1978 EDITION $1.50

ELECTRONICS

Electronics Theory Handbook

CC 02616

By the Editors of ELEMENTARY ELECTRONICS

SPECIAL FOR BEGINNERS
Ease into Amps, Volts, Ohms

CUT COMPUTER CONFUSION

How they work, What they'll do, Where they're going

PERSONAL COMMUNICATIONS PRIMER

Transmitting and receiving techniques, All about antennas, Learning Morse Code

PLUS–

The Battle of AM Stereo • Earning Big Money in Electronics • Understanding Superhets • The Causes and Cures of TVI • Mobile MD Cures CB Ills • Two-Meter Techniques • Inside Your Power Supply • The Uses of Negative Air Ions • Microprocessor Revolution • Cut the Cost of TV Repairs • Fix Oscillating Amplifiers • How Crystals Work • Solid State Multivibrators • How to Use Op-Amps • and much more!

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1978 EDITION

Electronics Theory Handbook

FEATURES

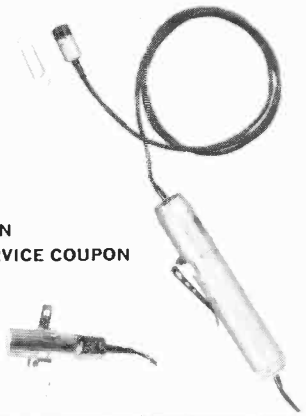
SPECIAL SECTION FOR BEGINNERS

DEPARTMENTS

New Products

Miniature Microphones

Audio-Technica is offering miniature microphones, made to be worn on the clothing when the situation demands faithful but unobtrusive sound pickup. The new microphones, designated the AT803S and AT805S, are electret condenser models with omnidirectional pick-up patterns. Accessories furnished with each include windscreen, battery, protective carrying case, lavalier neck cord, belt clip and tie clasp for fastening the mic to a necktie or shirt lapel. The AT803S is just 0.4 inches (-0.2 mm) in diameter and 0.78 inches (19.8 mm) long. Specifications include a frequency response of 50-20,000 Hz; —57 decibels sensitivity; —151 decibels EIA sensitivity; and 600-ohm impedance. The maximum input sound level is 130 decibels, and the signal-to-noise ratio is greater than 50 decibels. Suggested resale price is $80. A bit larger, the AT805S is merely 0.59 inches (15 mm) in diameter and two inches (52 mm) long. Specifications include frequency response of 50-15,000 Hz; —57 decibels sensitivity; —151 decibels EIA sensitivity; and 600-ohm impedance. The maximum input sound level is 130 decibels, and the signal-to-noise ratio is greater than 50 decibels. Suggested resale price is $50. Get all the facts complete from Audio-Technica, 33 Shiawassee Avenue, Fairlawn, OH 44313 or call (313) 644-8600.

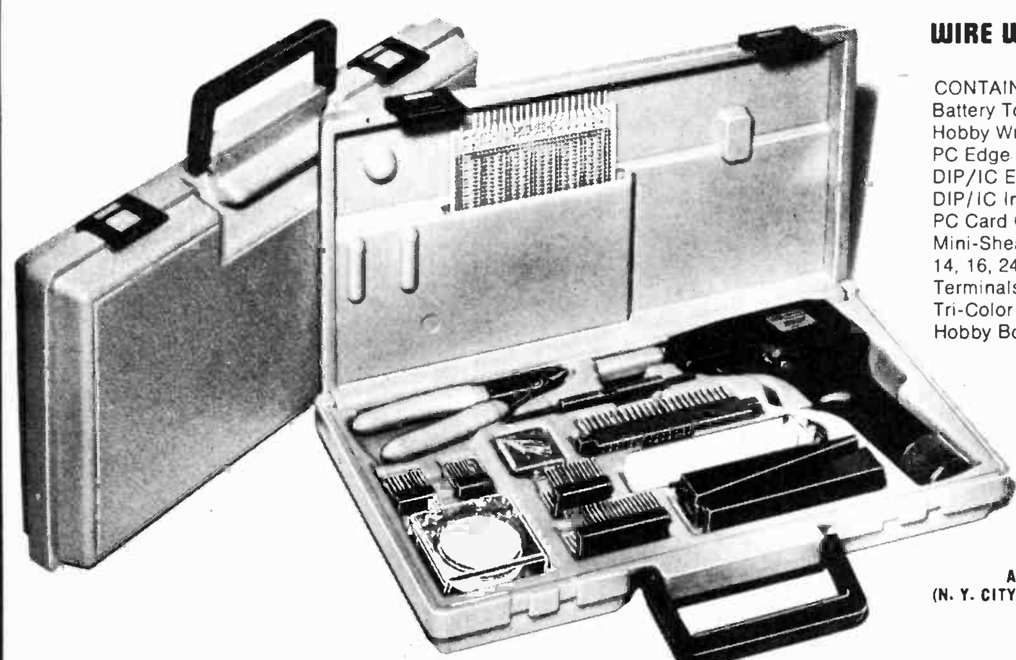


CIRCLE 52 ON READER SERVICE COUPON

Telephone Amplifier

Now even the most diligent businessperson or dedicated homemaker can continue working, with both hands free, when talking on the telephone—compliments of Panasonic's new telephone amplifiers, the Easaphones. Model KX-T1030 is a deluxe telephone amplifier featuring a built-in LED clock which may be used to time a phone call second by second (or a three-minute egg) or, when not in use, the LED clock displays hour and minutes. Other outstanding features of the Panasonic Easaphone include a sensitive condensor microphone, 3-in. speaker, piano-key type controls for on/off, timer and hold functions in addition to a sliding volume control and LED indicators for hold and power. The unit is equipped with record out and external DC adaptor packs and includes an AC adaptor, and two AA size batteries for use as a backup power supply to keep the clock functioning in the event of a power failure. Panasonic Easaphones are available nationwide at Panasonic retailers. Sells for $125.00. Get all the info direct from Panasonic, One Panasonic Way, Secaucus, NJ 07094.

CIRCLE 70 ON READER SERVICE COUPON



 CIRCLE 6 ON READER SERVICE COUPON

New Products

Scientific Calculators

A family of three, new, hand-held scientific calculators featuring a new display size, error messages, custom literature and a new packaging design was introduced by the Hewlett-Packard Company. The HP031E, priced at $60.00 is an advanced scientific calculator for the professional to use as a basic tool. In addition to the standard arithmetic, logarithmic and trigonometric functions, the HP-31E also has fixed and scientific display modes, and rectangular/polar, degree/radian, inch/millimeter, Farenheit/Centigrade and Pound-mass/kilogram conversion keys. The HP-31E also has the HP RPN logic system with four addressable storage registers. The HP-32E, priced at $80.00, incorporates all of the features and functions of the HP-31E

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with an engineering display mode and the first use of hyperbolic functions and their inverses in an HP hand-held calculator. It also features a U.S. Gallons/Liters key, a decimal degree and hour/hours, minutes, seconds key, and the most advanced collection of statistical functions ever offered on an HP calculator—including linear regression, correlation coefficient, x and y estimates, normal and inverse normal distribution and factorial. The HP-32E also features 15 addressable storage registers. The HP-33E, priced at $100.00, has all of the features of the HP-32E, except hyperbolics, metrics and certain statistical functions, and offers 49 lines of fully merged keystroke memory. Of particular interest is the calculator's capacity for three levels of subroutines. Get all the facts direct from Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, CA 94304.

Hear The World

Shortwave "DXing" is rapidly mushrooming in popularity amongst people of all ages and in all walks of life. To fill the need for an exceptionally stable and sensitive receiver capable of top performance, Yaesu Electronics Corporation has introduced its model FRG-7000. Table top in design, it offers stability, sensitivity, selectivity and calibration accuracy rarely found in consumer receivers. The FRG-7000 will allow you to explore the far corners of the world from the comforts of the living room, with digital accuracy, using all modes of reception, single sideband, AM (broadcast) as well as code (CW). It provides complete and continuous coverage of all frequencies from .25 kHz to 29.9 MHz. Sells for $599. For full details on technical specifications, write to Yaesu Electronics Corporation, 15954 Downey Avenue, P.O. Box 498, Paramount, CA 90723 or phone (213) 633-4007.

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Rotor for Super Antennas

Cornell-Dublier has introduced a new heavy-duty rotor, the Tail Twister, to handle antennas with up to 28 square feet of wind load area. The rotor incorporates the highly successful HAM II design with a new, thicker cast aluminum bell housing. Wider reinforced webs of the housing permit easy support of the largest antenna. On this model, the upper mast support is predrilled to have a bolt-through installation for positive locking. Also new is a three-ring ball bearing assembly to provide increased side thrust control and vertical load-carrying capacities. The motor is a new design with an automatic coast-down prebrake action and a metal pinion gear to guard against stripping. The control box features a full metered indication of the antenna direction with front panel control for calibration and brake. A separate on/off switch is provided for instant antenna location and brake operation. The Tail Twister system is designed for tower mounting as required for most "super" communications antennas. Weighing slightly over 18 pounds, the unit is secured with six 5/16-in. bolts provided. The mast diameter is a hefty 2 inches.

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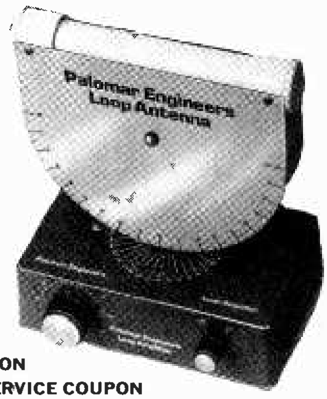
Loop Antenna

A new receiving antenna for the 80 and 160 meter amateur bands, the Broadcast and the VLF bands has been introduced by Palomar Engineers. The loop rotates 360° in azimuth and ±90° in elevation with calibrated scales for $299.95. For further information, write to Cornell-Dubilier Electric Co., 150 Avenue L, Newark, NJ 07101 or call (201) 589-7500.

both. The elevation or "tilt" of the loop gives much deeper nulls than ordinary direction finder loops. Loop nulls are very sharp on local and ground wave signals but are broad or nonexistent on distant skywave signals. This allows local interference to be eliminated while DX stations can still be heard from all directions. The loop picks up much less noise than the usual transmitting antenna. This, along with its ability to null out specific interfering signals, improves reception considerably. A Loop Amplifier serves as the mounting base for the antenna. It contains a tuning capacitor to resonate the loop and an amplifier to boost the signal and preserve the high "Q" of the loop. The Loop Antenna plugs



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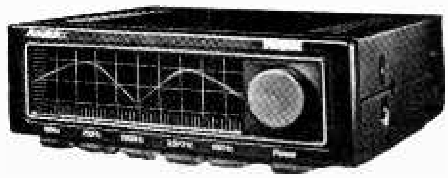
into the amplifier. Plug-in loops are available for 160/80 meters (1600-5000 kHz), broadcast band (550-1600 kHz) and VLF (150-550 kHz). The Loop Amplifier is $67.50 and the plug-in loops are $47.50 each. Add $2.00 shipping/handling. A free descriptive brochure is available from Palomar Engineers, P.O. Box 455, Escondido, CA 92025.

Booster Amp Shapes Up

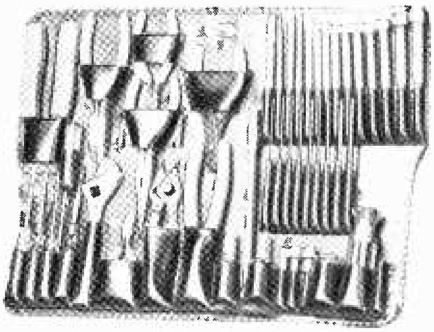
Highway hi-fi gets a new boost with Sparkomatic's car stereo booster amplifier which enables the user to "see" the amplifier response shaped by the various tone controls on the unit. As the new AcoustaTrac GE-500's controls are moved to adjust for tone, an illuminated, flexible rod changes its shape in conformance with the control movement. The GE-500 offers integrated circuitry for maximum reliability, wide frequency response, and 40 watts of RMS stereo power. Other features include slide controls that adjust five different frequency bands, a front-to-rear fader control, a power indicator light and an audio bypass switch. The unit can be used with all tape decks and radios and with all speakers that have a power handling capability of 15 watts or greater. Sells for $79.95. Get all the facts direct from Sparkomatic Corporation, Dept. EE, Milford, PA 18337 or call (717) 296-6444.



CIRCLE 46 ON READER SERVICE COUPON

Super Tool Set

The Vaco Super Tool Set contains 45 of the most popular professional tools including handy, interchangeable screwdriver, nutdriver and hexidriver blades and handles, plus pliers, screwdrivers and electrical tools. All these tools are mounted on an attractive deluxe pallet which can be hung near a workbench.

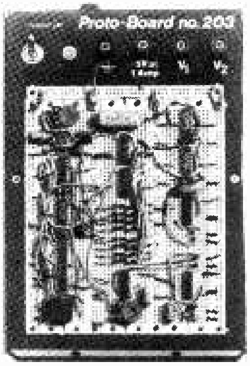


CIRCLE 75 ON READER SERVICE COUPON

Priced at $160.00. For more information, write to Vaco Products Company, 1510 Skokie Blvd., Northbrook, IL 60062 or phone (312) 564-3300.

Powered Breadboard

TTL logic system designers are finding an attractive design shortcut available to them, thanks to the Continental Specialties Model PB-203 Proto-Board, a high capacity solderless breadboard that includes a built-in 1%-regulated 5 VDC power supply. The advantage to a TTL hobby designer is the ability to design directly in hardware, assuring proper circuit operation, before hand wiring. This helps prevent the confusion in translating from gate schematics to actual IC packages, often providing valuable insight into ways of simplifying PC layouts. The breadboard area on the Proto-Board 203 includes enough tie

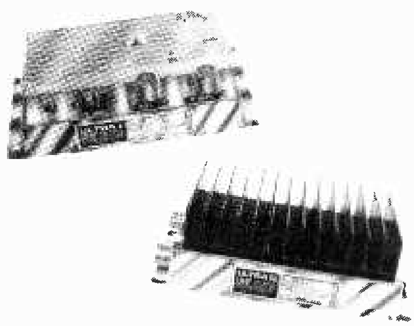


CIRCLE 57 ON READER SERVICE COUPON

points to support 24 14-pin DIP ICs. Four binding posts provide power and signal connections on and off the board. The built-in power supply is 1% regulated at 5 ±.25 Volts, rated at 1 A, and boasts a low 10 millivolts combined ripple and noise at 0.5 A out. And it's short-proof. The 5½-pound package measures 9¾-in. long, just over 6½-in. wide and 3¼-in. tall. CSC's low suggested resale price for the PB-203 is just $80.00 (per unit). Further information is available from CSC dealers and distributors, or direct from Continental Specialties Corporation, 70 Fulton Terrace, New Haven, CT 06509.

Legal Linears

Telco Products new Ultra series of 450 MHz RF Power Amplifiers is specifically designed for Amateur, Police, Emergency, Business Band and Class "A" (special license) CB radio applications up to 50 watts. Four new Ultra line UHF Power Amplifier models are American manufactured in full compliance with latest FCC specifications. They are: Ultra I—1-2W input 15W output. Ideal for use with Low Power Hand-Held transceivers, $259.00; Ultra II—3-5W input 25W output, $289.00; Ultra III—3-5W input 50W output, the legal limit for Class "A" Citizen and Radio, $379.00; Ultra IV—



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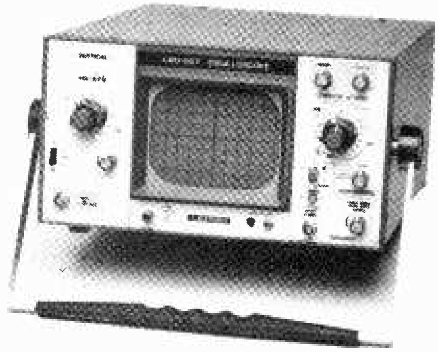
3-5W input 100W output, the "Ultra" powered amplifier for maximum output, $499.99. Frequency range is from 400 to 512 MHz. Specify transmit frequency with order. For additional information, contract Telco Products Corporation, 44 Sea Cliff Avenue, Glen Cove, New York 11542 or call (516) 759-0300.

20 MHz Triggered Scope

The Leader LBO-507, a 20 MHz triggered scope is designed for broad use in industry, hobby, laboratory and service. The LBO-507 offers automatic triggered circuitry to assure maximum display stability with minimal adjustments as well as a trigger sensitivity over the entire operational range. It



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provides convenience of pushbutton switch selection for every functional demand; 10 mV/cm vertical sensitivity calibrated in 11 steps—in a 1-2-5 sequence up to 50 V/cm with variance control; and a 17.5 nanosecond rise time. Bandwidth is DC to 20 MHz. Sweep speed for the LBO-507 is 0.5 uSec/cm, 18 steps in a 1-2-5 sequence up to 500 mS/cm with variable control. The LBO-complete with low capacitance probe and terminal adapter. Get the complete specs 507 is priced at less than $500 and is direct from Leader by writing to Leader Instruments Corp., 151 Dupont St., Plainview, NY 11803. ■

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CB NEW PRODUCTS

Electronics Theory Handbook looks at some of the newest CB rigs, antennas and accessories for youto use in CB contacts this year!

Viking Base Station

A new 40-channel Viking CB base station, the "Viking 430", is a desk-top unit with a wood-grain vinyl-clad steel cabinet. It incorporates Johnson's latest performance technology including noise blanker and automatic noise limiter circuits designed to do an excellent job of cleaning up signals. The built-in amplified speech compressor eliminates the need for power-boosting microphones and similar accessories. The Viking 430 also features PLL frequency synthesizer, solid-state T/R switching, two-position range

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control, touch-indexed knobs, built-in public address capability and can be operated from AC household current or 12-volt negative ground DC current. The unit comes with a detachable hand-held microphone. Viking 430 is U.S.-made and carries Johnson's one-year parts and labor warranty. Suggested retail price is $229.95. Write to the E. F. Johnson Company, 299 10th Avenue S.W., Waseca, MN 56093 for more information.

SSB/AM Transceiver

The new SBE Sidebander V is a compact, 40-channel SSB/AM mobile transceiver featuring digital PLL circuitry for accurate frequency generation of upper and lower sidebands, as well as the 40 AM channels. The Sidebander V has features such as a Channel 9 instant access switch for transfer to that emergency channel, and a channel scanning switch that scans all 40 channels and locks on the first clear channel found. It also features the exclusive SBE "Speech-Spander," automatic modulation level control, a rapid turn channel selector and large, bright LED channel readout. Other features include an

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SSB clarifier and switchable noise blanker and noise limiter, PA provision. The Sidebander V has a power output of 4 watts AM and 12 watts SSB PEP. Sells for $459.95. Further information is available by writing to SBE, Inc., Dept. P, 220 Airport Blvd., Watsonville, CA 95076.

One Hand CB

The new Royce CB 582 CB transceiver features true one-handed operation and reception clarity. All essential controls are built into the 582's compact, high-performance microphone. The result is maximum convenience and performance. Because LED digital channel readout and a unique LED sequential S/RF meter are engineered into the mike, driving safety is actually improved. The 582's operator can spend more time keeping his eyes on the road. Built-in two-speed/up-down channel advance, ANL/PA switch, TX (transmit) light, on-off/volume control and fully variable squelch control add up to true one-handed operation, maximum convenience and increased driving safety. A powerful dynamic microphone element and completely separate full-range dynamic speaker are designed for maximum reception clarity and talk power. In addition, the new Royce CB 582 can be easily integrated into a car's radio speaker system.

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When a CB signal is received, the 582 automatically mutes a selected speaker for clear CB reception and then returns the radio to its normal program mode. The Royce 582 sells for $179.95. For more information, write to Royce Electronics Corp., 1746 Levee Rd., N. Kansas City, MO 64116.

Radio/CB In-Dash

An in-dash pushbutton AM/FM/MPX radio combined with a citizens band two-way transceiver has been added to RCA's expanding line of AutoSound products. Model 14T405 is a 40-channel CB which features phase-lock loop frequency synthesizer; LED digital channel readout; delta tune switch; built-in automatic noise limiter (ANL); illuminated S/RF meter, and detachable microphone. A CB monitor switch lets CB transmissions break in on AM or FM radio. The AM/FM/MPX radio portion includes five quick-set push-buttons for any combination of AM and FM stations; slidebar control for

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AM/FM selection: fader and balance controls; built-in automatic frequency control (AFC); FM stereo indicator light; and AM antenna trimmer. This unit can be hooked-up as a two-speaker or four-speaker system, and features adjustable shafts and universal trim plate for a finished in-dash installation. Suggested list price for RCA model 14T405 combination CB/AM/FM/MPX in-dash push-button radio is $259.95. For further information, contact a local RCA AutoSound Distributor or RCA Distributor and Special Products Division, Deptford, NJ 08096.

Base Microphone

The Superex new power base station microphone, the electret condenser M-611, has an extra large "push-to-talk" paddle enabling more efficient communication in critical applications. To the right of this paddle is an

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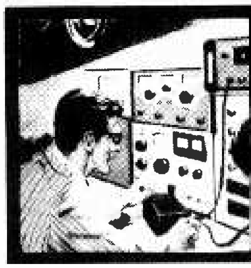
interlock control if continuous transmission is desired. The mike is an omnidirectional design with an FET pre-amp, and a transistor output amplifier stage. The output gain is controlled by a high quality linear potentiometer which is damped for smooth and precise adjustment. A self-contained C cell (supplied) provides the power for the M-611. An additional feature of the M-611 is that the mike stem can be quickly removed via a special connector and be inter-changed with a variety of mike designs. Plug in modules offered include a "Lapel Mike" and an "Acoustic Tube Mike Headset." This unique system offers the user maximum application flexibility. The M-611 is manufactured in the U.S. by Superex and is suggested for resale at $44.95. For additional information, write to Superex Electronics Corp., 151 Ludlow St., Yonkers, NY 10705. ■



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

Lightning's Too Fast

This may sound stupid, but can you use the thunderbolt sound-activated flash switch to take pictures of lightning when thunder sounds?

—H.F., Gainsville, FL

No, because by the time you hear the thunder, lightning is long gone. Sound travels 1100 feet per second, approximately. Lightning one mile away creates thunder that is heard about 5 seconds later, which is much too late to take the picture. Actually, what you need is a light actuated switch—a circuit very much like a photographic slave that will trip your camera when a flash of light trips it. Now that is a project worth designing.

Blinky Bow Tie

Hank, can the editors run a short story on how to wire up a bow tie to blink neon lamps? If they do, please have them give complete parts list and where to buy. Thanks. *—H. A. Chatsworth, CA*

Neon lamps are out and LEDs are in. I suggest you obtain the "LED Blinky Kit" from Ramsey Electronics, Box 4072L, Rochester, NY 14610. You can phone in the order: (716) 271-6487. Two jumbo LEDs are used in the kit and comes complete less batteries and bow tie.

Sight and Sound Collector

Hank, if your readers are looking for a parabolic reflector for a microphone, I suggest they write to Edmund Scientific for their catalog which lists one 18-inches in diameter. It's made of highly polished aluminum with a focal point six inches from the disk bottom. This reflector is designed for gathering solar energy so don't point it at the sun.

—B. M. McMinnville, TN

Thanks for the info! Our readers can get a copy of Edmund's catalog by writing to Edmund Scientific, 1776 Edscorp Building, Barrington, NJ 08007. The catalog stock number for the parabolic reflector is 80,254 and sells for $14.95 postpaid.

Curse that Noise!

