEN I=.55
560 IF P$(1)="LEMON" THEN I=.4
570 IF P$(1)="ORANGE" THEN I=.4
580 IF P$(1)="APPLE" THEN I=.3
590 GOTO 610
600 I=.2
610 P1=B*.40
620 P2=P1*I
630 Y=INT(P2/.25)*.25
660 PRINT "YOU WIN!! ==> $";Y
670 D=D+Y
680 B=B-Y
685 IF B<=0 THEN 710
690 Y=0
700 GOTO 365
710 PRINT "YOU HAVE DRIVEN THE COMPUTER TO POVERTY!"
720 STOP
800 I$="QUIT":GOTO 365
810 PRINT "THE JACKPOT STANDS AT $";B
820 D=0:PRINT :PRINT "NEW GAME!":PRINT :GOTO 390
9999 END
```

```
 SAMPLE RUN OF "JACKPOT"

RUN
NEED INSTRUCTIONS (Y/N) ?Y
JACKPOT - A SIMULATED SLOT
MACHINE. EACH PLAY IS $.25
PAYOFFS ARE FOR 3 OF A KIND,
2 OF A KIND ON THE FIRST 2 WHEELS,
OR CHERRIES FOR THE LAST 2 WHEELS.
THE OBJECTS ARE: JACKPOT, CHERRY
LEMON, ORANGE,APPLE, PEAR, PEACH.

THE HOUSE OWES YOU $ 0

PLAY OR QUIT  (P/Q)  ?P
THE LEVER HAS BEEN PULLED!
LEMON   APPLE   ORANGE
YOU LOSE!!!
YOU OWE THE HOUSE $ .25

PLAY OR QUIT  (P/Q)  ?P
THE LEVER HAS BEEN PULLED!
LEMON   ORANGE   LEMON
YOU LOSE!!!
YOU OWE THE HOUSE $ .25

PLAY OR QUIT  (P/Q)  ?P
THE LEVER HAS BEEN PULLED!
APPLE   LEMON   JACKPOT
YOU LOSE!!!
YOU OWE THE HOUSE $ .5

PLAY OR QUIT  (P/Q)  ?Q
YOU OWE THE HOUSE $ .5
THE JACKPOT STANDS AT $ 20.5

NEW GAME!

PLAY OR QUIT  (P/Q)  ?
```

wish, keeping in mind that at the moment they are pretty high.

When you are finished playing, enter Q for QUIT. The computer will print how much money you either have or owe, and how much money the computer has (it starts with $20). It will then reset the player's money to $0 for the next player, but will maintain the house's money as the standing jackpot.

If you wish to exit the entire program, just hit CONTRL/C (or whatever your computer's interrupt is) at any point in the game.

The program was writen for the HEATH H-8 computer. If you wish to use this program on another system, the following alterations must be made: lines 260 and 390 must be changed so as not to say LINE INPUT, since that statement is not recognized by all BASICs. It is the equivalent of saving INPUT I$, just a simple stringed variable. There may be some other minor alterations that are needed to tailor the program to your system, but the program is relatively standardized and should run on most systems with few changes. ■

SWL Logbook—Computerized radio log

MANY OF YOU HAVE WRITTEN requesting a logbook program—a computerized logbook to keep SWL records—which at the same time is easily adaptable for logging other forms of communication such as Amateur Radio. OK, here's your answer—"SWL LOGBOOK," a program that can store and retrieve as much data as your disk system or other storage device can hold.

"SWL LOGBOOK" has been kept as short as possible, to allow users of smaller-memory systems to run the program. The program operates much the same way as a standard logbook; information such as DATE, STATION, FREQUENCY, TIME, and LOCATION are recorded, and the data can be retrieved by the commands: STATION, FREQUENCY, TIME, or LOCATION. For example, if you wanted a listing of all the contacts with England, you would simply enter LOCATION, and then type ENGLAND. At this point, the computer will feed back to you all the stations from England in your logbook, or notify you that you have no listings of English stations in your logbook. For Amateurs, this can be used as a tool in contests so that you know what countries you have contacted, and what countries you must seek. The commands: STATION, FREQUENCY, and TIME, work the same way LOCATION does; enter the command and the data that you wish to retrieve.

The FILE COPY command has been installed so you can copy the logbook data into another sector of the disk. This permits you to have a SAFETY, or a copy of the logbook data, in case the first copy gets destroyed or damaged. It also allows you to have different logbooks for different types of communication, and to be able to move data back and forth on the disk.

Because of the need for a program that will run on lower-memory systems, we have ommited functions such as error correction and MAPPING (putting the data through two selective tests such as LOCATION and FREQUENCY to get a very selective set of output material). However, if you are interested in having error correction, here is a simple error correction loop that you can put into the program between lines 1120 and 1130.

```
1122 INPUT "SURE",Z$
1125 IF Z$="YES" THEN 1130
1128 GOTO 1120
```

The program, as mentioned earlier, has four retrieval commands: STATION, FREQUENCY, TIME, and LOCATION. The section that accommodates the retrieval system lies between lines 3000 and 3770. Rather than enlarge the program by having a separate section for each *keyword*, or word used to reference data, the four commands are simply merged into this one section, and all the data is processed here. Lines 3000-3030 determine what COMMAND you are using, and lines 3080-3130 sort the data file to look for the data that fits your needs. Instructions for using the program can be found at lines 190 to 320, but the program is really self-explanatory. You will see that most of the COMMAND functions are similar in operation, which makes de-bugging a snap. ■

```
0100 REM               "SWL LOGBOOK"
0110 REM             BY LARRY FRIEDMAN
0120 REM
0130 REM USES SWTP 6800 BASIC VERSION 2.0 WITH PERCOM
0140 REM LFD-400 DISK SYSTEM.
0145 REM
0150 INPUT "WHAT SECTOR DO YOU WISH TO START AT",X
0160 INPUT "DO YOU NEED INSTRUCTIONS",Y$
0170 IF LEFT$(Y$,1)="N" THEN 330
0180 PRINT
0190 PRINT "SWL LOGBOOK: A COMPUTERIZED LOGBOOK"
0200 PRINT "FOR SHORT WAVE LISTENERS. IT CAN STORE"
0210 PRINT "AN UNLIMITED AMOUNT OF DATA (WITHIN THE"
0215 PRINT "SPACE LIMITATIONS OF YOUR DISK), AND"
0220 PRINT "IS EASILY ACCESSIBLE OR RETRIEVABLE."
0230 PRINT "THE COMMANDS ARE:"
0240 PRINT "START                  TO ENTER DATA ONTO DISK"
0250 PRINT "UPDATE                 TO ADD DATA TO EXISTING DATA FILE"
0260 PRINT "TIME                   TO REFERENCE AN ENTRY BY TIME"
0270 PRINT "STATION                TO REFERENCE A PARTICULAR STATION"
0280 PRINT "FREQUENCY              TO REFERENCE ENTRIES BY FREQUENCY"
0290 PRINT "LOCATION               TO REFERENCE ENTRIES BY LOCATION"
0300 PRINT "FILE COPY              TO COPY DATA FILE TO A NEW SECTOR"
0310 PRINT "LIST                   TO LIST ENTIRE DATA FILE"
0320 PRINT "EXIT                   TO LEAVE PROGRAM"
0330 PRINT
0340 DATA START,UPDATE,TIME,STATION,FREQUENCY,LOCATION
0350 DATA FILE COPY,LIST,EXIT
0360 FOR N=1 TO 9
0370 READ X$(N)
0380 NEXT N
0390 INPUT "COMMAND",C$
0400 FOR N=1 TO 9
0410 IF X$(N)=C$ THEN 450
0420 NEXT N
0430 PRINT "ILLEGAL COMMAND."
0440 GOTO 390
0450 ON N GOTO 1000,2000,3000,3000,3000,3000,4000,5000,6000
1000 INPUT "NEED INSTRUCTIONS ON DATA ENTERING PROCEDURE",Y$
1010 IF LEFT$(Y$,1)="N" THEN 1100
1020 PRINT "ENTER DATA IN THE FOLLOWING ORDER:"
1030 PRINT "(1) DATE (IN FORM XX/YY/ZZ)"
1040 PRINT "(2) STATION       (3) FREQUENCY"
1050 PRINT "(4) TIME (IN GMT)     (5) LOCATION (COUNTRY, ETC)"
1060 PRINT "SEPARATE DATA ENTRIES WITH COMMAS"
1070 PRINT
1080 PRINT "TYPE  Q,,,, TO EXIT START MODE"
1100 IF U=1 THEN U=0:GOTO 1110
1105 OPEN #10,X
1110 INPUT D$,S$,F$,T$,L$
1120 IF D$="Q" THEN 1500
1130 PRINT #10,D$,S$,F$,T$,L$
1140 GOTO 1110
1500 CLOSE #10
1510 GOTO 390
2000  U=1
2010 OPEN #10,X
2020 READ #10,D$,S$,F$,T$,L$\2040
2030 GOTO 2020
2040 GOTO 1000
3000 IF C$="TIME" THEN Z=1:INPUT "TIME",T$(1)
3010 IF C$="STATION" THEN Z=2:INPUT "STATION",S$(1)
3020 IF C$="FREQUENCY" THEN Z=3:INPUT "FREQUENCY",F$(1)
3030 IF C$="LOCATION" THEN Z=4:INPUT "LOCATION",L$(1)
3035  V=0:C=0
3040 IF LEN(S$(1))<>15 THEN S$(1)=S$(1)+" ":GOTO 3040
3050 IF LEN(T$(1))<>15 THEN T$(1)=T$(1)+" ":GOTO 3050
3060 IF LEN(F$(1))<>15 THEN F$(1)=F$(1)+" ":GOTO 3060
3080 OPEN #10,X
3090 READ #10,D$,S$,F$,T$,L$\3750
3100 IF Z=1 THEN IF T$(1)=T$ THEN 3500
3110 IF Z=2 THEN IF S$(1)=S$ THEN 3500
3120 IF Z=3 THEN IF F$(1)=F$ THEN 3500
3130 IF Z=4 THEN IF L$(1)=L$ THEN 3500
3140 GOTO 3090
3500  C=1
3510 IF V=1 THEN 3600
3520 PRINT "DATE";TAB(11);"STATION";TAB(21);"FREQUENCY";TAB(31);
3530 PRINT "TIME";TAB(41);"LOCATION"
3540  V=1
3600  D$=LEFT$(D$,10):S$=LEFT$(S$,10)
3610  F$=LEFT$(F$,10):T$=LEFT$(T$,10)
3620  L$=LEFT$(L$,10)
3630 PRINT D$;S$;F$;T$;L$
3640 GOTO 3090
3750 IF C=0 PRINT "NO STATIONS IN LIST."
3760 CLOSE #10
3770 GOTO 390
4000 PRINT
4010 INPUT "  (ENTER SECTOR TO COPY FILE INTO)",K
4020 OPEN #11,K
4030 OPEN #10,X
4040 READ #10,D$,S$,F$,T$,L$\4070
4050 PRINT #11,D$,S$,F$,T$,L$
4090 PRINT "FILE HAS BEEN COPIED"
4095 CLOSE #10:CLOSE #11
4100 GOTO 390
5000 OPEN #10,X
5010 PRINT "DATE";TAB(11);"STATION";TAB(21);"FREQUENCY";TAB(31);
5020 PRINT "TIME";TAB(41);"LOCATION"
5040 READ #10,D$,S$,F$,T$,L$\5100
5050  D$=LEFT$(D$,10):S$=LEFT$(S$,10)
5060  F$=LEFT$(F$,10):T$=LEFT$(T$,10)
5070  L$=LEFT$(L$,10)
5080 PRINT D$;S$;F$;T$;L$
5090 GOTO 5040
5100 CLOSE #10
5110 PRINT :GOTO 390
6000 END
```

```
SAMPLE RUN OF "SWL LOGBOOK"
RUN
WHAT SECTOR DO YOU WISH TO START AT? 1200
DO YOU NEED INSTRUCTIONS? YES

SWL LOGBOOK: A COMPUTERIZED LOGBOOK
FOR SHORT WAVE LISTENERS. IT CAN STORE
AN UNLIMITED AMOUNT OF DATA (WITHIN THE
SPACE LIMITATIONS OF YOUR DISK), AND
IS EASILY ACCESSIBLE OR RETRIEVABLE.
THE COMMANDS ARE:
START              TO ENTER DATA ONTO DISK
UPDATE             TO ADD DATA TO EXISTING DATA FILE
TIME               TO REFERENCE AN ENTRY BY TIME
STATION            TO REFERENCE A PARTICULAR STATION
FREQUENCY          TO REFERENCE ENTRIES BY FREQUENCY
LOCATION           TO REFERENCE ENTRIES BY LOCATION
FILE COPY          TO COPY DATA FILE TO A NEW SECTOR
LIST               TO LIST ENTIRE DATA FILE
EXIT               TO LEAVE PROGRAM

COMMAND? START
NEED INSTRUCTIONS ON DATA ENTERING PROCEDURE? YES
ENTER DATA IN THE FOLLOWING ORDER:
(1) DATE (IN FORM XX/YY/ZZ)
(2) STATION       (3) FREQUENCY
(4) TIME (IN GMT)     (5) LOCATION (COUNTRY, ETC)
SEPARATE DATA ENTRIES WITH COMMAS

TYPE  Q,,,, TO EXIT START MODE
? 02/13/79,ETLF,7180 KHZ,1700,ETHIOPIA
? 03/14/79,CFRZ,6070 KHZ,2100,CANADA
? 04/06/79,G3AP,14 MHZ,1345,ENGLAND
? 04/21/79,G3CX,7 MHZ,1500,ENGLAND
? 05/02/79,2NR,7100 KHZ,1335,AUSTRALIA
? Q,,,,
COMMAND? LIST
DATE      STATION   FREQUENCY TIME      LOCATION
02/13/79  ETLF      7180 KHZ  1700      ETHIOPIA
03/14/79  CFRZ      6070 KHZ  2100      CANADA
04/06/79  G3AP      14 MHZ    1345      ENGLAND
04/21/79  G3CX      7 MHZ     1500      ENGLAND
05/02/79  2NR       7100 KHZ  1335      AUSTRALIA