I installed a coaxial capacitor in the line between the battery terminal on the spark coil and the car's wiring as shown in the January/February 1978 *issue of* ELEMENTARY ELECTRONICS *and the results were positive. So I tried it with the noisy heater motor, and again, the results were positive. Why can't Detroit do this?*

—W. M., Garland, TX

Beats me! If Detroit were to do their job correctly, who would need auto accessory stores, recalls and Ralph Nader.

Soups On TV

I would like to soup up my TV to be more sensitive to distant stations as I am in a fringe area. What would be the best way to go about this? To put higher gain transistors in the IF section or to try to get higher gain in the video amplifier section? I have tried boosters to no avail, also other antennas. My TV is in good shape, just not good enough for fringe areas. My brother who lives next door gets much better reception with an older TV (1970) compared to my newer set (1973).

—M. A., Julian, CA

Don't soup up the TV, soup up the TV signal. Install your antenna as high as you can; you may need a tower. Install a MATV (Multiple Antenna TV) system in your house with the signal booster as close to the antenna as possible. Use coax cables throughout, not 300-ohm ribbon lead-in wire. Matching transformers at the antenna and each TV set in the house is important. Finally, you may need a rotator if the TV signals come from different points on the compass.

If you are concerned about the quality or tune-up of your TV receiver, carry it over to your brothers house and see if it responds better to his TV antenna hook-up than yours. Chances are it's the antenna system or signal strength at your brother's house that is better than your home.

Wire Maze Removed

Regards to author Fred Chapman and his "Jack in the Box" project that appeared in the May/June 1978 issue of ELEMENTARY ELECTRONICS. *He claimed that the project saved 99-44/100% of his rats nest wiring behind his hi-fi. It worked for 100% of mine. How come so simple a project was so long in coming? (I'm not complaining).*

—V. J., Yucca Valley, CA

It's the simple ones we all overlook!

Cycles Still vs. Hertzs

Hank, why must we use the term "Hertz," when we talk about cycles? Do musicians use Hertz for cycles?

—G. A., Staten Island, NY

I'm all for honoring old man Hertz for his contribution to physics, even to go so far as to have his picture put in front of every physics book, but that's the bottom line. A cycle is a cycle and not a Hertz—a truly clumsy term Musicians are a lot smarter, I hope, and will stay away. Imagine if musicians were labeling our basic parameters! It would be 60 Sonny and Chers, .01% total harmonic Beatles, and an 8-Sinatra voice coil. It's time to get back to basics!

Pulled It In!

Hank, I pulled in Radio Panamericana at 6,025 on the dial. Where are they located? I couldn't copy enough to do much good.

—A. P., Tampa, FL

You pulled in a tough one! Radio Panamericana originates in La Paz, Bolivia. I hear that they transmit on 6,035 kHz so you should resort to "logging" as mentioned in the "DX Central Column" in the January/February 1978 issue of ELEMENTARY ELECTRONICS. Also, invest in a 100 kHz marker generator to increase accuracy.

Penpal Wanted

Hank, would you tell your readers that I would like to be a penpal DXer with some of them. I have started the hobby of shortwave listening and would like a friend to share it with. Thank you.

Eric Hughes
Route 2
Moore, SC 29369

You got it, Eric!

Racing With the Amp

I see a lot of raceways in buildings that add wiring on the internal wall. Is this a good practice?

—A.M., Silver Springs, MD

You bet it is! It may not look good in your living room, but in the office, garage, shop, and maybe the kitchen, it's alright. The raceway is a metal conduit that is secured to the wall. It is an inexpensive way to add outlets without breaking up walls and floors. Raceways can also be used to cheaply interconnect air conditioners to the main fuse panel.

One Score and Four Years Ago

Hank, what happened to the good old days? My old Dual turntable bit the dust after 12 years of faithful service, and while looking for a new one I must have seen over 100 different models. How can a guy chose?

—L.S., Elmwood Park, NJ

My dad had a 1927 Ford that lasted up until World War II, when he sold it because he couldn't get gas. You know what he bought after the war? That's right, a Ford. Once you like a brand, and its products are still very competitive and high in quality, why gamble and change.

Meters Lie

On my hi-fi receiver, when tuning FM, the signal strength is not at maximum position when the tuning indicator is centered. For maximum signal, the tuning indicator is about 1/32-in. to the left of zero. What should I do?

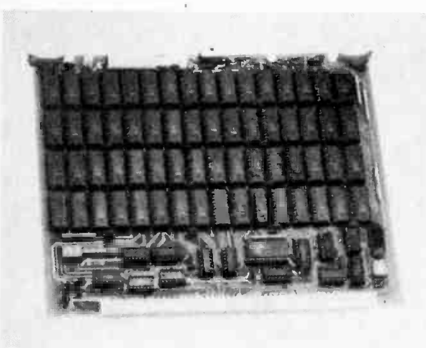
—W.D., Chatsworth, CA

You didn't say a thing about how the unit sounds! Tune for minimum distortion. I think you'll discover this occurs when the tuning meter is centered. If the sound is poor, then alignment is necessary. I know this should not happen, but it is fairly common.

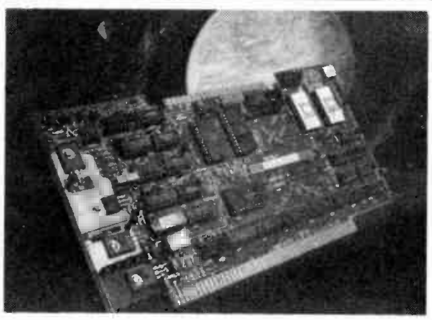
(Continued on page 104)

COMPUTER NEW PRODUCTS

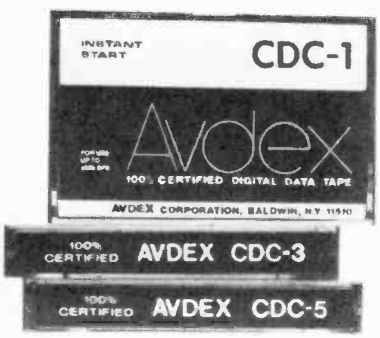
Here in ELECTRONICS THEORY HANDBOOK you will find information on the newest hobby computers and accessories.



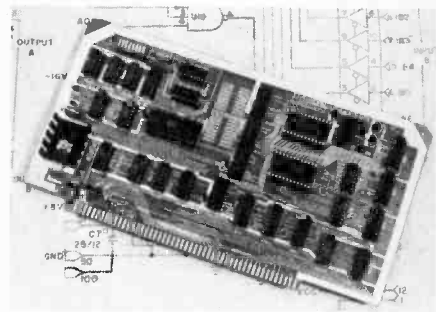
High Density Memory Module—PCS, Inc. offers a high density PCS 1814 CMOS RAM Memory Module that features 8K bytes of CMOS RAM and a 450 nanosecond memory cycle that ensures memory will run at CPU speeds. This is a low power module with built-in battery backup and charging circuitry which will retain information for a minimum of seven days. There's also provision for an external battery for increased battery support if needed. A switch selectable write protect is helpful for development and debugging purposes. The unit is available in two versions. The basic module has 4K bytes of RAM installed in sockets, with sockets provided for the additional 4K bytes. A switch selectable base starting address permits memory to be easily interlaced with existing systems while another switch allows disabling of the upper 4K bytes of RAM so that other memory in the system can utilize that memory space. Price of this basic module is $795. The second version ($995) has a full 8K bytes of RAM installed. Multiple 1814 CMOS RAM Memory Modules can be used in the same SuperPac 180 Series microcomputer system, facilitating sophisticated control techniques in a cost-effective manner, according to PCS. Circle No. 49 on Coupon.



General Purpose I/O Board—This general purpose I/O board from Infinite, Inc., designated the MFIO-1, is S-100 compatible and contains a major portion of all circuitry required for a complete microcomputer. Some of the features: Memory or I/O mapped parallel input port for keyboard; memory or I/O mapped serial I/O port with crystal controlled switch selectable baud rates of 50 to 19200; jumper selectable RS232 or 20mA current loop; memory or I/O mapped cassette interface with switch selectable data rates of 300 (Kansas City Standard), 600, 1200 and 2400 baud; 128 bytes of RAM; slots for two each 2708 EPROMs. A 21 command, two chip monitor program is available in PROM firmware as option 001. The total power requirement is less than 1A. Available in three versions: assembled, $282; kit, $234; bare boards, $49. A set of two ROMs costs $65.95. Circle No. 73 on Coupon.



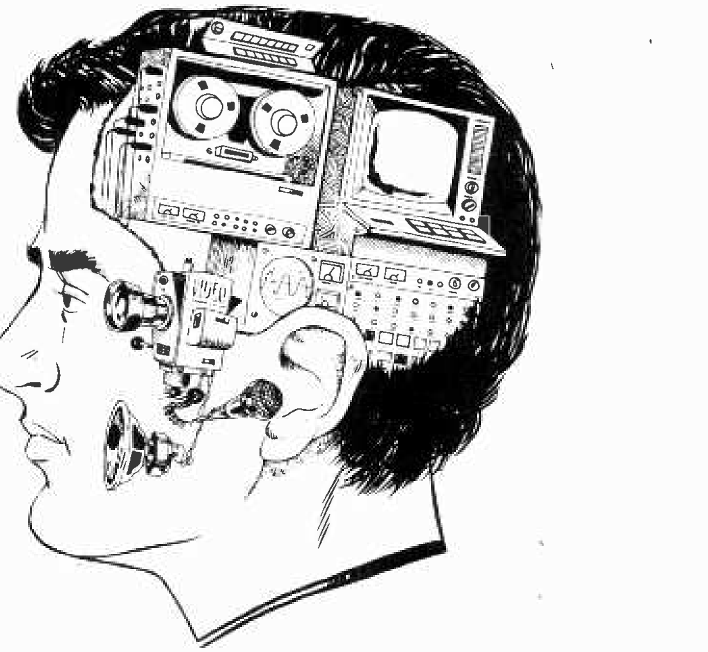
Data Cassettes for Hobby and Business Use—A full line of data cassettes specifically designed for use in hobby computers and small business computers are available from AVDEX Corp. The cassettes come in 1-, 3-, and 5-minute lengths for more convenient use than cassettes which have too much tape to be handy for hobby and business applications. According to the company, the cassettes have high quality computer shells, polyolefin slip sheets, machined guide rollers, stainless steel pins, special oversize pressure pads with Tyvec liners and oversize hubs for smoother, more uniform tape transport. The cassettes are custom loaded with extra short leaders to prevent the leaders from contacting recording heads, thereby providing instant start operation and eliminating the possibility of lost data. Prices for the short-load cassettes are: CDC-1, $4.95; CDC-3, $5.65; CDC-5, $6.35. Also available are three other cassettes in C-20, C-40 and C-60 configurations ($4.50, $5 and $5.50 respectively) which utilize the same computer shell components and are loaded with high quality, high density calendered ferric oxide formulation. Circle 68 on Reader Service Coupon.



"Bit Streamer" I/O Board—Vector Graphic's "Bit Streamer" I/O board combines two parallel input and output ports, and a serial I/O port using an 8251 programmable universal synchronous/asynchronous receiver-transmitter. Communications with board circuitry is accomplished by the CPU. One parallel port also can be used as a keyboard input port. The USART is designed to interface easily to an S-100 bus structure, and is capable of being configured for a wide variety of communication formats. Without introducing changes to the pre-jumpered options, the board can be installed in a computer and will operate as an RS232 serial port using the initialization and I/O software on the Vector Graphic option C PROM. Prices: kit, $155; assembled, $195. Circle No. 44 on Reader Service Coupon.

Paper Tape Transmitter—This Model 612 stand-alone paper tape reader, from Addmaster Corp., provides greater capacity than earlier models. The new features include an ability to read 5 to 8-level tape and to transmit 7 to 11 frames per character at 50 to 9600 baud. Other features: starting and stopping on character at all speeds; choice of manual control or X-on, X-off; 90 to 260 volts; 50 to 60 Hz; even, odd or no parity. Available options include RS 232, current loop or parallel outputs, choice of desk top or rack mounting. Single unit prices: $625 to $725. Circle No. 82 on Reader Coupon. ■

Inside Your Computer



☐ It seems that the day of the home computer has at last arrived. Everywhere, we read about these new machines that are changing our lives, running things better than we ever could ourselves. Everybody tells us that the solid state computer is the newest and most radically advanced thing to come along since the sun. But, you know, in spite of all these claims, the personal computer is not all that new. In fact, you've been using one all your life; it's called a brain.

Many people, electronics hobbyists in particular, have long suspected some fundamental similarities between brains and electronic computers. In this article we're going to compare these two types of information-processing systems.

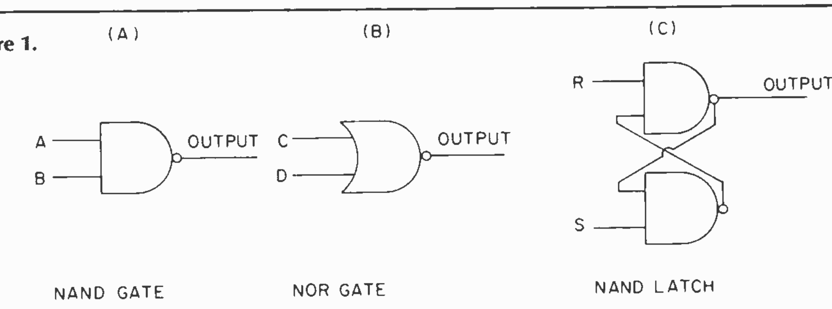
Let's begin on familiar ground. In Figure 1 we have the various logic gates; the important building blocks of any electronic computer, big or small. The NAND gate's output state is a function of its two inputs, and it remains at a logical 1 so long as the input state is not 11. An input of 11 sends the output to a logical 0. On the other hand, the NOR gate's output is usually a logical 0 except when the input is 00, in which case the output assumes a logic 1 value. Using combinations of just these two gates we can synthesize any desired logic function, no matter how complex.

As you know, the 0 and 1 symbols can denote voltages, with 1 usually representing a high voltage and 0 a low voltage. The ones and zeros may also be interpreted in a philosophical sense as True and False, respectively. Why should we use numbers to represent qualities such as truth and falsity? It's mainly a convenience which allows logic to be expressed in mathematical form. If logic can be handled algebraically, then solution of logical problems becomes routine, and can be handled by machines—computers.

But a computer needs more than decision-making apparatus (NAND and NOR gates); it needs memory. We store the computer's instructions (program) in memory, and also use memory to retain the solutions generated by the computing process. One basic form of memory is the NAND latch (Figure 1c). When a little control gating is added to this basic circuit, we can get various flip-flops, which are probably the most familiar storage elements. Other forms of storage include magnetic cores, magnetic tape, paper tape, and the exotic magnetic bubble devices. Regardless of the storage form, however, memory simply holds data until it's called up for processing or readout.

Neurons. Contrast the human information-processing system to the electronic computer. Like a computer, the human brain is a complex entity built up from enormous numbers of simpler fundamental units. These basic units are called nerve cells or neurons. Several classes of neurons exist; neverthless, all share the same generic traits. Figure 2 shows one typical neuron. The tentacle-like elements are called dendrites, and they function as the input leads to the cell. The single long filament leaving the

Figure 1.



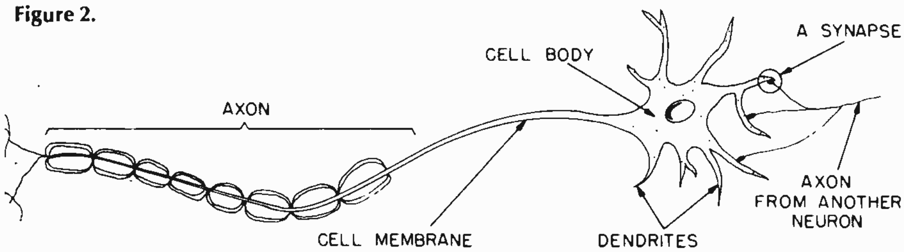
A	B	OUTPUT
0	0	1
1	0	1
0	1	1
1	1	0

C	D	OUTPUT
0	0	1
1	0	0
0	1	0
1	1	0

R	S	OUTPUT
0	0	NOT ALLOWED
1	0	0
0	1	1
1	1	NO CHANGE

Some Basic logic circuits: a) A NAND gate gives a 1 output for any input except 11. b) the NOR gate only gives a 1 output when both inputs are 0. The NAND latch (c) is a memory device which is the basis of the common flip-flop circuit.

Figure 2.

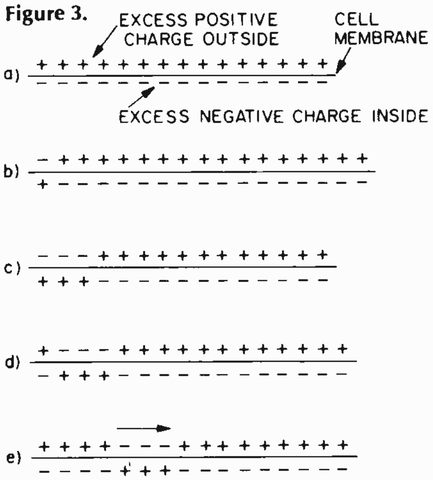


A motor neuron, one of the basic building blocks of the biological information processing system, is a single cell and functions as a multi-input majority gate. The inputs to the dendrites and the cell body come from other neurons. These inputs, often numbering in the hundreds, are averaged and the majority input determines the output along the axon—sort of biological democracy. The axon then leads to another neuron.

cell is an axon, which is the cell's output. Nerve signals travel along the thin membrane that encloses the cell's protoplasm. Adjacent cells communicate with one another across synapses—gaps between axons and dendrites of different cells.

Logically the neuron is more complex than a NAND or NOR gate. It functions as a majority gate, which may be described as follows: Suppose, for example, that we construct a gate with five inputs and one output, and that the output will be a logical 1 whenever a majority (3, 4, or 5) of the inputs is in the 1 state. If there are less than a majority (0, 1, or 2 that is) of logical 1 inputs, the output is a logical 0. Such majority gates are not encountered too frequently in electronics, one notable exception, however, being Motorola's

Figure 3.



Nerve signals are waves of temporary polarity reversal along the cell membane. In the first drawing above (a) the nerve membrane is in a quiescent state, in (b) the polarity reversal begins and progresses along the membrane (c & d). The polarity returns to normal (e) and this return travels behind the reversal at an equal speed (about 100 mps).

CMOS MC14530 dual 5-input majority gate. As a rule a neuron has more than five inputs—typically, up into the hundreds. Regardless of its complexity, however, a majority gate can be expressed in equivalent form as a combination of NAND and NOR gates.

From the foregoing you can see that computers can be logically equated to neuron networks; nevertheless, certain physical differences exist between biological and electronic systems. To begin with, electronic signals are viewed as differences in potential, which govern the flow of free electrons. Signals in nerve nets, however, consist of waves of polarity reversal on the surface of polarized neuronal membranes. In Figure 3 you can see that a nerve's membrane normally possesses excess positive charge on its outer surface, and excess negative charge on the inner surface. Excitation of the nerve brings about a polarity reversal at some point on the membrane, which then induces polarity reversal at adjacent points on the membrane, and the signal spreads. The reversed-polarity condition at any given point reverts to normal after several miliseconds, while the wave of polarity reversal propagates to new points on the membrane. Charge distribution on the membrane's surface is controlled by movements of sodium and potassium ions, and the rate of ion flow through the membrane limits the speed at which nerve signals travel to about 100 meters/second. Contrast this with the speed of an electronic signal traveling down a transmission line with a polyethylene dielectric: about 2×10^8 meters/second. Biological systems are thus inherently slower than electronic ones.

Memory. Two physical characteristics distinguish the human nervous system from the electronic computer. Communication between the functional units in a computer is established by connecting wires. Interneural communication involves diffusion of certain chemicals across synapses. Memory is likewise a chemical phenomenon, involving chemical changes in nerve cells and associated structures. Regardless of these physical differences, however, the two systems possess a fundamental logical similarity, as we've seen. Is it now possible to map the information flow in the human system in the same way that we are accustomed to in electronics?

Yes, to a certain extent. First of all, no one alive and in good health would consent to have men in white lab coats probing about inside his or her head. So direct information about the living, functioning nervous system is hard to come by. But a lot of data can be obtained concerning brain structure in an indirect way, and this is the domain of cognitive psychology. Research along these lines can be frustrating; it's very much like trying to figure out what's inside a computer by seeing how the machine responds to different sequences of input signals. Nevertheless, psychological data, together with whatever biologists can provide, has allowed many deductions about the brain's organizations.

Let's look at Figure 4, which is a simplified human cognitive map. Memory elements are represented by squares, while circles stand for control processes. This is an arbitrary distinction because both functions, memory and control, are apparently performed by cells. Keeping that fact in mind, let's analyze the major features of Figure 4, saving the details for later. First, visual and auditory information from the outside world are converted by the eyes and ears respectively into nervous impulses. These signals are routed to buffer memories, the sensory registers, which act to preserve fleeting data long enough for the rest of the system to process it. By convention the visual and auditory sensory registers are called, respectively, the "icon" and the "echo."

The block labelled LTM is long-term memory, a presumably permanent storehouse filled with all the important facts accumulated during a lifetime. For example, LTM contains enormous quantities of information such as 1+1=2, V=IR, the rules of English grammar, telephone numbers, and so on. In contrast, STM or short-term memory has a very limited capacity. Furthermore, information fades away or gets dislodged very easily from STM. It is possible to consciously retain STM information, however, by the process of rehearsal, repeating things mentally to one's self. As the arrows of Figure 4 indicate, rehearsal takes information out of STM and then re-enters it. At the

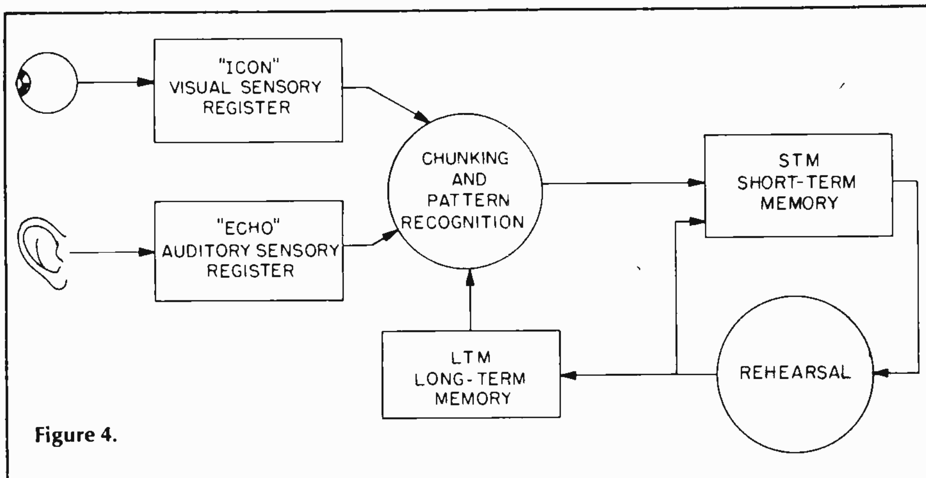


Figure 4.

A simplified model of the information processing system of humans and higher animals. In addition to the "ECHO" and "ICON" sensory registers there are others for taste, smell and touch. In the lower box, the LTM, is stored everything you know except for the most recent inputs which are being processed as you read this page. These immediate inputs are going into the short term memory and rehersal loop; some of what you have read will be recorded in the LTM—there is, however, no guarantee your brain will be able to recall it. Something may be in memory but the brain can't always find it.

same time, rehearsal can facilitate entry of information into LTM, as we'll see later.