COMMAND? LOCATION
LOCATION? ENGLAND
DATE      STATION   FREQUENCY TIME      LOCATION
04/06/79  G3AP      14 MHZ    1345      ENGLAND
04/21/79  G3CX      7 MHZ     1500      ENGLAND
```

UNDERSTANDING SUPERHETS

Enduring and vital, the superhet still rules radio communications

BORN OUT OF NECESSITY during World World I, the superheterodyne receiver circuit toppled all existing conventional receiver types on electronics' popularity chart. And, to this day, none of the "conventional" radios of that era have been able to recapture electronics' limelight. Stranger yet, every branch of electronics is still being swept along the path of Progress by a circuit that should have gone the way of the flivver and the flapper. From military and industrial to commercial and consumer—everybody who's ever seen a radio, and certainly a television set, has found himself staring face to face with a superheterodyne receiver. The fact is, you'd be hard-pressed to find any up-to-date radio that doesn't somehow utilize the superhet circuit.

After the First World War, the "All-American Five," at it was dubbed, took its place in living rooms and parlors from coast to coast. And it continues to be built today as its inventor generally conceived of it, way back when the circuit was made to track and help locate enemy aircraft spitting fire over French skies.

Narrow Squeeze. The superheterodyne found itself ruling the receiver roost largely because it had a redeeming quality no other receiver of that vintage era could boast. Called *selectivity,* this hitherto unheard-of quality endowed the superhet with the ability to select the particular station a listener wanted to hear (and later see), and reject all others. Indeed, it was a revolutionary step forward in receiver design. But selectivity was hardly a quality needed back in grandfather's day. Why?

First, grandpop used to listen to signals sent by spark-gap transmitters. The primitive spark signals generated by those common-as-apple-pie transmitters were extraordinarily broad. It was like listening to the lightning crashes you can pick up as you tune across the dial of an AM radio during a thunderstorm. More important, though, there were fewer signals on the air. So selectivity wasn't too important.

The year 1922 saw the meteoric rise of radio for entertainment and communication. As hundreds of stations took to the air it became apparent that the primitive receiving gear capable only of broad-bandwidth reception couldn't even begin to handle the impending traffic jam beginning to build on the airwaves. And the problems of receiving only one station, without an electronic cacaphony drowning it out, takes us back even further into electronics' primeval time.

Cat's Whiskers and TRF. Digging through to the bottom of the twentieth century, we uncover two electronic fossils: the cat's whisker crystal receiver, and the tuned radio frequency (TRF) receiver. These were popular predecessors of the superhet circuit.

The crystal set had the least selectivity of either circuit, and what it did have was obtained mostly from one measly tuning circuit. Consisting of a coil and a homemade variable capacitor, these crude tuning devices could barely pick out a desired radio signal and, hopefully, reject all RF intruders trying to elbow their way into the listener's headphone on either side of the signal. The cat's whisker consisted of a strand of fine wire for gently probing, or tickling, the crystal's natural galena surface in order to locate its most sensitive point. Though the cat's whisker detector could extract audio signals

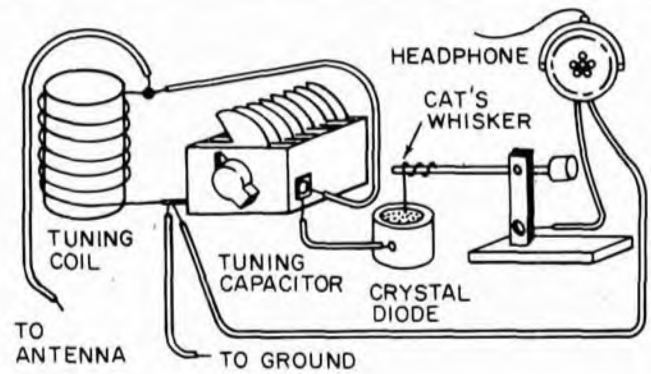
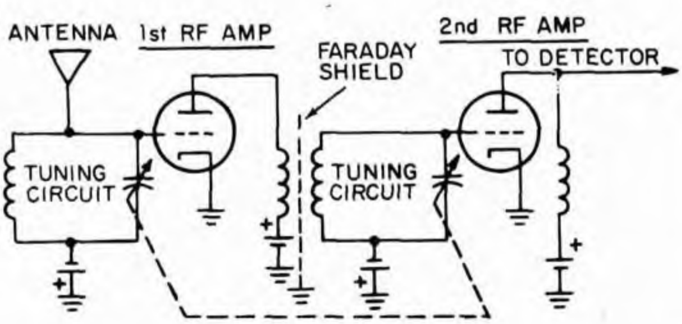


Fig. 1. Schematic representation of crystal radio shows how cat's whisker gently contacted diode surface in order to achieve demodulation of RF signal. Earliest semiconductor diodes made were miniature crystal diode/cat's whisker affairs encased in glass package.

Fig. 2. Our schematic shows relatively advanced tuned radio frequency receiver. First TRFs had individually adjusted tuning capacitors; ganged units were still to be invented. By adjusting battery voltage twist ground, tuning circuit, radio gain's varied.



from the amplitude-modulated radio frequency signal, the galena detector creasing the listener's chances of picking up stations other than the desired one.

Matters improved with the TRF receiver. It aimed for, and hit, sharper reception dead center, by adding more tuned circuits. This feat wasn't practical with crystal sets, because this circuit's inherent losses ran too high to gain any benefit from any additional coils.

The invention of the triode vacuum tube gave engineers the perfect amplifying device. Circuit losses could now be overcome with ease; the TRF took over where the cat's whisker left off, dooming the crystal set to mantelpiece and museum.

Three or four amplified radio-frequency stages were customarily added prior to the TRF's detector, all the while adding to selectivity's cause. However, all wasn't perfect in TRFville.

The amount of noise introduced by the tubes limited the number of TRF stages. So the Silver-Masked Tenor's strains could still be heard with those of the Clicquot Club Eskimos—but not by his choice, or that of the listener.

Pitching the Low Curve. The public soon learned that these newfangled TRF receivers weren't exactly the living end. The TRFs, as a rule, failed to perform satisfactorily as frequencies inched higher into kilohertz land. Seems that as the frequency of the signal went up, the TRF's tuned circuit efficiency for that frequency dropped almost proportionately.

To demonstrate this, look at our example. The bell-shaped curve represents response of a tuned circuit selecting some low-frequency station. The circuit delivers good selectivity, and interference on a slightly higher frequency is rejected.

But examine what happens when a similar tuned circuit is operated on a higher frequency. Although the curve's *proportions* remain the same, it's actually responding to a much greater span of frequencies. Now it's possible for *two* closely spaced stations to enter the response curve and ultimately be heard in the speaker.

Since tuned circuits grow more selective as frequency is lowered, wouldn't it be to our technical advantage to receive only low-frequency signals? This idea probably occurred to Major Edwin Armstrong, because his invention, the superheterodyne circuit, does just that.

Superselectivity. By stepping signals down to a lower frequency than they were originally, the new circuit could deliver neat-as-a-pin selectivity on almost any band. The fact is, this development helped open the high-frequency bands, and by the 1930s virtually every receiver adopted the Major's superheterodyne idea.

The word "superheterodyne" is, by itself, revealing. It begins with *super*, for supersonic, referring to a new signal created within the radio. The generated signal is neither in the audio nor higher radio-frequency range, but in between. *Hetero* means combining, the *dyne* is force. The newly-created ten-dollar term, *superheterodyne*, neatly sums up this circuit's action.

Major Blocks. You can get a good picture of the superhet in its natural habitat if you look at our block diagram. Though our schematic shows a tubed receiver, all equivalent stages tend to do the same job regardless of whether the receiver is transistor or tube. Now that you know what the superhet does and how it looks, let's take a peek at how it works.

For sake of illustration, assume a signal of 1010 kHz in the standard BC band enters the antenna, and from there is sent down the line to the mixer. But what, you ask, is mixed?

Our frequency mish-mash consists of the different frequencies made up of the desired station on 1010 kHz, and a second signal generated internally by the local oscillator. This oscillator perks at a frequency of 1465 kHz, for reasons which you'll understand in a moment.

True to its name, our mixer combines both signals from antenna and oscillator. And from these two frequencies, it delivers yet another frequency that is the *difference* between them—namely 455 kilohertz. So far, our superhet circuit changed, or reduced the desired signal to a frequency having an intermediate value. Beating two frequencies together in order to produce a third signal is known by members of the Frequency Fraternity as mixing, heterodyning, or beating. And some engineers prefer to call the lowly mixer a converter; this term often appears in schematics. But whatever name you throw its way, the result is the intermediate frequency.

There's something else you should know about the intermediate, or IF, frequency. It always remains the same no matter what station you tune to. If you sweep the dial across the broadcast band in one continuous motion, the IF frequency remains constant. How's this accomplished?

It's done by tuning the incoming signal simultaneously with the local oscillator. That's something akin to the mechanical rabbit which paces greyhounds at a race track. In the superhet a ganged tuning capacitor performs this dynamic-duo feat.

Take a close look at the tuning capacitor, and you'll see physically smaller plates assigned to the local oscillator. Since these plates are smaller than the antenna stage capacitor plates, the effect is to lower the capacity, and *raise* the frequency of the oscillator stage. That's how the oscillator stage consistently produces a signal which is 455 kHz above the incoming frequency. But why bother, you ask?

More Muscle, Too. When we convert each incoming station's frequency to the same IF, we gain another advantage besides better selectivity. A *fixed-tuned* amplifier always operates at higher efficiency than one which needs to muscle a multitude of frequencies. There are fewer technical bugaboos in

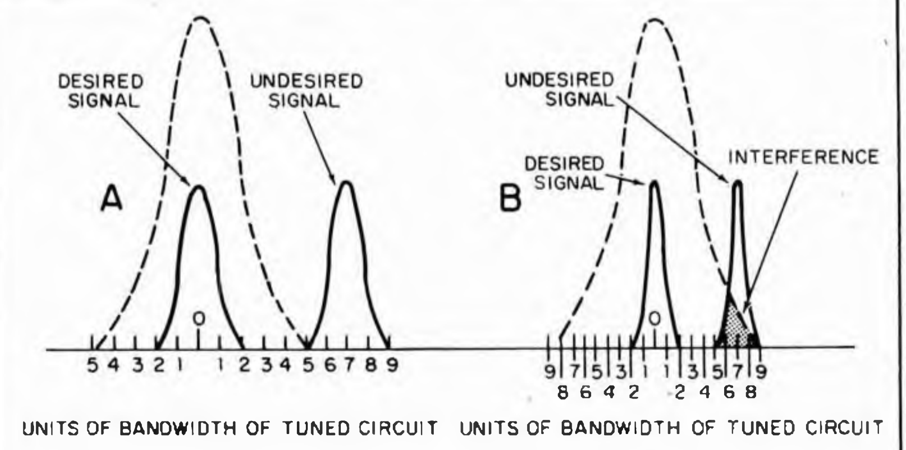


Fig. 3. Tuned-circuit bandwidth varies proportionally with frequency. Tuned circuit A, working at low frequency, rejects unwanted signal. Tuned circuit B, working at high frequency, can't completely reject undesired signal; interference results.

Superhets

a one-frequency amplifier, so our tubes or transistors can operate more effectively at this lower frequency. And, last but not least, circuit layout and wiring are less critical.

Sound Sniffing. The detector stage recovers original audio voltage from the station's signal. Since we're cranking the RF voltages through a superhet circuit, the RF signal did a quick disappearing act, only to appear as an IF frequency of 455 kHz. Though the original carrier (1010 kHz) is converted downward in frequency to 455 kHz, any audio voltage variations impressed upon the carrier remain the same. So if a musical note of 1000 Hz was sounded back in the radio studio, the note still remains that value in both RF and IF circuits, despite the mixing process.

Like a ladle skimming heavy cream off the top of a jug of fresh milk, the detector rectifies either the positive- or negative-going portion of the carrier, skimming off the audio signals from the carrier. Though audio modulation appears during both positive and negative swings of an amplitude-modulated carrier, only one half of the available signal is used. If both positive and negative portions of the RF signal were detected simultaneously, the audio signals would cancel each other at the output!

Now let's look at the stages of an ordinary solid-state superhet circuit that might be found in a common table radio or transistor portable.

Simplified Schematic. Our diagram is pretty typical of transistorized superheterodyne circuits. Of course, there may be variations on this circuit's theme, like the addition of an RF amplifier ahead of the mixer to improve sensitivity. The number of IF stages also varies with receiver quality, and specialized items such as filters may appear in ham and SWL rigs.

If you can follow our basic block diagram you'll have the key to virtually any solid-state superhet. In order to further simplify matters, many resistors and capacitors not essential to our tour through solid-state superhet country have been omitted.

Leading the pack on our superhet speedway is the antenna tuning circuit. Loopstick antenna L1 grabs the RF signal out of the ether, and also serves in partnership with the tuning capacitor in the tuning circuit. You sharpies will also notice that the antenna tuning capacitor is mechanically joined to the oscillator tuning capacitor. (This is represented schematically by a dotted line.) Remember now, we want to develop the IF frequency. This ganged antenna/oscillator capacitor ensures the necessary *tracking* of the local oscillator with the radio-frequency signal.

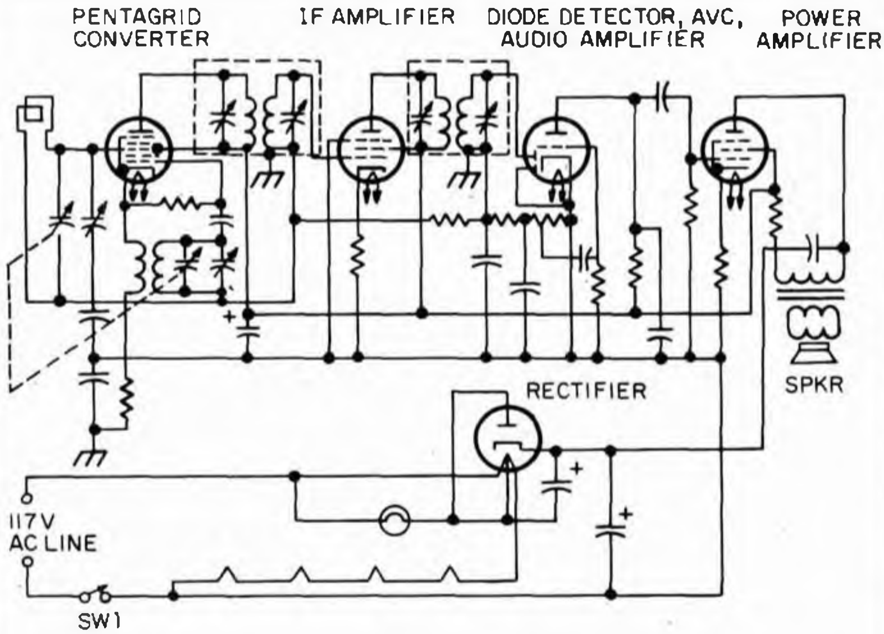


Fig. 4. Virtually all superhets sold commercially are five-tub rigs; most are also, in terms of design, electrically and mechanically equivalent.

The oscillator frequency is developed by the oscillator portion of our variable capacitor, and coil L2. In our superhet's schematic, the oscillator signal is capacitively coupled from the oscillator transistor base and sent on its way to the mixer stage. The mixer, therefore, "sees" both oscillator and incoming station frequencies. The electrons from oscillator and antenna circuit get it all together in the mixer's base, producing our intermediate frequency.

If you could look at the mixer's output, you'd see more than just the IF signal. In fact, the mixer's load contains a jumble of frequency byproducts. As signals combine in this circuit, they add, subtract, and recombine in many ways.

Only the desired signal emerges from the mixer stage because intermediate-frequency transformer IF1 picks the proper signal to the exclusion of all the others. Now our freshly-created signal passes through a stage of IF amplifica-

(Continued on page 104)

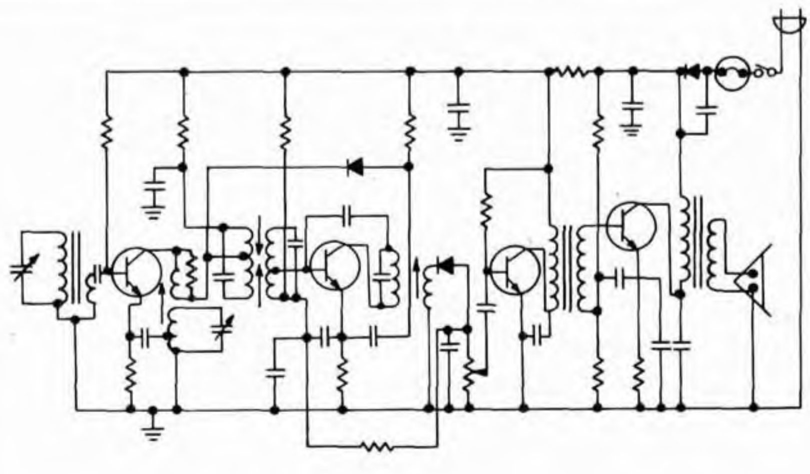


Fig. 5. Our schematic of a transistorized superheterodyne receiver is similar to the tubed superhet shown in Fig. 4. Biggest differences between the two are semiconductor diodes found in audio detector, AVC loop, and power rectifier stages.

Crystals and How They Work

From computers to clocks, broadcasting and hi-fi . . . the crystal is king!

☐ Can you imagine the chaos on the AM broadcast band if transmitters drifted as much as those inexpensive table radios? The broadcast station engineer must keep his station carrier within 20 hertz of its assigned frequency. How does he do it? What about the CBer unable to contact his base station with an unstable, super-regen walkie-talkie. Lost calls don't often happen to a CBer who can keep his receiver frequency right on the assigned channel center.

This and much more is, of course, all done with a little help from a very basic material, the quartz crystal. It is the single component that serves to fill a basic requirement for precision frequency control. Quartz crystals not only fix the frequency of radio transmitters (from CB installations to multi-kilowatt-broadcast installations), but also establish the frequency of timing pulses in many modern computers. In addition, they can provide the exceptional selectivity required to generate and receive single-sideband signals in today's crowded radio spectrum. Yet this list merely touches upon the many uses of quartz crystals. No exhaustive list has ever been compiled.

A Real Gem. This quiet controller is a substance surrounded by paradox. While quartz composes more than a third of the Earth's crust, it was one of the three most strategic minerals during World War II. And despite its plenitude, several semiprecious gems (including agate and onyx) are composed only of quartz.

Unfortunately, quartz exercises its control in only a relative manner. When it's misused, the control can easily be lost. For this reason, if you use it in any way—either in your CB rig, your ham station, or your SWL receiver—you should become acquainted with the way in which this quiet controller functions. Only then can you be sure of obtaining its maximum benefits.

What Is It? One of the best starting points for a study of quartz crystals is to examine quartz itself. The mineral, silicon dioxide (SiO_2), occurs in two broad groups of mineral forms: crystalline and non-crystalline. Only the large crystalline form of quartz is of use as a controller.

The crystalline group has many varieties, one of which is common sand. The variety which is used for control, however, is a large, single crystal, usually six-sided. The leading source of this type of quartz is Brazil. However, it also is found in Arkansas. Attempts have been made to produce quartz crystals in the laboratory, but to date synthetic quartz has not proven practical for general use.

A property of crystalline quartz, the one which makes it of special use for control, is known as *piezoelectricity*. Many other crystals, both natural and synthetic, also have this property. However, none of them also have the hardness of quartz. To see why hardness and the piezoelectric property, when combined, make quartz so important, we must take a slight detour and briefly examine the idea of resonance and resonators.

Resonators and Resonance. As physicists developed the science of radio (the basis for modern electronics), they borrowed the acoustic notion of resonance and applied it to electrical circuits where it shapes electrical waves in a manner similar to an acoustic resonator. For instance, both coils and capacitors store energy and can be connected as a resonator (more often termed a resonant circuit). When AC of appropriate frequency is applied to the resonator, special things happen.

Pendulum Demonstrates. The principle involved is identical to that of a pendulum, which is itself a resonator closely similar in operation to our quartz crystals. To try it you can hang a pendulum of any arbitrary length (Fig. 1), start it swinging, then time its *period*—one complete swing or cycle. The number of such swings accomplished in exactly one second is the *natural* or *resonant* frequency of the pendulum in cycles per second (hertz).

You can, by experiment, prove that the frequency at which the pendulum swings or oscillates is determined by the length of the pendulum. The shorter the pendulum (Fig. 2), the faster it swings (the greater the frequency). The weight of the pendulum has no effect on frequency, but has a marked effect upon the length of time the pendulum will swing after a single initial push—the heavier the pendulum, the greater the number of cycles.

A Real Swinger. Once the pendulum begins to swing, very little effort is required to keep it swinging. Only a tiny push is needed each cycle, provided that the push is always applied just as the pendulum begins to move *away* from the pushing point. If the push is given too soon, it will interfere with the swinging and actually cause the swing

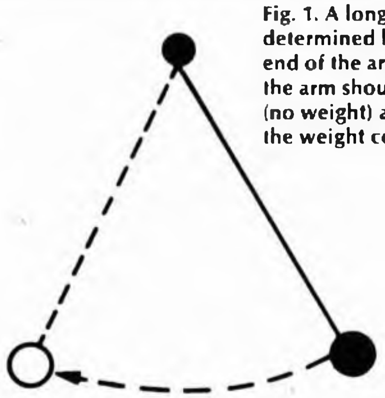


Fig. 1. A long pendulum swings at a rate determined by its length and weight at the end of the arm. To experiment at home, the arm should be made of light thread (no weight) and a small heavy mass (all the weight concentrated at one point).

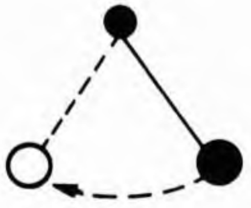


Fig. 2. A short pendulum swings at a faster rate no matter what the weight is. The heavier the weight, the longer the pendulum will swing at the faster rate.

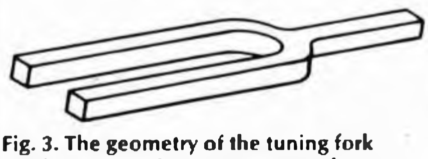


Fig. 3. The geometry of the tuning fork produces a continuous pure tone for a long time when struck gently. It is favored by piano tuners as a convenient way to carry a source of accurately-known tone or pitch.

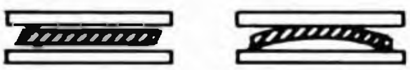


Fig. 4. Depending on how the crystal is cut or sliced from the mother crystal, some crystals warp or bend as in A and others shear as shown in B. Each of the many cuts have special characteristics.

to stop sooner than it would without added energy; while if too late, added push will have virtually no effect at all. It is this principle—a tiny push at exactly the right time interval—which makes a resonator sustain sound or AC waves. You can prove it with the pendulum by first determining the resonant frequency of a pendulum, then stopping it so that it is completely still. A series of small pushes, delivered at the natural resonant frequency, (each too tiny to have more than a minute effect) will very rapidly cause the pendulum to swing to its full arc again. Pushes of the same strength at any other frequency will have little or no effect.

The pendulum is an excellent control mechanism for regulating a clock to keep time to the second, since the resonant frequency of the pendulum can readily be adjusted to be precisely one cycle per second. However, for control of audio frequencies from tens of hertz (cycles per second) up to tens of thousands of cycles per second (kilohertz), or for radio frequencies ranging up to hundreds of millions of cycles per second (megahertz), the pendulum is too cumbersome a device.

The Tuning Fork. In the audio range, the equivalent of the pendulum is the tuning fork. This is an extremely elongated U-shaped piece of metal (Fig. 3), usually with a small handle at the base. When struck, it emits a single musical tone.

The operating principle is exactly the same as the pendulum. Each of the arms or tines of the fork corresponds to a pendulum arm. But here the arms are extremely short and much heavier in proportion to their size than the pendulum. (The shorter the arms of a tuning fork, the higher the resonant frequency in the audio range.) This greatly increased mass causes them to oscillate much longer when struck.

Not all tuning forks operate precisely like pendulums. The pendulum principle is based on a *flexing* of the arm upon its long dimension. While this is the most common operation, the fork may flex along any dimension.

It's even possible for a single, solid resonator such as a tuning fork to flex along several dimensions at once. A main part of the design of a good tuning fork is to insure that only a single dimension flexes or, in the language of resonators, only a single mode is excited.

Area Too. There's no requirement that the resonator be a completely solid substance. A mass of air, suitably enclosed, forms a resonator. This is the resonator that works on a classic guitar or violin. Here, single-mode operation is distinctly *not* desired. Instead, multiple-mode operation is encouraged so that all musical tones within the range of the instrument will be reinforced equally.

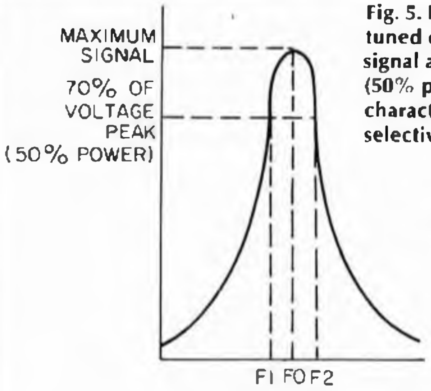


Fig. 5. Bandwidth characteristic of a typical tuned circuit shows the peak or maximum signal amplitude and the 70% voltage peak (50% power) points. This is the characteristic that determines overall selectivity.

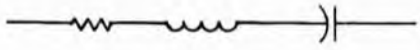


Fig. 6. Diagram is a typical equivalent circuit for a crystal. As resistance is lowered to near zero, crystal efficiency increases. In use, the crystal holder and external circuit add some capacitance across the entire circuit.

Now, with the principles of resonance firmly established, we can return to the quartz crystal and its operation.

Quartz Crystal as Resonators. Like the tuning fork or, for that matter, any sufficiently hard object, the quartz crystal is capable of oscillation when struck physically or in some other way excited.

But unlike the tuning fork, or indeed any other object except for certain extremely recent synthetic materials, the quartz crystal is not only sufficiently hard to oscillate at one or more resonant frequencies, but is piezoelectric.

Piezoelectricity. This piezoelectric property means simply that the crystal generates an electric voltage when physically stressed or, on the other hand, will be physically deformed when subjected to a voltage (see Fig. 4). Other familiar objects making use of piezoelectricity include crystal and ceramic microphone elements and phonograph cartridges.

This virtually unique combination of properties (sufficient hardness for oscillation and piezoelectricity) found in quartz crystals, makes it possible to provide the initial push to the crystal by impressing a voltage across it. To provide the subsequent regular pushes, a voltage can be applied at appropriate instants.

Quality Factor. Almost any discussion of resonance and resonant circuits (or for that matter, inductance) eventually gets to a rather sticky subject labelled in the earliest days of radio as *quality factor* but now known universally as Q.

As used in radio and electronics, Q is usually defined by other means. Some of the definitions put forth at various times and places include:

- *The ratio of resistance to reactance in a coil.*
- *The ratio of capacitive reactance in a resonant circuit to the load resistance.*
- *The impedance multiplication factor, and others even more confusingly worded.*

All, however, come out in the end to be identical to the definitions cited above: The Q of a resonator is the ratio of the energy stored per cycle to the energy lost per cycle.

In a resonator, high Q is desirable. Q is a measure of this energy loss. The less energy lost, the greater the Q of the circuit.

Not so obvious (and rather difficult to prove without going into mathematics) are some of the other effects of Q. A resonant circuit is never completely selective; frequencies which are near resonance but not precisely equal to the resonant frequency pass through also!

An Interesting Fraction. The greater the Q, the narrower the band of frequencies which can affect the resonator. Specifically, the so-called half-power bandwidth (Fig. 5) of a resonator (that band in which signals are passed with half or more of the power possessed by signals at the exact resonant frequency) is expressible by the fraction Fo/Q, where Fo is the resonant frequency and Q is the circuit Q. Thus a 455 kHz resonant circuit with a Q of 100 will have a half-power bandwidth of 455/100 kHz, or 4.55 kHz. This relation is an approximation valid only for single-tuned circuits; more complex circuits are beyond this basic discussion.

The Q of Quartz Crystals. When we talk of the Q of conventional resonant circuits composed of coils and capacitors, a figure of 100 is usually taken as denoting very good performance and Q values above 300 are generally considered to be very rare.

The Q of a quartz crystal, however, is much higher. Values from 25,000 to 50,000 are not unheard of.

The extremely high Q makes the crystal a much more selective resonator than can be achieved with L-C circuitry. At 455 kHz, for example, the bandwidth will be between 10 and 20 hertz (*cycles* per second) unless measures are taken to reduce Q. Even in practice (which almost never agrees with theory), 50-hertz bandwidths are common with 455-kHz crystal filters.

So far as external circuitry is concerned, the crystal appears to be exactly the same as an L-C resonant circuit except for its phenomenal Q value. See Fig. 6.

At series resonance, the crystal has very low impedance. You may hear this effect referred to as a *zero* of the crystal. At parallel resonance, impedance is very high; this is sometimes called a *pole*. Fig. 7 shows a plot of *pole* and *zero* for a typical crystal. The special kind of crystal filter known as a half-lattice circuit matches the *pole* of one crystal against the *zero* of another, to produce a passband capable of splitting one sideband from a radio signal. Such filters are widely used in ham, commercial and, to a lesser extent, in CB transmitters.

When a crystal is used to control the frequency of a radio signal or provide a source of accurate timing signals, either the *pole* or the *zero* may be used. Circuits making use of the *pole* allow more simple adjustment of exact frequency, while those making use of the *zero* often feature parts economy. Later we'll examine several of each type.

From Rock to Finished Crystal. To perform its control functions properly, a quartz crystal requires extensive processing. The raw quartz crystal must be sliced into plates of proper dimension, then ground to the precise size required. Each plate must be as close to precisely parallel, and as perfectly flat, as possible. The electrodes must be in proper contact with the polished plate; in many modern units, the electrodes are actually plated directly to the crystal surface, usually with gold.

The crystal plate is known as a *blank* when it is sliced from the raw crystal. The blank is cut at a precise angle with respect to the optical and electrical axes of the raw crystal, as shown in Fig. 8. Each has its own characteristics for use in specific applications. Some, notably the X- and Y- cuts, are of only historic interest. The Y- cut, one of the first types used, had a bad habit of jumping in frequency at critical temperatures.

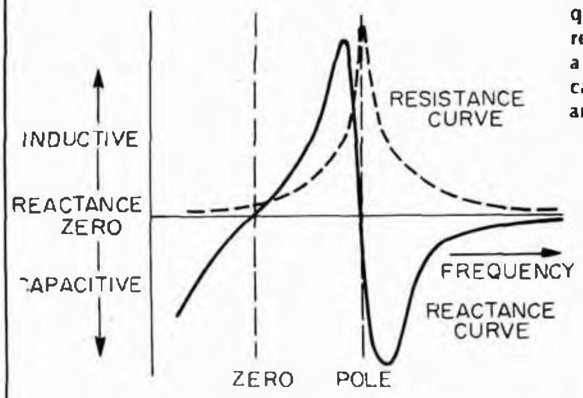


Fig. 7. Some characteristics of a quartz crystal. When slightly off resonant frequency (at the pole) a crystal exhibits inductive or capacitive reactance—just like an LC circuit.

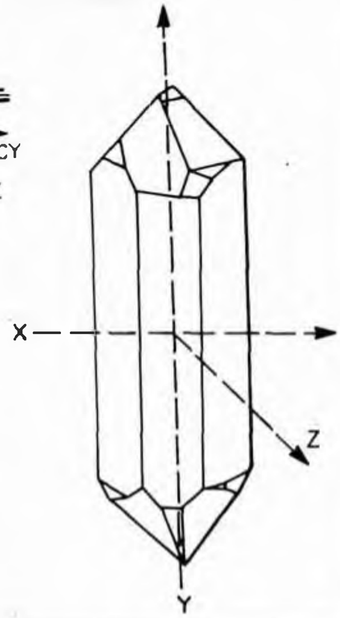


Fig. 8. A view of a mother crystal showing X, Y, and Z axes. Crystal is sliced into blanks, ground to frequency, polished and plated (on facing sides) to make permanent electrodes. All crystals are not made perfect by Mother Nature and must be examined optically before being sliced.

The X- cut did not jump, but still varied widely in frequency as temperature changed.

Today's crystals most frequently use the *AT* cut for frequencies between 500 kHz and about 6 MHz, and the BT cut for between 6 and 12 MHz. Above 12 MHz, most crystals are specially processed *BT* or *AT* cuts used in *overtone* modes. These cuts are important to crystal makers and not relevant to our layman's theory.

The blanks are cut only to approximate size. The plates are then polished to final size in optical "lapping" machines which preserve parallelism between critical surfaces. During the final stages of polishing, crystals are frequently tested against standard frequency sources to determine exact frequency of operation.

If electrodes are to be plated onto the crystal surfaces, frequency cannot be set precisely by grinding since the electrodes themselves load the crystal slightly and cause a slight decrease in operating frequencies. These crystals are ground just a trifle above their intended frequencies, and the thickness of the electrodes is varied by varying plating time to achieve precision.

Accuracy. The precision which can be attained in production of quartz crystals is astounding. Accuracy of ±0.001 percent is routine, and 10-times-better accuracy is not difficult. In absolute figures, this means an error of one cycle per megahertz. In another frame of reference, a clock with the same accuracy would require more than 11 days to gain or lose a single second.

However, such accuracy can be achieved only when certain precautions are taken. For instance, the frequency of a crystal depends upon the circuit in which it is used as well as upon its manufacture. For an accuracy of ±0.005% or greater, the crystal must be ground for a single specific oscillator. If ±0.001% (or better) circuit accuracy is required, it must be tested in that circuit only. Thus, CB transmitters are on the narrow edge of being critical. This is why all operating manuals include a caution to use only crystals made specifically for that transmitter.

When one-part-per-million accuracy is required, not only must the crystal be ground for a single specific oscillator, but most often the oscillator circuit must then be adjusted for best operation with the crystal; this round-robin adjustment must be kept up until required accuracy is achieved. Even then, crystal aging may make readjustment necessary for the first 12 to 18 months.

Frequency Variation—Causes and Cures. Possible variations in frequency stem from three major causes, while cures depend entirely upon the application.

The most obvious cause of frequency variation is temperature. Like anything else, the crystal will change in size when

Crystals

heated and the frequency is determined by size. Certain cuts show less change with temperature than do others, but all have at least some change.

For most noncommercial applications, the heat-resistant cuts do well enough. For stringent broadcast station and critical time-signal requirements, the crystal may be enclosed in a small thermostatically-regulated oven. This assures that the steady temperature will cure one cause of frequency change.

The second well-known cause for variation of frequency is external capacitance. Some capacitance is always present because the crystal electrodes form the plates of a capacitor where the crystal itself is the dielectric. Most crystals intended for amateur use are designed to accommodate an external capacitance of 32 pF, so if external capacitance is greater than this, the marked frequency may not be correct. Crystals for commercial applications are ground to capacitance specifications for the specific equipment in which they are to be used. CB crystals also are ground for specific equipment, although many transceivers employ the 32 pF standard.

Trim a Frequency. When utmost precision is required, a small variable capacitor may be connected in parallel with the crystal and adjusted to change frequency slightly. The greater the capacitance, the lower the frequency. Changes of up to 10 kHz may be accomplished by this means, although oscillation may cease when excessive changes are attempted.

Like temperature-caused variations, frequency variations due to capacitance may be useful in special cases. Hams operating in the VHF regions obtain frequency modulation by varying load capacitance applied to the crystal in their transmitters.

The third cause for variation of frequency is a change in operating conditions in the associated circuit. This cause is more important with vacuum-tube circuits than with semiconductor equipment. As a rule, operating voltages for any vacuum-tube oscillator providing critical signals should be regulated to prevent change.

Again, this cause can be used to provide FM by deliberately varying voltages.

Crystal Aging. A final cause of frequency variation, small enough to be negligible in all except the most hypersensitive applications, is crystal aging. When a crystal is first processed, micro-

(Continued on page 101)

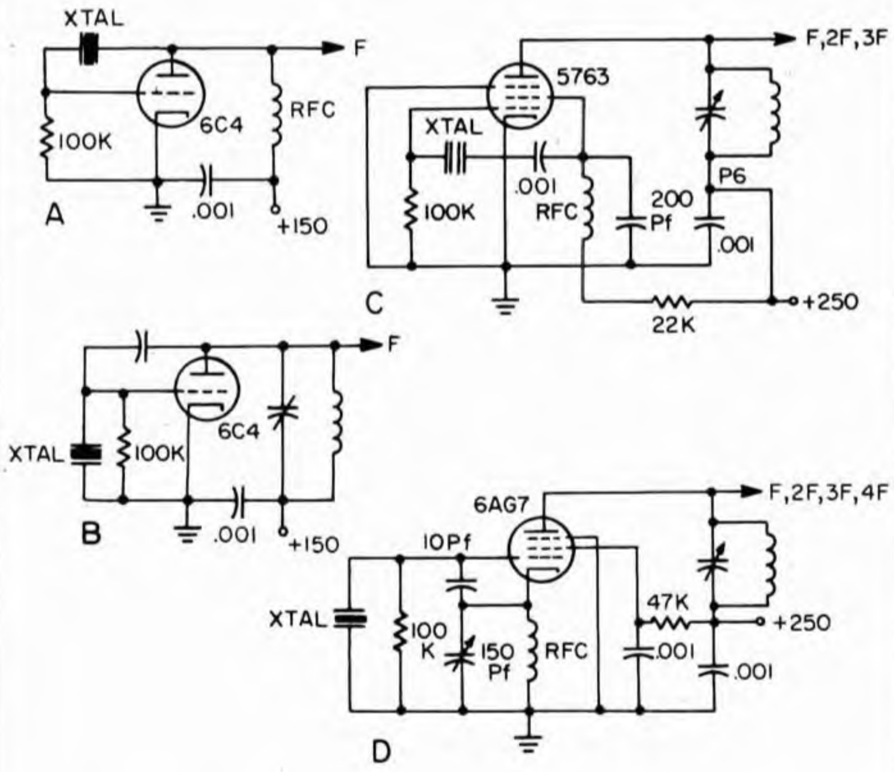


Fig. 9. The simplest crystal oscillator circuit (A) has no tuned circuits. To change frequency it is only necessary to change crystals, although a small variable capacitor across the crystal will cause some small frequency change. Miller oscillator (B) is nearly as simple as Pierce type shown in (A). Tuned circuit can pick out fundamental frequency or harmonics. Pierce electron-coupled oscillator (C) derives its feedback from the screen circuit, eliminating need for a buffer amplifier in most cases. Colpitts oscillator (D) gets its feedback from cathode circuit. Variable capacitor in the grid-cathode circuit can trim frequency.

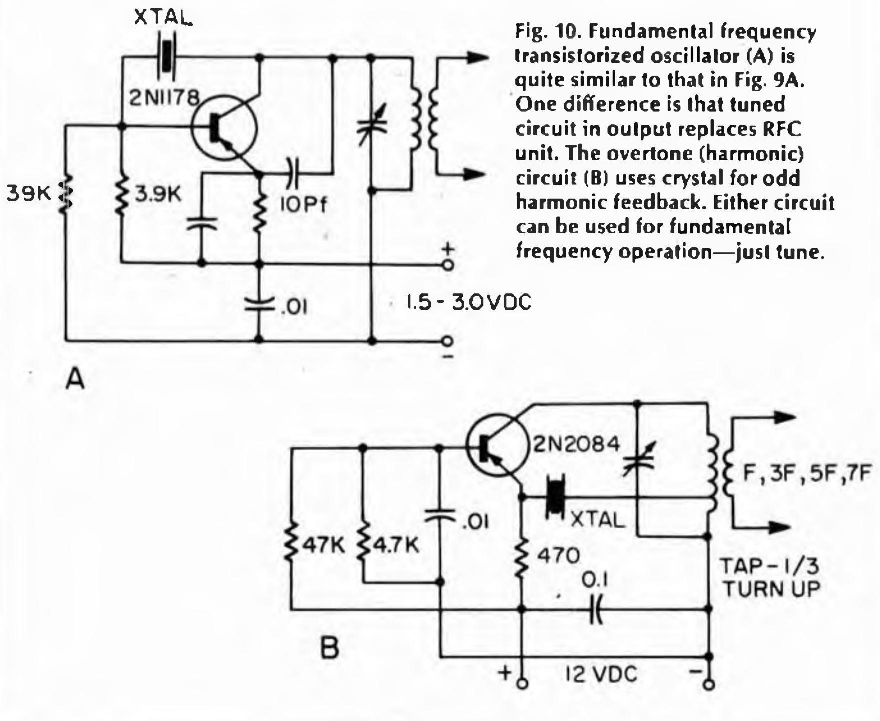


Fig. 10. Fundamental frequency transistorized oscillator (A) is quite similar to that in Fig. 9A. One difference is that tuned circuit in output replaces RFC unit. The overtone (harmonic) circuit (B) uses crystal for odd harmonic feedback. Either circuit can be used for fundamental frequency operation—just tune.

MINI POWER MAXI FUN

Discover a whole new way to enjoy Amateur Radio by learning the skills of low power transmission

Do you still get that "old thrill" out of hamming? Is the challenge gone, replaced with humdrum, "push-button" contacts made with 500-watt transceivers and multielement beams? There is nothing like trading *down* to low-power operation to restore that lost thrill, as many Amateurs both old and new have discovered.

Operation with low power, especially power levels under five-watts, presents a real challenge, both in eliciting the most from your equipment and from your operating skills, and the personal satisfaction and rewards are great. We're going to demonstrate that operating with very low power levels is indeed realistic and exciting, even under today's crowded band conditions, and we'll point out some of the equipment choices to make for best results.

Included are some tried-and-proven QRP operating tips that you can use for deriving the most enjoyable results from your gear. We'll also discuss some of the operating awards you can apply for, mention some of the contests you can enter, and tell you where you can get more information about a most interesting aspect of ham radio.

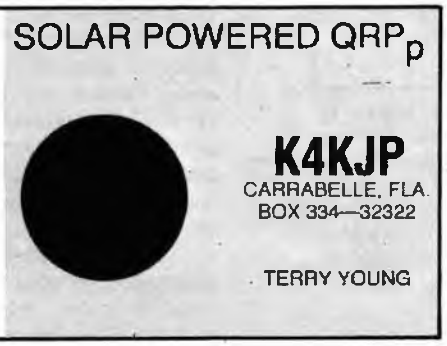
If you look up the Q-signal "QRP," you will see that it means "Shall I decrease power?" or "Decrease power" as a reply. But the term has also come to designate communications with lower power in general. Nobody has really defined low power, but for our purposes, consider "QRP" as being anything under 100-watts input; QRPp as 10-watts in, or 5 out; and "milliwatt power" as 2-watts in, 1-watt out. For simplicity, we will talk about QRP as collectively covering all three.

QRP? Why Should I? How important is transmitter power in the ham station? On the one hand, Amateurs are allowed to run power levels up to 1,000-watts input—yet many have good luck with extremely low-power, milliwatt-level stations. No doubt, the higher-powered station has a distinct advantage in "getting out" and making contacts. But one shouldn't *overestimate* the importance of high power—when propagation conditions are favorable, and good operating techniques are used, the advantage narrows and even the lowest-powered station has a chance.

A look at the mechanics of the decibel and its relationship to the familiar "S-unit" will help to place relative power levels into perspective. First of all, raising the strength of a received signal by one S-unit (6 dB) requires that *transmitter* power be upped by a factor of four. Expressed in decibels (dBs), a 4-to-1 increase in power is equivalent to a 6 dB increase, a 2-to-1 increase to 3 dB, and a 25% increase to but 1 dB. Relating S-units to transmitter power levels and received signal strength, assume that a 1 KW (1000-watt) transmitter is laying down a solid S-9 signal into your receiver. What happens—all other conditions being equal—when power is reduced? With power quartered to 250-watts, the S-meter would register around S-8; at 62-watts, S-7; at 16-watts, S-6; and at four-watts, S-5. Reducing power even further into the "QRPp" area, one-watt would yield an S-4 signal; ¼-watt, or 250-milliwatts, S-3; 62-milliwatts, S-2; and 16-milliwatts, S-1. From these figures, it's apparent that the effect on received signal strength isn't all that great even with large changes in transmitter power. In other words, it takes a very large power increase to cause a dramatically stronger signal to be received on the other end. On the other hand, if you can get through with medium or high power, your signal is likely to make it even with very low power; you'll just be weaker, and you won't cause so much QRM to other operators. Yes, QRP works!

QRP Equipment and Accessories. Getting your QRP station on the air

K4KJP is what you might term a "fair weather" QRPer. He uses photocells to convert sunlight into electrical power for his QRP rig. Since QRP power requirements are low, this isn't as hard to do as you might suspect.



CIRCLE 65 ON READER SERVICE COUPON

Kantronics' popular Rock Hound crystal controlled transmitter will fit in your pocket or purse in case you ever feel the need to call CQ from your favorite restaurant. It goes without saying that this is an excellent emergency rig.

MINI POWER

isn't difficult. Building the transmitter can be a particularly "fun" project, since QRP transmitters are usually simple, straightforward affairs and use a minimum of components. Construction plans for QRP transmitters (and some transceivers) abound in the pages of all the popular ham magazines, and are also found in the *ARRL Radio Amateur's Handbook* and the ARRL booklet, *Understanding Amateur Radio*.

If you lean toward "store-bought" equipment, several QRP transmitters and transceivers are available. The Ten-Tec Argonaut 509 is probably the most popular SSB and CW transceiver, while the Heath HW-8 is a good bet if you'd like to construct a kit. MFJ's ready-made MFJ-40T transmitter is a good selection for 40-meter single-band operation (especially when used in tandem with the accessory VFO, the MFJ-40V). A popular two-band transmitter is the new Kantronics RockHound (for 80 and 40) along with the matching "Freedom" VFO. If your taste runs to older equipment, the Heath HW-7 and Ten-Tec PM series are usually available at reasonable prices at hamfests and swap meets. All of these rigs are very portable—they can be powered by lantern or storage batteries and taken along on field days or used on vacation trips without recourse to AC lines—and most can be used mobile in a car, plane, boat, or RV. Also, if you shop for used QRP gear, seek out solid-state equipment; it will be lighter and more portable than older vacuum-tube gear and will draw much less current, a real consideration in portable operation from batteries. Also, transistor output circuitry is usually low-impedance and broadbanded, meaning that there is little time-wasting tuneup required when shifting frequency.

An important point: A VFO is a near-must for satisfactory QRP work; crystal control is just too limiting to be useful. Much more so than when operating at higher power levels, you need the flexibility of being able to move your frequency at will in order to duck QRM and to reply to stations on, or very near their own frequency. Start with a crystal-controlled rig if you like, but consider adding a VFO at the earliest opportunity.

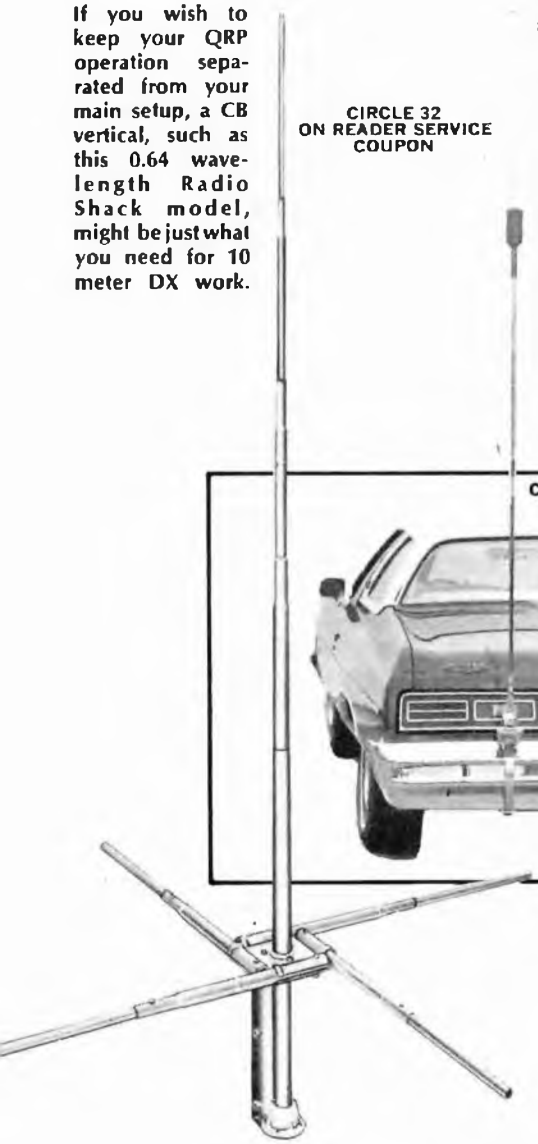
For the CW buff, correctly-shaped keying is especially important in effective QRP work. A weak but clean, crisp, and click-free QRP signal can often slice through interference better than far stronger signals with poor keying characteristics. A good keyer is a help, too, in sending easy-to-copy code and in reducing operator sending fatigue.

If you're really serious about QRP, you'll soon tire of the single-band transmitter, since if band conditions are poor on *that band*, you're stranded. It's better to purchase or construct a rig that works on two or more bands. In fact, depending on the gear you presently own, you may find it unnecessary to acquire separate QRP equipment. Many transmitters and transceivers can be scaled down to QRP power levels simply by adjusting the CW level, microphone gain, or final amplifier bias controls; the rigs will loaf nicely at such low power levels.

The other half of the QRP equation is the receiver. A stable, sensitive and selective receiver is especially important, since many of the stations you work will also be running QRP and they will be putting in relatively weak signals. And, when you make a QRP contact, you don't want to lose it because of some receiver fault. If your receiver lacks sensitivity, install a high-gain preamplifier or preselector (Palomar Engineers and Ameco both sell excellent units). If selectivity is a problem, consider the addition of an active audio filter; the Autek Research QF-1, and any of the half-dozen MFJ audio filters are worthwhile accessories and are relatively inexpensive. Not to be overlooked is the accuracy of receiver calibration, important since you will likely be using your receiver to cross-check your transmitter's frequency. If your receiver doesn't already contain one, a frequency calibrator that places known marker signals every 100, 50 and 25 kHz is a welcome addition for determining band and sub-band edges.