Recognition. The final circle represents two independent processes, chunking and pattern recognition. Because these processes seem to have the same inputs and output, they coincide on the map. Chunking is an organizational process whereby sensory register information gets grouped by means of LTM rules before entering STM. This chunking does two important things: 1) it allows more information to be crammed into STM, and 2) it makes the information easier for LTM to assimilate. Note that information cannot enter LTM directly; instead, it must be worked on in STM first. For this reason, STM is commonly called working memory by psychologists. Apparently, STM is the site of what we experience as consciousness. The last process, pattern recognition, is the identification of visual or auditory inputs, and is a very important part of conscious experience.

As we stated earlier, the map in Figure 4 is far from complete. Missing entirely are the autonomic processes, such as breathing, which the brain controls. Gone too are the ouputs which, for example, would control muscular action. It would also appear from Figure 4 that all inputs are processed equally, yet we kow this is not true. As you read these lines countless sounds, sights, and pressure sensations are available to your senses, yet your attention is fixed on the letters that you scan. This phenomenon of selective attention is extremely important, but a little too complex to cover here.

Keeping in mind the fact that our cognitive map is greatly simplified, let's consider its features in more detail, starting with the sensory registers. Experiments with the icon have revealed that visual information is stored for less than a second before fading. Moreover, new visual stimuli erase the old iconic information. If this did not happen, our apprehension of an image would lag about a second behind its appearance. By contrast, echoic storage lasts longer than that of the icon (the exact duration is subject to dispute, however), and erasure per se doesn't seem to occur. The necessity of echoic storage is readily seen when you consider that language is a serial phenomenon, made up of sounds which follow each other in time. To make sense out of language, what is and what was must both be available. For example, a single word like *computer* is made up of many basic sounds called phonemes. All must be available in order for the pattern recognition process to identify the word.

STM. Let's consider STM. One piece of evidence suggesting an STM that is distinct from LTM is Milner's Syndrome, a mental impairment caused by damage to the hippocampal area of the brain. Victims of this syndrome are quite normal in most respects, but are unable to permanently memorize new information. For example, given a list of words, they can retain the list in memory for any desired length of time by continually rehearsing. When instructed to stop rehearsing, they lose the list in a matter of a minute or so. One patient was able to read the same magazine again and again without getting bored. The patient's doctor had to introduce himself daily, even though he had been treating the man for years. Yet, the patient could recall the events in his life before the accident. According to our cognitive map, we can theorize that the damage broke the link between LTM and STM. The victim could use STM and recall old items from LTM, but he was unable to put new information into long-term storage.

Not only is STM storage temporary but it also possesses only limited capacity—typically five to nine items. This figure varies according to the nature of the items being memorized, but the average person's short-term capacity is about seven letters, numbers, or words. This seven-item limit is commonly referred to as the memory span. Let's clarify the memory span concept now. If a list of items is presented one at a time to a subject, that person can recall the list in perfect order, after seeing the items just once, if the list length is less than or equal to about seven items. Mistakes will appear with longer lists. Of course, we can memorize more than seven items, but to do so will require several presentations of the list plus some rehearsing. Since rehearsal both refreshes STM and transfers information to LTM, learning of lists longer than the memory span evidently requires storage space in LTM.

Suppose that the following list of letters is presented to you. Could you memorize it at one pass?

VTVMSCRFETUJT

You could if you treated the items like this:

VTVM SCR FET UJT

This type of organization is called chunking, which means ordering the list into meaningful groups. Since meanings are governed by the pattern of storage in LTM, previously acquired LTM information is being used here to facilitate STM storage. The chunked list has four items, well within the memory span, and can be quickly memorized by anyone familiar with electronics. But to an uninitiated person the list contains thirteen items; a few rehearsals would be necessary to enable perfect recall.

Let's try another experiment. Can you memorize the following list quickly and without a lot of rehearsing?

110001100101000011

If you can count in binary, it's a cinch. Look at the list in this way:

110 001 100 101 000 011
6 1 4 5 0 3

Below each triplet is its decimal equivalent. If you can mentally do such a conversion, you're left with only six decimal digits to memorize. When the time comes for recall, simply change the decimal numbers you've memorized back to binary. With some practice, you should be able to handle lists of about twenty-one ones and zeros, much to the amazement of your friends. Note that you're using old LTM information —the rules of binary-to-decimal and decimal-to-binary conversion—to assist in memorizing new material.

RAM. Leave STM now and consider long-term storage. First of all, think of all the different kinds of information contained in LTM. Sights, sounds, tastes, smells, and words are all stored in some codified form. The information can be reached quickly without first searching through a lot of extraneous material. In electronics we call such a memory structure random-access. This random-access characteristic is one of LTM's most important features, and current theories hold that a close relationship exists between the structure of LTM and the grammar of language.

Certainly one of the most important characteristics of LTM is its relative permanence of storage. However, we all know that recall is often marred by forgetting. Is this a memory failure? It might be, but some say no. Consider the experiences of the neurosurgeon Wilder Penfield. While performing surgery he electrically stimulated areas of patients' brains. Since the patients were conscious during brain surgery (there are no pain receptors in the brain), they were able to report their sensations. Many reported long-since forgotten, seemingly trivial incidents from the past. These sensations were vivid, filled with minute visual and auditory details. In fact, they were often described as being like movies. This type of evidence is frequently cited in support of the notion that everything stored remains stored, and that forgetting is the inability to find stored information. However, we don't know that the patients' sensations were true memories. They might contain some factual information, but the great bulk of detail could be manufactured, just as in a dream. The question of the permanence of LTM storage remains open.

There is no question, however, about the role of the chunking process in LTM. Chunking is the most effective method of guaranteeing long-term storage. Tests on mnemonists, people with exceptional powers of memory, show conclusively that structuring information in some imaginative way is the key to successful memorization. For instance, given a list of words to memorize, the mnemonist might weave them together into a fanciful story. Even if the process sounds silly, it works remarkably well.

So far we've only scratched the surface of the topic of human information-processing, and in an article of this size we can't do much more than that. Many questions remain unresolved. For instance, are STM and LTM two physically separate blocks of memory in the brain, as they would be in a calculator or computer? Probably not. For more fascinating unanswered questions try *Human Memory* by Roberta Klatzky ($6.95, W. H. Freeman and Co., 660 Market St., San Francisco, Calif., 94104). Much work remains to be done in this field, and if you like computers, you may just become hooked on cognitive psychology—the psychology of comprehension. ■

Solid State Multivibrators

☐ 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

Fig. 1

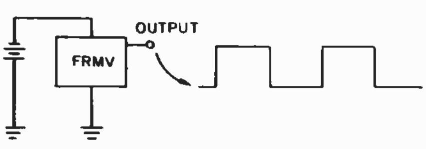


Fig. 2

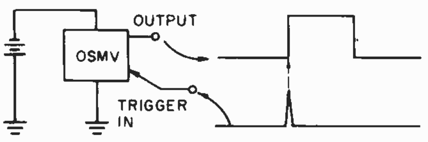


Fig. 3

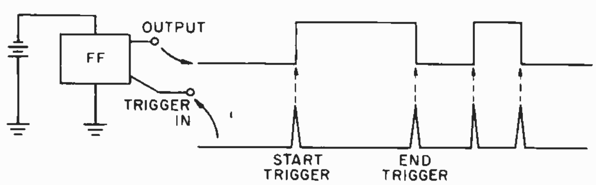
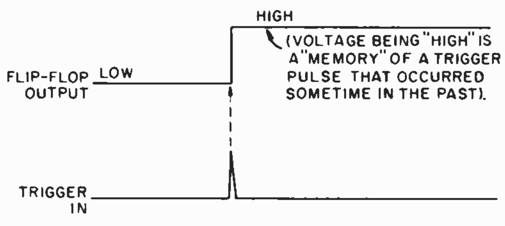


Fig. 4



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, grumpily doing absolutely 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.

Fig. 5

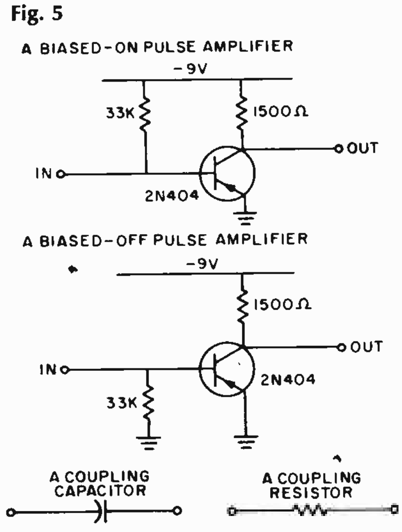


Fig. 6

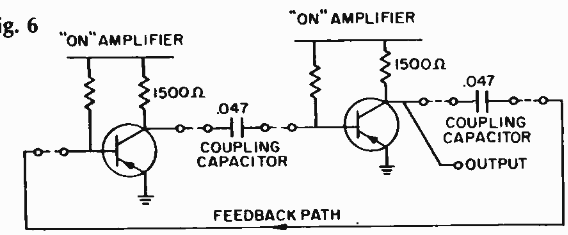


Fig. 7

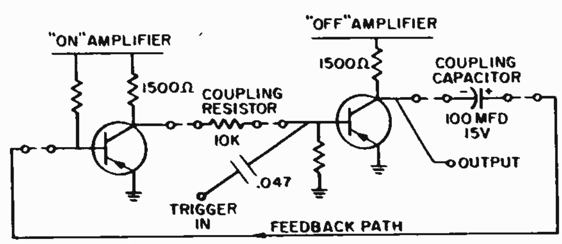


Fig. 8

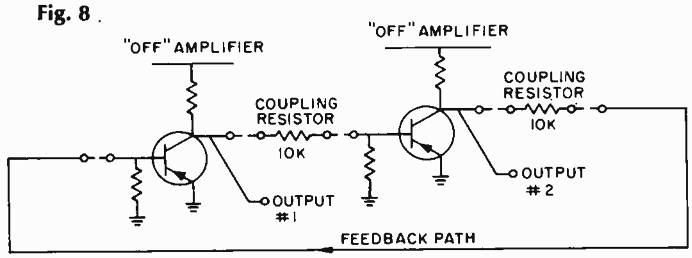
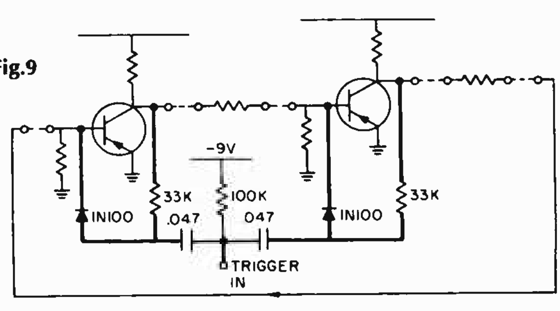


Fig.9



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 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. Now, leaving the voltmeter connected to one output as above, you can trigger the flip-flop by momentarily connecting the point marked "trigger in" to ground. Each time a trigger is supplied, the output that was at zero volts will jump to –9 volts. A second trigger will cause the same output to revert to zero volts.

Since it takes two triggers to make one complete output pulse from a flip-flop, feeding 500 pulses per second to the trigger input will cause only 250 pulses per second to come from the output. If these pulses are, in turn, fed to another flip-flop, its output will provide only 125 pulses per second. This ability of flip-flops to act as a frequency divider finds very wide usage in applications ranging from computers to TV and electronic organs.

So much, then, for the three basic types of multivibrators. What about that long list of names we bandied about in the first paragraph? Where do they come in?

We can parcel out all those names among the three basic types. For example, the free-running multivibrator is known in formal electron-ese as an *astable* multivibrator. The prefix "a-" tells us that it lacks a stable condition, and hence runs endlessly as long as power is supplied. The one-shot MV also answers to the name *monostable* multivibrator, "mono" stable being the state in which it grumpily sits while awaiting a trigger.

And, the flip-flop is also a *bistable* multivibrator because it has two, or "bi-" stable states, and will sit happily forever with a given output either "high" (–9 volts in the above example) or "low" (zero volts).

Other Names, Yet. Other names for the flip-flop include *toggle,* from its action in response to two successive triggers; *binary,* from its ability to rest in either of two states, and *Eccles-Jordan,* after the two men who described the circuit many years ago.

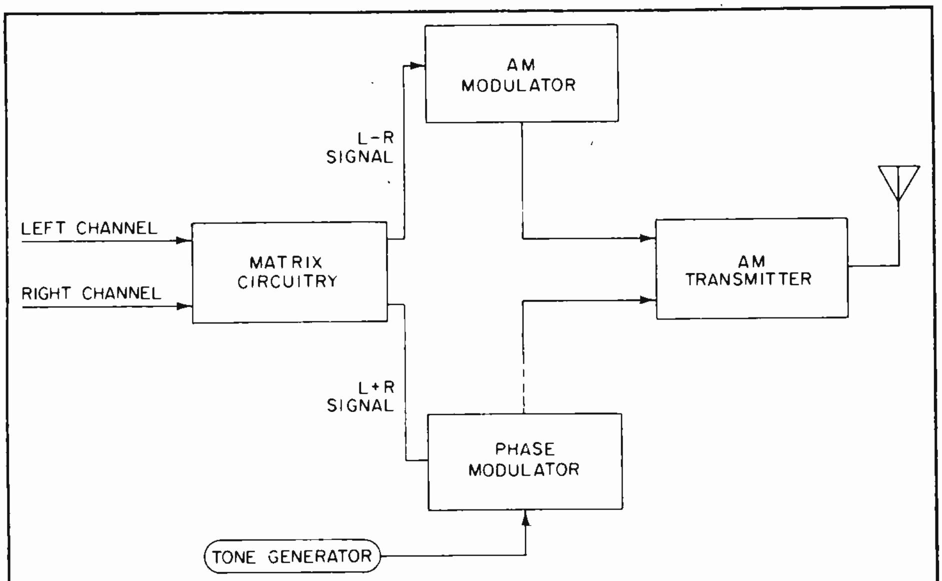
The names *one-step* and *univibrator,* as well as *single-step, single-cycle,* and *monovibrator,* are all much less common names for the one-shot. Similarly, the free-runing multivibrator is rather infrequently referred to as an *unstable* multivibrator or an *Abraham-Bloch circuit.*

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. ■

The Battle of AM Stereo

☐ The audio and broadcasting industries are currently on the brink of a revolution. Within a few months, the Federal Communications Commission (FCC) will almost certainly give the go-ahead for AM broadcast stations to begin operations in full *stereo,* placing them on better competitive footing with FM broadcasters and opening a new spectrum of possibilities for both audiophiles and DXers. The technology for AM stereo already exists—in fact, test broadcasts have already been conducted in the United States!

The concept of AM stereo is not a new idea. In 1958 the FCC was petitioned to allow AM stereo broadcasting, but refused to do so in an order released on October 2, 1961. The FCC cited technical problems for its refusal to allow AM stereo. Undaunted, several firms continued work on AM stereo systems, and one system was actually used for regular broadcasts by station XETRA, 690 kHz, in Tijuana, Mexico, during 1970! The technical difficulties that caused the 1961 rejection of AM stereo were gradually resolved, leading the FCC to formally propose the establishment of AM stereo on July 6, 1977, in docket 21313. Insiders in the broadcasting industry agree that AM stereo is inevitable—only the decision as to which method will be used to transmit and receive AM stereo is left for the FCC to decide.



The Motorola idea is to use dual summing networks and balanced modulators in order to separately modulate two carriers at the same frequency but at different phases. The carrier frequency oscillator is used to set the transmitter frequency. Output from the balanced modulators is combined with that of the carrier frequency oscillator's in a summing network and is then fed to a RF power amplifier. A system on the Motorola principle must use phase detection and balanced modulators, but avoids the use of matrices.

Why AM Stereo? It's difficult to believe that FM broadcasting was once an economic disaster area when one observes the huge market for FM receivers and tuners that exists today. But in the 1950's FM was at an extreme competitive disadvantage to AM. Stereo broadcasts for FM were authorized in April, 1961 and one of the reasons given by the FCC for FM stereo was that it could help FM broadcasters compete more effectively with their AM brethern. But, in subsequent years, the entire audio industry has shifted to stereo, and even quadraphonic sound, while AM radio has remained a monophonic medium. Many in the broadcasting industry now feel that FM is a more economically successful medium than AM due to the stereo advantage. It is widely felt that only the introduction of AM stereo can restore competitive balance between the two.

The widespread support for AM stereo is demonstrated by the composition of The National AM Stereophonic Radio Committee, one of the prime movers behind the drive for AM stereo. Included in the Committee's membership are the Institute of Electrical and Electronics Engineers, the Electronics Industries Association, the National Association of Broadcasters, and the National Radio Broadcasters Association. The Committee arranged for on-the-air tests of three stereo AM systems during August, 1977 and submitted the results to the FCC in reply to Docket 21313. Individual broadcasters are also anxious to begin AM stereo service.

"When the FCC approves a system, WBT is planning to broadcast in AM stereo on a full-time basis," says Richard Mertz, technical operations manager for station WBT in Charlotte, North Carolina. WBT was one of the stations that conducted AM stereo tests in August, 1977.

How AM Stereo Works. There are four basic systems for AM stereo competing for the FCC's approval. All four, like FM stereo, make use of two separate channels commonly referred to as the left and right channels. Beyond that, however, the four systems differ significantly from each other. The various methods are not compatible with the others; only one will be selected by the FCC for use.

The oldest system for AM stereo is known as the *Kahn system*, developed by Kahn Communications, Inc. Kahn was one of those who petitioned the FCC for AM stereo back in 1958. Although the petition was denied, Kahn continued work on their system, eventually leading to full-time use of it over station XETRA in Mexico, as mentioned earlier. While located in and licensed to operate in Mexico, XETRA puts a potent signal into the San Diego, California area and programs almost entirely in English for the San Diego market. Mexican broadcasting regulations are somewhat more flexible than those in the United States, and in 1970 permission was granted for XETRA to use the Kahn system for its regular broadcasts.

A regular AM signal consists of a carrier frequency and two identical sidebands on either side of the carrier frequency. Thus, for XETRA's 690 kHz frequency, its carrier was on 690 with two 3 kHz wide sidebands on 687-690 kHz and from 690-693 kHz. In simplified form, the Kahn system put one stereo channel on the lower frequency sideband and the other stereo channel on the upper frequency sideband. This system made it possible to receive AM stereo broadcasts by using two ordinary AM receivers. One receiver was tuned to XETRA's upper sideband while a second receiver was tuned to the lower sideband. All other stereo AM systems require receivers designed specifically for stereo reception. Proponents of the Kahn system have stressed this availability of AM stereo using conventional equipment in their proposals to the FCC.

The XETRA experiment was eventually discontinued. The FCC allowed Kahn to conduct tests of its system over station WFBR, Baltimore, Maryland during 1975. Yet despite Kahn's head start, most observers feel that it is highly unlikely that the Kahn system will be adopted by the FCC. More recent systems offer the potential for better fidelity and stereo quality than the Kahn system. Perhaps significantly, the National AM Stereophonic Radio Committee omitted the Kahn system from the series of AM stereo tests it conducted in 1977.

The AM stereo system that the FCC eventually selects will almost certainly be either the Magnavox, Motorola, or Belar System. The Magnovox and Belar systems use a combination of amplitude and phase/frequency modulation while the Motorola system uses phase differences between two signals to transmit both stereo channels on the same carrier wave. Stereo signals transmitted by all three methods can be received in mono on monophonic receivers without modification, while stereo reception will require receivers designed for stereo AM.

The *Magnavox system* uses a matrix circuit to convert the two channels into two new signals, one the sum of the frequencies of the left and right channels with the other the difference in frequency between left and right. The difference (L–R) frequency is AM modulated in the conventional manner while the sum (L+R) frequency is fed to a *phase modulator*. The phase modulator varies the phase, or time interval, between changes in the amplitude of the carrier current wave. The output of the phase modulator is fed to the AM transmitter and transmitted with the output of the AM modulator. An added feature of the Magnavox system is a tone generator which feeds a subaudible 5 Hz tone into the phase modulator. When received on a receiver designed for the Magnavox system, it lights a stereo indicator lamp similar to those found on FM stereo tuners. This is the only system with such a stereo identification provision and it is a strong point in favor of it. A receiver for the Magnavox system uses both AM and phase modulated detectors to recover the stereo transmissions.

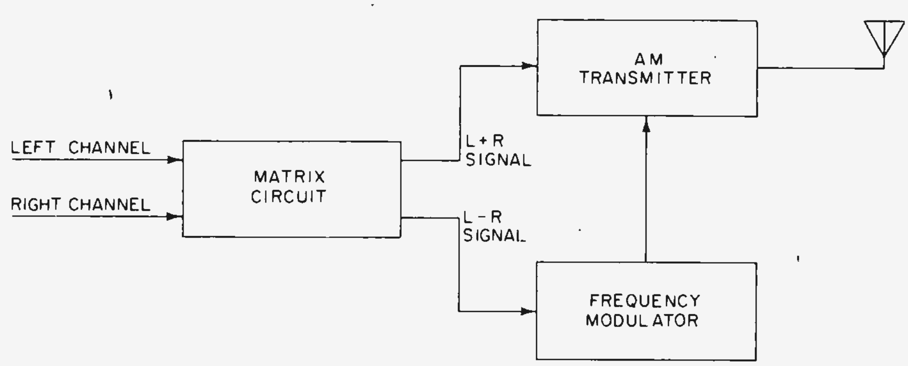
The *Belar system* was originally developed by RCA, although RCA is no longer actively involved in the development of AM stereo systems. Like the Magnavox system, the Belar method uses a matrix circuit to produce sum and difference signals from the two channel inputs. The sum signal is amplitude modulated in a conventional manner while the difference frequency is applied to a frequency modulator. The output of the frequency modulator is fed to a conventional AM transmitter along with the output of the amplitude modulator. The combined AM/FM signal is then transmitted as an AM signal in the usual manner. A Belar system receiver uses separate AM and FM detectors and a matrix circuit to reproduce the two channels.

The stereo AM system developed by *Motorola* uses summing networks and balanced modulators to separately modulate two carriers at the same frequency but in different phases. The transmitter frequency is determined by a carrier frequency oscillator. The output of the balanced modulators is combined with the carrier frequency oscillator output in a summing network circuit and then fed into a RF power amplifier. A Motorola system receiver uses phase detection and balanced modulators to recover the two stereo channels. An advantage of this system is that it avoids the use of matrix circuits.

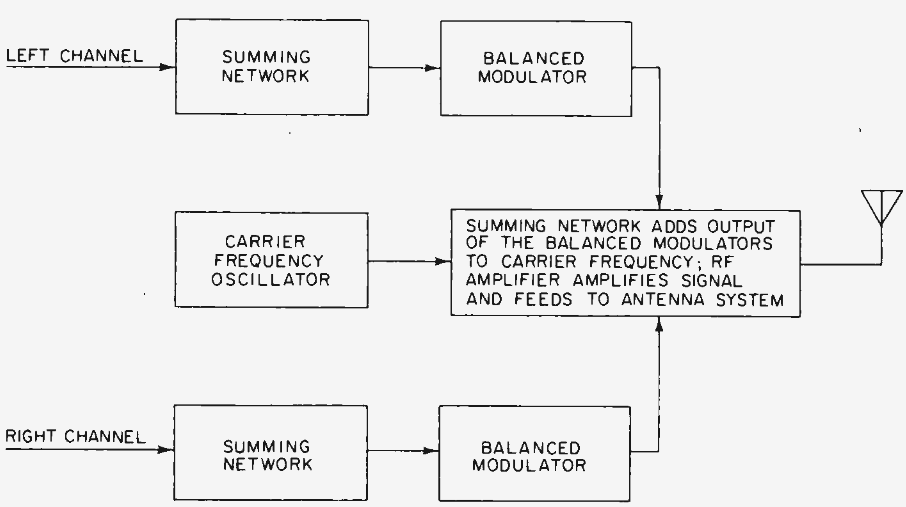
The Tests. The National AM Stereophonic Radio Committee has established a receiving site and laboratory in Bethesda, Maryland for the purpose of evaluating tests of the three AM stereo systems. The first tests were conducted over WGMS, 570 kHz, in Bethesda, Md., from August 7 to 10, 1977. The tests were conducted from midnight to 5:00 a.m., local time. The next series ran from August 11 through 15 over WTOP, 1500 kHz, in Washington, D.C. The potentially most significant tests were conducted over WBT, 1110 kHz, in Charlotte. N.C., on August 21. The tests were run from midnight to 5:00 a.m. WBT is a 50-kilowatt clear-channel outlet whose nighttime coverage is from Cuba to the Canadian Maritimes and provided an ideal test for the effects of skywave propagation on AM stereo signals. It is widely believed that the system that performs best as far as skywave propagation is concerned will be the one accepted by the FCC.