A costly, elaborate antenna system isn't necessary for satisfctory results. While directional beams and quads will have the same beneficial effect at QRP power levels, the effect is no more dramatic than the raw power differences discussed earlier. A full-size half-wave dipole at least 30-feet high, or a quarter-wave vertical will do a fine job. The keyword is *antenna system efficiency*, not elaborateness. For best results—to make every milliwatt count—the antenna should be resonant at the operating frequency and the feedline should be properly matched to the antenna and kept to a minimum length. A small antenna tuner, preferably one with a built-in RF wattmeter/SWR bridge, can

If you wish to keep your QRP operation separated from your main setup, a CB vertical, such as this 0.64 wavelength Radio Shack model, might be just what you need for 10 meter DX work.



Newtronics' Hustler series of mobile whips provides the ham with another venue for QRP (or regular power) work. The execllent radiation patterns from these high-quality antennas make them highly suitable for QRP DX applications.

QRP operation connotes compactness and simplicity of equipment. A keyer and antenna tuner from MFJ fit this concept.

Don't be misled by size—it's just as easy to find quality in a compact unit as in a larger one. You just have to squint a little.

be used to "fine tune" your antenna system and match it to your transmitter or transceiver. The coupler also helps to reduce harmonic radiation from your rig, a common problem particularly with simple QRP gear.

Paying close attention to these small, but very important equipment and antenna details can make all the difference in the world to your overall QRP operating results.

QRP Operating Technique. The difference between success and failure in QRP work is largely dependent upon operating skill, technique and perseverance. The QRP operator must rely heavily on his skill, rather than on the brute force of high power. Besides such basics as having a clean signal and using a good antenna system, there are a number of things you can do to increase your operating effectiveness:

Determine when band conditions are best for low-power operation. Follow propagation reports closely, realizing that while poor band conditions may make the high-power station weaker on the other end, QRP signals may just not "make the trip" at all. For example, on 40 meters, probably the most popular QRP band, conditions for low-power operation are usually best during the daylight and early evening hours; later on, skip lengthens out and signal levels decrease somewhat. Watch the strength of received signals for a clue as to propagation conditions and go after DX when S-meter readings are up. Bear in mind, too, that operating activity and interference are greatest in the later evening hours and on weekends; your results may improve if you operate outside these periods. Having a bandswitching QRP rig helps too—you can pick and choose your band at will in order to take advantage of changing band conditions.

Choose your band carefully. Forty, fifteen and ten meters are the most popular bands with QRP'ers. Eighty's QRN (static) level is high, especially in the summertime, and this often overwhelms weak QRP signals. Twenty is kilowatt alley, and your chances of simply being overwhelmed by higher-powered stations are great. My personal favorite is ten, where even the lowest-powered stations can work the world with ease. Excellent conditions now existing on the band at the 11-year sunspot peak make for good low-power DX, both for Novices (in the 28.1-28.2 MHz CW band segment) and for QRP SSB'ers using converted Citizens Band sets on the phone segment. A rule I try to observe is to use the highest frequency band that is open for DX, and right now it's usually ten, at least during the daylight hours. However, many QRP'ers prefer 40 meters, especially for ragchewing; conditions are usually fairly predictable and reliable, with 400 to 600-mile contacts during the day the rule, and worldwide DX possible at night.

Know the right frequencies. Stay flexible, and know *where* to operate in the band. Many QRP'ers hang out on the "unofficial" QRP frequencies. Some popular CW spots are 1,810, 3,540, 3,560, 7,040, 7,060, 14,060, 21,040, 21,060, 28,040, and 50,360 kHz; Novice frequencies are 10 kHz inside each sub-band. On SSB, 1,810, 3,985, 7,285, 14,285, 14,340, 21,385, 28,885, and 50,385 kHz are popular calling and working frequencies. Although most QRP'ers frown on CQs as a way of making contacts, a "CQ QRP" on any of these frequencies will often bring a snappy reply from another flea-power station. Choose a part of the band that is not overly crowded; a good QRP signal can sometimes punch through QRM, but it is generally better to stay clear of interfering signals. If you operate on 40 meters, be especially careful to avoid the high-power foreign broadcast stations' frequencies; you can't compete with them!

Call the other fellow on his frequency. You will enhance your chances of working those whom you call if you can respond on or close to the other station's operating frequency. A crystal-controlled QRP transmitter is at a distinct disadvantage; a VFO (variable frequency oscillator) will greatly improve your rig's flexibility. In fact, a VFO is almost a necessity today, especially since even Novices are no longer limited to crystal control, and the habit of "tuning the band" for replies to one's CQs is fading rapidly. If you don't care to use a VFO, at least purchase a handful of "rocks" (crystals) to allow you to spot yourself across the band.

Listen before calling. Before calling a station, be sure no one else is; never strike out in the blind for a DX station that you can't hear, simply because you hear others calling. In fact, most experienced QRP operators do not waste their time calling CQ. They know that most hams won't reply to a weaker station if a scan of the band indicates that stronger ones are available to work. It's usually best to listen carefully for another station that is either finishing up a QSO (contact) or calling CQ. Zero-beat him with your VFO, or if you are using crystal control, call as close as possible to his frequency using your crystals. Two exceptions: When working on the QRP calling and working frequencies mentioned earlier, a CQ is often productive. Also, during contests, an occasional CQ is in order.

Watch your sending. Call and sign your own callsign a little longer than when running higher power and speak clearly and distinctly, using standard phonetics. On CW, take care to send at a comfortable speed, possibly a little slower than usual, to yield cleanly-spaced characters and words. Bear in

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mind that the fellow on the other end may be straining just to pull you in, so help him out with precision sending. A speed of 10-15 words-per-minute is probably best for QRP work.

Let them know you're running QRP. You may want to sign your call and add the fact that you are operating QRP. Many "big gun" operators will make a special effort to contact you if they know that you are running very low power. Also, identifying yourself as a QRP'er will let other low power stations know that another enthusiast is on the air; you will likely get a call from them as well.

Shoot for DX. There is probably no greater thrill in Amateur Radio than working halfway across the world using just a few watts; surely, the "DX bug" bites the QRP operator at least as hard as others. Successfully and consistently working DX is difficult and a real challenge. Nevertheless, many QRP'ers have qualified for DXCC (the DX Century Club), the WAS (Worked All States), and the WAC (Worked All Continents) awards using under five-watts; a few have claimed these trophies running all of *one*-watt! The odds are that you may not work the DX station you call on your first, second or even third call; *persistence* counts. Have patience in working DX, and don't be discouraged if it takes many calls to get a reply; too many new QRP'ers quit prematurely and eventually give up trying to work DX. When you finally *do* raise that DX station, the resulting satisfaction will make it all worthwhile.

Now that we have the basic techniques mastered, let's talk about how to go about testing your skills in QRP contests and in going after some operating awards.

Contests, Awards and the QRP Gang. A great way to build up your states-worked score, add countries to your DXCC list, or work stations you need to complete a particular operating award, is to participate in a contest. Contests tend to concentrate or "telescope" operating opportunities; enough stations are usually on the air to allow you to make continuous contacts. Some contests with a low-power multiplier have even been *won* by QRP'ers.

A few contest "tips" should help. First, avoid the first few "panic" hours of major contests; recognize that the "big guns" will be there and will likely swamp your signal. Second, make your calls short and snappy; start sending immediately when the other station finishes transmitting. Third, make frequent band changes; this will help you catch band openings to different areas, and will also help you to balance out between DX multipliers and QSOs per operating hour. Fourth, go where the activity is, but take care not to waste time calling in the midst of pileups.

What are the popular QRP operating activities? They include several ARRL and JRP-ARC-1 (QRP Amateur Club International) sponsored events, such as the Spring and Fall QRP QSO Parties; the QRPp Section of the *CQ Magazine* World-Wide WPX Contests; and the DL (Germany) QRP Activity CW Contest. The most popular and coveted QRP operating awards include the QRP-25 (working 25 club members); WAC-QRP; WAS-QRP; DXCC-QRP; and the KM/W (1,000 mile-per-watt) awards. There are also several special QRPp (5-watt) and milliwatt class awards you can compete for.

The various QRP QSO Parties sponsored by the QRP-ARC-I are especially exciting and rewarding operating events for QRP'ers, and they are open to both members and nonmembers alike. The scoring multipliers used in the formal QSO Parties become much more favorable as you compete with lower power levels. For example, running over 100-watts nets but a "1" for a scoring multiplier, while power levels between 1 and 5-watts carry a "3" multiplier; milliwatt stations yield a full "5" for a multiplier. Thus, the incentive is there for QRPp and milliwatt entrants to try their best, since they have a sporting chance at bringing home an award. In fact, a special certificate is presented to the station showing three "skip" contacts using the lowest power level of any entrant.

Besides these activities, QRP'ers enjoy many of the popular operating events and manage to be quite competitive, especially in those which have special QRP scoring multipliers or which otherwise encourage QRP entrants. The ARRL Field Day is ready-made for QRP operation, with its emphasis on portable and emergency power operations. The ARRL Sweepstakes, various 10-10 Club net QSO parties, the YL-OM Contest, the Forty Meter Contest, and the ARRL QSO Parties are all popular with flea-power participants.

QRP operators have banded together to form their own association of like-minded "under 100-watts" enthusiasts. The QRP Amateur Radio Club International (QRP-ARC-I), formed in 1961, is made up of several thousand QRP'ers throughout the world. The club sponsors various operating awards and activities, and it publishes a quarterly newsletter which is included in its $2 annual dues. You can obtain membership information from the club secretary/treasurer, Joseph Szempias, W8-JKB, 2359 Woodford St., Toledo, Ohio 43605. Joining up with the group is an excellent way to acquire an up-to-date, working knowledge of QRP activities.

CQ Magazine carries a popular monthly QRP column that presents timely flea-power operating reports and news, awards, club activities, DXpeditions, contests, parts sources, and individual accomplishments.

Note: When writing to any of the organizations and individuals listed, enclosing a SASE (self-addressed, stamped envelope) is a courtesy.

Conclusion. Operating QRP can be a very satisfying experience, but without a lot of RF power backing you up, a great deal depends on your equipment, your operating techniques, your attitude, and an extra measure of patience. Above all, remember that successful QRP operation requires careful attention to details that might not be so necessary in high-power hamming; work carefully and deliberately at improving both your flea-power installation and operating skills. As you develop your *modus operandi*, you will derive increasing satisfaction from low-power work and will indeed be surprised and excited by the results. You will find, as I did, that mini-power operation yields maxi-fun. Good luck and think small! ■

Heath's HW-8, successor to the venerable HW-7, is a 4-band QRP transceiver (80-15m) which will dine lightly on your car battery. With a 3-watt input and 0.2 microvolt sensitivity, it's a good choice for field or portable operations.

CIRCLE 1 ON READER SERVICE COUPON

BASIC THEORY NOTEBOOK

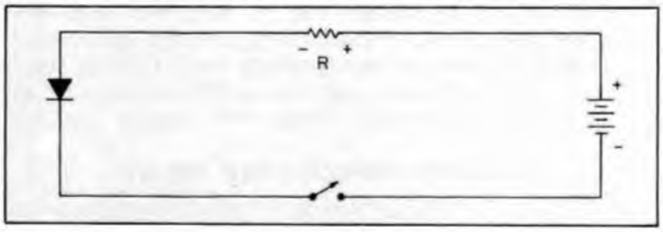
In this section, we will cover some fundamental aspects of electronics which are necessary for the experimenter and technician before further study or application is made. Areas examined are silicon controlled rectifiers (SCR's), capacitance, cathode ray tubes (CRT's) and horizontal dipole antennas. A chart of Prefixes and Exponents is also included to help standardize this terminology.

SCR Basic Principles

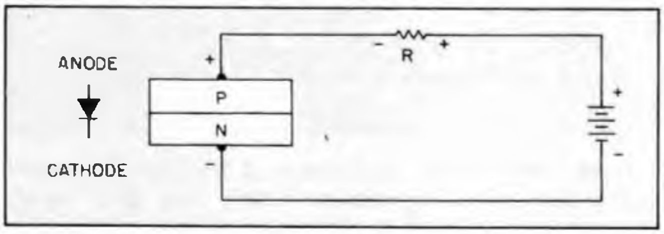
WHAT IS AN SCR?

An SCR, in practice, is basically a **standard rectifier** placed in series with a **switch.** When the switch is

FUNCTIONAL SCR DIAGRAM



SIMPLE DIODE

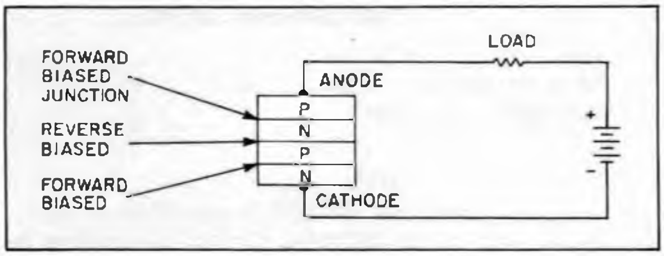


closed, the rectifier will conduct in one direction.

The difference between the diode/switch combination and the SCR is that the switch is built right into the SCR itself, and is commonly referred to as the **gate**. More about this later on.

A basic, four-layer silicon device has three junctions. With a battery connected as shown, the device **cannot** conduct because no current can flow through the reverse-biased junction in the middle. In this configuration, there are only three ways in which current flow can be induced: the current level can be increased to the point where the junction is simply overwhelmed, light can be directed at the junction until enough electron excitation is created to bridge the reverse-biased junction, or the device can be heated to the point where electron excitation occurs. Of course, these are all clumsy methods.

FOUR-LAYER DEVICE



QUESTIONS

Q1. The basic component around which an SCR is built is the __________.

Q2. The SCR's gate functions as a __________.

ANSWERS

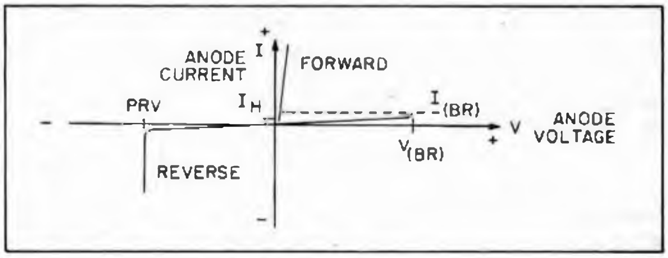
A1. diode

A2. switch

TRIGGERING

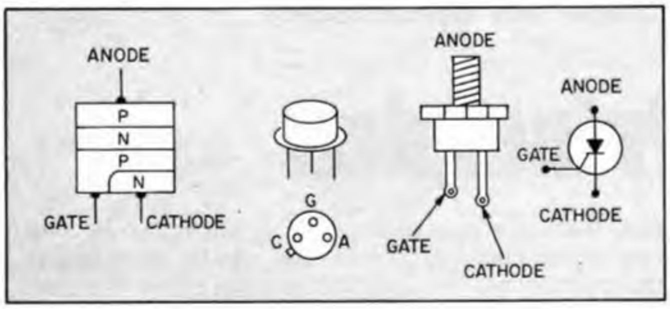
If we were to plot the voltage and current characteristics of this four-layer device, the result of the **forward voltage breakover** (VBR)—the point at which the SCR begins to conduct—can be observed. Initially, a small current (IBR) is required to trigger the device. In this application, it can be derived from any of the three sources mentioned above. In addition, a **minimum current** level (IH), or holding current, must be present in the external circuit in order to keep the device in a conducting state. Once the device has been triggered, and as long as the holding current is sufficient, no further triggering action is necessary.

CURRENT AND VOLTAGE BREAKOVER GRAPH



As noted earlier, the physical methods required to trigger the four-layer device are all clumsy and in fact may be destructive to the silicon wafer upon which the device is constructed. The difference between the four-layer device and the SCR, is that the "P" region **nearest** the **cathode** has a lead attached to it (the **gate**) which, when current is directed into it (IBR), negates the normal reverse bias of the middle junction and allows the SCR to behave like a normal rectifier. Again, once the gate has allowed the cathode to trigger, only a small current level (IH) is required to keep the device

INTERNAL AND EXTERNAL SCR CONFIGURATION



in a conducting state. Even with gate current **removed**, the device will continue to operate until the holding current in the rest of the circuit falls below the minimum level.

QUESTIONS
Q3. The ____________ is a measure of the point at at which an SCR will conduct.
Q4. It is necessary to apply the ____________ to the gate in order for the SCR to conduct.
Q5. The SCR will cease to conduct only if ____________.

ANSWERS
A3. forward voltage breakover
A4. breakover current (IBR)
A5. the holding current (IH) drops below the threshold level.

SCR OPERATIONAL PROBLEMS

One of the problems that engineers encounter when using the SCR in a switching capacity is **time.** As mentioned earlier, once the SCR has been triggered and current starts to flow from cathode to anode (typically this requires a time period of about 5-microseconds), it will continue to flow through the SCR until and unless the current level drops below the minimum required to hold the SCR open. Suppose, however, that we wish to use the SCR to switch a high-speed DC pulse current. Remember the center junction of the four-layer device that held the reverse (blocking) bias? Because all of the forward voltage flowing through the device must cross this junction, the "P" and "N" regions which comprise the junction actually act as the plates of a **capacitor,** charged to the voltage which is flowing through the SCR.

As a result of this phenomenon, an abrupt application of forward voltage to the junction (as may be supplied by a high-speed pulsed driver or other pulse source) may, through this capacitive effect, cause the SCR to trigger **before** a gate current is ever applied. Typically then, one must allow 50-microseconds to elapse before applying another pulse of forward voltage to the SCR to insure that it has reset itself.

This necessity limits the applications in which the SCR can be used, although newer types of switching transistors can operate at much higher speeds and have, in many cases, obsoleted the SCR in high-speed switching applications.

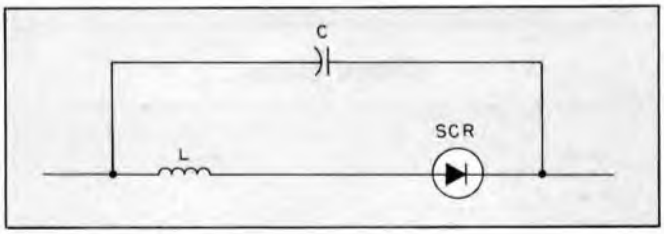
QUESTIONS
Q6. It takes ____________ for an SCR to reach full conductance level.
Q7. An SCR can be falsely triggered because the middle junction has a ____________ effect.
Q8. An SCR must be allowed a period of ____________ to reset itself.

ANSWERS
A6. 5-microseconds
A7. capacitative
A8. 50-microseconds

RADIO FREQUENCY INTERFERENCE

Another problem encountered when incorporating the SCR into a circuit (especially one which operates at radio frequencies, such as digital clocks, ham receivers, and microcomputers) is that the relatively abrupt triggering and conductance process associated with the SCR, and the concurrently swift current level rise through the circuit, can cause RF frequencies to be spuriously generated. These RF signals can be

INDUCTIVE/CAPACITATIVE SHUNT



radiated directly into other parts of the circuit, or can be coupled into the power supply line and travel through it to other parts of the circuit just as easily.

Normal RF shielding precautions can be taken (good grounding, use of shielded cable, etc.), and in addition, an **inductive/capacitative shunt** may be employed to effectively slow down the current rise time across the SCR. Usually, a value of 0.1-uF for the capacitor, and 75-uH (microHenrys) for the inductor will suffice. Be sure, however, that both components are capable of handling the maximum voltage and current levels which will appear across the SCR normally as a result of the circuit's operation.

QUESTIONS
Q9. An SCR's switching action may create ____________.
Q10. An ____________ will help quiet an SCR.

ANSWERS
Q9. RF interference
Q10. inductive/capacitative shunt

SUMMARY

You have learned that the SCR is essentially a rectifier diode with an incorporated switch. The switch is comprised of two extra "P" and "N" layers which form a reverse-biased junction which effectively cuts off the forward flow of current and voltage. The **gate,** which is a lead attached to the "P" junction nearest the cathode, can, when a suitably large current (IBR) is passed along it, negate the reverse bias at the middle junction and allow current to flow. Once the current is fully flowing, removal of the breakover current **will not** open the gate, and the flow can only be stopped when current in the rest of the circuit drops below the level (IH) necessary to hold the junction open. In addition, you now know that it takes ap-approximately 50-microseconds for the capacitative charge on the "P" and "N" layers adjacent to the middle junction to drop to a level where the junction will not be closed by application of a forward voltage to the cathode. The swift rise of current associated with the closing of the middle junction (just as the closing of a light switch will cause a "pop" to come through an AM radio near it) can create RF interference, and suitable shielding and shunting may be necessary in certain circuit applications to avoid this. ■

Capacitance Basics