If you'd like to delve deeper into the highs and lows of AM stereo you could send for the *AM Stereo Report* from the Electronic Industries Association. The 500-plus page, spiral-bound book is available for $20.00 from: *AM Stereo Report*, Electronic Industries Association, 2001 Eye St., N.W., Washington, D.C. 20006.

Effects of AM Stereo. The introduction of AM stereo will have several effects on broadcasters, equipment manufacturers, and DXers. Broadcasters will likely have to upgrade their studio to transmitter link equipment, as most such links are today handled by telephone lines having virtually no response over 5 kHz. Considering that most AM tuners today cannot reproduce frequencies above 5 kHz, such a limitation poses no problem for monophonic transmission. Yet AM stereo



The Belar System begins like the Magnavox in that matrix circuitry produces sum and difference signals from the two channel inputs. The sum signal is conventially amplitude modulated while the difference frequency is applied to a frequency modulator. Both the outputs from the AM modulator and Frequency modulator are fed, in combination, to an AM transmitter. The combined AM/FM signal is then transmitted as an AM signal, in the usual way. Separate AM and FM detectors and matrix circuit must be used in Belar receiver.



Stereo's two channels, using the Magnavox system, are first converted by matrix circuitry into two new signals; one the sum of the left and right channel frequencies and the other being the difference between those frequencies. The difference (L—R) frequency is AM modulated while the sum frequency (L+R) is phase modulated. A nice touch is a tone generator which adds a subaudible, 5 Hz tone to the phase modulation. A receiver may be designed with a stereo indicator lamp which will light up whenever the tone is received.

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Check box for G.I. Bill information: ☐ Veteran ☐ On Active Duty receivers are envisioned as having response equal to that of stereo FM tuners, on the order of 15 kHz. The introduction of AM stereo will finally force AM broadcasters to pay attention to the range of audio frequencies they transmit. Likewise, equipment manufacturers will devote more attention to the AM section of AM/FM receivers. Current design practice seems to regard the AM section almost as a necessary evil.

DXers will find themselves hunting for distant stations broadcasting in stereo, and the improved AM receivers will be a boon for BCB DXers. Other special equipment, such as directional BCB loop antennas, will likely become available. Yet the improved audio range of AM stereo stations will cause more co-channel interference and may make digging out weak foreign stations on the "split" frequencies between the even 10 kHz frequencies a difficult task.

And even those who only tune the shortwave bands may not be left out—international shortwave broadcasts are AM, after all! Wouldn't you like to spend a cold winter evening listening to South Seas music from Radio Tahiti—in stereo? ■

How Transmitters Work

☐ One if by land, and two if by sea..." says the famous poem by Longfellow commemorating the midnight ride of Paul Revere in April of 1775. Revere's fellow patriot, who hung the two (if by sea) lanterns in the steeple of the Old North Church of Boston 200 years ago, was engaged in *communicating by modulation,* just as surely as today's CBer who presses the PTT switch on his microphone. For *modulation* simply means *variation,* or *change*—and it's modulation, whether you're changing the number of lanterns hanging in a church steeple, or using electronic circuitry to change the radio wave emitted by an antenna in accordance with your voice.

All communication is by modulation. For centuries, the American Indians sent messages by "modulating" a smoke stream with a wet blanket, and primitive tribes have long communicated by modulating the beat of their jungle drums. Later, semaphore flags were used to send messages by modulating their position. Even these words you are reading can be considered modulation of the surface of a piece of paper with spots of ink.

But almost all of today's long-distance instantaneous communication is carried out by modulating radio waves. In fact, this means of communicating is now so commonplace that even the Man the Street unknowingly refers to modulation when he speaks of "AM" and "FM". These familiar abbreviations stand for *Amplitude Modulation* and *Frequency Modulation,* respectively, and refer to the two common methods of changing a radio wave to make it broadcast words or music from one place to another.

Introducing the Carrier. A radio wave broadcast from the antenna of a transmitter is, in the absence modulation by speech or music, an unchanging, constant sine wave, as shown in Fig. 1. It is as constant and as unchanging as the steeple of the Old North Church, and conveys no more information than a steeple. It simply gives you something to monitor for the possible later appearance of a signal.

Just as the steeple was a support or carrier on which to hang the information-giving lanterns, so the radio wave becomes the carrier upon which the speech or music is "hung". In fact, the unmodulated wave is usually referred to as the *carrier.*

The carrier may be shown as a simple sine wave, as in Fig. 1.

The height, or amplitude of the wave, indicates the strength of the signal, while the time it takes the wave to complete a certain number of cycles determines the spot on the radio dial where the signal will be received. For example, as shown in Fig. 2a if it takes only a millionth of a second for the carrier to complete seven cycles, then it will complete 7,000,000 cycles in one second, and the signal will appear on a receiver's dial at the 7,000,000-cycle-per-second (7-megahertz) point, which is on the edge of the 40-meter ham band. Such a carrier has a *frequency* of seven MHz.

On the other hand, a carrier taking longer to complete the same number of cycles—say, seven cycles in 10 millionths of a second (Fig. 2b)—would complete only 700,000 cycles in one second, and would be found on the dial at 700 kHz (700 thousand Hertz), which is in the standard broadcast band.

As can be seen from the above numbers, carrier frequencies are normally very high—much higher than the speech or music (audio) frequencies which we will cause the carrier to carry. For example, when a flutist plays the note F above middle C, he produces vibrations in the air which can be visualized as in Fig. 2c. Here, the time for 7 vibrations is only *one fiftieth* of a second, which is a frequency of only 350 cycles per second (350 Hertz).

But a constant (*unchanging*) carrier wave conveys no information. Something about the wave must be *varied*

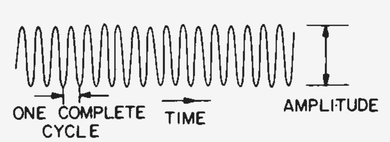


Fig. 1—Unmodulated carrier (RF) wave.

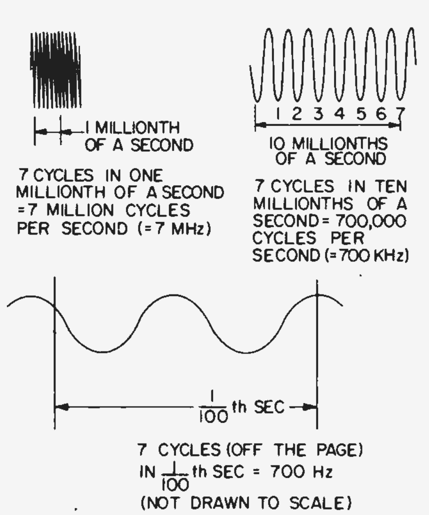


Fig. 2—Three different frequency waves. 700 Hz (bottom) is partial, not drawn to same scale as the two higher frequencies.

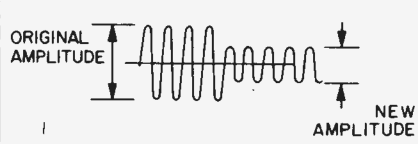


Fig. 3—Simplified amplitude modulation of the RF carrier wave.

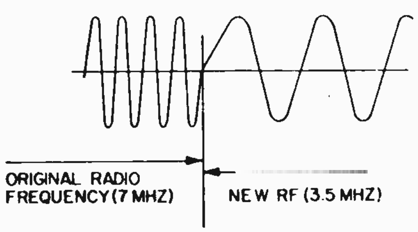


Fig. 4—Simplified frequency modulation of the RF carrier wave.

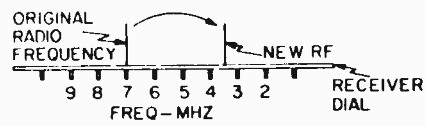


Fig. 5—If the frequency modulation were a simple change from one RF carrier frequency to another, an AM receiver could receive it if retuned.

(modulated) to convey information to the listener. What can be changed, so that the listener can recognize that a signal has been sent to him?

AM and FM. Looking again at Fig. 1, you can see that a carrier has two obvious characteristics—its height, or *amplitude*, and its *frequency*. Changing either of these can cause a receiver to recognize that a message has been sent. If the amplitude is changed, we call it *amplitude modulation*, or AM. If the frequency is changed, we call it *frequency modulation*, or FM.

A very simple type of AM is shown in Fig. 3. Here the amplitude of the carrier wave has been changed suddenly to half its former value.

This change in amplitude is a simple form of AM, and can convey simple messages. If Paul Revere had been a CBer, he could just as easily have prearranged a code signal which said ". . . one drop in carrier amplitude if by land; two drops in carrier amplitude if by sea . . ." and served the American cause just as well (though Longfellow's poetry might have suffered).

The other obvious characteristic of the carrier wave of Fig. 1 is its *frequency*. We can also modulate this characteristic, as shown in Fig. 4. Here, instead of a sudden change in amplitude, there is a sudden change in frequency, from 7 MHz to 3.5 MHz. This is a very simple form of FM, and can also be used to convey simple messages. Since the drop in frequency represents a shift in the carrier's location on the dial, as shown in Fig. 5, two receivers, one tuned to 7 MHz and the other to 3.5 MHz, could detect this shift in frequency, and the listener could interpret it as a signal, according to a pre-arranged code.

What's PM? While the Man in the Street has made AM and FM household phrases, these modulation methods are only two of the three ways a radio frequency carrier wave may be modulated. The third method, *Phase Modulation*, or *PM*, although virtually unknown to most people, is nonetheless extremely important in such fields as data transmission and color television.

Phase modulation can be visualized as in Fig. 6. Here, neither the amplitude nor the frequency is varied, but the carrier is made to pause for a moment, and then to continue as a sine wave slightly delayed from the original. This delay is called a *phase shift*. Phase shift is usually measured in *degrees*. A phase shift equal to the time needed for an entire cycle is 360°. In the sketch, a sudden phase shift of about 70° (less than a quarter cycle) is indicated. By suitable receiver circuitry (found in every color TV receiver), this sudden change in phase can be interpreted as a signal. In color TV, it might represent a shift in hue from green to yellow.

Amplitude Modulation—A Closer Look. The sudden drop in amplitude shown in Fig. 3 is a good way to show the general scheme of AM, but it fails to tell us very much about how AM is used, every day, in our AM receivers and CB rigs. Here there are (hopefully) no sudden shifts in carrier amplitude, but instead, there is a remarkable recreation of speech and music from a distant transmitter. How is this done?

To explain, let us assume that our flutist stands before a microphone in a broadcasting studio, ready to play his 350-Hz F-above-middle-C. Let's also

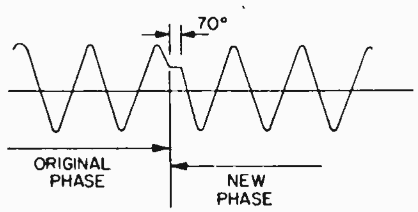


Fig. 6—Simplified phase modulation of the RF carrier wave.

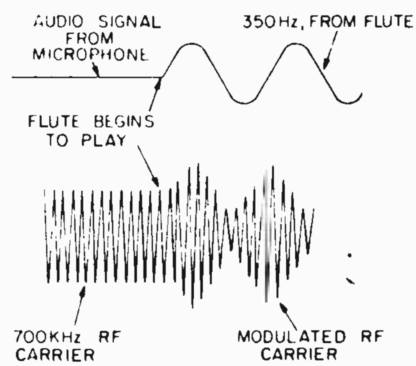


Fig. 7—The audio signal (sound) modulates the RF carrier wave.

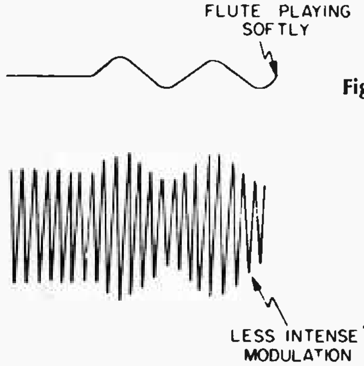


Fig. 8—Smaller audio signal modulates the RF carrier wave less.

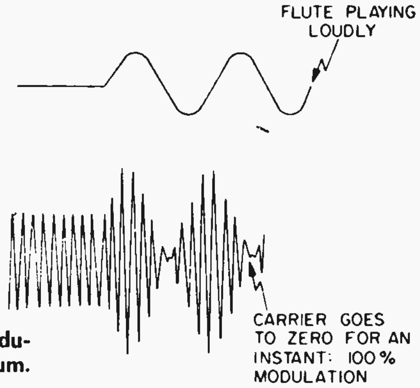


Fig. 9—Louder audio signal (sound) modulates the RF carrier wave to maximum.

assume that the broadcasting station is assigned a carrier frequency of 700 kHz. Figure 7 shows how the carrier wave will appear just before the flutist plays, and just after he begins.

As you can see, the 350-Hz audio tone from the flute causes the amplitude of the carrier to rise or fall in accordance with the rise or fall of the flute wave. Note that both the top and bottom of the carrier wave are affected by the flute waveform. It is as though the carrier had been squeezed into a snug-fitting envelope, forcing it to conform to the waveform of the flute sound. The shape thus formed by the tips of the modulated carrier wave is often called the *envelope*.

The envelope of an amplitude-modulated carrier is therefore a good replica of the audio waveform coming from the studio microphone. Every shading, every change, in the sound striking the microphone will be faithfully traced out by the tips of the carrier wave. For example, if the flutist were to play more softly, the result will be as in Figure 8. If he plays more loudly, Figure 9 is the result. You will note that in Fig. 9 the amplitude modulation is so intense that, at one point, the carrier's amplitude goes to zero for an instant. This is called 100% modulation, and represents the loudest sound AM can handle. If the flutist plays even *more* loudly, the result is as shown in Fig. 10. As the figure shows, the envelope is no longer a faithful replica of the original audio waveform, so the listener will receive a distorted sound. This condition is called *overmodulation*, and is undesirable.

Hardware for AM Systems. One of the most-straightforward methods of producing AM is the method invented by the Canadian Reginald Fessenden, in 1905. In his system, a radio frequency generator produced the carrier wave, which was fed to the antenna through a carbon (variable-resistance) microphone. See Fig. 11.

Since a carbon microphone varies its resistance in accordance with the speech or music, the microphone in this primitive system acted as a valve to allow more or less of the RF carrier wave to pass to the antenna. In this way the carrier wave broadcast by the antenna was amplitude modulated by the sound waves striking the microphone.

More Up-to-date Modulation Methods. Although nobody puts carbon microphones in series with antennas any more, the more modern modulation methods, such as those found in AM broadcast transmitters or CB transmitters are still rather similar to the primitive carbon-mike method. The typical modern AM system (Fig. 12), still employs an oscillator (which is crystal-controlled, to ensure that the carrier frequency is constant, and thus is found at a known spot on the dial), and a power amplifier to strengthen the carrier before feeding it to the antenna. The amount of "strengthening" is con-

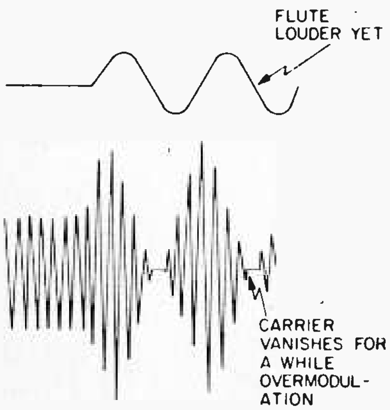


Fig. 10—Further increase in amplitude of audio signal causes overmodulation.

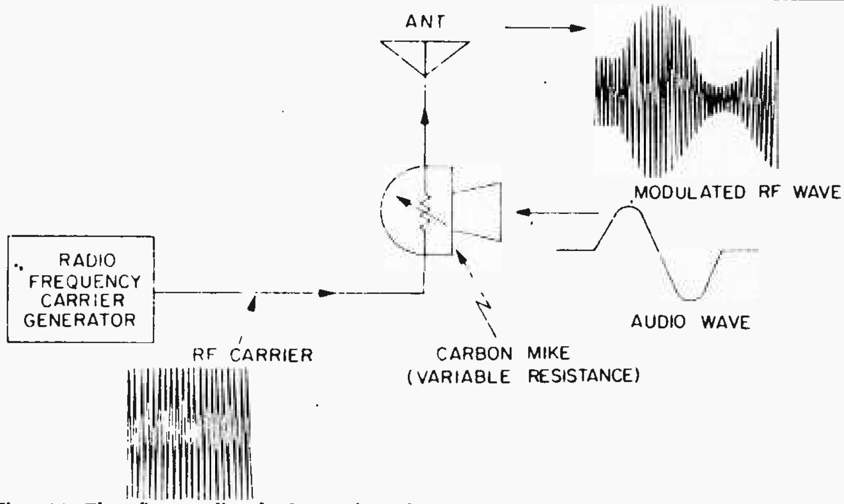


Fig. 11—The first radiotelephone broadcast transmitter, invented by Canadian Reginald Fessenden, who broadcast voice and music to a few ships at sea on Christmas Eve, 1905. It worked, but was very noisy.

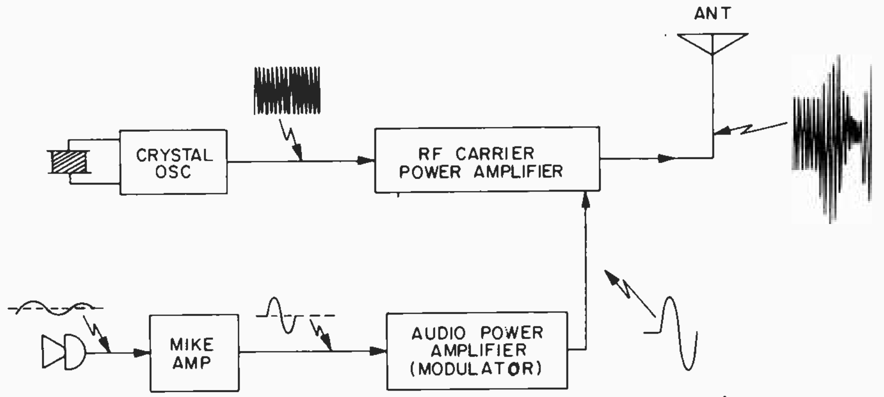


Fig. 12—Typical amplitude-modulated RF (radio frequency) transmitter.

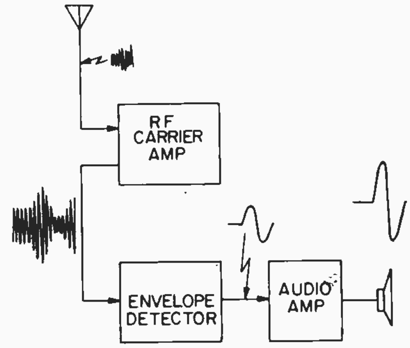


Fig. 13—Block diagram of receiver for amplitude-modulated radio frequency (RF) signals.

trolled by the audio signal, and the music to a distant point.

Receiving the Signal. At that distant point, we all know that the carrier power delivered to the antenna is in this way amplitude-modulated and the radiated carrier will convey the speech or wave may be intercepted by a suitable antenna and applied to a receiver. A simple receiver is shown in block diagram form in Fig. 13. Here, the weak signal from the antenna is first amplified in a carrier-wave amplifier, (an RF (radio frequency) amplifier, and applied to a *detector* which can extract the original audio signal from the amplitude-modulated RF carrier. This audio wave is further amplified and then fed to a loudspeaker, which re-creates the original speech or music.

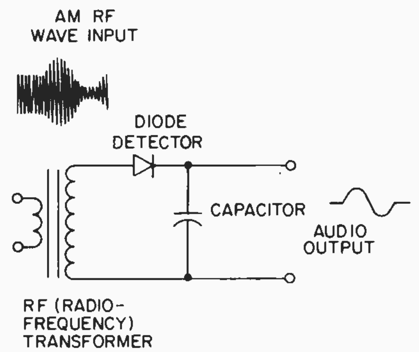


Fig. 14—Simple receiver of amplitude-modulated (AM) RF signals.

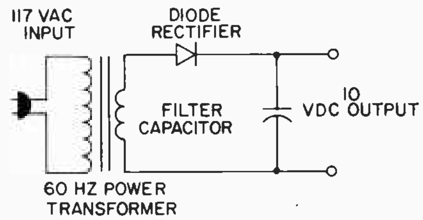


Fig. 15—DC power supply from AC house current has circuit similar to that of the simple AM receiver.

The Detector—Heart of the Receiver. By looking at Fig. 13, you can see the detector is the heart of the AM receiver which extracts the original signal from the amplitude-modulated carrier. The circuit that does this job is suprisingly simple. It resembles very closely the circuit of a typical power supply. In an AC power supply, when 117-volts AC is applied at the input plug, a DC voltage appears at the output. If, because of a brown-out or for some other reason, the 117 volts at the input drops to, say, 105 volts, the DC output will drop correspondingly. In a power supply, this output drop is undesirable—we want the DC output to remain constant even though the input AC varies. Notice that the drop in voltage of the 60-Hz power line input from 117 volts to 105 volts is *actually amplitude modulation,* of the 60-Hz input sine wave, and *the drop in the output DC has "detected" the AM that occurred at the input!* This is shown in Fig. 16.

So a simple AM detector may be thought of as a power supply arranged to change its output very quickly in accordance with the amplitude changes in the AC (carrier) at its input. And, since these fluctuations in amplitude of carrier represent the original audio signals, the "power supply" (detector) output will be the same as the original audio. It's interesting to note the power supply's undesirable trait, unsteadiness in output when the input is unsteady, is the useful operating characteristic of the same circuit when used as a detector! ■

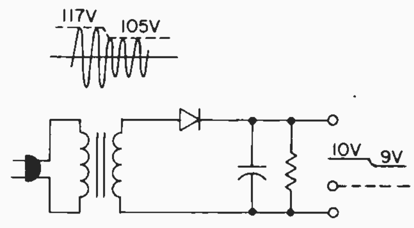


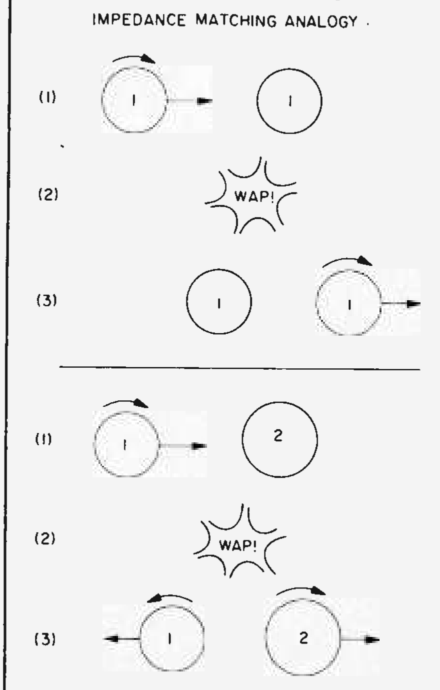
Fig. 16—Changing amplitude of voltage input to power supply provides changed (modulated) output.

Antennas for Two-Way Radio

☐ If you happen to be a two-way radio enthusiast and are interested in "getting out" in the CB slang sense of the phrase, then you have come to the right place, for here you will find everything you need to know in order to squeeze every last inch of range out of your two-way radio.

Here are six things to think about while trying to boost your CB's range.

Antenna Height. First, for maximum range your antenna should be as high



Impedance matching can be represented by the transmission of energy from one rolling ball to another stationary one. If both have equal mass the first will stop and the second take off at equal speed (in a frictionless system). If the second ball is more massive, as illustrated in the three bottom drawings, the first ball will bounce back just as RF will bounce back if an antenna is improperly matched to the transmitter and line.

as legally possible. It is said that you can talk about one-third farther than the line-of-sight distance between the tip of your antenna and the tip of the other fellow's antenna, and the higher the antennas, the greater the line-of-sight distance. This effect comes from the fact that although light travels in a straight path, radio waves tend to follow the shape of the earth's surface somewhat. Therefore, although someone's antenna may be below the horizon so you can't see it, your radio signals may still reach him if he isn't too far below.

The question, then, is what is the legal maximum height? For omnidirectional antennas (those which radiate equally in all horizontal directions), the height limit for the tip is 60 feet. The limit for directional antennas is 20 feet.

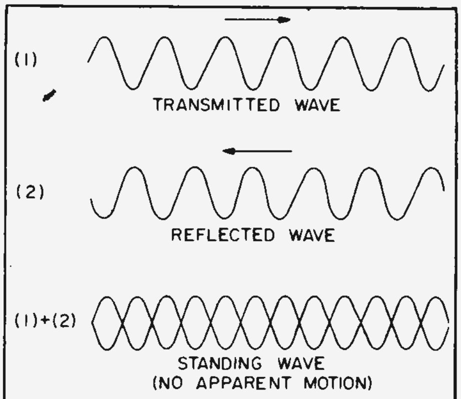
But it is possible to do a lot within these limits if you want to increase your range badly enough. For example, put your antenna on top of a nearby hill instead of right next to your house. But of course, you will need a lot of line for this trick.

Another thing you can do is put your antenna on top of a tall building. If the building is more than 40 feet high, you are allowed 20 feet above the top of it. Obviously, mounting your antenna on top of a good-sized building can put it well above what a neighbor could achieve working from the ground up.

Standing Wave Ratio. Second, there is the matter of SWR or standing wave ratio. A good way to visualize this is through a physical analogy. Imagine a ball bearing rolling along. Since it is moving, it possesses some energy of motion (kinetic energy). Suppose this ball bearing were to collide with another ball bearing which had equal mass and was stationary. Upon collision, the rolling bearing's kinetic energy will be totally transferred to the formerly stationary bearing. The transfer of kinetic energy will be 100 percent, but only because the bearings are of the same mass. It reminds one of head-on collisions between billiard balls.

In electronics, impedance (like resistance) plays the role that mass played in the ball bearing analogy. Ideally you want 100 percent energy transfer from the transmitter to the antenna, but this can happen only if the impedance of the transmitter and that of the antenna match. Otherwise, some of the energy is reflected back from the antenna to the transmitter.

What you have then is waves traveling from your transmitter to your antenna and from your antenna to your transmitter, both at the same time. The two sets of waves interact to form standing waves, which decrease the efficiency from maximum and could damage your radio to boot.



These diagrams show how the transmitted wave and the reflected wave interact to form a standing wave that decreases the efficiency of your transmission.

The presence of such waves can be detected by an instrument which measures standing wave ratio. This quantity is a number which you want to be as low as possible.

Here are some sample SWR readings together with what they will do to your radiated power:

SWR	Percent Reflected Power	Radiated Power
1:1	0%	4.00 watts
1.5:1	4%	3.84 watts
2:1	11%	3.56 watts
2.5:1	18%	3.28 watts
3:1	25%	3.00 watts
∞:1	100%	0.00 watts

3:1 generally is considered to be the highest SWR a CB radio can live with. And really, that is too high, too. 1.5:1 or less is more like it.

So buy yourself an SWR meter (they're inexpensive) and check your radio from time to time. If the SWR is too high, getting it down to size usually is just a matter of changing the length of the antenna, provided it is not a fiberglass one.

The procedure for checking a mobile antenna's SWR goes like this: Check the SWR on the highest channel, and then check it on the lowest channel. Ideally, these two numbers will be the same and as low as possible. If the SWR on the highest channel is higher, this indicates the antenna is a bit too long and must be shortened. If the SWR on the lowest channel is higher, then the antenna is too short and must be extended a little. When the two SWR's are identical, then the SWR on the middle channel should be as low as it is going to get, hopefully near 1:1.

Changing the SWR of a base antenna is another story. There is no convenient little screw to allow you to manipulate the length. If a base antenna's SWR is too high, there is probably something wrong with it or the line leading to it, like bad or wet connections or broken wires. Use your own ingenuity to figure out just what is messed up.

Antenna Gain. Third, there is the fact that all antennas are not created equal. There are those which radiate the legal 4 watts and that's it, and there are those which radiate 4 watts but seem as though they have more effective radiated power (ERP). By mathematically relating the real power output with the ERP we can derive the antenna gain which is normally measured in dBs or decibels.

An easy way to visualize this is to try the following simple experiment: Look at a low-power electric lightbulb, say 10 watts. Your eyes are perceiving 10 watts of light power. Now, hold up a mirror next to the bulb so that you now see two bulbs side by side. Your eyes perceive 20 watts of light power. If you put up a second mirror to see three images you will see 30 watts even though the bulb is still only putting out 10 watts. The ratio of ERP to power is three to one and the ERP multiplication factor is three.

All antenna gain measurements work in much the same way but instead of a 10-watt bulb we use a "standard dipole" antenna. The power received from a test antenna is compared to the power received from the "standard dipole" and the ERP multiplication factor and gain is determined by applying the mathematical equation that is explained elsewhere in this article.

This equation, if reduced to a more readily useable graph form, looks like figure 1. The graph can be used to find an antenna's multiplication factor (and hence ERP) whenever its dB gain is known. If you know the dB gain, just go up to that number on the dB gain axis, then go straight across until you hit the curve, and then drop down to the multiplication factor axis and read off the antenna's multiplication factor. That number times 4 will get ERP.

ERP and Range. So now you know just what your ERP is. What does this mean in a practical sense? If your ERP is, say, three times the basic 4 watts, does this mean you can talk three times as far?

No, it doesn't. You will be able to talk farther, but not three times as far. To find out exactly how much farther, consider the following:

Suppose that at some distance R some radio signal comes in just as strong as some other radio signal at some other distance r. For the two signals to come in at the same strength, their intensities (power per unit area) must be the same, but the ERP must be greater for the signal to travel distance R. By turning this all around mathematically it is possible to discover how much farther a signal will reach (in terms of r) if you know the ERP. Again the mathematics are shown elsewhere in this article and can be reduced to the graph form as shown in Figure 2.

On the graph, the range of an antenna whose ERP is only 4 watts is taken as 1. The range of other antennas will then be so many times this distance.

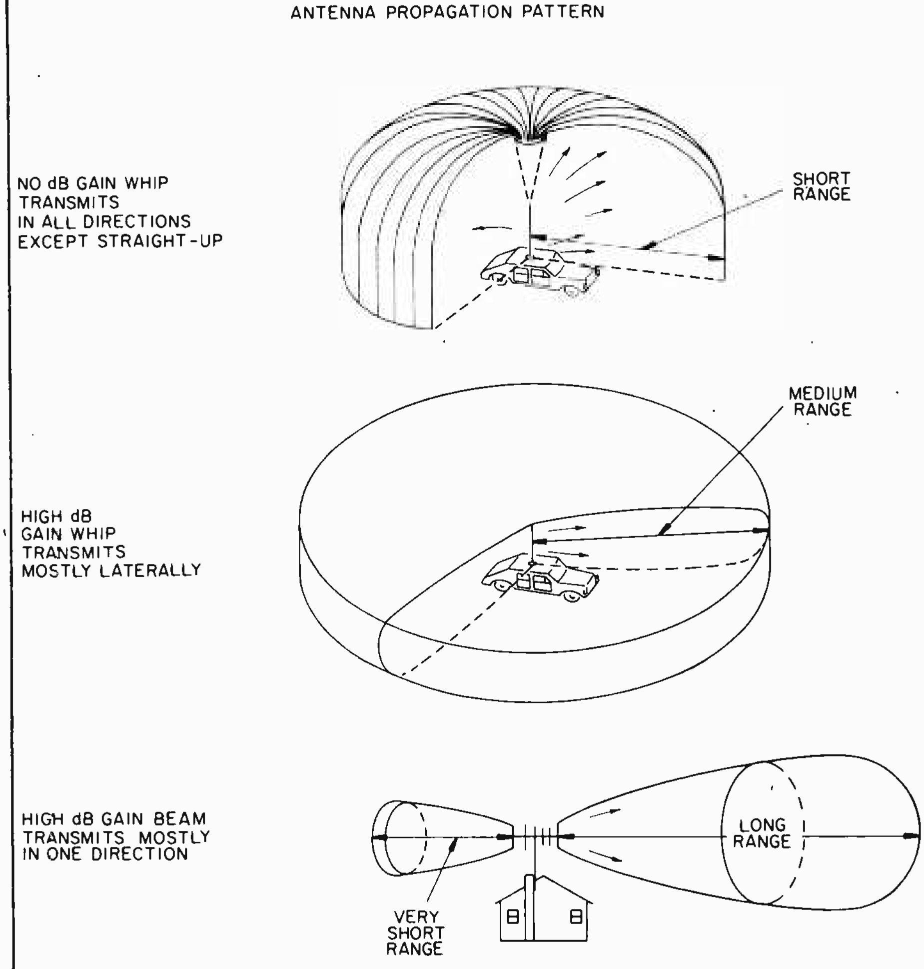
For example, the original question was, if an antenna's ERP is 12 watts, how much farther should you be able to talk than with just the basic 4 watts? The answer is readily attained using the graph. Go up the ERP axis until you find 12, then go straight to the right until you hit the curve, and then drop down to the range axis and read off the relative range. In the case of 12 watts you get 1.73, which means you can talk 1.73 times as far as with an antenna with no dB gain.

Beams. But there is just so much dB gain which can be built into an omnidirectional antenna, no matter how clever the designer is. If you want more than five or so dB gain, then you have to move on to a directional antenna, a beam.

A beam gets its super dB gain from taking the idea behind omnidirectional antennas with gain and taking it one step further. An omnidirectional antenna with no gain takes your 4 watts and sprays it all over the place, a lot of it skyward. The skyward part is of no use to anyone, so if it could be eliminated, there would be more to spray out parallel to the ground where it is needed—there would be a gain in useful power, a dB gain.

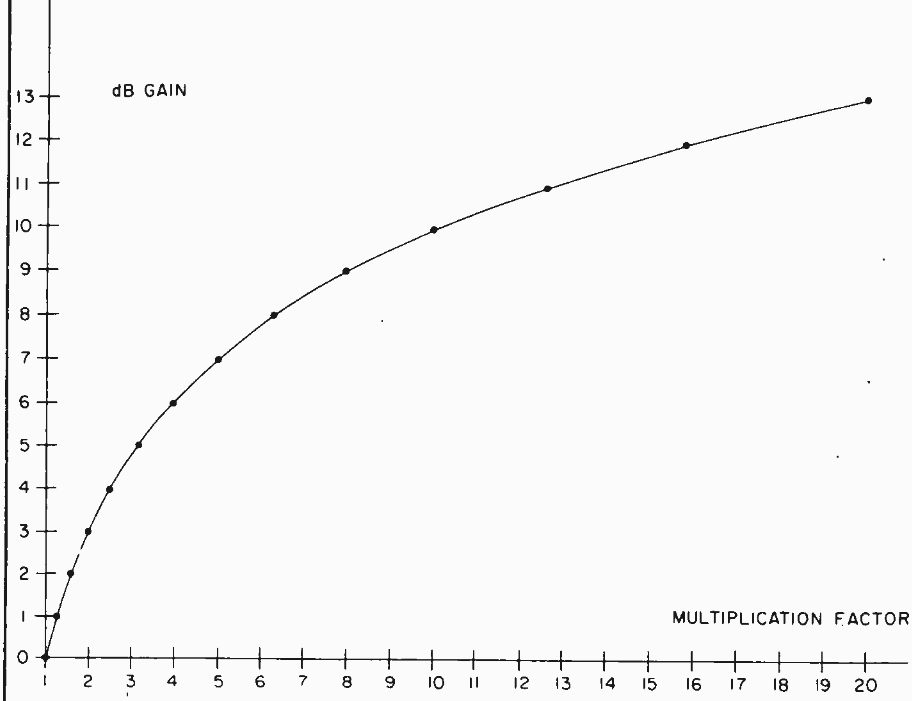
But even if all your power were sprayed out parallel to the ground, a lot of it still would be wasted. Since generally you are interested in being heard in only one horizontal direction at a time, why waste a lot of power in all the other horizontal, non-skyward directions, too? Why, indeed. So a beam more or less eliminates all wasted energy and radiates in one and only one direction at a time.

It is a neat trick and is accomplished like this: The simplest beam antenna is composed of three parts or elements. The radio signal is fed into the driver element, which radiates in the usual way. But the reflector element tends to bounce back any waves radiated towards it. This tends to strengthen the signal in the other direction. On the other side of the driver is a director element. It tends to reradiate any energy which is passing by it, narrowing the radiated energy into a stronger, more concentrated beam. More than



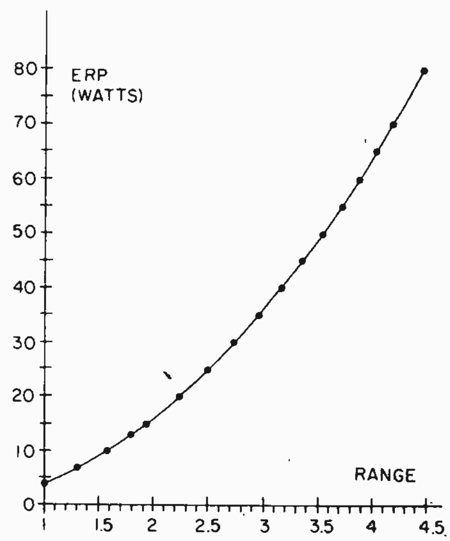
These three drawings are simplified illustrations of antenna propagation patterns. The top diagram is of a unity gain whip antenna—RF propagates equally in almost every direction. The middle antenna is a whip with some gain such as a 5/8 wave VHF antenna or an antenna with an effective ground plane. It will transmit more of its radiation horizontally rather than waste it trying to reach birds. There are thousands of different types of beam antennas but they all try to achieve the results shown in the third drawing—to put the RF out in one direction with as little wasted energy as possible. These antennas also receive directionally. At short ranges they transmit and receive in all directions.

FIGURE 1.



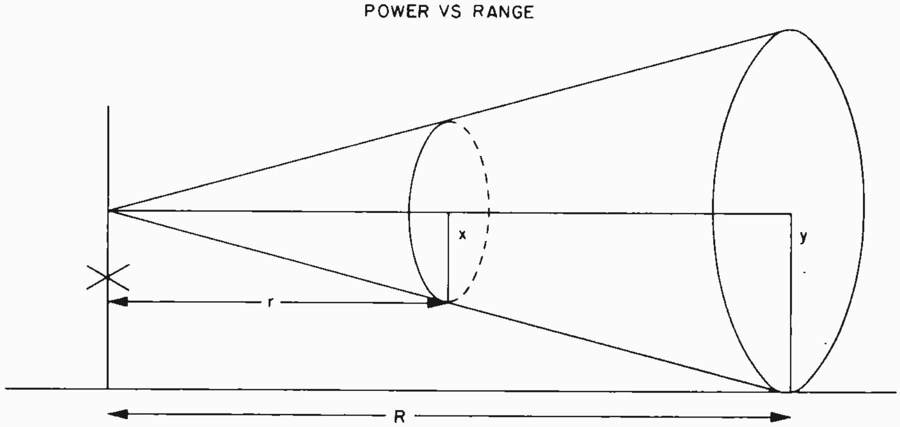
This graph can be used to determine the dB gain if you know the multiplication factor or the multiplication factor if you know the gain. For example; a 12 dB gain will equal a multiplication factor of 15.5. This is much more convenient than the formula.

FIGURE 2.



By using this graph your probable range can be determined if you know your effective radiated power (ERP). For example: If your set has a range of 5 miles with no gain (ERP 4 watts for CB), increasing the ERP to 35 watts will up your range to 15 miles (Range factor of 3, times 5 miles).

POWER VS RANGE



Power is measured in milliwatts per unit of area—usually milliwatts per square meter—and by using some basic geometry you can see that if R is twice r then it would take four times as much energy to send an equal signal the longer distance.

If you don't mind doing a little math you can derive your dB gain and the range that gain should give you by using the following equations.

dB Gain. This factor can be determined by using the antenna multiplication factor and a logarithm table or the *log* button on your calculator, and applying the following formula, where ERP = Effective Radiated Power and P = Power:

$$\text{dB gain} = 10 \log \frac{ERP}{P}$$

or

$$\text{dB gain} = 10 \log (\text{multiplication factor})$$

Range. In the diagram below two transmitters put out signals that are received at equal strength at distances R and r respectively. That is, the power per unit area is the same at each point of reception. From these geometrical relationships we can derive the following formula.

$$R = r \sqrt{\frac{ERP}{P}}$$

In this equation R represents the larger range provided by an antenna with a dB gain, and r represents the range of an antenna with no dB gain.

one director will increase this effect, so there are beams with more than three elements.

The only problem is that if someone is trying to talk to you from a direction other than the one in which your beam is pointed, you may never even notice him. Therefore, a beam is seldom used all by itself. An omnidirectional antenna is usually used with the beam as a stand-by antenna. You listen for callers on the stand-by antenna and then point the beam at them to talk.

Power Mikes. And finally, there are power mikes. When a microphone is keyed, a carrier wave is sent out. It is a steady kind of radio wave, having the same amplitude always. (On a wave diagram, the amplitude is represented by the height of the wave.)

When a microphone is keyed and then someone talks into it, the voice signal causes changes to take place in the amplitude of the carrier wave. These changes are called modulation. Given two signals of equal strength, the one with the better modulation will be clearer, louder, and more easily understood.

There are various ways to increase your modulation. You can hold the microphone very close to your lips and talk loudly into it, and this will give good modulation. Or you can buy a power mike and then not worry about where the mike is or how loudly you speak—the power mike will take care

of it.

If you do want to buy a power mike, there are some things to remember. First, not all power mikes fit all radios. Second, it takes some skill to install a power mike. And third, if your radio has a mike gain knob on it, you already have a power mike.

Now, I don't want to offend you or make you feel unwelcome, but why don't you take your radio and get out?! ■

Understanding Superhets

☐ Born out of necessity during World War 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—even the integrated-circuit-and-ceramic-transformer variety—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

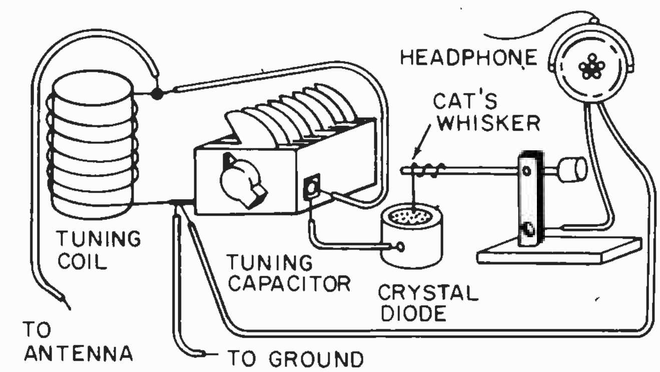
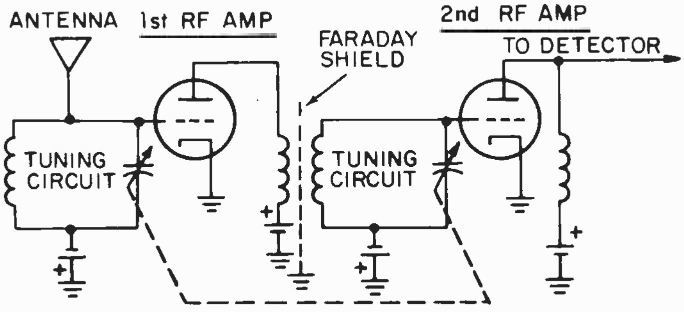


Fig. 1. Schematic representation of crystal radio shows how cat's whisker gently contacted diode surface in order to achieve demodulation of RF signal. Earliest semiconductor diodes made were miniature crystal diode/cat's whisker affairs encased in glass package.

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

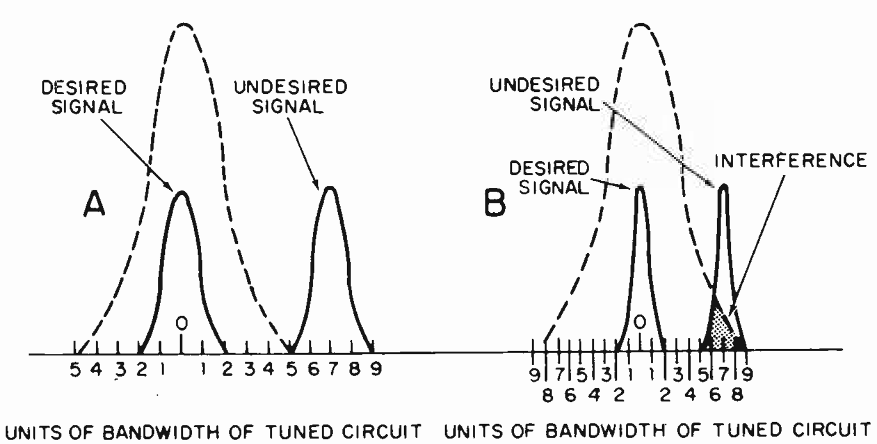


Fig. 3. Tuned-circuit bandwidth varies proportionally with frequency. Tuned circuit A, working at low frequency, rejects unwanted signal. Tuned circuit B, working at high frequency, can't completely reject undesired signal; interference results.

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. All of this is well and good, but how do we actually extract our Top-Forty tunes, news, and weather from our super-duper-het?