You will learn how capacitance can be used to block direct current (DC) and to pass alternating current (AC) signals. You will also learn how capacitance causes applied AC voltage to lag behind the current in a given circuit, and how capacitance distorts the voltage waveform of pulses. When you have finished you will be familiar with the units we use to measure capacitance and the factors influencing the size of a capacitor.

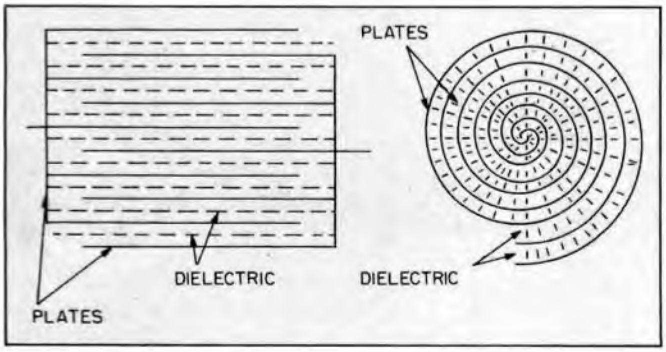
WHAT IS CAPACITANCE?

Capacitance is the property of an electrical circuit that **opposes a change in voltage.** Capacitance has the same reaction to voltage that inductance has to current. This means that if the voltage applied *across* a circuit is increased, the capacitance will resist that change. If the voltage applied across a circuit is decreased, the capacitance will oppose the decrease and try to maintain the original voltage.

In a DC circuit, capacitance has an effect only when voltage is first applied, and then again when it is removed. **Note that direct current cannot flow through a capacitance.** However, alternating current **appears** to flow through a capacitance—you will learn how later. Since voltage is constantly changing in AC circuits, capacitance acts at all times to retard these changes.

A basic capacitor is shown in the first diagram. It consists of two conducting metal plates separated by a layer of air or other insulating material, such as paper, glass, mica, oil, etc. The layer is called the **dielectric.**

STACKED AND ROLLED CAPACITOR TYPES

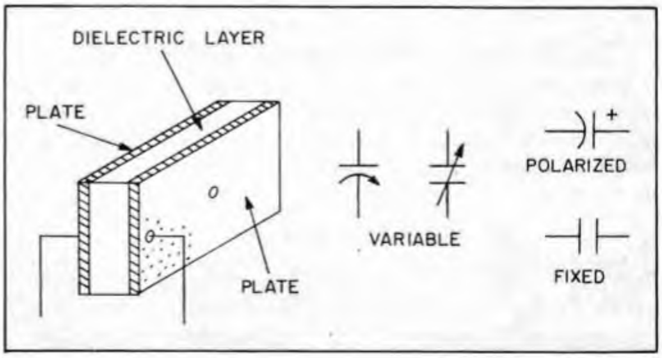


All capacitors have these two plates and a separating layer. In practice, the plates and dielectric are often stacked or even rolled into a compact form. Sometimes the dielectric is a paste or a liquid instead of a solid.

When a capacitor is first connected to a battery, electrons from the negative terminal of the battery flow to the nearest capacitor plate and remain there. They can go no farther, since the opposite plate is separated from the first by an insulating layer. Electrons are attracted from the opposite capacitor plate and flow into the positive terminal of the battery. After this initial movement of electrons, the negative-most plate of the capacitor is filled with all the electrons that the battery voltage can force into it, and the other capacitor plate loses the same number of electrons to the battery's positive terminal. This means that one plate has a negative charge and the other plate has a positive charge—the charge being equal to the battery's potential. No further current flows; the capacitor is "charged."

Positive and negative charges attract each other, so there will be a force between the plates of the capacitor. There is also a voltage between them that is equal to, and which opposes the voltage of the battery.

CIRCUIT SYMBOLS AND CORRESPONDING PARTS



Because it takes a certain specific number of electrons to fill the negative plate, we say that the capacitor has a certain capacity, or **capacitance.**

QUESTIONS

Q1. Name two differences between capacitance and inductance.

Q2. Draw a circuit diagram of a capacitor connected

across the terminals of a battery.

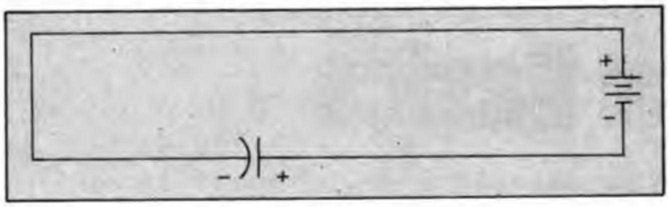
Q3. Explain what happens when you disconnect the battery terminals from a charged capacitor and place a wire across the leads of the capacitor.

ANSWERS

A1. Capacitance opposes a change in voltage while inductance opposes changes in current. **Capacitance blocks DC** while inductance does not.

A2. Your circuit diagram should look like this.

ANSWER TO QUESTION 2



A3. The **electrons** from the capacitor's negative plate **flow through the wire to the positive plate** until both plates have the same number of electrons. The **voltage across the plates is then zero.**

CAPACITANCE MEASUREMENTS

The usual written symbol for capacitance is **C.** Capacitance is measured in **farads.** The amount of capacitance in a capacitor is the quantity of electrical charges (measured in coulombs) which must be moved from one plate to the other in order to create a potential difference of 1 volt between plates. The number of coulombs transferred is called the **charge**.

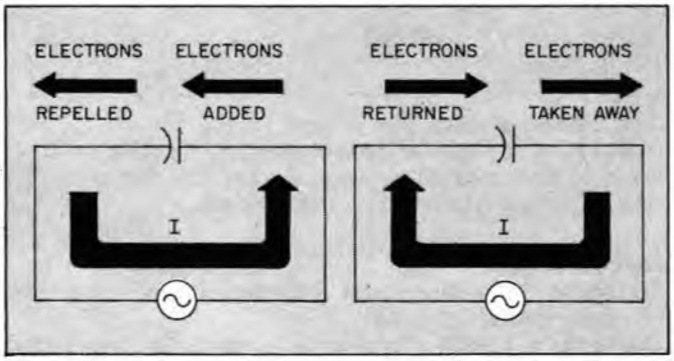
One farad is the capacitance in which a charge of 1 coulomb produces a difference of 1 volt between the plates. The larger the area of a capacitor's plates, and the closer these plates are to each other, the more charge (current) the capacitor will hold with the same voltage applied across the plates.

Capacitance values are usually specified in microfarads (millionths of a farad, abbreviated **mfd** or **μF**) or in **picofarads** (millionths of a microfarad, abbreviated **pF**).

HOW DOES CAPACITANCE AFFECT AC?

Although current cannot flow through a capacitor, an AC current appears to do just that. The reason lies in the nature of capacitance. If the voltage across the plates is continuously varied, the number of electrons on the plates varies.

AC THROUGH A CAPACITOR



Increasing the number of electrons on one plate of a capacitor repels electrons from the other plate. Decreasing the number of electrons on the first plate allows electrons to be attracted back to the other plate.

An AC current can, **in effect,** get across the dielectric. Since the voltage is alternating, it causes a corresponding varying current to flow between one side of the capacitor to the other side. In other words, **voltage changes** appear to be transmitted across the dielectric.

If a capacitor has the same voltage as the applied voltage, no current will flow to or from it. If the applied voltage changes, the capacitor voltage will no longer equal the applied voltage. Current will flow, **trying to equalize** the two potential sources.

In a circuit this means that if an AC sine-wave voltage is applied across a capacitor, an AC sine-wave current will appear on the opposite side, even though no electrons flow through the dielectric layer.

QUESTIONS

Q4. The capacitance of a capacitor is measured in ______ . ______

Q5. A millionth of a farad is called a ______ and is abbreviated as ______ or ______.

Q6. A ______ is a millionth of a microfarad and is abbreviated ______ . ______

Q7. Current will flow from one plate of a capacitor to the other plate only when ______ is changing.

ANSWERS

A4. The capacitance of a capacitor is measured in **farads.**

A5. A millionth of farad is called a **microfarad** and is abbreviated as **mfd** or **μF.**

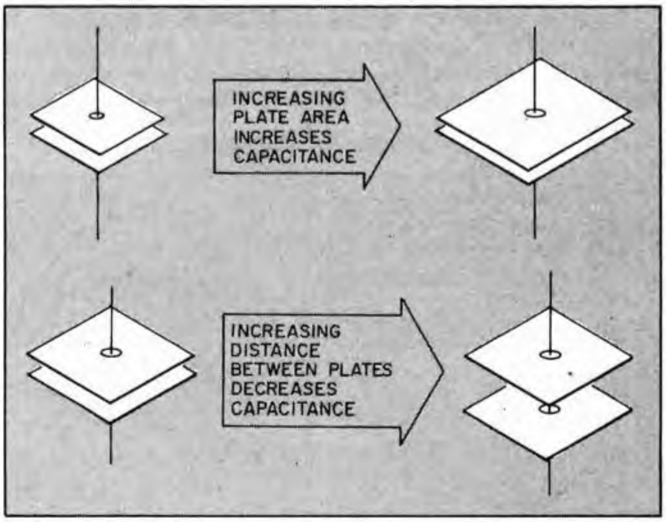
A6. A picofarad is a millionth of a microfarad and is abbreviated **pF.**

A7. Current will flow through a capacitor only when **voltage** is changing.

FACTORS AFFECTING CAPACITANCE VALUE

The amount of electrical charge that can be stored in a capacitor (the number of electrons that can be placed on the plate) varies with the **area** of the plates. Consequently, capacitance varies directly with area—if the

PHYSICAL FACTORS AFFECTING CAPACITANCE

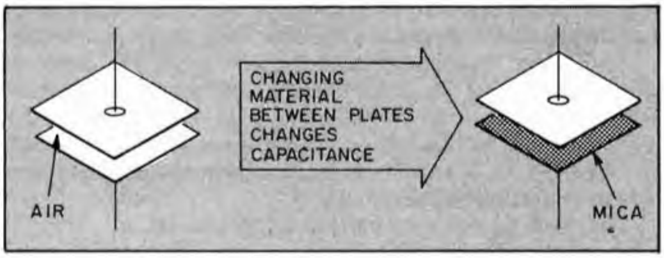


area is doubled, the capacitance is doubled. When the area is doubled, or twice as many plates are connected in parallel, there is twice as much area to store electrons. Therefore the capacitance is twice as great.

Capacitance can also be increased by placing the plates closer together. When the plates are closer the attraction between the negative charges on one side and the positive charges on the other side is greater. It is, of course, necessary to keep the plates suffciently separated so that the charge does not jump through the dielectric, possibly damaging the capacitor.

Higher values of capacitance can be obtained by using an insulating material (dielectric) other than air. In this way the plates can be placed closer together. Dielectrics such as mica, glass, oil, and **mylar** are a few of the materials that can withstand a high electric potential without breaking down. This property is called **dieletric constant.** The higher the dielectric constant, the better its ability to retain its insulating characteristics under unusual operating conditions. Air has a constant of 1, glass about 5, and mica 2.5 to 6.6.

DIELECTRIC FACTORS AFFECTING CAPACITANCE



Besides allowing the plates to be placed closer together, a dielectric has another effect on capacitance. Dielectric material contains a large number of electrons and other carriers of electrical charge. Although electrons cannot flow as in a conductor, they are held rather loosely in the structure and can move slightly. The distortion of the structure of the dielectric, which is caused by charging the capacitor, has a large effect on the forces of attraction and repulsion that aid or oppose the flow of the electrons. This factor has a substantial effect on capacitance.

When materials such as mica or glass are used as the dielectric, the capacitors have a much higher value than the same size units with an air dielectric.

QUESTIONS

Q8. How does a mica capacitor differ from an air capacitor of the same physical size?

Q9. What are three factors that affect the capacitance of a capacitor?

Q10. A screw-type variable capacitor is made with an adjusting screw that is used to vary the distance between the capacitor plates. How would you increase its capacitance?

ANSWERS

A8. A mica capacitor has a **higher capacitance** than an air capacitor of the same physical size.

A9. The capacitance of a capacitor depends on these three factors: the **area** of the plates, the **spacing** between the plates, and the nature of the **dielectric material.**

A10. Tightening the screw moves the plates closer together and **increases capacitance**. Loosening the screw **decreases the capacitance.**

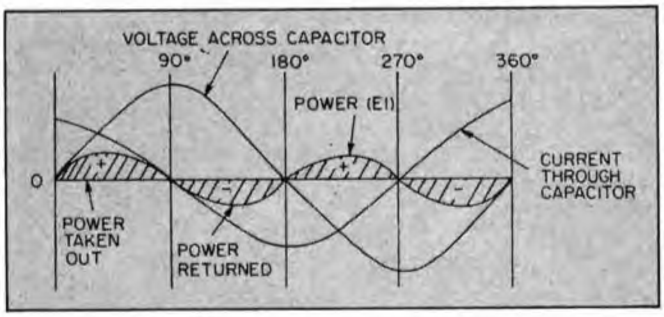
POWER

A perfect capacitor consumes no power. During the sine-wave cycle, the capacitor takes energy out of the circuit and stores it in the form of an electric field during a quarter cycle. The capacitor returns it to the circuit in the next quarter cycle. **Energy is borrowed, but it is returned later.**

If the product of E times I is taken at every instant of the cycle, the power waveform will show that energy is taken out and returned in alternate quarter cycles.

To find the amount of energy (in **coulombs**) stored in a capacitor, multiply the capacity in farads by the applied voltage. In a circuit containing only pure capacitance, it makes no difference how long the voltage is applied—the same amount of energy will always be stored at a given voltage.

ENERGY STORAGE CYCLE



CAPACITIVE REACTANCE

Like inductance, capacitance has a reactance—an opposition to the flow of AC. But capacitive reactance **decreases** as frequency increases.

Suppose a capacitor is connected in series with an alternating voltage source. There is no resistance present at all in the circuit.

Because the circuit below contains no resistance, the voltage across the capacitor will be the same value as the source voltage at every instant.

RESISTANCE-FREE CIRCUIT

When a capacitor is charged up to voltage E, it stores an amount of energy equal to the capacitance times the voltage. If the peak voltage of the AC source is E, the capacitor will have stored a particular amount of energy every time the voltage sine wave reaches its peak, and again stores that amount whenever the voltage reaches its negative peak. The energy depends only on capacitance and peak voltage.

QUESTION

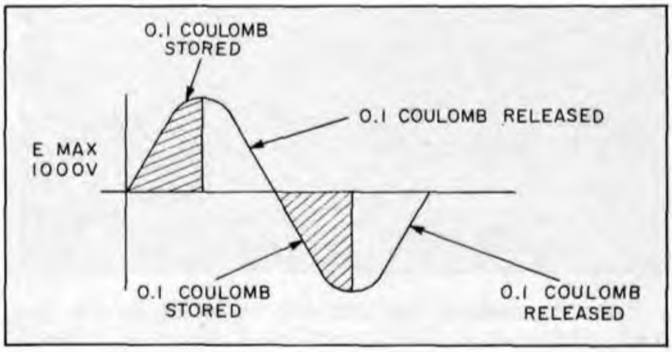
Q11. How much energy will be stored in a 100-mfd capacitor in the first quarter cycle of an applied AC voltage of 1,000 volts maximum?

ANSWER

A11. 1,000 volts × .0001 farad = **0.1 coulomb**

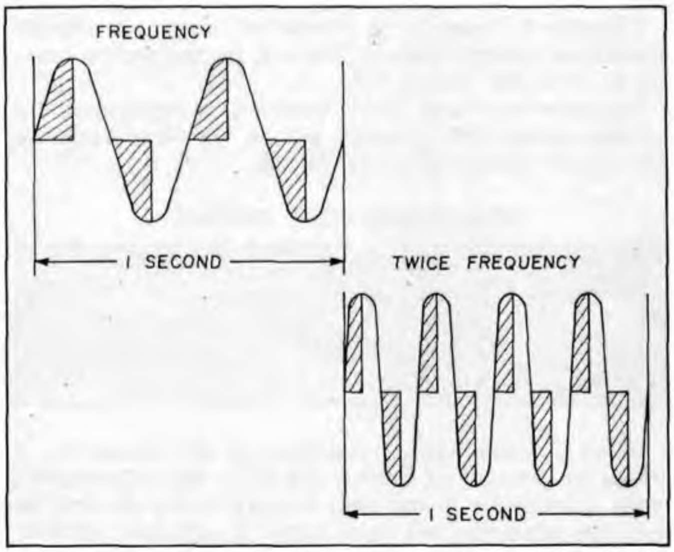
What happens when the frequency of the power source is doubled? If the peak voltage (E) is unchanged, the capacitor will charge every half cycle to the same amount as before. But it will have to do this twice as fast because the energy is doubled. This means that the same amount of energy must flow into the capacitor in only half the time. And since the voltage is the same, we must have twice the current to supply this same amount of energy.

ENERGY STORAGE POTENTIAL



What does this mean? The frequency was doubled, and this doubled the current flowing into the capacitor. Yet, the input voltage remained the same. A pure capacitance lets twice as much current flow if the frequency is doubled.

POTENTIAL VERSUS FREQUENCY



Capacitive reactance is the opposition that pure capacitance offers to the flow of current. It is expressed in **ohms,** and its symbol is **X_c**. Capacitive reactance depends on frequency. As the frequency increases, the rate of change of applied voltage *increases*, and the current flowing also increases. As the frequency is reduced, the rate of change of voltage goes down, and less current flows.

At this point you can more easily see why capacitor current leads the voltage across the capacitor. It is necessary for the capacitor to charge up to the given voltage, and this charging is done by the current. Hence, the charging current will reach its maximum value at the time the charging is going on at the greatest rate; that is, when the rate of change of voltage is the most rapid.

As the capacitor approaches full charge, the voltage rate of change slows down, and the current decreases. When the capacitor is fully charged and its voltage has reached maximum, there is no charging current flowing at all—the current has already dropped to zero at this time. A similar process occurs during discharging. At all times, current leads the voltage by 90°, or one quarter of the cycle. In a steady-state AC situation, when the applied voltage is a sine wave, both voltage and *current* will be sine waves.

Capacitive reactance depends on frequency. Since it lets more current flow as frequency increases, **capacitive reactance must decrease as the frequency increases.**

Capacitive reactance also depends on the size of the capacitance. As capacitance increases, more current must flow into the capacitor to charge it to the same voltage (since the amount of energy stored equals C times E). As a result, **capacitive reactance decreases when capacitance increases.**

The formula for capacitive reactance is:

$$X_c = \frac{1}{2\pi fC} \text{ ohms}$$

where,

f is the frequency in Hz,

C is the capacitance in farads.

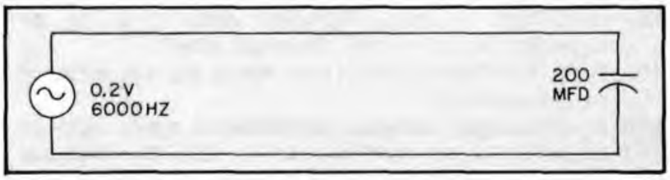
Capacitive reactance can be used in calculating current in a purely capacitive circuit by Ohm's law.

$$I = \frac{E}{X_c}$$

QUESTIONS

Q12. What is X_c if $f = 6{,}000$ Hz and $C = 200$ mfd?

CIRCUIT FOR QUESTION 12



Q13. What is the current in the circuit?

Q14. What would the current in the above circuit be if the input signal were 0.01 volt at 120 kHz?

ANSWERS

A12. $X_c = \frac{1}{2\pi fC} =$

$$\frac{1}{2 \times 3.14 \times 6{,}000 \times 200 \times 10^{-6}}$$

$$= \frac{1}{7.53} = \mathbf{0.133\ ohm}$$

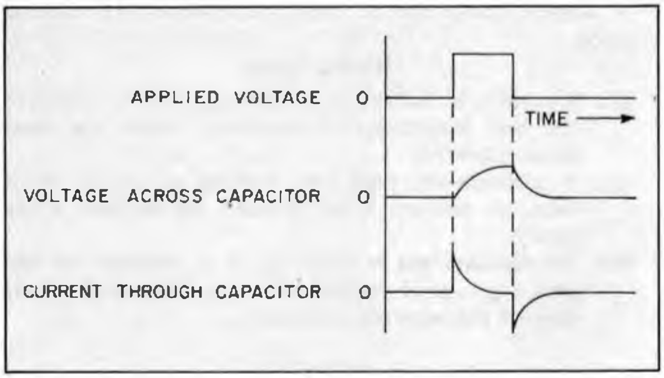
A13. $I = \frac{E}{X_C} = \frac{0.2}{0.133} = \mathbf{1.5\ amps}$

A14. $I = \frac{0.01}{0.0066} = \mathbf{1.52\ amps}$

PULSE RESPONSE OF CAPACITANCE

When a sharp pulse, such as a square wave, is applied to a circuit containing capacitance, the capacitance opposes the sudden change of voltage. This results in a rounding off of the sudden voltage rise. Similarly, when the pulse voltage is suddenly decreased, the voltage across the capacitor does not decrease suddenly, but it trails off. Current is greatest when the change of voltage is greatest, so the current waveform will have a peak when the voltage rises suddenly, and another peak (but in the opposite direction) when it drops.

CAPACITANCE VERSUS TIME



There is always some resistance in a practical circuit. By choosing the right values of capacitance and resistance, a circuit can be designed in which the voltage takes a predetermined length of time to reach a certain value. This type of circuit can provide a time delay.

STRAY CAPACITANCE

Capacitive reactance decreases as frequency increases. In communications, pulse, and radar work, where very high frequencies are used, **stray capacitance** can present quite a problem.

In a vacuum tube, an antenna, or a receiver chassis, there are always small capacitances between adjacent conductors and between conductors and nearby objects which are meant to be isolated from each other. With audio and lower radio frequencies these capacitances are not important. But as the frequency increases, the capacitive **reactances** of these small capacitances decrease. Enough decrease in reactance can actually cause leakage of the signal.

Thus, at high frequencies, placement of wires and components is very important in order to keep the effects of stray capacitance to a minimum.

QUESTIONS

Q15. How does capacitance affect pulses?

Q16. Compare and contrast capacitive reactance and inductive reactance on these points:
1. Effect of an increase in frequency on reactance.
2. Effect of reactance on DC.
3. Effect of phase relations in AC.

Q17. What constant value appears in the formulas for both capacitive and inductive reactance?

ANSWERS

A15. Capacitance **rounds off the voltage waveform and produces spikes in the current waveform**.

A16. 1. X_C **decreases** as frequency increases, while X_L **increases.**
2. X_C **blocks DC,** while X_L **passes DC.**
3. Capacitance causes current to **lead** the applied voltage, while inductance causes it to **lag.**

A17. **2π** appears as a constant in both formulas.

WHAT YOU HAVE LEARNED

1. Capacitance offers opposition to any change in voltage.
2. A basic capacitor consists of metal plates separated by a dielectric.
3. A capacitor stores electrical energy in the form of an electric field as the capacitor charges, and releases this energy when it discharges.
4. Capacitance is a measure of the energy storage capacity of a capacitor. This capacity is measured in farads.
5. A capacitor blocks DC but allows AC to flow.
6. Pure capacitance in a circuit causes current to lead the applied voltage by 90°.
7. The amount of capacitance is determined by the area of the plates, the distance between them, and the dielectric material.
8. A capacitor stores energy and returns it to the circuit.
9. The opposition of capacitance to the flow of AC is called capacitive reactance.
10. The formula for capacitive reactance is:

$$X_C = \frac{1}{2\pi fC}$$

11. Capacitance rounds off the voltage waveform of a pulse.
12. Stray capacitance can cause signal leakage at high frequencies. ■

The information in this section is based on material in the 5-volume set, BASIC ELECTRICITY/ELECTRONICS, published by Howard W. Sams & Co., Inc. For details, write the publisher at 4300 West 62nd St., Indianapolis, IN 46268.

BASIC THEORY NOTEBOOK

CRT's in 'Scopes and TV's

WHAT YOU WILL LEARN. When you have finished reading this article you will have learned how the cathode-ray tube, which is the display device for oscilloscopes, as well as for all television receivers, works. In addition, you will know what the differences are between cathode-ray tubes used in 'scopes and those used in TVs.

THE CATHODE-RAY TUBE

The cathode-ray tube (which we'll refer to as CRT from here on) is a large vacuum tube which has three main parts. They are, first, the **electron gun,** which produces a steady stream of electrons and aims them at the large, flat end of the tube, second, **deflecting** devices, which move the electron beam in accordance with the signal to be observed, and third, the chemical coating on the large flat end of the CRT, commonly called the **screen.**

The oscilloscope displays electrical signals on the screen to show what's going on in electrical or electronic circuits. The TV set shows pictures transmitted from the TV station. In both cases the CRT used in the 'scope or the TV set are almost exactly the same.

The main difference in the picture tube in TV sets and the CRT in scopes today is that the electron beam is moved back and forth in the TV set *electromagnetically,* by coils of copper wire placed around the neck of the tube, while the electron beam in a 'scope is moved about by the changing *electrostatic* voltages between small deflection plates inside the neck of the tube. In fact, the earliest TV picture tubes were electrostatic-deflection CRTs, and during the Korean War, when copper for the magnetic deflection coils was scarce, TV set makers stopped making electromagnetic-deflection picture tubes and went back to the earlier, electrostatically-deflected tubes!

THE CRT IN OSCILLOSCOPES

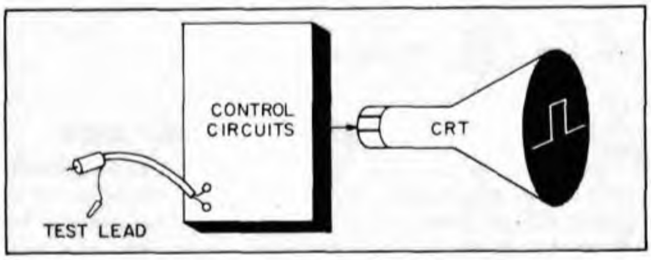
The oscilloscope is really a not-very-exact *measuring* instrument for voltages and waveforms which also shows what the voltages or signals *look* like. Although it *can* be pretty exact in its measurement of signals, only the most expensive 'scopes are nearly as precise as even cheap meters, so their main purpose is usually to show what the signals look like.

The oscilloscope contains, in addition to the CRT, a power supply which generally provides 2,000-volts or more, and some control circuits which take the signal voltage(s) to be displayed, amplify and otherwise process them and feed them to the CRT for display.

'Scope CRTs have a screen usually made of phosphorescent (give off light when struck by electrons) chemicals which create a green display. Some very expensive 'scopes use CRTs with blue, or even purple-emitting phosphor-coated screens. TV sets of course have screens with white light-emitting screens (in black and white sets).

The CRT in oscilloscopes uses electrostatic deflection, with the deflecting voltages applied to the vertical-deflecting plates and to the horizontal deflecting plates, as shown in the diagram.

SIMPLIFIED OSCILLOSCOPE



The signal voltage size is indicated by the *amplitude* (height, up-and-down dimension) of the beam movement on the screen. The *time period* (duration) is shown by the distance the beam travels across the screen horizontally, from left to right.

By relating the time a signal takes to its amplitude (size) and its shape, we can get a very accurate idea of what's going on in most circuits at any desired point.

QUESTIONS

Q1. A waveform can be described in terms of its vertical and horizontal dimensions. What are these dimensions? a__________, t_______.

Q2. A cathode-ray tube can display a picture on its face, or screen. What causes the picture to appear?

Q3. An oscilloscope is made up of a cathode-ray tube and a group of control circuits. What is the function of the control circuits?

ANSWERS

A1. The vertical and horizontal dimensions of a waveform are **amplitude** and **time.**

A2. The picture on a CRT is developed by a **moving electron beam** that strikes and illuminates a chemical coating on the inside face of the tube.

A3. The function of the oscilloscope control circuits is to process, amplify, and deliver the **signal** to the CRT.

THE CRT IN TV SETS

The cathode-ray tube is the display device in the television set. The CRT operates by moving a controllable beam of electrons across the inside face of the tube. The number of electrons in the beam is determined by the blacks, grays, and whites of the scene the TV camera is viewing. White is produced by a large number of electrons striking a chemical coating on the inside of the tube. The electrons cause the coating to give off light. Black is achieved by stopping the electron flow, and shades of gray are obtained by varying the amount of electrons between the amounts required for black and white.

The picture is "painted" on the screen by the narrow electron beam moving back and forth across the tube many times a second. This movement is due to varying magnetic fields produced by a set of horizontal and vertical deflection coils around the CRT's neck.

The principle of putting a picture of a waveform on the screen of an oscilloscope is similar. The movement of the electron beam in the 'scope is controlled *electrostatically* so that the beam traces out the pattern of the waveform being measured. As in the TV tube, the electron beam illuminates a coating on the inside of the tube.

ELECTROSTATIC FIELDS

To understand how the CRT operates, you must know that an electrostatic field is a space in which electric forces act.

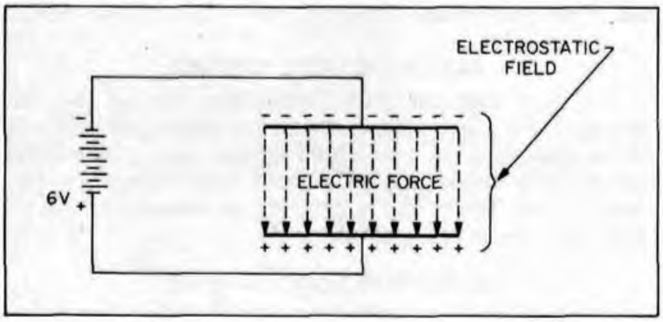
An electrostatic field can be developed between two charged plates. If one plate is negative with respect to the other, the direction of the electric force can be determined.

In the drawing shown, lines of electric force take a direction from negative to positive. This means a negatively-charged body entering the field would be moved downward (from negative to positive). A positively-charged body, however, would be moved upward (positive to negative). (Like charges repel, and unlike charges attract). How do you think an electrostatic field is formed?

An electrostatic field is formed with a voltage source and a pair of metallic plates to hold the charges.

If a 6-volt battery is connected to the plates in the manner shown, the battery will draw elecrons from the bottom plate and deposit them on the top plate until the difference in potential between the plates

ELECTROSTATIC FIELDS



equals the battery voltage. The potential of the plate having an excess of electrons will be negative. The other plate, being deficient in electrons, will be positive.

QUESTIONS

Q4. What is an electrostatic field?
Q5. What causes an electrostatic field to exist between two metallic plates?

ANSWERS

A4. An electrostatic field is a region in which **electric forces** are acting.
A5. An electrostatic field is formed when one plate has an excess of and the other a deficiency of electrons.

ELECTROSTATIC FORCES BETWEEN CIRCULAR AND TUBULAR PLATES

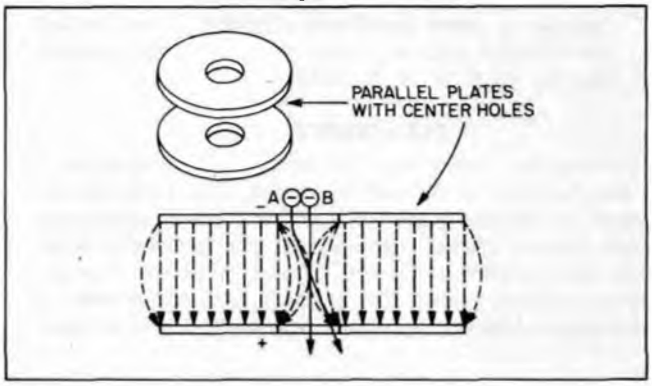
In the drawing, an electrostatic field between two plates having center holes is shown. Observe the curvature of the force lines under the holes.

PRODUCING AN ELECTROSTATIC FIELD

Since its path is parallel to the force lines, electron B will pass straight through the axis (center line) of the holes. Electron A starts in the same direction as electron B. When electron A enters the field, it turns in the direction of the force lines. Just before it leaves the field, it is turned even further and in the direction of the curvature of the force lines.

Suppose a small and a large cylinder, both charged with a positive potential, are placed so the electrons

ELECTROSTATIC LENS I

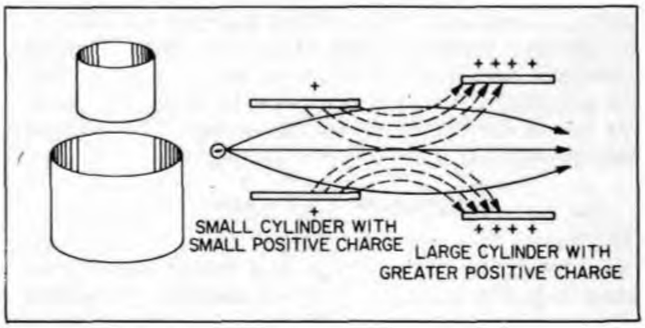


must pass through them. Also suppose the larger cylinder has a more positive charge. The distribution of the lines of force would look like the next illustration.

An electron in the space at the left of the small cylinder would be attracted toward the cylinder by the positive charge. If the electron was travelling along the axis of the cylinder, it would pass through without crossing a line of force. As it approached the larger, more positively charged cylinder, the velocity of the electron would increase.

An electron entering the small cylinder at an angle will cut the lines of force and be turned in their direction as shown by the top and bottom electron paths.

ELECTROSTATIC LENS II



ELECTROSTATIC FOCUS

As it approaches the larger cylinder, the electron will be accelerated by the higher positive potential.

Because of the higher electron velocity, the force lines in the larger cylinder will have a smaller turning effect on the electron. If the difference of potential between the cylinders is adjusted properly, the electrons will unite at a given distance after passing through the second cylinder. The action of the electrons as they pass through the influence of the two cylinders provides a convenient method of focusing the beam.

QUESTIONS

Q6. As an electron approaches the larger cylinder, the velocity of the electron will ....

Q7. Why is the above statement true?

ANSWERS

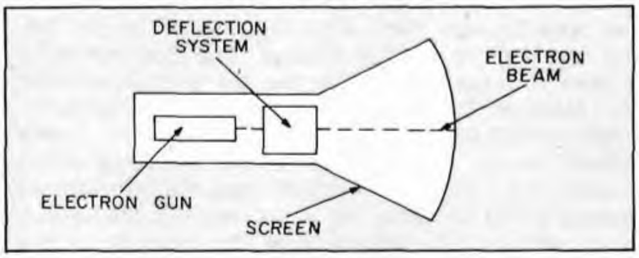
A6. As an electron approaches the larger cylinder, the velocity of the electron will **increase.**

A7. The above statement is true because the larger cylinder is **more positively charged.** It will attract the electron with a greater force, thereby increasing the velocity of the electron.

ELECTRON GUN

Cathode-ray tubes used in oscilloscopes consist of an *electron gun*, a *deflection system*, and a *fluorescent screen*. All elements are enclosed in an evacuated container, usually glass. The electron gun generates electrons and focuses them into a narrow beam. The deflection system moves the beam across the screen in the manner desired. The screen is coated with a material that glows when struck by the electrons.

BASIC CATHODE-RAY TUBE



An electron gun has a cathode to generate electrons, a grid to control electron flow, and a positive element to accelerate electron movement. The control grid is cylindrical in shape and has a small opening in a baffle at one end. The positive element consists of two cylinders, called anodes. They also contain baffles (or plates) having small holes in their centers. The main purpose of the first anode is to focus the electrons into a narrow beam on the screen. The second anode speeds up the electrons as they pass.

CATHODE AND GRID

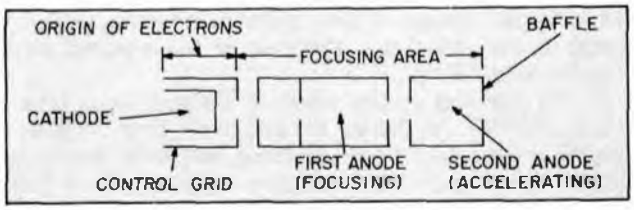
The cathode is indirectly heated and emits a cloud of electrons. The control grid is a hollow metal tube placed over the cathode. A small opening is located in the center of a baffle at the end opposite the cathode. The grid is maintained at a negative potential with respect to the cathode.

A high positive potential on the anodes pulls electrons through the hole in the grid. Since the grid is near the cathode, it can control the number of electrons that are emitted. As in an ordinary vacuum tube, the negative voltage of the grid can be changed to vary electron flow or stop it completely. The brightness of the image on the fluorescent screen is determined by the number of electrons striking the screen. Intensity (brightness) can, therefore, be controlled by the voltage on the control grid.

FOCUS CONTROL

Focusing is accomplished by controlling the electrostatic fields that exist between the grid and first anode and between the first and second anodes. Study the diagram. See if you can determine the paths of electrons through the gun.

DIAGRAM FOR Q8 and Q9



QUESTIONS

Q8. Which element controls the number of electrons striking the screen in the drawing titled *electrostatic fields?*

Q9. Which element controls the focus of the beam?

ANSWERS

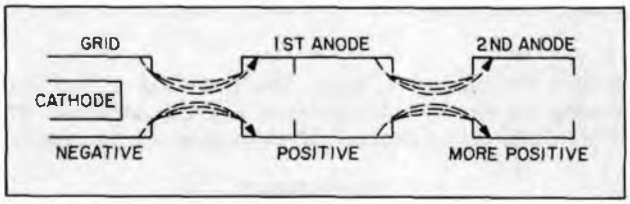
A8. The **control grid** controls the number of electrons striking the screen.

A9. The **first anode** controls the focus of the beam.

ELECTROSTATIC LENSES

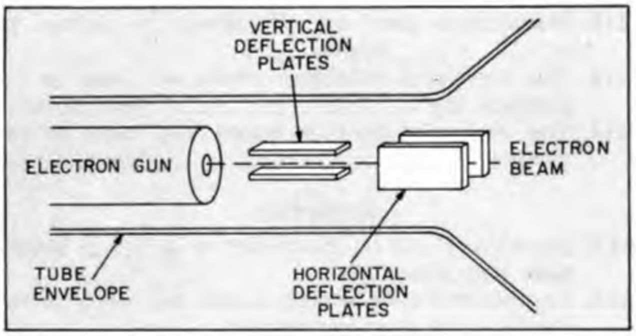
The next diagram shows electrons moving through the gun. The electrostatic field areas are often referred to as *lenses.* The first electrostatic lens causes the electrons to cross at a focal point within the field. The second lens bends the spreading streams and returns them to a new focal point.

ELECTRON GUN "LENSES"



The diagram also shows the voltage relationships on the electron-gun elements. The cathode is at a fixed positive voltage with respect to ground. The grid is at a variable negative voltage with respect to the cathode. A fixed positive voltage of several thousand volts is connected to the second (accelerating) anode. The potential of the first (focusing) anode is less positive than the potential of the second anode. It can be varied to place the focal point of the electron beam on the screen of the tube. Control-grid potential is established at the proper level to allow the correct number of electrons through the gun for the desired intensity.

ELECTRON GUN AND BEAM FORMATION

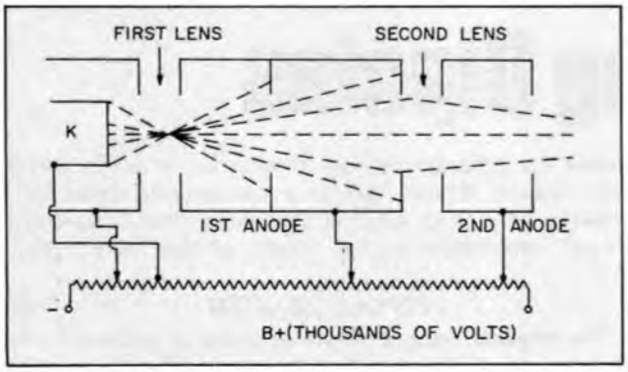


ELECTRON-BEAM DEFLECTION SYSTEM

The electron beam is developed, focused, and pulled toward the screen by the electron gun. It appears on the screen of the CRT as a small, bright dot. If the beam were left in one position, the electrons would soon burn away the illuminating coating in that one area. To be of any use, the beam must move. As you have learned, an electrostatic field can bend the path of a moving electron, or an electron stream.

Assume the beam of electrons passes through an electrostatic field between two plates. Since electrons are negatively charged, they will be deflected in the direction of the electric force (from negative to positive). The electrons will follow a curved path through the field. When the electrons leave the field, they will take a straight path to the screen at the angle at which they left the field. Although the beam is still wide (the focal point is at the screen), all the electrons will be traveling toward the same spot. This is assuming, of course, that the proper voltages are existing on the anodes which produce the electrostatic field. Changing the voltages changes the focal point of the beam.

ELECTRON GUN FIELDS



QUESTION

Q10. Why are the electrostatic fields between electron-gun elements called lenses?

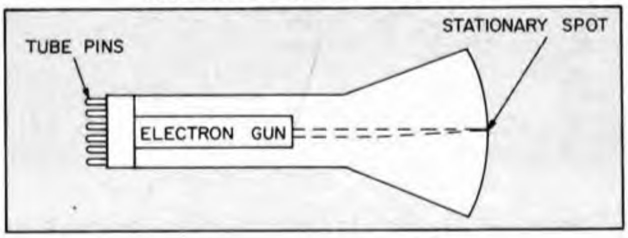
ANSWER

A10. They are called lenses because the fields **concentrate and focus** the electron streams in the same manner that optical lenses bend light rays.

VERTICAL AND HORIZONTAL PLATES

If two sets of deflection plates are placed at right angles to each other inside a CRT, the electron beam can be controlled in any direction.

CRT WITHOUT DEFLECTION



By varying the voltage between the two vertical-deflection plates, the spot on the face of the tube can be made to move up and down. The distance will be proportional to the change in voltage between the plates. Changing the voltage difference between the horizontal-deflection plates will cause the beam to move a given distance from one side to the other. There are directions other than up-down and left-right. The beam must be deflected in all directions.

Note the double diagram. You can see that the beam may be moved to any position on the screen simply by moving it both vertically and horizontally.

In the top diagram, position A of the beam is in the center. It can be moved to position B by going up two units and then right two units. Movement of the beam is the result of the simultaneous action of both sets of deflection plates. The electrostatic field between the vertical plates moves the electrons up an amount proportional to two units at the screen. As the beam passes between the horizontal plates, it is moved to the right an amount proportional to two units.

QUESTION

Q11. In the right figure, how many units, and in which direction, will each set of deflection plates move beam A′ to B′?

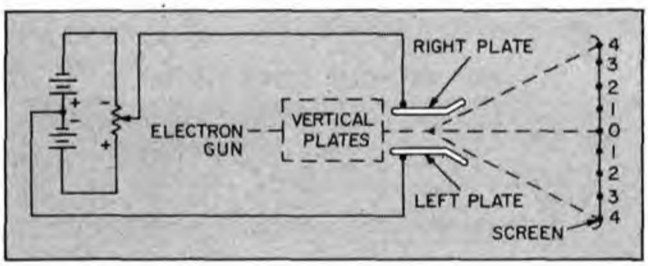
ANSWER

A11. The vertical plates will move the beam **down three units.** The horizontal plates will move the spot **one unit to the left.**

VOLTAGE CONTROL OF HORIZONTAL PLATES

Assume that the resistance of the potentiometer in the figure is spread evenly along its length. When the arm of the potentiometer is at the middle position, there is the same potential on each plate. Since there is zero potential between the plates, an electrostatic field is not produced. The beam will be at zero on the screen. If the arm is moved downward at a uniform rate, the right plate will become more positive than the left. The electron beam will move from 0 through 1, 2, 3, and 4 in equal time intervals. If the potentiometer arm moves at the same rate in the other direction, the right plate will decrease in positive potential. The beam returns to the zero position when the potential difference between the plates again becomes zero. Moving the arm toward the other end of the resistance

HORIZONTAL PLATES—TOP VIEW



will cause the left plate to become more positive than the right. The direction of the electric force reverses, and the beam moves from 0 through 4'. If the movement of the potentiometer arm is at a linear (uniform) rate, the beam will move at a steady rate.

AMPLITUDE VERSUS TIME

Do you recall the statement made earlier that waveforms could be described in terms of amplitude and time? You have just seen how the movement of the beam depends on both potential (amplitude) and time.

From zero time to 1-second, the waveform in the diagram is at zero volts. In the CRT the vertical plates remain at the same potential difference while the potential difference between the horizontal plates increases 1 unit in the direction necessary to move the beam toward the right. When time is equal to 1-second, the waveform rises to +2-volts. The potential difference between the vertical plates increases enough to move the electron beam 2 units in the positive direction. From 1 to 4-seconds, the waveform remains at +2-volts and then decreases to —2-volts. As the horizontal-plate potential difference increases by 3 units, the vertical potential remains the same (+2 units) and then drops sharply 4 units. For the next 3-seconds, the waveform remains at —2-volts. In the CRT, the potential difference between the vertical plates remains unchanged as the horizontal potential increases uniformly.

QUESTIONS

Q12. Waveforms can be described in terms of a______ and t______.

Q13. The horizontal-deflection plates are used to reproduce the a______ t______. (choose one)

Q14. The vertical-deflection plates are used to reproduce the a______ t______. (choose one)

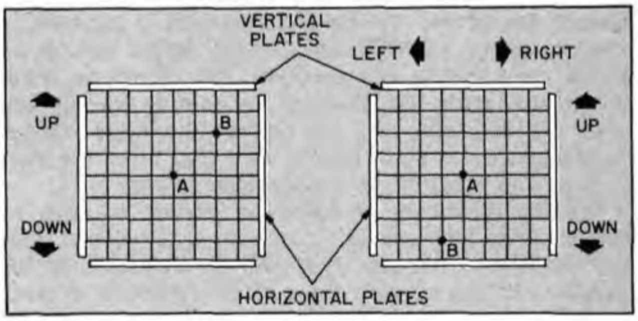
ANSWERS

A12. Waveforms can be described in terms of **amplitude** and **time.**

A13. The horizontal-deflection plates are used to reproduce the **time component.**

A14. The vertical-deflection plates are used to reproduce the **amplitude component.**

DEFLECTION OF CRT BEAM



WHAT YOU HAVE LEARNED

An electron gun contains a cathode (to emit electrons), a control grid (to control the intensity of the trace on the screen), a first anode (to develop the electric lenses that focus the beam on the screen), and a second anode (to accelerate the electrons toward the screen). Deflection plates in vertical and horizontal pairs are used to position the beam on the screen. ■

Understanding Dipoles

The most critical part of any radio transmitting installation is the antenna. It is the last element of control in transmission of signals, and the first element in reception. As a cost-saving device, the dipole provides an inexpensive, yet efficient antenna, and the knowledge needed to construct one serves as the basis for understanding all types of radio antennas, whether you build your own, or purchase a ready-made one.

WHAT IS A DIPOLE?

The horizontal dipole is a simple, effective antenna. Antenna wire and accessories for its construction are inexpensive and readily available. It is of a length that makes for efficient use as a receptor of an incoming radio waves. When used as a transmitting antenna, it radiates efficiently and, at the same time, displays a proper impedance to the output of the transmitter.

DIPOLE LENGTH

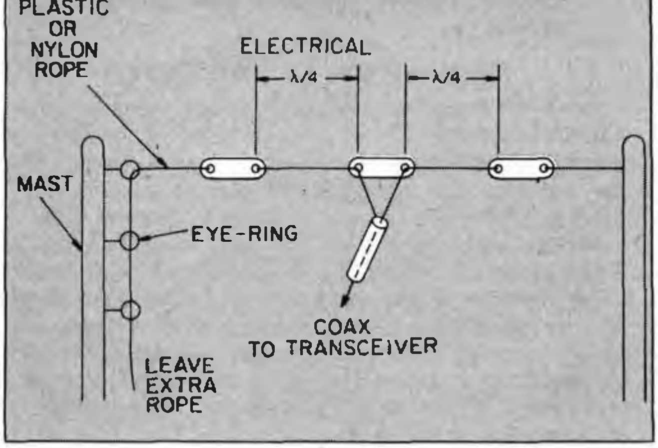
The **physical length** of the antenna is **related** to the **wavelength** of the signal frequency to be received or transmitted. Frequency in megaHertz, and wavelength in meters are related as follows:

Wavelength in Meters = 300/Frequency in mHz.

For example, the wavelength of a 3.75 mHz signal frequency would be:

$$\text{Wavelength} = \frac{300}{3.75} = 80 \text{ meters}$$

FIG. 1 BASIC DIPOLE



A dipole is a **half-wavelength** antenna and, therefore, its theoretical length would be one-half of this value, or 40-meters long. In practice, however, there are capacitive end-effects which cause a dipole that is cut to exactly the so-called "free-space" wavelength to be resonant on a lower frequency than the calculated value. In fact, to make the antenna an **exact** "electrical" half-wavelength long, it is necessary to shorten the physical length by **5-percent.** Hence the dipole length for 3.75 mHz resonance would be:

$$\text{Dipole Half-Wavelength} = 0.95 \times 40 = 38\text{-meters}$$

Since the dipole antenna is fed at the center and separated into two quarter-wavelength segments, as shown in Fig. 1, each side of the antenna would be 19 (38/2) meters long.

Physical antenna length for each quarter-wave segment of the dipole can be obtained by multiplying the 19 meters times the meters-to-feet conversion constant of 3.2808, obtaining a value of 62.34 feet.

A conversion from metric to linear length results in a very simple equation that can be used to determine the length of the quarter-wavelength segment of a dipole:

$$\text{Length in Feet} = \frac{234}{f(\text{mHz})}$$

A hand calculator is an aid if you wish to make your own antenna calculations.

QUESTIONS

Q1. What factor accounts for the 5% difference between the theoretical length and the electrical length of a dipole?

Q2. Compute the length of a dipole which will be resonant at 3.9 mHz.

Q3. Compute the length of a dipole which will be resonant at 7.225 mHz.

Q4. Compute the length of a dipole which will be resonant at 29.6 mHz.

Q5. Compute the length of a dipole which will be resonant at 14.325 mHz.

ANSWERS

A1. Capacitive end-effects, which are created by proximity to other objects in the immediate area such as support masts, etc.

A2. 120-feet

A3. 64.78-feet

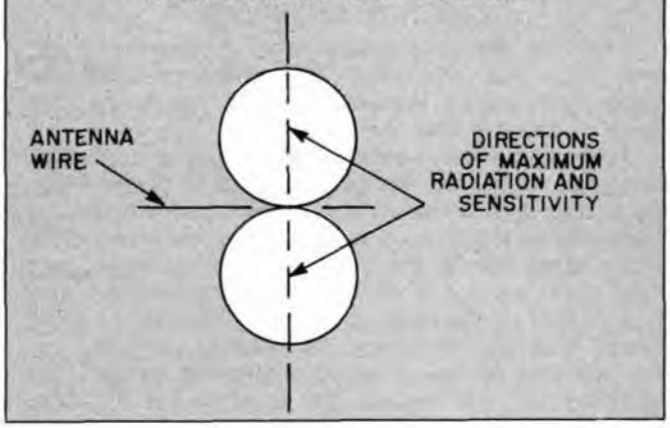
A4. 15.82-feet

A5. 32.66-feet

DIPOLE DIRECTIVITY

The horizontal dipole is **directional.** As a transmitting antenna, it sends out maximum radio energy (radiation) in the two directions broadside (**perpendicular**) to the antenna wires (Fig. 2). As a receiving antenna, it displays maximum sensitivity to radio signals arriving from the **same** two directions. Radiation and sensitivity taper off at angles away from the perpendicular, declining to a minimum in the direction along the line (parallel) of the antenna wire. The response pattern of Fig. 2 is a theoretical one. The antenna **does** radiate energy at other angles and is sensitive to incoming signals as well. The extent of the differential depends upon a number of variables including type of antenna, proximity of ground, nearby metallic structures, propagation conditions, transmission line system, etc. It is a fact though, that **maximum** radiation and sensitivity occur perpendicular to the antenna wire and minimum in the direction of the antenna wire. The figure-eight pattern is itself rather broad, and it is only at angles near to the angle of the antenna wire that the response is sharply down.

FIG. 2 RADIATION PATTERN



DIPOLE ANTENNA COMPONENTS

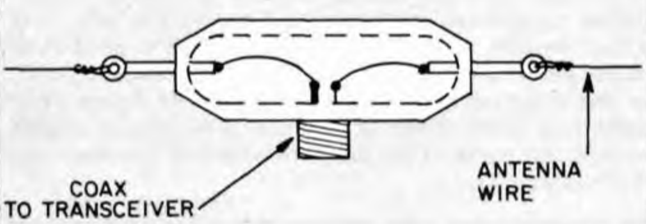
Essential components of the dipole antenna are: antenna wire, dipole center connector, end insulators, support rope, transmission line, and other accessories as needed. The antenna wire can be the popular 7-strand, #22 type, which is common and inexpensive. When it can be found at low cost, our personal preference is for #14 or #16 solid, insulated wire. A good-quality, insulated wire gives you added safety and weather protection. Insulation in **no way interferes** with the radiation or pick-up of signal.

Available end insulators are usually made of porcelain and are 1.75 to 3-inches long. They are oval-shaped or rectangular, some having a ribbed construction. Two holes are provided, one for the antenna wire itself and the other for the support line. Support line can be nylon rope or strong plastic clothes-line with a nonmetallic core. To make it easy to lower the antenna, for cleaning or experimentation, the support line at one end can be fed down through eye-bolts to ground level, as shown in Fig. 1.