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

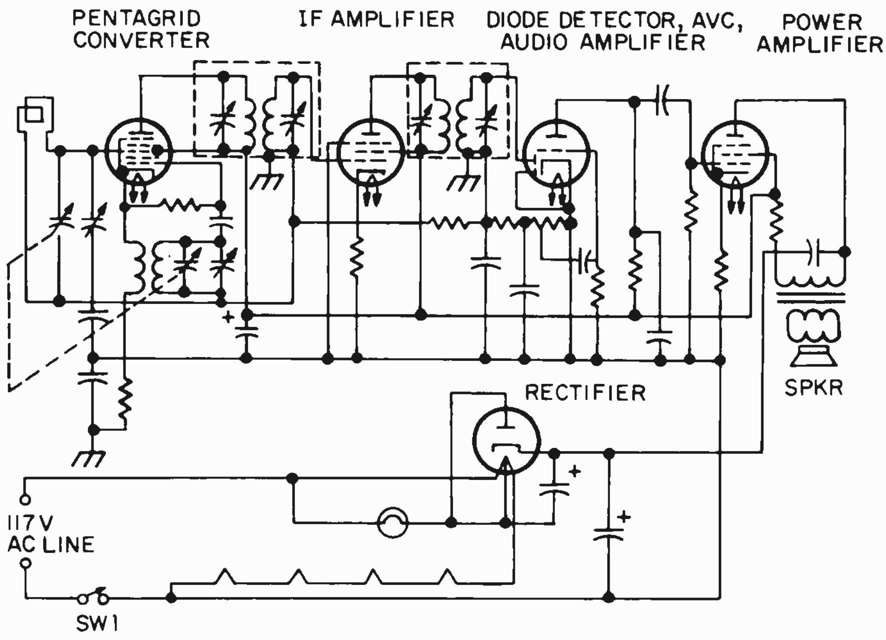


Fig. 4. Virtually all superhets sold commercially are five-tub rigs; most are also, in terms of design, electrically and mechanically equivalent.

IF frequency. This ganged antenna/oscillator capacitor ensures the necessary *tracking* of the local oscillator with the radio-frequency signal.

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. It's as if you had to separate the wheat from the chaff with a pair of tweezers!

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 pasess through a stage of IF amplifica-

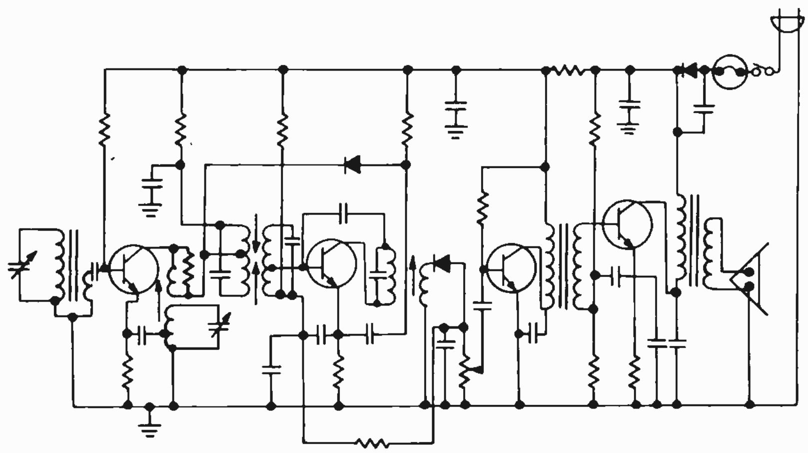


Fig. 5. Our schematic of a transistorized superheterodyne receiver is similar to the tubed superhet shown in Fig. 4. Biggest differences between the two are semiconductor diodes found in audio detector, AVC loop, and power rectifier stages.

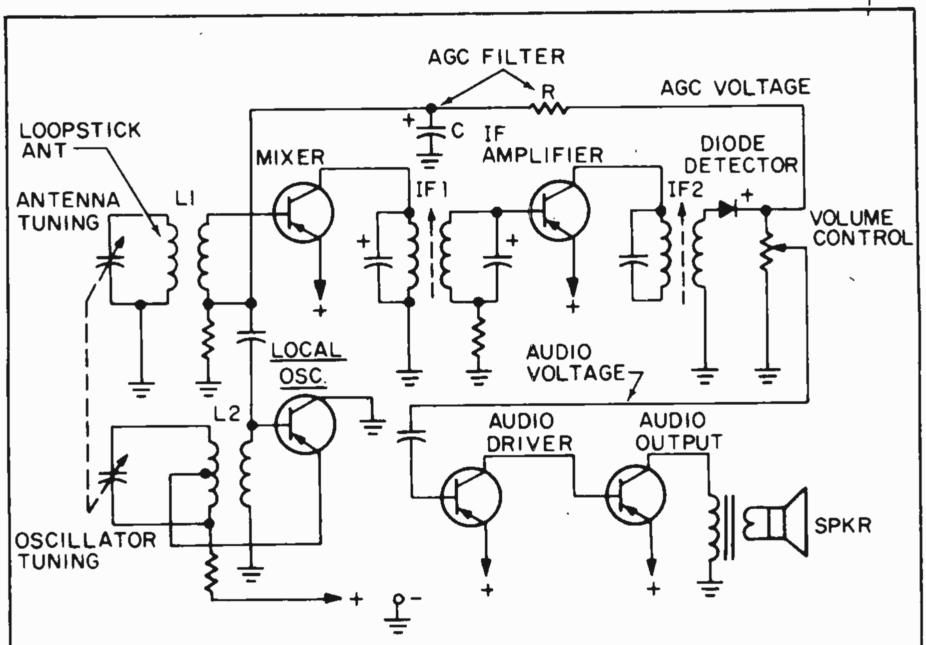


Fig. 6. Most superhets don't have separate local oscillator, mixer function; this schematic is more typical of BCB set. Communications-type receiver needs added usefulness of separate stages—it's easier to suppress images.

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. Thus, if a strong RF signal tries to muscle its way through this stage, the mixer is subjected to a higher bias voltage on its base terminal, which tends to put the brakes on our mixer's gain.

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.

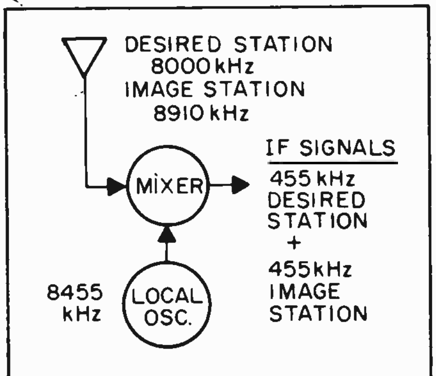


Fig. 7. Mixer is superhet's weakest link as signal handler. Too strong input signal can develop image frequency. Too much local oscillator signal pumped into mixer has same effect.

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 sidebands in an FM stereo program and kill its multiplexed chan-

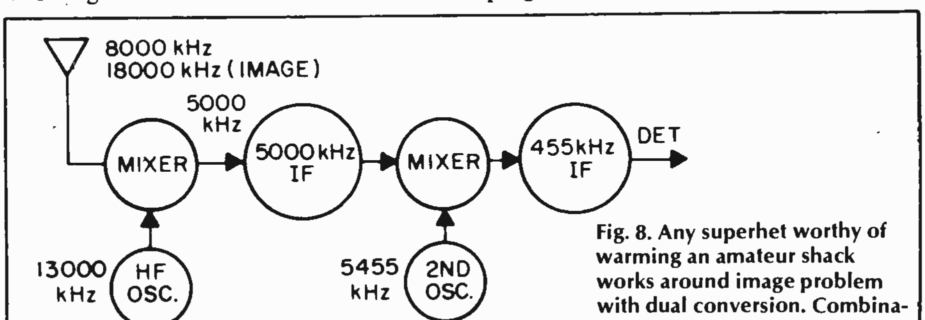


Fig. 8. Any superhet worthy of warming an amateur shack works around image problem with dual conversion. Combination of IFs puts image out of range of either stage.

nel, or rob a TV image of its fine picture detail.

But, for all its faults, the basic superhet circuit we've been talking about must be doing something right. Every years several million superhets are sold in the U.S. Not bad for a circuit that might have gone the way of the hip flask, eh? ■

Big Money in Electronics

☐ You've seen the ads many times, and you will see them again in this very publication. "Step into the digital age," they coax. "Don't envy the man with skills in electronics . . . become one!" "Prepare now for a rewarding career in electronics," they beckon. And you are sorely tempted to at long last take that big step and sign up for a course that will free you from your present drab, low-paying job with no future. Boy! Won't it be sweet one day to tell you boss what he can do with his . . . (you complete the sentence).

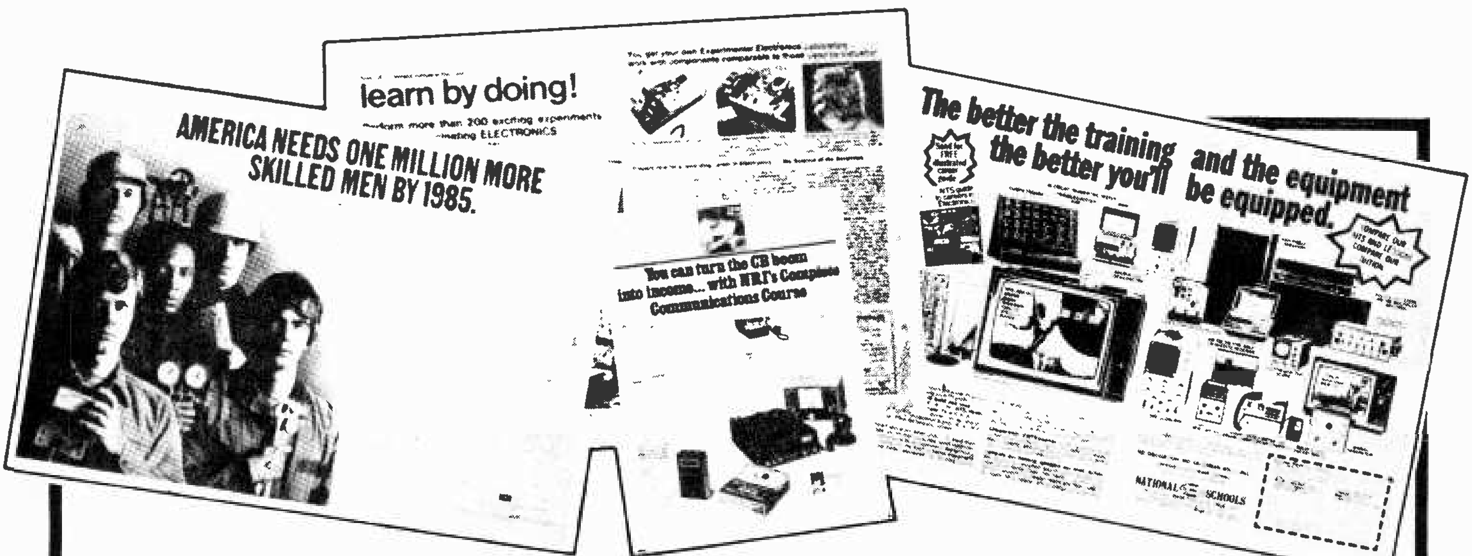
If you aren't yet fully convinced that a correspondence course in electronics is your escape hatch to a better future, you might be thinking: "What the heck, even if I don't go all the way, I'll at least get myself a new color TV set and enough training to keep it in good shape." If that's the best argument you can muster, back off and re-think your plans. If you are willing to settle for a TV set "if things don't work out," you'll save money in the long run by just buying a set from your nearest dealer and letting professional servicemen take care of it; you can buy a lot of service with the money you will save by not wasting it on a correspondence course that is the wrong one for you. However, if you pick the right course, for the right reasons, you may truly be on the way to the kind of career the school ads offer.

You won't find any pat answers to questions like "Which school is best?" in this article because there are no such answers to give. Every prospective student has different personal needs to satisfy, so each must decide for himself what training will best meet those needs at lowest possible cost. However, we can point you in the right direction by underscoring some of the things you should evaluate as you pore over the fascinating promotional brochures that the various correspondence schools are eager to send to you.

Bucket of Parts. The lure of kit building is undeniable, and the schools see to it that you are made aware of the mouth-watering kits you will build, including a yours-to-keep color TV set. Practical hands-on kit assembly and electronic experimentation is indeed an important part of a good training program, but you must be aware that kit-building cannot be a substitute for basic book learning. The schools can make the learning of theory as easy as possible by use of carefully prepared texts, but you will still have to work to grasp and remember the fundamentals that you *must* acquire to become a professional in any electronics field.

The building of a color TV set can be a very worthwhile part of your training *if* you are aiming for a career in TV repair or some related field. For certain other career objectives such set building would be a waste of time and money, and in fact you would not get the set with such study programs. You should also know that your school probably won't ship the TV set, if it is included in the course, until you have progressed far enough to have paid at least 75 percent of the cost of the program—in which case you are by then *obligated* by contract to pay the *full* course fee whether or not you complete the course. So there's no way you can go "just far enough" to grab a TV set and then pull out—except at a stiff price.

If you read the promotional literature of competing schools carefully, you will detect the in-fighting that has developed around the TV bit. While one school emphasizes that you will get a "com-



Some of the ads for electronics correspondence schools are shown above. As you can see, many of them feature big-size color TV kits, as well as various other pieces of electronic equipment—from simple to sophisticated—for your training use. Some of the schools feature tear-out cards in their ads to make it easier for you to get various catalogs, course offerings, and other information right away. Which school is right for you? It's easy to find out!

plete" TV, rather than a stripped down version used only for teaching, another school proclaims that it doesn't stoop to using "hobby" type TV kits, but instead uses a TV set specially designed to aid in the teaching process. So there you have it—the same situation argued from two points of view to draw diametrically opposite conclusions. If you want the most for your tuition money, do your best to find out—in advance of signing the contract—just how thoroughly the TV set building is integrated with the teaching of both electronic theory and TV troubleshooting. If all you do is put together a kit without direct correlation with textbook learning, you gain precious little practical experience from all the work except the ability to plug things together and solder A to B in follow-the-directions cookbook style. You don't need a course in electronics to do that; just buy a kit and soldering iron.

We should qualify these comments about kit-building when dealing with test instruments. Here again you hope to learn some theory through the kit assembly process; but even if you don't, you are at least putting together instruments that you will be able to use in practical manner to test and troubleshoot electronic equipment.

Finally, don't be swayed too much by the numbers game sometimes used to suggest that "our" course offers more fascinating "experiments" than does some other school's course. You will undoubtedly perform 200 or some other number of experiments if the school in question says so, but not all of the experiments will involve the use of sophisticated electronic equipment. Some of the experiments will require the use of *very* simple pieces of equipment—a magnet and some iron filings, for example. This does not mean that the simple experiments have no purpose; in fact, you may be learning very important electronic principles through such experimentation. All we are doing here is to warn you not to get too starry-eyed about the presumed truckload of equipment you must need to do so many experiments.

Also note that some schools offer the *use* of very expensive, specialized equipment needed for some types of course work. You can use the equipment at the school's laboratories, or have it shipped to your home for a week or two, but you must return it within the specified time and pay all shipping and insurance charges. If you can get the same type of equipment on loan locally, you should be free to do so.

How Much Will Your Training Cost? The usual magazine advertising used by electronic correspondence schools doesn't even begin to reveal, much less describe, the many different types of courses that are available. So don't be surprised that you can pay anywhere from about $100 for a "basic" electronics course to as much as $1700 for a course that leads to an engineering degree as well as a diploma. A course that involves the building of a color TV set can run anywhere from about $700 to $1800.

These approximate quotes are for *cash* payment of the full tuition at the time of enrollment. If you opt for time payments, know exactly how much extra you will pay in interest—in both actual dollars and the *true annual interest* rate (which enables you to realistically compare the time payment offerings of different schools even if the total course fees are substantially different). You will probably be required to keep up regular monthly payments even if you fall behind in your studies. So don't count on slowing down your study program just to avoid putting off a monthly payment when you happen to be financially strapped.

If you pay cash on the barrelhead, you avoid the additional charges. On the other hand, you will lose out on savings bank interest you could be earning on part of the money. Thus, if you have the money to pay cash, figure out how much more you would actually pay using the time payment plan as compared to the cash payment plus lost interest.

If you are a veteran eligible for benefits under the GI bill, be sure to file the necessary applications on time or you could lose out on some payments. After expiration of ten days following your enrollment in a school program (provided by a school recognized by the Veterans Administration, of course), submit a written affirmation of your enrollment with the VA. Don't assume that the school will do this for you. The VA will not authorize payment for any lessons you might have completed before the filing of the affirmation. The VA pays 90 percent of the cost of tuition. You (not the school) are paid quarterly, and the size of each VA check is calculated by multiplying the number of completed lessons by the cost per lesson. This means that you must have the money to pay the school on time, even though you will get 90 percent of it back from VA months later.

Termination and Refunds. The best laid plans can go awry, so know in advance what it will cost you to drop out of your training program at any point along the way.

You are given a brief initial time period in which to examine the first package of course material and send it back without suffering a monetary penalty. Usually this examination period is ten days, but it could be as short as five days, so check it out. After that the amount you are obligated to pay depends on how much course material has been sent to you. A typical condition involves the payment of $50 or 10 percent of the total tuition charge (whichever is the smaller amount) as a "registration fee," if you drop out after the initial free examination period but before any assignment has been graded by the school. If less than a quarter of the program is completed, you pay the registration fee plus 25 percent of the total tuition. If you've completed more than 25 percent but less than 50 percent of the program, you pay the registration fee plus 50 percent of the tuition. If you have completed more than half of the program when you decide to quit, you are obligated to pay the *full* tuition. Also bear in mind that you would be obligated to return any unused equipment and pay for the insurance and shipping charges.

Be sure to check out the actual contract conditions specified by the school

LEADING ELECTRONICS CORRESPONDENCE SCHOOLS

Cleveland Institute of Electronics, Inc. (CIE)
1776 East 17th Street
Cleveland, OH 44114

Grantham School of Engineering
2000 Stoner Avenue
Los Angeles, CA 90025

National Technical Schools (NTS)
4000 South Figueroa Street
Los Angeles, CA 90037

NRI Schools
McGraw-Hill Continuing Education Center
3939 Wisconsin Avenue
Washington, DC 20016

International Correspondence Schools (ICS)
Scranton, PA 18515

Technical Home Study Schools
Electronics Technical Institute Div.
1500 Cardinal Drive
Little Falls, NJ 07424

A letter or postcard to these schools will bring you a quick reply, and all the appropriate information about their programs of instruction.

you choose. Also bear in mind that even when a school uses a refund plan much like this one for most of the offered courses, the refund may be substantially *less* if you happen to enroll in one of certain "introductory" courses having relatively low tuition fees.

Some schools will give a *full refund* even after you have completed one of the courses designed to prepare you for an FCC First Class license. If you fail to pass the government examination, after graduation from the school, you may be entitled to a full refund. But watch the conditions because they are not the same for every school. The time in which you can take advantage of the refund opportunity may be as short as 90 days or as long as six months. One school insists that you try again, after undergoing additional no-charge training specified by the school, at a location also specified by the school. If you still can't pass the FCC exam, you get the refund.

No Job Guarantees. Aside from the just-mentioned warranty concerning the acquisition of an FCC license, offered by some schools but not all, there is no guarantee that you will automatically get a well-paying and exciting new job. No one could possibly guarantee anything like that. The only reasonable assurance you can expect is that your school will prepare you to compete effectively for the jobs that may be available in any given location at a given time, or prepare you to go out and establish your own business with adequate technical preparation (you would still have to acquire management and other business skills if you work for yourself).

Although we will be living in an "electronic age" for a very long time, it does not follow that job opportunities will be equally good in all areas of electronic technnology. So you should do some thoughtful crystal-balling to determine where your best opportunities might lie about the time you complete a correspondence course. For example, even if you figure that there already are plenty of TV servicemen around, it does not follow that there are enough really *competent* servicemen in all localities; if you excel in this type of work, you will probably find work. And think also about the new technologies that are opening up. There are expectations, for example, that within a few years millions of people will be buying movies on discs much like phonograph records to play them through their TV sets. Someone will have to service all that equipment. Computers are finding new applications constantly. Many libraries now check out books and keep track of book inventories with computers. And Supermarkets are fast moving to use of computerized food checkout systems. So perhaps your best opportunities lie in electronic fields far different from the one you might now imagine. Reading course description contained in the brochures distributed by correspondence schools can be a real eye-opener.

Better Than a Pen Pal. You'll need a friend now and then as you work your way through your chosen electronics course. You may already have discovered that one of the most frustrating ways to spend your time is to attempt carrying on an intelligent conversation with someone else's computer. So even if the school of your choice uses computers to check out the answers on your examination papers, be sure that there are real, living and breathing human being you can turn to for advice when you get bogged down on some technical problem. You may be asked to send your questions to the school by letter; however, at least one school has a toll-free telephone number you can call from anywhere in the U.S. when you want a quick answer to a problem.

One school offers "Saturday Help Sessions" at eight or more locations in the U.S. which could be very useful if you live near enough to take advantage of them. Or you may be offered "after graduation" classroom training at no extra cost. One school allows you to attend such classes as often as you wish over a period of one full month. You of course must pay your own transportation and living costs if you must travel to another town for the extra training.

In order to attract more students, one school offers to pay you ten bucks for every "friend" you can talk into taking a correspondence course in the same school. It's pointed out that if you and a friend take a course at the same time, you can bounce ideas back and forth to clear up technical points and increase the fun of learning. There's much to be said for this work-with-a-friend idea, even if the friend insists on taking a course offered by another school. In fact, there might even be some advantages to the different-school approach because if school A doesn't make a particular concept crystal clear, school B might do better—and vice versa.

Throughout your training you will be filling out periodic examination papers to test your learning progress. You will do this at home where you can refer to your study materials. For this reason, a future employer isn't likely to be too impressed by the grades you get on the tests, and will want some additional proof that you really do know your stuff. So if your school provides an opportunity to take a *supervised* final examination after completion of the course, by all means take advantage of it if at all possible. Not only do you have something more meaningful to show a prospective employer but, even more importantly, *you* will have a clearer measure of your personal achievement.

Do You Have the Drive? Many students drop out of correspondence training programs for many different reasons. But one of the main causes has to be the failure of some students to objectively evaluate their own personalities and drive. You should be enthusiastic and inspired by real hopes of a better life; but you should not kid yourself, because it will cost you both time and money.

Will you be able to settle down and work on a regular daily basis for many months to achieve your ends without having someone else pressure you constantly? If the lure of the beer parlor or movie theatre is greater than the lure of a new profession, save your money. If you just aren't sure how you would hold up, look around for a school that will allow you to transfer to a regular classroom program if you find that you are weak on self-discipline. Check out where the classes are held, and how much extra you would have to pay.

On the other hand, you may be a completely different sort of individual. Maybe you didn't make out too well in your former schooling because classroom work made you restless. It could be that if you can choose your own working hours, and concentrate on the kind of subject that really turns you on, you may turn out to be a far better student than you ever dreamed possible. You might have been completely bored and confounded by Byron and Keats in your English class, yet be a whiz at analyzing the invisible migrations of electrons through complex circuits.

Some individuals learn quickly. Others only seem to learn quickly because their learning is superficial. But it's the slow learner, even one who nonetheless learns thoroughly, who can be really handicapped in a conventional classroom. Given adequate time, he may in fact become more competent in a given job than a fast learner.

This is why you should not only consider the "average" times schools say students require to complete various courses, but also how much extra time you are given if you can't breeze through bcause of difficulties with the course, or because wholly unrelated personal problems force you to suspend study temporarily. Just keep at it, and you'll do great, you'll find. ■

Understanding Electronics

Amps, Ohms and Volts

☐ One of the most thought-provoking discoveries of modern physics is the fact that matter and energy are interchangeable. Centuries of scientific head-scratching about the nature of matter, the mystery of fire, and the once-terrifying crack of lightning have all come to focus on the smallest particle that is the building block of any given substance: the atom. An atom is necessarily matter and yet this atom of matter can undergo nuclear fission and release quantities of energy that are beyond the imagination. In the atom lies the secret of all phenomena. One theory of the universe, hypothesized by Georges Lemaitre, even regards the present universe as resulting from the radioactive disintegration of one primeval atom!

By the beginning of the 19th century, the atomic theory of matter—which actually originated in 5th century Greece when the atom was named—was firmly established. It was due primarily to the efforts of 17th century scientists who—actually working in the tradition of medieval alchemy—sought the prime constituent of all matter. Mainly through the work of John Dalton, whose investigations as to how various elements combine to form chemical compounds, it came to be regarded that *an atom* was the indivisible and indestructible unit of matter.

This viable and working view of the indestructible atom served science until 1897 when the atom itself was found to be destructible! To anyone concerned with electricity or electronics, the year 1897 is a memorable one: it was the year J. J. Thomson, the English physicist, identified and experimentally revealed the existence of the first subatomic particle—the *electron!*

The First "Electronic" Experiment. We blithely speak of electricity as the flow of electrons yet, often, we are little aware of the great body of research that went into elucidating this fundamental of basic electricity. In fact, before the discovery of the electron, convention held that the flow of electric current was in the direction that a positive charge moved. This convention of *positive current,* being the flow of positive charges and opposite to the direction of electron flow, is still found to be useful in circuit analysis and is used even today.

Thomson's experiment established that a particle much lighter than the lightest atom did indeed exist. The electron, as it was named, was the first subatomic particle to be defined.

The experiment was conducted utilizing a rudimentary version of a cathode ray tube—the modern version of which is in almost every home today in the form of the television picture tube. Before Thomson's experiment, it was discovered that when electric current was passed through a gas in a discharge tube, a beam of unknown nature traveled through the tube from the negative to positive terminal (opposite to the direction conventionally held as the direction of the flow of current).

This "cathode ray" beam also traveled in a straight line and was deflected by electric or magnetic forces applied perpendicular to the beam. What Thompson did was to use these facts to determine for one of the mysterious particles comprising the beam of cathode rays the relationship of its mass, m, to its electric charge, e. By deflecting the beam with a known electric force (Fig. 1) and then measuring what magnetic force applied in the opposite direction would bring the beam back to its original undeflected position, he could determine the relationship of e to m. He established a definite value for e/m and thereby "discovered" the electron which, as we now know, is 1,837 times smaller in mass than the lightest atom, the hydrogen atom. It also carries the smallest charge that occurs in nature; every electric charge is actually an integral multiple of the charge of the electron.

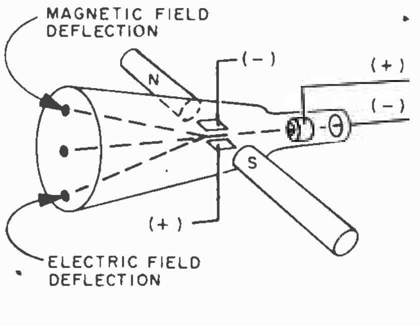


Fig. 1. Electron beam, like that in a TV picture tube (CRT), can be deflected magnetically or by an electric field. Force needed "measured" the electron.

From Minus to Plus. With the discovery of the electron, it was still over a dozen years into the 20th century before a graphic conception of the atom evolved. Since the atom is electrically neutral and electrons are negatively charged, the existence of positively charged particles was a necessity, and the existence of a *proton* was postulated. Eventually the nuclear model of the atom was evolved. Each atom was conceived to resemble a solar system in miniature. The nucleus—positively charged—is surrounded by a number of electrons revolving around it; the charges balance and the atom is electrically neutral (Fig. 2). Further research in the 20th century has gone on to reveal more elementary particles than you can shake a stick at: neutrons, positrons, neutrinos, mesons, and more. The number continues to grow and yet the ultimate nature of matter remains a riddle. But, in a discussion of basic electricity, only the electron and proton need concern us.

Electrons in Orbit. An atom of matter has a number of electrons orbiting around its nucleus. A hydrogen atom, for example, has a single electron; carbon on the other hand has 6. These electrons are arranged in rings or shells around the central nucleus—each ring

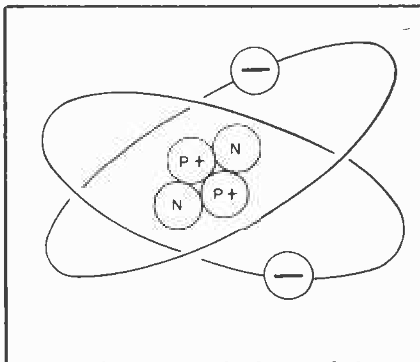
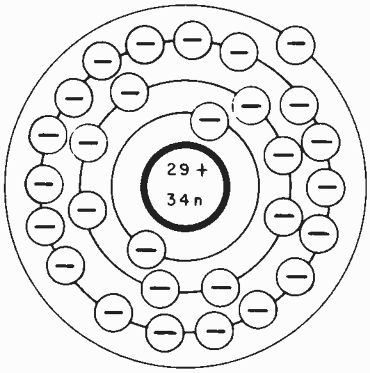


Fig. 2. Charge of each electron balances that of a proton. Other particles affect atomic mass but can be ignored in study of electronics.

Fig. 3. The number of electrons to each ring are limited—2 in first; 8 in second; 18 for the third; and a total of 32 in fourth orbital ring.



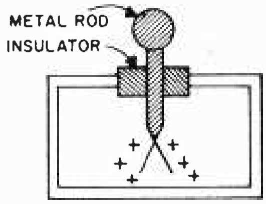


Fig. 4. Electroscope is a simple device to indicate electrical charges that are too weak to be measured with standard meters.

having a definite maximum capacity of electrons which it can retain. For example, in the copper atom shown in Fig. 3 the maximum number of electrons that can exist in the first ring (the ring nearest the nucleus) is two. The next ring can have a maximum of eight, the third ring a maximum of 18, and the fourth ring a maximum of 32. However, the outer ring or shell of electrons for any atom cannot exceed eight electrons. However, heavier atoms may have more than four rings.

The Outer Orbit. The ring of electrons furthest from the atom's nucleus is known as the *valence ring* and the electrons orbiting in this rings are known as *valence electrons*. These valence electrons, being further from the nucleus, are not held as tightly in their orbits as electrons in the inner rings and can therefore be fairly easily dislodged by an external force such as heat, light, friction, and electrical potential. The fewer electrons in the valence ring of an atom, the less these electrons are bound to the central nucleus. As an example, the copper atom has only one electron in its valence ring. Consequently, it can be easily removed by the application of only the slightest amount of external energy. Ordinary room temperature is sufficient to dislodge large numbers of electrons from copper atoms; these electrons circulate about as free electrons. It is because of these large numbers of free electrons that copper is such a good electrical conductor. There could be no electrical or electronics industry as we know it today if it were not for the fact that electrons can fairly easily escape, or be stripped from the valence ring of certain elements.

Electronic Charges. If an electron is stripped from an atom, the atom will assume a positive charge because the number of positively charged protons in its nucleus now exceeds the number of negatively charged orbiting electrons. If, on the other hand, the atom should gain an electron, it will become negatively charged as the number of electrons now exceeds the protons in its nucleus. The atom with the deficiency of electrons is known as a *positive ion,* while an atom with a surplus of electrons is known as a *negative ion.*

Presence of an electrical charge on a body can be illustrated by use of an electroscope (Fig. 4). Two leaves of aluminum or gold foil hang from a metal rod inside a glass case so they're free from air disturbances. When the metal rod is touched by a charged body, the leaves acquire static electricity of the same polarity and, since like charges repel, they stand apart. The greater the charge, the further apart the leaves spread.

Electron Flow. When an electrical conductor is placed between these two oppositely charged bodies, free electrons are attracted by the positive body—free electrons will move through the wire. This movement of free electrons will continue only until the excess of electrons is equally divided between the two bodies. Under these conditions, the charges on both bodies will be equal and the electron flow will end.

In Fig. 5 are a battery, lamp, and connecting leads between the battery and lamp. In this instance, the battery serves as an electric charge pump—free electrons continually developed at its negative terminal by chemical action flow through the connecting leads and lamp back to the positive terminal of the battery by the attraction of oppositely charged bodies. The battery, connecting leads, and lamp form an electrical circuit which must be complete before the free electrons can flow from the battery's negative terminal to its positive terminal via the lamp. Thus, the battery serves as a source of potential difference or voltage by continually supplying a surplus of electrons at its negative terminal. Summing up, we can say a flow of electric current consists of the movement of electrons between two oppositely charged bodies.

We cannot progress very far into the study of electricity without first becoming familiar with the basic properties of electrical circuits. Just as we define distance in feet and inches, so do we define electrical properties in specific terms and units.

Potential. Earlier, we saw that an electric charge difference has to exist between the ends of an electrical conductor in order to cause a flow of free electrons through the conductor. This flow of electrons constitutes the electric current. The electric charge difference, or potential difference, exerts a force on the flow of free electrons, forcing them through the conductor. This electric force or pressure is referred to as electromotive force, abbreviated EMF.

The greater the charge or potential difference, the greater will be the movement of free electrons (current) through the conductor as there will be more "push and pull" on the free electrons. The symbol used to designate electrical potential is the letter E which stands for electromotive force. The quantity of EMF is measured by a unit called the volt. Hence, the common name most often used in place of EMF is *voltage.*

Current Intensity. We have learned that an electric current consists of a flow of charge carriers (generally free electrons) between two points of different electrical potential. The rate of flow of these chages determines the intensity or strength of this current flow. Current strength is expressed in units known as *amperes.* One ampere of current flows in a circuit when 6,240,000,000,000,000,000 electrons flow out of a negative terminal, through a conductor, and back into a positive terminal in one second. The symbol for the ampere is the letter *I* which stands for intensity.

Resistance. The flow of electric current through a conductor is caused by the movement of free electrons present in the atoms of the conductor. A bit

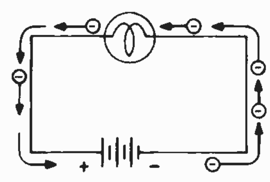


Fig. 5. Electron flow in any circuit is from negative to positive.

of thought then indicates that the greater the number of free electrons present in the atoms of a particular conductor, the greater will be its electrical conductivity. Gold, silver, and copper rank as excellent electrical conductors, as their atoms readily release free electrons. On the other hand, the atoms of such elements as sulphur have almost no free electrons available and they are thus very poor electrical conductors. Such materials are known as electrical insulators. Between these extremes lie elements such as carbon whose atoms have a moderate number of free electrons available and thus are moderately good electrical conductors.

Even the best electrical conductors offer some opposition to the passage of free electrons. This opposition is called resistance. You might consider electrical resistance similar to mechanical friction. As in the case of mechanical friction, electrical resistance generates heat. When current flows through a resistance, heat is generated; the greater the current flow, the greater the heat. Also, for a given current flow, the greater the resistance, the greater the heat produced.

Electrical resistance can be both beneficial and undesirable. Toasters, electric irons, etc. all make use of the heat generated by current flowing through wire coils. Resistance is also often intentionally added to an electrical circuit to limit the flow of current. This type of resistance is generally lumped together in a single unit known as a resistor.

There are also instances where resistance is undesirable. Excessive resistance in the connecting leads of an electrical circuit can cause both heating and electrical loss. The heating, if sufficient, can cause a fire hazard, particularly in house wiring, and the circuit losses are a waste of electrical power.

Electrical resistance is expressed by a unit known as the *ohm*, indicated by the letter *R*. An electrical conductor has a resistance of one ohm when an applied EMF of one volt causes a current of one ampere to flow through it.

Resistance Factors. There are other factors beside the composition of the material that determine its resistance. For example, temperature has an effect on the resistance of a conductor. As the temperature of copper increases, for example, its resistance increases. The increase in temperature causes the electrons in the outer ring of the atom to resist release to the free electron state. This increase in resistance is known as a *positive temperature coefficient*. Not all conductors show this increase in resistance with an increase in temperature; their resistance decreases with an increase in temperature. Such materials are said to have a *negative temperature coefficient*. Certain metallic alloys have been developed which exhibit a *zero temperature coefficient:* their resistance does not change with changes in temperature.

As you might suspect, the length of a conductor has an effect upon its resistance. Doubling the length of a conductor will double its resistance. By the same token, halving the length of a conductor will cut its resistance in half. Just remember that the resistance of a conductor is *directly proportional to its length.*

The cross-sectional area of a conductor also determines its resistance. As you double the cross-section of a conductor, you halve its resistance; halving its cross-section doubles its resistance. Here again, the "why" of this is pretty easy to see: there are more current carrying electrons available in a large cross-section conductor than in a small cross-section conductor of the same length. Therefore, the resistance of a conductor is *inversely proportional to its cross-sectional area.*

Circuit Relationship. Now that we have a basic understanding of voltage, current, and resistance, let's take a look at just how they interact under circuit conditions.

Fig. 6A shows a battery, ammeter (a device to indicate current strength), and resistor connected in series. Notice that the ammeter indicates that 4 amperes are flowing in the circuit.

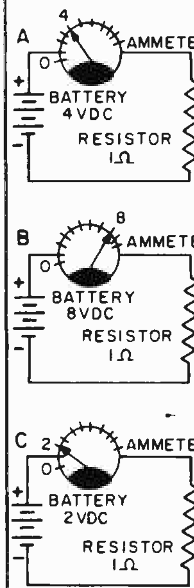
Fig. 6B shows the identical setup with the exception that the battery voltage has now been doubled. The ammeter now shows that twice the original current, or 8 amperes, is now flowing in the circuit. Therefore, we can see that doubling the voltage applied to the circuit will double the current flowing in the circuit.

In Fig. 6C the same circuit appears again; this time, however, the battery voltage is one half its original value. The ammeter shows that one half of the original current, or 2 amperes, is now flowing in the circuit. This shows us that halving the voltage applied to the circuit will halve the current flowing through the circuit.

All this boils down to the fact that, assuming the same circuit resistance in all cases, *the current flowing in a circuit will be directly proportional to the applied voltage*—increasing as the voltage is increased, and decreasing as the applied voltage is decreased.

In Fig. 7A we again see the circuit consisting of the battery, ammeter, and resistance. Notice that the ammeter indicates that 4 amperes are flowing through the circuit.

Fig. 6. In A, B, and C, the value of the resistor remains constant while the supply voltage is altered with a resulting current change.



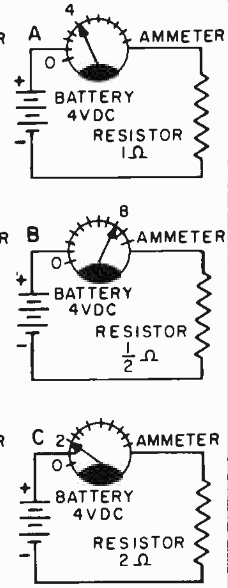


Fig. 7. Battery voltage A, B, and C is held constant while resistor is halved and doubled in value. Resulting current changes are basis for Ohm's law.

In Fig. 7B we see that the value of resistance has been cut in half and as a result, the ammeter indicates that twice the original current, or 8 amperes, is now flowing in the circuit. This leads us to the correct assumption that for a given supply voltage, halving the circuit resistance will double the current flowing in the circuit.

Fig. 7C again shows our basic circuit, but with the resistance now doubled from its original value. The ammeter indicates that the current in the circuit is now one half of its original value.

Summing things up: for a given supply voltage, *the current flowing in a circuit will be inversely proportional to the resistance in the circuit.*

Ohm's Law. From what you have seen so far, you are probably getting the idea that you can determine the current flowing in a circuit if you know the voltage and resistance present in the circuit, and the voltage if you know the current and resistance, or the resistance if the voltage and current are known.

All this is quite correct, and is formally stated by Ohm's law as follows:

$$I = \frac{E}{R}$$

Where: E = voltage
I = current
R = resistance

Now, let's take a look at how this formula is used:
To find voltage:

E (voltage) = I (current) × R (resistance)
To find current:

$$I\ (\text{current}) = \frac{E\ (\text{voltage})}{R\ (\text{resistance})}$$

To find resistance:

$$R\ (\text{resistance}) = \frac{E\ (\text{voltage})}{I\ (\text{current})}$$

A handy way to remember Ohm's law is by means of the triangle shown in Fig. 8. Simply cover the quantity (voltage, current, or resistance) that you want to determine, and read the correct relationship of the remaining two quantities. For example, if you want to know the correct current (I), put your finger over I and read $\frac{E}{R}$. Covering E or R will yield I × R or $\frac{E}{I}$, respectively.

Ohm's Law to Determine Voltage. Let's delve a bit more deeply into Ohm's law by applying it to a few cases where we want to determine the unknown voltage in an electrical circuit. Take a look at Fig. 9, which shows a simple series circuit consisting of a battery and resistor. The value of this resistor is given as 200 ohms, and 0.5 ampere of current

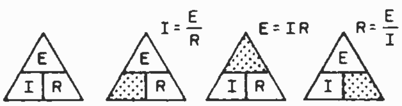


Fig. 8. Shaded portion of triangle indicates unknown quantity in the formula. Visible factors appear in their proper mathematical relation. Just fill in the known values and go on with multiplication or division.

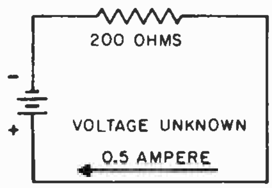


Fig. 9. Unknown quantity, voltage, found easily by applying Ohm's law.

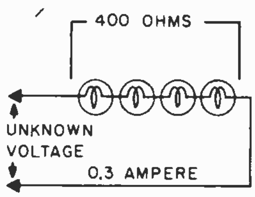


Fig. 10. Although problem looks different the basic circuit is same as that for Fig. 9.

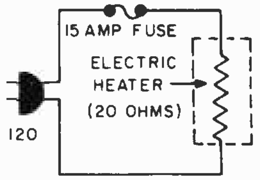


Fig. 11. Formula needed here is different since current is unknown. Just look for triangle in Fig. 8 that has I shaded.

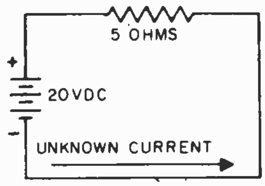


Fig. 12. Basic circuit is same as that in Fig. 11. Although three factors are given, current is unknown quantity.

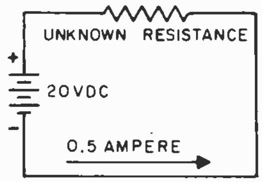


Fig. 13. Most Ohm's law problems are simple series circuits or can be reduced to simple series circuits.

is flowing through the circuit. We want to find the value of battery voltage. This is easily done by applying Ohm's law for voltage as follows:

$$E = I \times R$$

Let's go through this again, this time using a practical illustration. Fig. 10 shows a string of light bulbs, the total resistance of which is 400 ohms. You find that the bulbs draw 0.3 amperes when lighted. Let's say you would like to operate this string of bulbs from the standard 120-volt house current, but you don't know the voltage rating of the individual bulbs. By using Ohm's law for voltage, you can easily determine the voltage to light the bulbs as follows: (unknown voltage) = 0.3 (amperes) x 400 (bulb resistance) = 120 volts.

Ohm's Law to Determine Current. Now, let's take a look at a few examples of how to determine the value of unknown current in a circuit in which both the voltage and resistance are known.

Fig. 11 shows a series circuit with a battery and resistor. The battery voltage is 20 volts DC and the value of resistance is 5 ohms. How much current is flowing through the circuit?

$$\text{Ohm's law for current: } I = \frac{E}{R}$$

$$I\ (\text{unknown current}) = \frac{20\ (\text{battery voltage})}{5\ (\text{resistance in ohms})}$$

$$I = 4 \text{ amperes}$$

Again to get a bit more practical, let's take a look at Fig. 12. Here we see an electric heater element connected to the 120-volt house line. We know that this particular heater element has a resistance of 20 ohms. The house current line is fused with a 15-ampere fuse. We want to know whether the heater will draw sufficient current to blow the fuse. Here's how to find this out by use of Ohm's law for current.

$$I\ (\text{unknown current}) = \frac{120\ (\text{line voltage})}{20\ (\text{Heater resistance in ohms})}$$

$$I = 6 \text{ amperes}$$

We find from the above use of Ohm's law for current that the heater draws 6 amperes, so it can be safely used on the line fused with the 15-ampere fuse. In fact, a 10-ampere fused line can also do the job.

Ohm's Law to Determine Resistance. Ohm's law for resistance enables us to determine the unknown value of resistance in a circuit. Fig. 13 again shows a simple series circuit with the battery voltage given as 20 volts and the current flowing through the circuit as 0.5 ampere. The unknown resistance value in this circuit is found as follows:

$$\text{Ohm's law for resistance: } R = \frac{E}{I}$$

$$R\ (\text{unknown resistance}) = \frac{20\ (\text{battery voltage})}{0.5\ (\text{current in amperes})}$$

$$R = 40 \text{ ohms}$$

Fig. 14 is a practical example of how to determine unknown resistance. Here, we want to operate a 6-volt light bulb

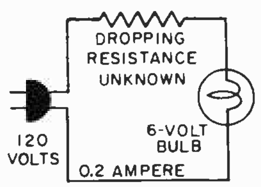


Fig. 14. This Ohm's law problem is somewhat more complex.

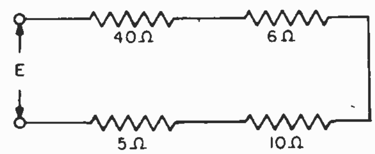


Fig. 15. Resistance in series is added. As far as voltage applied and current flow is concerned the individual resistors are only one.

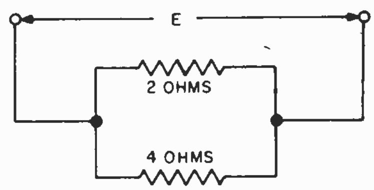


Fig. 16. Resistors in parallel are added algebraically—the result will aways be a value less than that of the lowest in the circuit.

from the 120-volt house line. What value of series dropping resistor do we need to drop the 120-volt house current down to 6 volts? The bulb draws 0.2 ampere.

We must first determine the voltage which must be dropped across the series dropping resistor. This is done by subtracting the line voltage (120) from the bulb's voltage (6). This gives us a value of 114 volts which we use in conjunction with Ohm's law for resistance as follows:

$$R\text{ (unknown resistance)} = \frac{114\text{ (voltage dropped by resistor)}}{0.2\text{ (bulb current in amperes)}}$$

$$R = 570\text{ ohms}$$

Resistance in Series. Many practical electrical and electronic circuits use two or more resistances connected in series. The point to remember in this case is that the total resistance is the sum of the individual resistances. This is expressed by the formula:

$$R\text{ (total resistance)} = R1 + R2 + R3 + \text{etc.}$$

where R1, R2, R3, etc. are the individual resistances. Thus, in Fig. 15 the total of the individual resistances is R (total) $= 40 + 6 + 10 + 5 = 61$ ohms.

Resistances may also be connected in parallel in a circuit as in Fig. 16. In this case the current flowing in the circuit will divide between the resistances, the greater current flowing through the lowest resistance. Also, the total resistance in the circuit will always be less than the smallest resistance since the total current is greater than the current in any of the individual resistors. The formula for determining the combined resistance of the two resistors is:

$$R\text{ (total)} = \frac{R1 \times R2}{R1 + R2}$$

Thus, in Fig. 16 the effective resistance of R1 and R2 is:

$$R\text{ (total)} = \frac{2 \times 4}{2 + 4} = \frac{8}{6}\text{ or } 1.33\text{ ohms.}$$

In a circuit containing more than two parallel resistors as in Fig. 17 the easiest way to determine the total circuit resistance is as follows: first, assume that a 6-volt battery is connected across the resistor network. Pick a value that will make your computations simple. Then determine the current flowing through each of the resistors using Ohm's law:

$$I = \frac{E}{R1} = \frac{6}{2} = 3\text{ amperes}$$

$$I = \frac{E}{R2} = \frac{6}{3} = 2\text{ amperes}$$

$$I = \frac{E}{R3} = \frac{6}{6} = 1\text{ ampere}$$

Next, add the individual currents flowing through the circuit:

2 amperes + 3 amperes + 1 ampere
I = 6 amperes

Inserting this 6 amperes in Ohm's law, the total circuit resistance is found to be:

$$R = \frac{6}{6} = 1\text{ ohm}$$

The combined equation for determining the total resistance of *n* number of resistances would be:

$$\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots \frac{1}{Rn}$$

Quite often an electronic circuit will contain a combination of series and parallel resistances as in Fig. 18. To solve this type of problem, first determine the combined resistance of R2 and R3:

$$R\text{ (total)} \frac{6 \times 12}{6 + 12} = \frac{72}{18} = 4\text{ ohms}$$

This total value of R2 and R3 may be considered a single resistance which is in series with R1, and forms a simple series circuit. This simple series circuit is solved as follows:

R (total) $= 6 + 4$ or a total of 10 ohms.