A **coax-to-dipole connector,** Fig. 3, is the **ideal** method of linking the dipole antenna to the coaxial transmission line. This connector provides a durable and reasonably weather-proofed connection, providing for convenient connection and detachment of transmission line. An alternative plan is to use an end insulator at the center. The two conductors of the transmission line can be attached firmly, soldered and taped to the antenna wire on each side of the center insulator.

Use good quality coaxial line, either 50-ohm or 70-ohm. Preferred types are RG-58A/U (50 ohms) or RG-59A/U (70 ohms) for low power applications. RG-8A/U is recommended for higher-powered applications, and installations where a long feed line, from antenna to transmitter, is necessary.

FIG. 3 COAX-TO-DIPOLE CONNECTOR



ERECTION OF DIPOLE

Plan your installation according to length, height, and directional orientation. You **must** consider the space required by the antenna, and where the line must be brought into the house.

Safety and **performance** are **important** criteria. For safety reasons, keep the antenna clear of power lines. Be certain that if the antenna falls when erected, or while under erection, it cannot fall across electrical wires. Make certain that **under no circumstances,** can mast or wire come in contact with power lines if you lose control of the mast or antenna. Keeping clear of power lines also improves the antenna performance. You will pick up less power line noise on receive. On transmit, you will radiate the least signal into the power lines, minimizing loss and possible interference with home entertainment units such as television receivers and high-fidelity amplifiers.

QUESTIONS

Q6. Along what axis is the dipole antenna most sensitive to incoming signals?

Q7. True or False—Using insulated wire for the dipole elements is not recommended because the insulation creates capacitive effects which can raise the effective SWR.

Q8. True or False—Placing a dipole antenna close to and parallel to power transmission lines aids the antenna in transmitting and receiving because the lines act as additional antenna elements.

ANSWERS

A6. The axis **perpendicular** to the line of the antenna wire.

A7. False—Insulated wire has little or no effect at all.

A8. False—It can adversely affect the SWR, and may introduce power line noise and hum into the receiver.

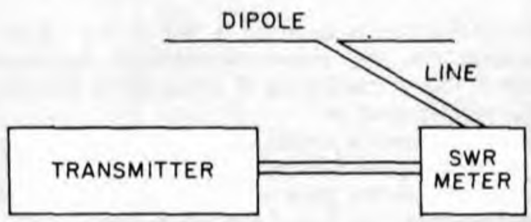
TUNING WITH AN SWR METER

An SWR meter connected between transmitter and transmission line, Fig. 4, can be used to measure the **resonant** frequency of a dipole. To go a step further, the antenna can now be trimmed or extended if it does not resonate to the desired frequency. The results can be observed on the SWR meter, as the antenna resonant frequency is moved up or down the band. Since it is **easier** to trim off rather than to add on wire length, cut the initial antenna wire longer than specified value for the particular frequency, in order to catch up with any variables that might influence resonance. A practical example will demonstrate an acceptable procedure.

Assume an antenna is to be cut for 7150 kHz in the 40 Meter Amateur band. This suggests a dipole length of 32-feet, 9-inches. Cut **each** dipole element to 33-feet, which would be for a resonant frequency of 7100 kHz. Erect the antenna on a temporary basis.

Measure the SWR every 25 kHz between 7025 and 7225. Set the readings down in a table form of frequency vs. SWR. Determine the precise frequency at which the SWR reading is minimum. This would be the resonant frequency. Then, trim accordingly.

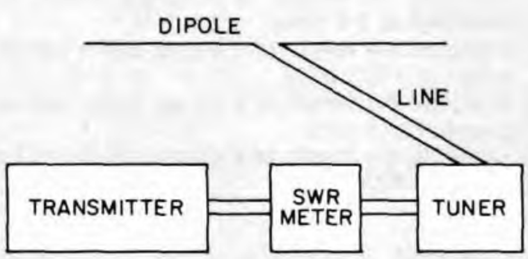
FIG. 4 SWR METER IN LINE



ANTENNA TUNERS AT WORK

The **primary** function of an antenna tuner, Fig. 5, is to provide a proper match between your antenna system and transmitter. In so doing, your transmitter sees a proper load and is able to operate at the optimum conditions of its design. The tuner **does not** alter the performance of the antenna or the SWR on its transmission line. Rather, it makes certain that an improper

FIG. 5 ANTENNA TUNER IN LINE



SWR does not result in unfavorable operation or possible damage to your transmitter.

A tuner makes the dimensioning of a horizontal dipole antenna less critical. It extends the range of operation of the antenna that will provide an ideal match to the transmitter. For example, an 80 Meter dipole cut to 3750 kHz, will be made operable over the entire 80 Meter band from 3500-4000 kHz. The electrical performance of the antenna will not differ greatly from an antenna cut precisely to some specific frequency on the band. Even though the SWR on the transmission line might be rather high at the band extremes, the transmitter itself will look into an optimum load.

QUESTIONS

Q9. What function is served by an SWR meter?

Q10. Where in the transmission line should an antenna tuner be placed?

Q11. True or False—An antenna tuner will correct the SWR of an improperly cut antenna, as far as the transmitter is concerned.

ANSWERS

A9. The SWR meter tells you what **percentage** of transmitter power is being **sent out** of the antenna, and what percentage is being **reflected back** to the transmitter.

A10. An antenna tuner should be placed **between** the **antenna** and the **SWR meter,** so that it can be adjusted to show **minimum** SWR to the transmitter's output stage.

A11. True. However, the SWR in the transmission line will remain **unchanged,** and the antenna will not be as efficient as one which is dimensioned **correctly.**

CONCLUSION

The horizontal dipole, as we mentioned earlier, forms the basis for most of the other modern types of antennae. If you were to examine the driven element of a **beam,** you would find it to be nothing more than a **simple dipole** with adjustable tuning tips at both ends. It is even posssible to make a three or four-element beam by **paralleling** several **dipoles** with fractional wavelength spaces between them. Of course, if you are not in the position to "grow" your own antenna farm due to space limitations, a single dipole's performance is not to be laughed at.

The dipole itself can take on other physical configurations, such as a "vee;" an "inverted vee;" a "sloper;" or even a "vertical" dipole.

The horizontal dipole is indeed a versatile antenna, giving good performance at low cost. It should be dimensioned properly, and should be used with an SWR meter to evaluate its performance. ■

Prefixes and Exponents

☐ Anyone who's dipped his little toe into electronics is certain to have run across such terms as *micro*Farad, *milli*-Henry, and *milli*Ampere—not to mention *mega*Hertz *meg*Ohm, and *kilo*-Hertz. The prefixes here, *micro-*, *milli-*, *mega-*, and *kilo-*, are an important part of the electronic vocabulary. It follows, then, that anyone who wants to be proficient in electronics will have to develop skill in understanding and using them.

These prefixes are used to change the value of an electronic unit of measure. For example, if you see a resistor with the familiar brown/black/green color code, you *could* call it a 1,000,000-ohm resistor. The thing is, it's usually less awkward to call it a 1-megohm resistor. Putting the prefix *meg-* or *mega-* before the Ohm inflates the value of the unit, Ohm, by 1,000,000 times.

Similarly, one kiloVolt is recognizable as 1,000 Volts, and one kiloHertz as 1,000 Hertz, and so on. These prefixes are usually so automatic with electronics aficionados that they will invariably refer to a millionaire as a guy who has one megabuck!

The Debit Side. At the other end of the scale, the *milli-* and *micro-* prefixes are useful for shrinking units. A Farad, for example, is too big a unit to use in everyday electronics. In dealing with the real-life capacitors (the kind you solder into circuits), we normally use a basic unit of *one-millionth* of a Farad —a *micro*Farad. The prefix *micro-* cuts up a unit into a million tiny slices, enabling us to use one such slice as a convenient-sized unit. A microAmpere, similarly, is a millionth of an Ampere; a microVolt, one millionth of a Volt.

If you need larger slices, the *milli-* prefix is available, which provides a unit only one-thousandth the size of the basic unit. A milliAmpere, for example, is a thousandth of an Ampere; that is, it takes 1000 mA (milliAmperes) to equal 1 Ampere.

To handle these tiny slices of units, it's wise to spend a few minutes learning *scientific notation*, which is designed to make it easy to handle very large and very small numbers. Once you've mastered this technique, you can manipulate all the various-sized units of electronics as easily as you can add two and two!

Take, for example, the familiar *kilo-Hertz* (known at one time as the *kilocycle*). A broadcasting station operating at 840 kHz (kiloHertz) in the broadcasting band is radiating 840,000 cycles of RF energy every second. To change from 840 kHz to 840,000 Hz, you can think of the "kilo-" as being replaced by "x 1000", thus:

840	kilo	Hertz
840	× 1000	Hertz
840,000		Hertz

But you can also write "1000" as "10 x 10 x 10". And you can write "10 x 10 x 10" as "10^3". (Ten to the third power, or ten cubed.) As we develop these ideas further, you will see how you can greatly simplify your future work in electronics by thinking of the prefix "kilo-" as being replaceable by "x 10^3", thus:

$$840 \text{ kiloHertz} = 840 \times 10^3 \text{ Hertz}$$

Similarly, a 6.8 megohm resistor, measured on an ohmmeter, will indicate 6,800,000 ohms. In this case, the prefix "meg-" can be replaced by "x 1,000,000":

6.8	meg	Ohms

6.8	× 1,000,000	Ohms
6,800,000		Ohms

But you can write "1,000,000" as "10 x 10 x 10 x 10 x 10 x 10" (six of 'em; count 'em), which is 10^6. Thus, you should learn to mentally replace "meg-" with x 10^6, so that 6.8 megOhms becomes a 6.8 x 10^6 Ohms. The 6 is called an *exponent*, and shows how many 10s are multiplied together.

The Minus Crowd. What about the "milli-" and "micro-" prefixes? "Milli-", we've said, is one-thousandth; in a way, it is the opposite of the "kilo-" prefix. Make a mental note, then, that milli- can be replaced with "10^{-3}" (read as "ten to the *minus* three power"), which is 1/10 x 1/10 x 1/10 = 1/1000. Similarly, the "micro-" prefix can be considered as the opposite of "meg-", and replaced by 10^{-6}.

The beauty of this approach appears when you are faced with a practical problem, such as, "if 1.2 milliAmperes flows through 3.3 megOhms, what voltage appears across the resistor?" From our knowledge of Ohm's law, we know that E = IR; that is, to get Volts (E) we multiply current (I) times resistance (R). Without the aid of scientific notation, the problem is to multiply 0.0012 Amperes by 3,300,000 Ohms, which is rather awkward to carry out. The same problem, however, is very easy in scientific notation, as can be seen below:

$$\begin{array}{r} 1.2 \times 10^{-3} \\ 3.3 \times 10^{6} \\ \hline 3.96 \times 10^{3} \end{array}$$

The answer is 3.96 x 10^3 Volts, or 3.96 kiloVolts. We obtained the answer by multiplying 1.2 x 3.3 to get 3.96, and adding the -3 exponent to the 6 exponent to get 3 for the exponent of the answer. The advantage of scientific notation is that the largeness and smallness of the numbers involved is indicated by numbers like 10^6 and 10^{-3}, and the largeness or smallness of the answer is found by *adding* the 6 and the -3.

What about a division problem? For the sake of a good illustrative example, consider the unlikely problem of finding the current when 4.8 megaVolts is applied across 2 kilOhms. The problem is written as:

$$I = \frac{E}{R}$$

$$= \frac{4.8 \text{ megaVolts}}{2 \text{ kilOhms}} = \frac{4.8 \times 10^6 \text{ Volts}}{2.0 \times 10^3 \text{ Ohms}}$$

$$4.8 \div 2 = 2.4$$

$$2.4 \times 10^3 \text{ Amperes} = 2.4 \text{ kiloAmperes}$$

In division, then finding the size of the answer becomes a *subtraction* problem, in which the exponent representing the size of the divisor ("bottom" number) is subtracted from the exponent representing the size of the dividend ("top" number).

A more practical division problem answers the question, "What current flows when 5 Volts is applied across 2.5 kilOhms?"

$$I = \frac{E}{R} = \frac{5 \text{ Volts}}{2.5 \text{ kilOhms}}$$

$$= \frac{5.0 \times 10^0}{2.5 \times 10^3} = \frac{5.0 \times 10^{(0-3)}}{2.5}$$

$$= 2.0 \times 10^{-3} \text{ Amperes}$$

$$= 2.0 \text{ milliAmperes}$$

Note that it's perfectly legal to use 10^0 (ten to the zero power) to indicate a unit that has no prefix—in other words, one of anything.

For the Solving. Here are a few more problems:

1. The inductive reactance of a coil is given by

$$X_L = 2\pi fL.$$

What is the reactance of a coil whose inductance L = 22 milliHenries, when an alternating current of frequency f = 1.5 megaHertz is applied to it?

$$\begin{aligned} X_L &= 2 \times \pi \times (1.5 \times 10^6) \times (22 \times 10^{-3}) \\ &= 207.24 \times 10^3 \text{ Ohms} \\ &= 207.24 \text{ kilOhms} \end{aligned}$$

2. An oscillator is connected to a wavelength-measuring apparatus, and the wavelength of its oscillations is determined to be 2.1 meters. What is the frequency of the oscillator?

$$F = \frac{\text{speed of light}}{\text{wavelength}}$$

$$= \frac{3.0 \times 10^8 \text{ meters per second}}{\text{wavelength}}$$

ELECTRONIC PREFIXES AND THEIR MEANINGS

Prefix	Pronunciation	Symbol	Exponent	Example
tera-	TEHR-uh	T	10^{12}	Frequency of infrared light is approx. 1 teraHertz
giga-	GIG-uh	G	10^9	Frequency of TV channel 82 is approx. 1 gigaHertz
mega-	MEG-uh	M	10^6	Frequency of a typical medium wave broadcast station is 1 megaHertz
kilo-	KILL-oh	k	10^3	Top note on a piano is approx. 4 kiloHertz
hecto-	HEK-toh	h	10^2	(not often used in electronics)
deka-	DEK-uh	da	10^1	(not often used in electronics)
deci-	DESS-ih	d	10^{-1}	A decibel is 1/10th bel
centi-	SENT-ih	c	10^{-2}	Wavelength of TV channel 82 is approx. 30 centimeters
milli-	MILL-ee	m	10^{-3}	Collector current of a typical small transistor is approx. 1 milliAmpere
micro-	MY-kroh	μ	10^{-6}	Base current of a typical small transistor is approx. 20 microAmperes
nano-	NAN-oh	n	10^{-9}	Time for a radio wave to travel 1 foot is approx. 1 nanosecond
pico-	PY-koh	p	10^{-12}	Collector-to-base capacity of a good high-frequency transistor is approx. 1 picoFarad
femto-	FEM-toh	f	10^{-15}	Resistance of 6 microinches of 0000 gauge wire is approx. 1 femtOhm
atto-	AT-toh	a	10^{-18}	6 electrons per second is 1 atto-Ampere

$$= \frac{3.0 \times 10^8}{2.1 \times 10^0} = 1.4286 \times 10^8 \text{ Hertz}$$

We wish this answer had come out with a "10^6", instead of a "10^8", because we can convert 10^6 Hertz directly to megaHertz. However, we can change the answer to 10^6, by shifting the decimal point of the 1.4286. Remember this rule: To *lower* the exponent, shift the decimal point to the *right*. (Of course, the opposite rule is also true.) Since we wish to lower the exponent by 2, we must shift the decimal point to the right by two places:

142.86×10^6 Hertz = 142.86 megaHertz

3. A 3.3 microfarad capacitor is being charged from a 20-volt battery through a 6.8-kilOhm resistor. It charges to half the battery voltage in a time given by

$$T = 0.69RC$$

For the particular values given in the problem, what is the time taken to charge to half the battery voltage?

$$T = 0.69 \times (6.8 \times 10^3) \times (3.3 \times 10^6)$$
$$= 15.4 \text{ milliseconds}$$

4. A 365-pF variable capacitor and a 2-uH coil are found collecting dust in your junk box. You decide you might like to incorporate them into a radio but you need to know the resonant frequency of this inductive/capacative circuit. You apply the formula:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Since C = 365-pF or 365×10^{-12} farads and L = 2-uH or 2×10^{-6} henrys we can use these numbers, the formula and our new knowledge of exponents to determine the frequency.

$$f = \frac{1}{2\pi\sqrt{(2 \times 10^{-6}) \times (365 \times 10^{-12})}}$$
= 5,894,627.6 Hertz
= 5,894 kiloHertz
= 5.894 megaHertz

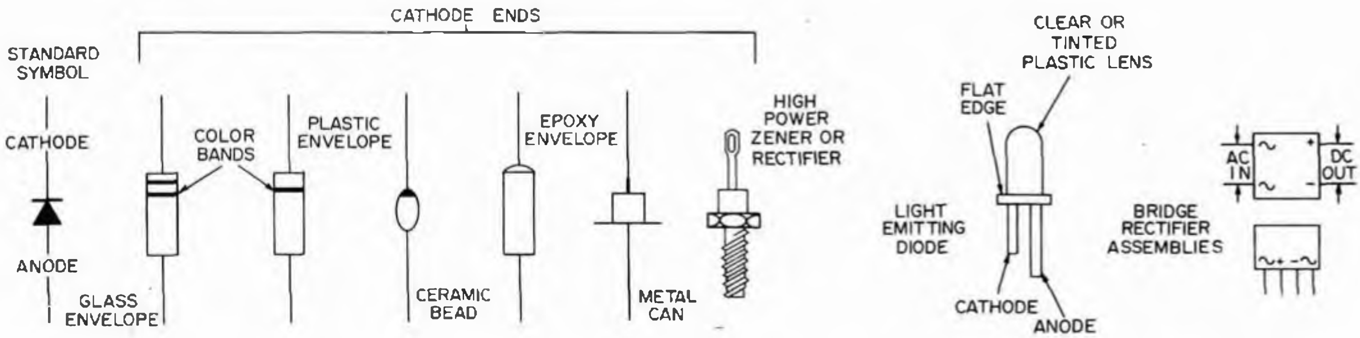
Tera to Atto. Since scientific notation is so potent, you'll probably be interested in the meaning of *all* the prefixes used in the scientific community, not just the four (micro-, milli-, kilo-, and mega-)—that we've discussed so far. Very common in electronics is the *micro-microFarad*, which is $10^{-6} \times 10^{-6}$ Farad, or 10^{-12} Farad. This is more commonly known as the *picoFarad*. Similarly, a thousandth of a microAmpere is $10^{-3} \times 10^{-6}$ Ampere, or 10^{-9} Ampere. This is known as a nanoAmpere. At the other extreme, 1000 megaHertz is called a gigaHertz. See the table of all these prefixes for a rundown of their meanings and pronunciations.

The jargon of electronics which has grown up around their prefixes is just as important as the prefixes themselves. Here are some examples of "jargonized" prefixes as they might appear in speech:

Puff—a picoFarad (from the abbreviation, PF).
Mickey-mike—a micro-microFarad (which is the same as a **puff**).
Meg—a megohm. Also, less often, a megaHertz.
Mill—a milliAmpere.
Megger—a device for measuring megOhms.
dB (pronounced "dee-bee")—a decibel, which is one-tenth of a Bel.
Mike—a microFarad. Also, to measure with a micrometer.

So, if you understand the prefixes and know their corresponding exponents, you'll have command of another set of important tools to help you do practical work in electronics. In addition, you'll be ready for the inevitable wise guy who'll ask if you can tell him the reactance of a 100-puff capacitor at 200 gigaHertz. After calculating the answer in gigaseconds, reply in femtOhms! ■

DIODE DIGEST



IT MAY SOUND SILLY, but it seems that a lot of people still don't know which end of a diode is up. A letter we received recently from O.M.S. of Guilford, Connecticut illustrates this point. He writes:

"I have been trying for the last three months to purchase a power supply that I can use to power a walky-talky from house current. I've finally given up and decided to build my own. I have a transformer that converts 110 VAC to 12.6 VAC, some large filter capacitors salvaged from an old television, and some 'bargain bag' diodes I purchased from a discount store. The diodes are black, unmarked, and have one rounded end. Can I use them, or will I have to shell out for ones with known values?"

Of course, we couldn't be sure of just exactly what he had in hand, but from the description, and basing our guess on the chart, we were pretty sure that these were epoxy-encapsulated rectifiers, with probably about a 100 to 200-PIV rating. These would fill his needs if our guess was right. Although we haven't heard any more from that gentleman, we assume he didn't blow himself up. By tearing out the chart and pasting it up inside the cover of your spare parts box, you can have a handy reference guide for identifying the leads and types of whatever diodes happen to find their way into your hands. ■

THE MICROPROCESSOR WORLD

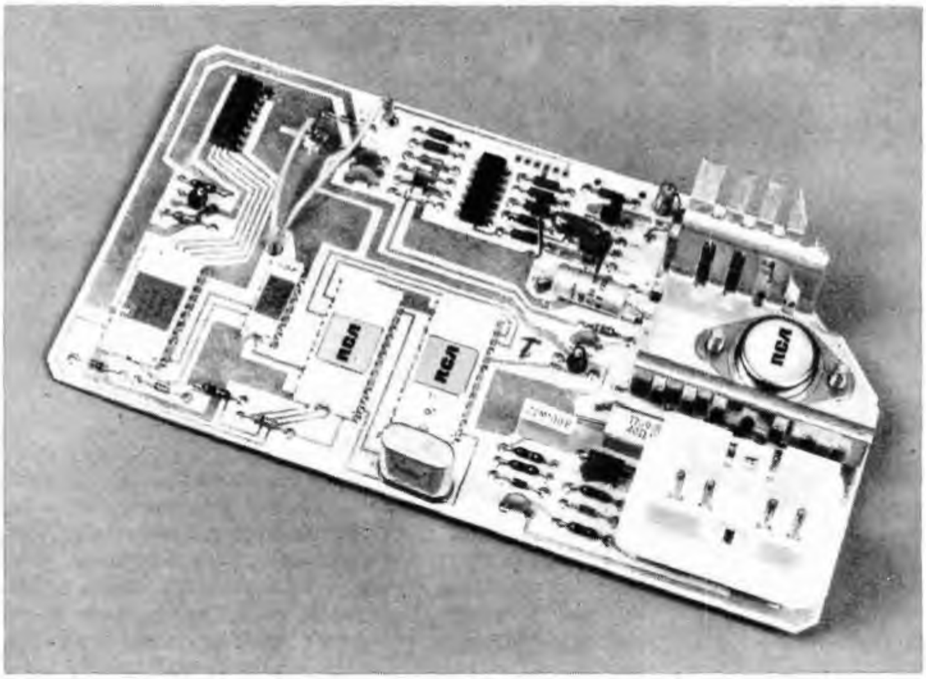
On wheels, or in the kitchen, microprocessors are here to stay

☐ Our world has already changed because of microcomputers, and it will change much more. In ten to fifteen years, your home will likely have many microprocessors in it. They will be in your kitchen, garage, basement, living room, gameroom, and bedroom. Many people will be using microcomputers without knowing it. Others will be expanding their thinking processes as they pit themselves against complex but fascinating learning machines. Math, science, even history and art will be programmed into shoebox sized computers that you can buy or that you can borrow from a library or school.

We are talking about a subject as broad as your imagination—the applications of microcomputers. Let's face it, your goal and that of every electronics outfit in this business, is to first understand some principles of microcomputers and then to figure out what to do with them. You may be a hobbyist who is simply curious and trying to expand his horizons. But, you may be more than that. You may want to start your own business to make and market a product of your own invention. The time has come to understand what is being done with microcomputers, what some companies are thinking about doing, and to pipedream a bit about how we can improve our world with some futuristic inventions.

The area of microprocessor applications is extremely broad, and in this article we can only begin to cover it. In fact, we'll confine ourselves to microcomputers in business, transportation systems, and the home. But the home applications will only be touched on, because it's so broad. After all, home uses include games, and we all know how many games for microcompressors and TV sets there are around.

Computers in the Office. The use of computers in business can be broken up conveniently enough into two broad areas of inventory and control. Inventory here means keeping track of something. It can be the recordkeeping of a doctor's office or of an accountant for billing purposes, or it can be keeping track of what items are in stock. Let's take a look at some actual cases. There is, of course, the one most of you have seen by now in some of the grocery stores. A light pen reads the international strip code from a label, enters the code into the cashier's terminal which passes it onto the central computer in the back room. For each label code, the computer memory knows the price of the item, how many are in stock, and where to place an order for more. When stock of an item gets too low, the computer writes an order for more. We have here a central computer controlling small microcomputers in the cashiers' terminals. Commands flow back and forth to control the light pen, give pricing, tax computation, *et cetera*. Then there is your local hamburger heaven. Have you noticed the key pad on a Burger King cashier's terminal? Only a microcomputer can provide the kind of flexibility you see there. You say hamburger, for example, and the order taker presses a touch-type key with a picture of a hamburger on it. The price is built into the computer memory. To change prices the store manager calls in the terminal experts to do a simple software change. Hardware does not have to be discarded. After you have placed your large order, this computer provides a listing that is easy for the cooks to follow—how many shakes, how many hot dogs, *et cetera*. Now let's think of how we can improve on this smart terminal. What would you do? Well, the first thing to notice is that the terminal operators have to call the order to the kitchen. We know from all the TV and magazine articles that video screens are a blooming output medium. It seems archaic to go from a computer to a person to a microphone to the kitchen. The kitchen should perhaps have a video display that shows the hamburger person how many burgers he has on order of various types (small, large, no pickle, etc.). As the



This PC board assembly is Chrysler's next generation of electronic fuel control, which will serve as an alternative to its present lean-burn system. The four dual-in-line packages on the lower left of the PC board contain the heart of the system, (left to right) the CDP 1833 ROM, the CDP 1824 RAM, a custom-made CPU and a custom input/output port.

outgoing tray is filled, the computer would subtract the items from computer memory card from the screen. Inventory ability could be added by connecting the terminals to a central inventory control computer that ordered food as necessary via a data link to the warehouse computer. Eventually, you could build an entirely automated entry. Drive in, push the key for the food you want, the kitchen would be composed of conveyor belts and ovens—out comes your food.

That is a bit astray from pure inventory control, but that kind of leapfrogging is exactly what is making small computer businesses take off to big things today. Inventory control is very much in demand, and every case has to be nearly custom tailored to the client. Through software control, that customizing is no problem. If you want to imagine how you could get started with an inventory control system, simply imagine getting a small computer that takes BASIC instructions (see our tutorial on BASIC elsewhere in the magazine) via a typewriter keyboard, and next imagine programming a small and simple inventory system to keep track of shoes in a store. You are on your way.

. . . And In The Factory. Computer control in industry is presently widespread, but the potential is really unlimited. The needs are great, and the microcomputers available today literally sit waiting for someone to apply their power to the jobs. Take, for example, the computer-automated control of metal parts. Machines that stamp or bend metal parts are becoming nearly commonplace in industry. The operator loads a hopper with pipes or other metal pieces, presses the button and the computer controls the machine. Out come car ash trays, hingles, you-name-it. If a new hinge design is to be fabricated, the computer program is simply updated with new holes to drill and bends to make.

The ideas here are not new, and in many cases only the surface is being scratched. Microcomputers of the futur will be tied together in an industrial plant. The ordering of raw material to meet schedules on new orders, the actual fabrications, and the shipping and billing would all be computer controlled. And remember, you need not sit by and watch. There is a big market out there and learning about microcomputer operations as a hobby at home will give you a big foot in the door.

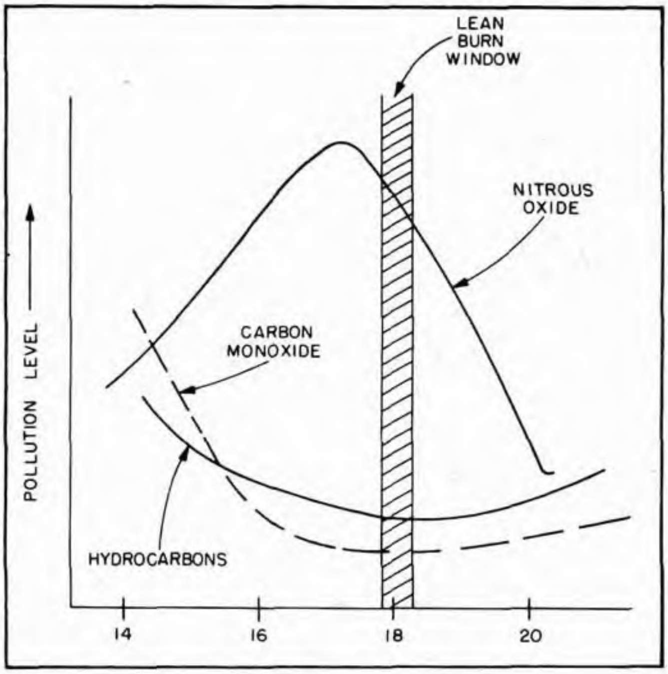
The Millers Ferry Hydroelectric Plant in Alabama is controlled by an Interdata 70 that communicates with three IMP microprocessor boards to control water flow and generators at Jones Bluff Dam that is many miles away. The system is estimated to save tens of thousands of dollars by increasing efficiency of the power plant—so the computers will pay for themselves. Control of open hearth furnace feeding and temperatures, monitor and control of electric power to giant aluminum smelting pots, monitoring of the quantity of ingredients that go into anything from cake mixes to tire rubber—all of these use microcomputers today. The computer acts as a kind of central brain that may have several smaller microprocessors feeding it, which in turn have sensors telling them what is happening. So sensor technology is an area that is absolutely booming as computers push the need for new and cheaper devices. Sensors can smell (such as smoke detectors), feel (like strain gauges), hear (special frequency response transducers), and see (like infra red sensors). Still, there is the need for more. The more intelligence that can be built into the sensors, the less time the central computer has to spend interpreting.

In Your Car, Too! Transportation is an area much in need of micro-processors—and the future will show a fantastic set of changes in this area. The Chrysler Lean-Burn system is one of the popular examples of how people can have a computer in their garage without knowing it. The concept there is to control the spark firing so as to always have the air/fuel ratio equal to 18 to 1. While maximum fuel economy is achieved at a ratio of about 16.5 to 1, a ratio of 18 to 1 leads to minimum levels of carbon monoxide and unburned hydrocarbons. In 1981, nitrous emissions will be tightened from 2 grams per mile to only 1 gram per mile. Several manufacturers plan to use a new type catalytic converter to absorb the bad exhaust, but for that new converter to work well, and for fuel economy to be kept as high as possible, a more elaborate computer control system is being developed. ■

MICRO PROCESSOR USES IN AUTOS

Fuel Economy and Emission Control	Driving Aids	Safety
• Firing of plugs • Air/fuel ratio • Rate of deceleration • Speed control for highest m.p.g. • Automatic adjustment for weather conditions	• All electronic instrument panel • Radar with speed control • Computer navigation following road beacons • Computation of best rest stops, expected arrival time, type fuel to use for trip, best tire pressure for load, etc.	• Computer warning of weak spots like tires, battery, brakes, radar, etc. • Anti-skid braking • Anti-theft computer combination locks • Air-bag control

Microprocessors can be especially useful in aiding operators of complex equipment, such as the family car. The auto industry hopes to perfect all the above uses of microprocessors in the coming years. "Dumb" cars will be in museums instead of on freeways!



A lean-burn computer keeps the air/fuel mixture at 18:1 under all driving conditions in order to keep pollution levels low. A new computer system must be devised by 1981—when Congress will cut allowable nitrous oxide levels by fifty percent.

LITERATURE LIBRARY

403. *PAIA Electronics* gives you "Advanced Electronics For The '80s and Beyond." Brochure features computerized music synthesizers.

402. *Technical Electronics* has descriptions galore of all kinds of electrical gadgets—transistors, computer power supplies, and logic probes—in its latest (6-80 B) *mail order* catalog.

401. *AP Products'* "Faster and Easier Book" is designed to eliminate any problems with breadboarding, interconnection and testing devices. All-circuit evaluators *with power* are featured.

400. *Global Specialties* provides new product info in its catalog of Testing and Design Instruments. A Digital Capacitance Meter and Tri-Mode Comparator are just some of the featured projects.

399. *"Firestik" Antenna Company* has introduced a new and informative product catalog on top-loaded, helically wire-wound antennas and mounts.

398. *Hamtronics, Inc.* has announced a new model R110 VHF AM Receiver Kit which employs an AM detector and a dual-loop agc system. A complete catalog is yours for the asking!

397. *Instant Software, Inc.* is offering a special holiday catalog for all kinds of year 'round software package gift-giving, as well as their regular microcomputer catalog.

396. *Creative Computing's* first software catalog of various education and recreation simulation programs as well as sophisticated technical application packages is available now.

395. *OK Machine and Tool* explains the technology of wire-wrapping, complete with illustrations, in its catalog of industrial and hobby products. The 60-page book (80-36N) is available now.

394. *KEF Electronics Ltd.* is offering two speaker systems in kit form at a significant cost-savings. The Model 104aB and the Cantata can be easily assembled and may be auditioned before purchasing.

389. You can't buy a bargain unless you know about it! *Fair Radio Sales'* latest electronics surplus catalog is packed with government and commercial buys.

388. SWLs need *Gilfer's Shortwave Mail Order Catalog* for economy one-stop armchair shopping. From top-notch rigs to reporting pads, Gilfer supplies all your hobby needs.

327. *Avanti's* new brochure compares the quality difference between an Avanti Racer 27 base loaded mobile antenna and a typical imported base loaded antenna.

362. A new catalog crunched full of military, commercial and industrial surplus electronics for every hobbyist is offered by *B&F Industries*. 44 pages of bargains you've got to see!

384. *B&K-Precision* has issued BK-10, a condensed catalog describing their oscilloscopes, semi-conductor testers as well as test instruments for CB, radio and TV repair.

310. *Compumart Corp.*, formerly NCE, has been selling computers by mail since '71, and is offering a 10-day return policy on many items featured *in their latest catalog.*

322. *Radio Shack's* latest full color catalog, "The Expanding World of TRS-80," is out now, packed with up to the date information on this microcomputer. Specifications for the new Model II as well as the Model I are included.

386. If you're looking for books on computers, calculators, and games, then get *BITS, Inc.* catalog. It includes novel items.

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Crystals

(Continued from page 76)

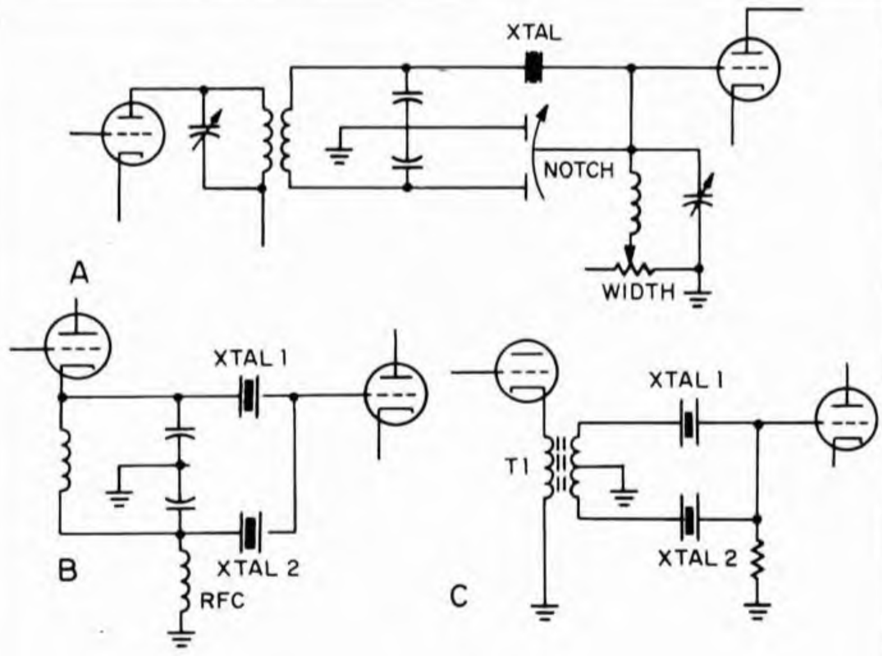

Fig. 11. Crystal filter used in the IF amplifier of a receiver sharpens the selectivity. Circuit in A uses special variable capacitor to adjust notch frequency. Potentiometer varies width (selectivity) of notch. Adding resistance lowers Q of crystal circuit which increases bandwidth. Two-crystal circuits (B, C) are more expensive since specially matched pairs are required. The mechanical filter gives the crystal-type circuit a lot of competition where fixed bandwidth is wanted. Trifilar-wound transformer T1 (C) can be wound by experimenters of home-brew receivers.

scopic bits of debris remain embedded in its structure. These bits are displaced during the first 12 months or so of use, but during that time the crystal frequency changes by a few parts per million. Extreme accuracy applications must take this change into account. For most uses, though, it may be ignored.

Using Quartz Crystals. After all the discussion of crystal theory, it's time to examine some typical circuits. While dozens of special crystal circuits have been developed for special applications, a sampling will suffice for discussion. Fig. 9 shows four typical vacuum tube crystal oscillator circuits.

The simplest of these is the Pierce circuit, Fig. 9A. While at first glance this circuit appears to employ the crystal's *zero* to feed back energy from plate to grid, the *pole* is actually used through a mathematically-complex analysis. This circuit has one unique advantage: it contains no tuned elements and, therefore, can be used at any frequency for which a crystal is available. This makes it an excellent low-cost test signal source. The major disadvantage is that excessive current may be driven through the crystal if DC plate voltage rises above 90 or so.

The Miller oscillator (Fig. 9B) is almost as simple to construct and operate as is the Pierce and has an additional advantage of operation with overtone crystals. This is the circuit recommended by *International Crystal Mfg. Co.* for use with their overtone crystals. The capacitor shown between plate and grid is usually composed of grid-plate capacitance alone. The *pole* is used here also, energy feeds back through the grid-plate capacitance, and the *pole* selects only the parallel-resonant frequency (shorting the rest to ground).

ECO. The electron-coupled Pierce oscillator (Fig. 9C) is similar to the basic Pierce. The tuned circuit in the plate offers the possibility of emphasizing a harmonic—an RF choke may be used instead if freedom from tuning is desired and fundamental-frequency operation will suffice.

GPO. One of the most popular oscillators of all time is the Colpitts Crystal oscillator of Fig. 9D, sometimes known as the *grid-plate* oscillator. The feedback arrangement here consists of the two capacitors in the grid circuit; feedback is adjusted by means of the 150 pF variable capacitor (the greater the capacitance, the less the feedback) until reliable oscillation is obtained. Like the other three oscillators, this circuit employs the crystal *pole* frequency.

Since all four of these oscillator circuits utilize the *pole* for frequency control, exact frequency adjustment capability may be obtained by connecting a 3-30 pF trimmer capacitor in parallel with the crystal.

Crystal oscillators may, of course, be built with transistors, too. Two typical circuits are shown in Fig. 10. Feedback mechanisms differ somewhat because of the basic differences between tubes and transistors. In general, transistorized oscillators are more stable.

As a Clock. To use a crystal as the timing element of a clock, an oscillator identical to those shown in Figs. 9 and 10 is the starting point. Crystal frequency is chosen at a low, easily-checked value such as 100 kHz. This frequency is then divided and redivided by synchronized multivibrators to produce one-cycle-per-second pulses. These may then be counted by computer counting circuits.

In addition to being used as oscillators and timing elements, crystals find wide application in filters. Fig. 11 shows some typical crystal-filter circuits.

The single-crystal filter circuit shown in Fig. 11A provides spectacularly narrow reception. When the notch control is set to precisely balance out the crystal stray capacitance, the resonance curve of the filter is almost perfectly symmetrical. When the notch control is offset to one side or the other, a notch of almost infinite rejection appears in the curve (the *pole*). The width control varies effective *Q* of the filter.

More popular for general usage today is the band-pass filter, shown in Figs. 11B and 11C.
Both circuits make use of matched crystals (X1 and X2)—the *pole* of one must match the *zero* of the other for proper results. When this condition is met, the reactances of the two crystals cancel over the passband. The passband is roughly equal to the *pole-zero* spacing.

While the two circuits shown are virtually identical in operation, the transformer-coupled circuit of Fig. 11C is easiest for home construction. The only critical component is the transformer. It should be tightly coupled, with both halves of the secondary absolutely balanced. This is done by winding a trifilar layer of wire (wind three wires at the same time); the center wire becomes the primary winding and the remaining two wires become the secondary. The left end of one secondary half connects to the right end of the other, and this junction forms the center tap. The remaining two ends connect to the crystals. If you have sufficient patience to wind on it, a toroid form is recommended. ■

Bookmark

(Continued from page 8)

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Ask Hank, He Knows

(Continued from page 12)

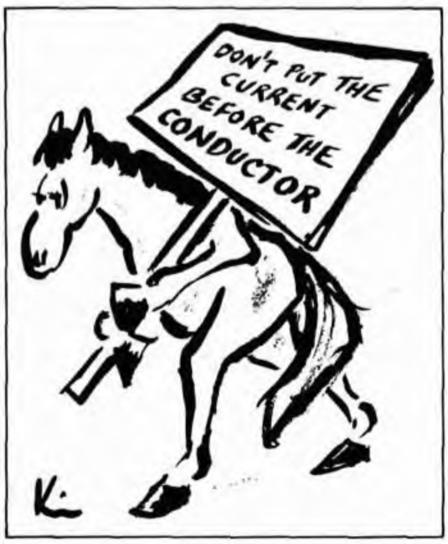
of maker; Prescott V. Murphy, Sr., 530 Forest St., Kearny, NJ 07032.

△ Jackson 648-IT tube tester; require schematic diagram; Mike Kazas, Hummelstown, PA (no zip given).

△ Gretsch Safari AC/DC guitar amp; needs schematic diagram; David Calhoun, Rt. 2, Box 111, Mt. Olive, MS 39119.

△ Hallicrafters S-129 receiver; wants copy of operating instructions; Frank H. Groth, 5355 Quartz Dr., Loves Park, IL 61111.

△ Pace Sidetalk 1000BC 40-channel transceiver; needs schematic diagram and service data; Edward Gooden, RR #4, Box 47, Bloomfield, IA 52537.



△ Haynes Bass King II bass amplifier made by Amplifier Corp. of America; urgently needs schematic diagram; David Calhoun, Rt. 2, Box 111, Mt. Olive, MS 39119.

△ Radio Shack tube tester, Model 105, needs operating instructions and/or circuit diagram; Dr. Ali Martin Allmaker, Woodstock Rd., Williamstown, MD 01267.

△ Simpson Electric 333 tube tester; needs lid (cover?) and tube chart; James D. MacDonald, RR #1, West Bay Road, N.S., Canada B0E 3L0.

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△ Dyn Sonic Model DS-3056 stereo multiplex receiver with 8-track cartridge player; needs owners manual, schematic diagram and service data; Curtis Galloway, 4301 Arlington Drive, N.L.R., AR 72116.

△ Magnecord reel-to-reel tape recorder, consisting of Model PT6-R amplifier and Model PT6-A tape recorder/playback panel; needs PT6 full track record/playback head, part no. 91A57;. A. Cramer, 1208 Berkshire Ct., Hasbrouck Heights, NJ 07604.

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Superhets
(*Continued from page 70*)

tion, and receiver selectivity is further whipped into shape by the second intermediate-frequency transformer, IF2.

As we've already described, the detection process takes place at the diode, regaining the radio station's original audio signal. This audio voltage is fed from the volume control to both audio stages where they're further amplified and sent to the loudspeaker.

The detector diode doesn't merely extract soul sounds from the ether; it also delivers a second voltage output. Called AGC (Automatic Gain Control), this voltage controls our mixer's amplification, preventing the speaker from blasting when you suddenly tune your radio to a strong station. In our simplified schematic, the AGC voltage is a positive-going voltage which increases proportionately with rising signal strength. But before AGC can control receiver gain, it's filtered for pure DC in a resistor and capacitor network.

The result is a DC signal which can be used to control the gain of the mixer transistor.

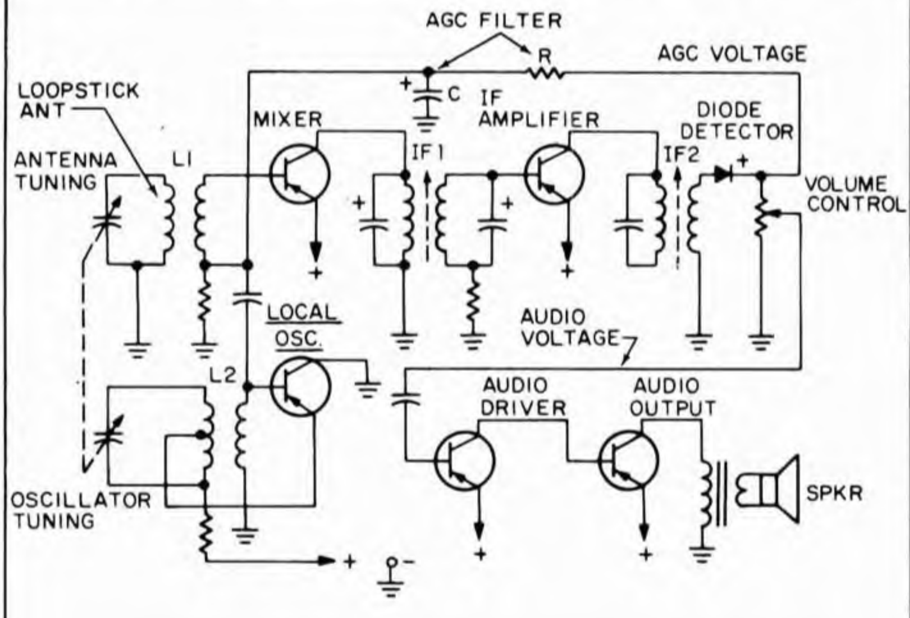

Fig. 6. Most superhets don't have separate local oscillator, mixer function; this schematic is more typical of BCB set. Communications-type receiver needs added usefulness of separate stages—it's easier to suppress images.

Pitfalls, Yet. Let's not lionize the king of receivers, though, for sometimes its growl turns to a puny purr. The biggest problem, and the most annoying, is a form of interference peculiar to the superhet known as an *image*. Produced by a mathematical mixup, images are all of those undesired signals finding easy routes to travel through your receiver. Take a look at our image explanation; you'll see the receiver is tuned to a desired signal of 8000 kHz.

The local oscillator generates a frequency of 8455 kHz, which places it exactly in our IF signal ball park. But note that a second station—a pop fly on 8910 kHz—also happens to be 455 kHz away from the local oscillator. For each oscillator frequency there are now two station frequencies giving identical IF frequencies. It's up to your receiver to strike out the image station. Otherwise, the RF ball game will turn into a rout!

You might expect the receiver's antenna tuning circuit to completely reject the image signal. After all, it's supposed to be tuned to generate a very high IF frequency, positioning any images developed by the mixer well outside the tuning range of the antenna circuit. Looking at our example of a double superhet, you'll see one IF amplifier perking at 5000 kHz and another working on 455 kHz. Now if we receive an incoming signal on 8000 kHz, the local oscillator, now called a high-frequency oscillator, generates a frequency at 13,000 kHz, so the first IF signal works out to 5000 kHz. Your receiver would have to pick up a signal falling on 18,000 kHz to produce any image. Naturally, the image frequency in this instance is significantly removed from the antenna circuit, so the image is greatly attenuated.

While high IF frequencies work well against image interference, they also revive Nagging Problem Number One: the higher the frequency of a tuned circuit, the poorer its selectivity. Since this situation also applies to IF stages, a *second* conversion is required, bringing the first IF signal down to 455 kHz, where we can sharpen our receiver's selectivity curve. That's how the double-conversion receiver solves both image and selectivity hassles. Any ham or SWL rig worthy of an on/off switch is sure to have this feature. But don't think of dual conversion as a receiver cure-all.

Dual conversion is *not* usually found in entertainment receivers—radio broadcast and TV for example, because it's too sharp! High selectivity could easily slice away FM stereo sidebands ■

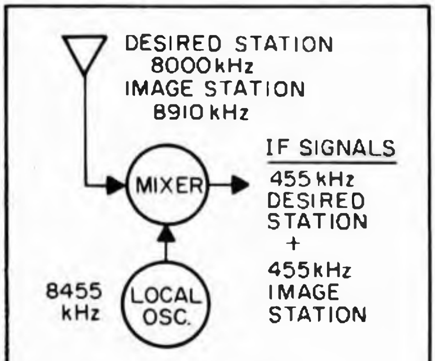

Fig. 7. Mixer is superhet's weakest link as signal handler. Too strong input signal can develop image frequency. Too much local oscillator signal pumped into mixer has same effect.

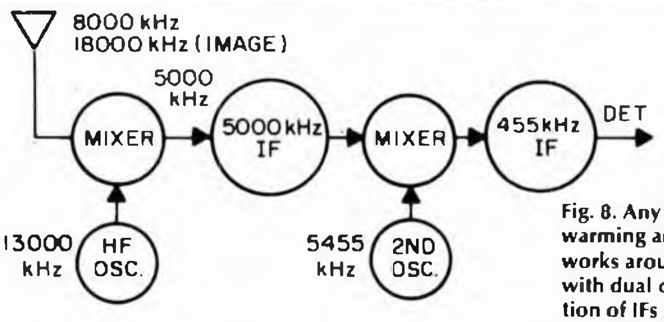

Fig. 8. Any superhet worthy of warming an amateur shack works around image problem with dual conversion. Combination of IFs puts image out of range of either stage.