Power. The amount of work done by electricity is termed the *watt* and one watt is equal to one volt multiplied by one ampere. This may be expressed as: $P = E \times I$ where E = voltage in volts, I = the current in amperes. Also:

$$P = \frac{E^2}{R}\text{ and } P = I^2R$$

As an example, assume that a toaster draws 5 amperes at an applied voltage of 115 volts. Its wattage would then be:

$$P = 115 \times 5\text{ or } 575\text{ watts.}$$

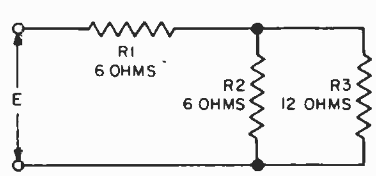


Fig. 17. Ohm's law can be used to determine the equivalent resistance of two or more resistors in parallel. Total current—then solve for ohms.

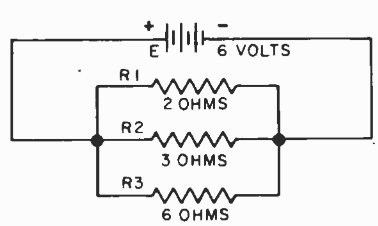


Fig. 18. Series-parallel circuit is not really difficult. Add R2 and R3 algebraically. Add effective resistance to R1 for total resistance.

Magnetism and the Electron. The atom and a concept of its structure were a necessary preface to our discussion of basic electricity. By the same token, both are necessary to understanding basic magnetism.

As we've mentioned, electrons are in continual motion about the nucleus. The orbit is, in fact, a small loop of current and has a magnetic field that's associated with a current loop. In addition, experimental and theoretical investigation seems to indicate that the electron itself has a spin. Each electron, having its own axis, is a spinning sphere of electric charge. *Electron spin,* like the quantum and wave theories of light, is not so much a literal interpretation of a phenomenon as a useful concept that holds water when applied to the phenomenon of magnetism.

When the electron spins, the charge that is in motion produces a magnetic field. And, to briefly state the electronic explanation of magnetism, it seems that the magnetic properties of matter can be attributed to the orbital and spinning motion of the electrons comprising the atoms of the matter.

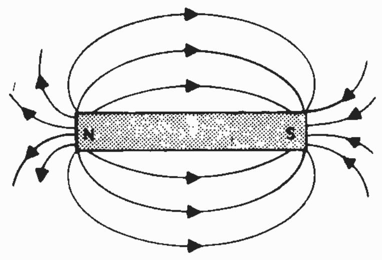
Millennia of Magnetism. Some of the basic principles and effects of magnetism have been known for centuries. The Greeks are credited as the ones who first discovered magnetism. They noted that a certain type of rock had the ability of attracting iron. Later, the Chinese noted that an elongated piece of this rock had the useful property of always pointing in a north-south direction when suspended by a string. This was the beginning of our compass.

This strange stone which intrigued people over the centuries is actually a form of iron ore known as magnetite. Not all magnetite shows magnetic properties. Another name for the magnetic variety of magnetite is lodestone—the term lodestone being derived from two separate words, lode and stone. The term "lode" stands for guide, hence lodestone means "guide stone."

All magnets, whether natural or man-made, possess magnetic poles, which are commonly known as the magnet's north and south poles. As is the case of the electrical charges (which we studied earlier) between unlike magnetic poles and repulsion between like poles, it has been found that this magnetic attraction and repulsion force varies inversely as the square of the distance from the magnetic poles.

The Magnetic Field. We all know how a magnet exerts a force of attraction on a piece of magnetic material such as iron or steel. Also, when the north poles of two magnets are brought close together, they will try to repel each other, while there will be attraction between the north and south poles of two magnets. Although it is not clearly understood just what this force of magnetic attraction and repulsion is, it is convenient to visualize magnetic lines of force which extend outward from one magnetic pole to the other as illustrated in Fig. 19.

Fig. 19. Lines of force around bar magnet can be made visible by sprinkling iron filings onto white paper over magnet.



Permeability. Magnetic lines of force can pass through various materials with varying ease. Iron and steel, for example, offer little resistance to magnetic lines of force. It is because of this that these materials are so readily attracted by magnets. On the other hand, materials such as wood, aluminum and brass do not concentrate or encourage the passage of magnetic lines of force, and as a consequence are not attracted by magnets.

The amount of attraction a material offers to magnetic lines of force is known as its permeability. Iron and steel, for example, possess high permeability since they offer little resistance to magnetic lines of force. Nonmagnetic materials have low permeability. For practical purposes, we can say that reluctance is to magnetic lines of force what resistance is to an electrical current.

Electromagnetism. Any electrical conductor through which flows an electrical current will generate a magnetic field about it which is perpendicular to its axis as shown in Fig. 20. The direction of this field is dependent upon the direction of current flow, and the magnetic field strength proportional to the current strength. If this current-carrying conductor is wound into a coil, forming a solenoid, the magnetic field will be increased by each individual turn that is added. If an iron core is inserted in this current-carrying coil, the generated field will be increased still further. This is because the lines of force are concentrated within the iron core which has considerably less reluctance than the surrounding air.

The magnetic power of a multi-turn current-carrying coil through which a core is inserted is proportional to the current flowing through the coil as well as the number of turns in the coil. The current through the coil is termed *ampere turns.* As an example, if a coil consisting of 200 turns is carrying 2 amperes, its ampere turns equal:

Ampere turns = 200 turns x
2 amperes or 400 ampere turns

Similarly a coil of 100 turns through which a current of four amperes flows also has 400 ampere turns.

Electromagnetic Induction. We saw earlier how a current-carrying conductor will generate a magnetic field which is perpendicular to the conductor's axis. Conversely, a current will be induced in a conductor when the conductor is passed through a magnetic field. The strength of this induced current is proportional to both the speed at which it passes through the field and the strength of the field. One of the basic laws pertaining to electromagnetic induction is Lenz's law which states: "The magnetic action of an induced current is of such a direction as to resist the motion by which it is produced."

Fig. 21 illustrates two coils, A and B, which are placed in close proximity to each other. Coil A is connected in series with a switch and battery so that a current may be sent through it when the switch is closed, and coil B is connected with a current-indicating DC meter. When the switch is closed, current will flow through coil A, causing a magnetic field to be built up around it. In the brief instant that the field is building up to maximum, it will "cut" the turns of coil B, inducing a current in it, as indicated by a momentary flick of the indicating meter. When the switch is opened, breaking the current flow through coil A, the field around coil A will collapse, and in so doing will again induce a current in coil B. This time, however, the flow of current will be in the opposite direction. The meter will now flick in the direction opposite to when the switch was closed. The important thing to remember is that the conductor must be in motion with respect to the magnetic field or vice versa in order to induce a current flow. You can perform this simple experiment using two coils made of bell wire wrapped around large nails, a few dry cells in series, and a DC zero-center scale meter.

Self Induction. As mentioned a short while ago, a magnetic field is built up around a coil at the application of current through the coil. As this field is building up, its moving lines of flux will cut the turns of the coil inducing a counter-electromotive force or counter-EMF which opposes the current flowing into the coil.

The amount of counter-EMF generated depends upon the rate of change in amplitude of the applied current as well as the inductance of the coil. This value of inductance is dependent upon the number of turns in the coil; a coil with many turns will have greater inductance than a coil with few turns. Also, if an iron core is inserted into the coil, the inductance of the coil will increase sharply. The unit of inductance is known as the *henry*.

The Transformer. One of the most important and widely used applications of magnetic induction is the transformer.

Fig. 22 shows the basic construction of a typical transformer. While two separate windings are shown here, some transformers can have as many as five or six windings.

A transformer consists of two or more separate windings, electrically insulated from each other. One winding, known as the primary winding, is fed from a source of alternating current.

The alternating currents flowing through the primary induce a current in the secondary winding by virtue of magnetic induction. The transformer core is constructed from a relatively high permeability material such as iron which readily conducts magnetic flux between the primary winding and secondary winding.

The alternating current flowing in the primary of the transformer produces a variation in the magnetic flux circulation in the transformer core which tends to oppose the current flowing in the primary winding by virtue of self-induction. The counter-EMF is just about equal to the voltage applied to the primary winding when no load is connected to the transformer's secondary winding. This accounts for the fact that very little current flows through the primary winding when no load is connected to the secondary. The negligible current that does flow under this no-load condition is known as the transformer magnetizing current. As the current drawn from the secondary winding increases, the primary current will increase proportionately due to the reduction in the counter-EMF developed in the primary winding of the transformer.

In any transformer the ratio of the primary to secondary voltage is equal to the ratio of the number of turns in the primary and secondary windings. This is expressed mathematically as follows:

$$\frac{Ep}{Es} = \frac{Np}{Ns}$$

where Ep = primary supply voltage
Es = voltage developed across secondary
Np = number of primary turns
Ns = number of secondary turns

The above formula assumes that there are no losses in the transformer. Actually, all transformers possess some losses which must be taken into account.

Transformer Losses. No transformer can be 100 percent efficient due to losses in the magnetic flux coupling the primary and secondary windings, eddy current losses in the transformer core, and copper losses due to the resistance of the windings.

Loss of magnetic flux leakage occurs when *not all* the flux generated by current flowing in the primary reaches the secondary winding. The proper choice of core material and physical core design can reduce flux leakage to a negligible value.

Practical transformers have a certain amount of power loss which is due to power being absorbed in the resistance of the primary and secondary windings. This power loss, known as the copper loss, appears as heating of the primary and secondary windings.

There are several forms of core loss—hysteresis and eddy current losses. Hysteresis losses are the result of the energy required to continually realign the magnetic domain of the core material. Eddy current loss results from circulating currents induced in the transformer core by current flowing in the primary winding. These eddy currents cause heating of the core.

Eddy current loss can be greatly reduced by forming the core from a stack of individual sheets, known as laminations, rather than from a single solid piece of steel. Since eddy current losses are proportional to the square of core thickness, it is easy to see that the individual thin laminations will have much less eddy current loss as compared with a single thick core.

Another factor which effects eddy current loss is the operating frequency for which the transformer is designed to operate. As the operating frequency is increased, the eddy current losses increase. It is for this reason that transformers designed to operate at radio frequencies often have air cores and are void of ferrous metals.

Theory and Practice. We've come a long way from our initial discussion of the atom and its importance for an understanding of electricity and magnetism. And there's still a long way to travel to understand all about the subatomic nucleus and its satellities and how they are being harnessed in an ever-expanding electronics technology. But, we move ahead by mixing theory with practice—so, put your new knowledge to work in a project or two! ■

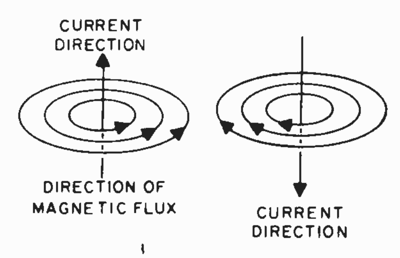


Fig. 20. Direction of flux lines is changed by direction of the current. Heavy current is needed to make flux lines visible with sprinkled filings.

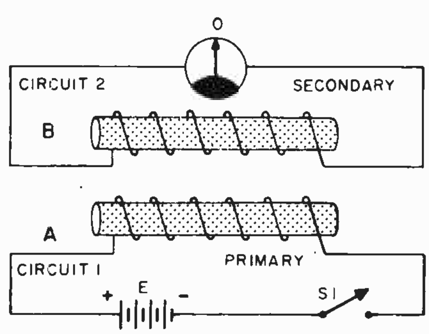


Fig. 21. Two-core transformer is inefficient since an air gap at either end does not have permeability of a ferrous metal and some flux lines do not go through core of secondary winding (B)—their effect is lost.

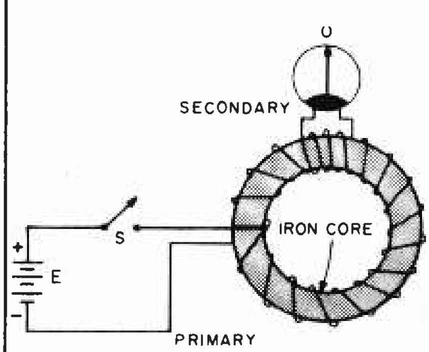


Fig. 22. Toroidal core is highly efficient but is very difficult to manufacture. Familiar C- and E-shape core has less waste and windings are slipped over the core. Efficiency is good—about 90 percent for most designs.

Prefixes and Exponents

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 attoAmpere

☐ 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 *kiloHertz* (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	$\times$ 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 kiloHertz = 840 $\times$ 10^3 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	$\times$ 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?

$$X_L = 2 \times \pi \times (1.5 \times 10^{6}) \times (22 \times 10^{-3})$$

$$= 207.24 \times 10^{3} \text{ Ohms}$$

$$= 207.24 \text{ kilOhms}$$

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?

$$F = \frac{\text{speed of light}}{\text{wavelength}}$$

$$= \frac{3.0 \times 10^{8} \text{ meters per second}}{\text{wavelength}}$$

$$= \frac{3.0 \times 10^{8}}{2.1 \times 10^{0}} = 1.4286 \times 10^{8} \text{ Hertz}$$

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:

$$142.86 \times 10^{6} \text{ Hertz} = 142.86 \text{ megaHertz}$$

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 $\times 10^{-12}$ farads and L = 2-uH or 2 $\times 10^{-6}$ henrys we can use these numbers, the formula and our new knowledge of exponents to determine the frequency.

$$f = \frac{1}{2\pi\sqrt{(2 \times 10^{-6}) \times (365 \times 10^{-12})}}$$

$$= 5{,}894{,}627.6 \text{ Hertz}$$

$$= 5{,}894 \text{ kiloHertz}$$

$$= 5.894 \text{ megaHertz}$$

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} x 10^{-6} Farad, or 10^{-12} Farad. This is more commonly known as the *picoFarad*. Similarly, a thousandth of a microAmpere is 10^{-3} x 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 "jargon-ized" 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! ■

Understanding Resistance

☐ Whether you're working at home on the final stages of a pet project or on the job servicing an electronic system, nothing is quite as frustrating as discovering that the resistance value you need isn't available. And, your usual source of supply either is closed or doesn't stock the particular value. Or maybe you want a resistance within a tolerance of 1%, and just don't feel justified in paying the extra cost.

Whatever the problem, the experienced guy doesn't lose his cool. because he knows he can come up with any resistor value he needs by connecting available resistors in series and/or parallel. This combination can either be left in the circuit or replaced at some later time with a single resistor.

Making Resistors. Making resistors by *series-ing* several resistors to reach a desired value poses no problem as the resistances are additive; i.e., if you connect a 51-ohm resistor in series with a 68-ohm resistor the final resistance of the combination is 119 ohms.

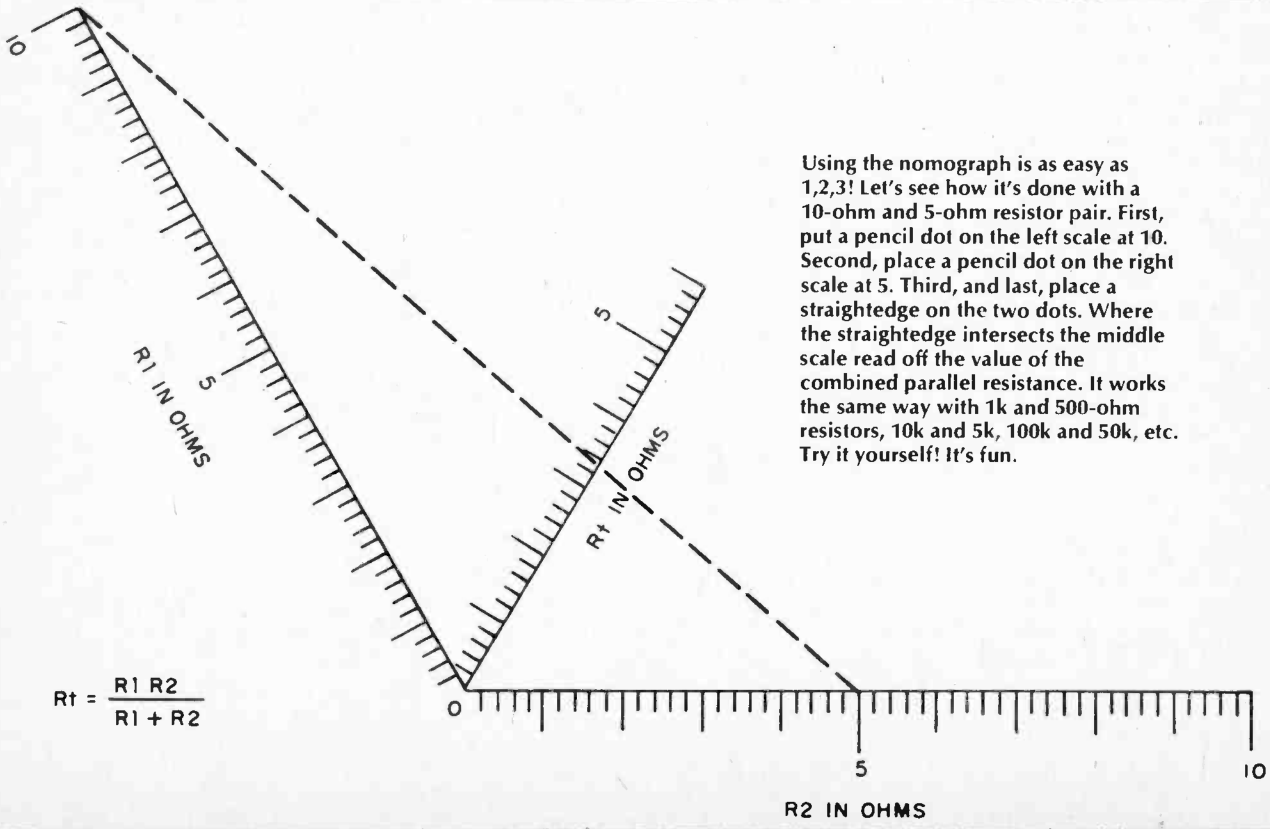
However, when you parallel resistors, the resultant resistance is no longer so easy to calculate. If you connect a 51-ohm resistor in parallel with a 68-ohm resistor the net resistance value is about 29 ohms. About the only thing you know is that the equivalent resistance of a parallel combination will be less than the value of the smallest resistor in the combination. You can't determine the equivalent resistance of a parallel combination with simple mathematics. The formula isn't complex. but it does take time to write down and solve. The easiest, fastest modern method for determining the values of parallel resistor combinations for the serviceman is by using an equivalent resistance nomograph.

What's A Nomograph? Everyone's familiar with the old old Chinese proverb about one picture worth a thousand words. A nomograph is simply a graphic picture of a simple approach to solving a mathematical calculation. And technicians in all fields are using nomographs in ever-increasing numbers. A nomograph can be constructed to solve almost any problem, and though the actual construction may require a master's degree in math, anyone can use the final end product to solve problems which might normally require a college degree and bushels of valuable time.

This is one of the most appealing features of most nomographs. i.e., that you don't need theoretical knowledge of the subject to use a nomograph to solve problems in that field. All that's necessary is to lay a straightedge. or draw a line, between two known values on given scales, and read the answer where the line intersects a third scale.

Making A Nomograph. The nomograph printed in these pages is an equivalent resistance nomograph that can be cut out for use in your work. With it you can determine the resistance of any two resistors connected in parallel in much less time than you could normally write down the mathematics required to solve the problem.

The R1 and R2 scales are equal in length, and positions at an angle of 120° with respect to one another. The Rt scale is a little more than one half the length of the other two scales, and bisects the angle between them. The scale lengths and angular positioning are usually by courtesy of some slaving mathematician somewhere, but, if you



$$Rt = \frac{R1\ R2}{R1 + R2}$$

Using the nomograph is as easy as 1,2,3! Let's see how it's done with a 10-ohm and 5-ohm resistor pair. First, put a pencil dot on the left scale at 10. Second, place a pencil dot on the right scale at 5. Third, and last, place a straightedge on the two dots. Where the straightedge intersects the middle scale read off the value of the combined parallel resistance. It works the same way with 1k and 500-ohm resistors, 10k and 5k, 100k and 50k, etc. Try it yourself! It's fun.

have the time and patience, you can construct some nomographs by trial and error. The graduations on all scales of our nomograph are of the same length and can be assigned any value that you desire as long as the same size and values are used on all scales. For example, if one major division on the R1 scale is valued 100 ohms, then one major division on the R2 scale and one major division on the Rt scale must also be valued 100 ohms. With this in mind, let's find out how to use the equivalent resistance nomograph to solve parallel resistance problems.

Using A Nomograph. The equivalent resistance nomograph can be used in either of two ways. In one application you have two resistors connected in parallel and want to know what value single resistor will be needed to replace the parallel combination. This situation often arises in breadboarding new circuits. To solve this problem you simply locate one resistance value on the R1 scale, and the other resistance value on the R2 scale. Then lay a ruler, or draw a straight line between the points located on the R1 and R2 scales. The equivalent resistance will be where the straightedge crosses the Rt scale.

In another application you know the value of one resistor and want to know what value of resistance must be connected in parallel with it to obtain a desired value. This problem may arise because your stock of resistors is depleted, or because the required resistor is not a standard value. Non-standard values of resistance cost more, of course, and at times two resistors in parallel will enable you to get the desired resistance at a much lower cost. To arrive at the value of the resistor that you need to parallel with one of known value to reach the odd-ball resistance you want, find the mark on either the R1 or the R2 scale for the known resistance value. Next locate the resistance of the desired resistor value on the Rt scale. Then lay a straightedge between the two points, and read the value of the required parallel resistor on the remaining scale.

Typical Problems. A typical problem will serve as an example that should bring everything into sharp focus now. Let's suppose that we have two resistors, 100,000 ohms and 47,000 ohms, connected in parallel in a project that's breadboarded and now ready for finalizing. With this parallel combination in the circuit our little jewel works fine, but the combination is bulky, unsightly, and expensive for quantity production. So obviously it's desirable to replace the bulky parallel resistor combination with a single fixed resistor.

Using the Equivalent Resistance Nomograph, locate the 100,000-ohm value on either the R1 or R2 scale (we used the R1 scale). We could have chosen any point on the scale as 100,000 ohms, but for better resolution the maximum point is the best choice. Next locate 47,000 ohms on the R2 scale, remembering that each major division is equal to 10,000 ohms because of the location of our assignment of the 100,000-ohm point on R1.

Now lay a straightedge across the nomograph so that it intersects the 100,000 and 47,000-ohm points on R1 and R2. Where the straightedge crosses the Rt scale, a line can be drawn on the nomograph, or, if you prefer, you will read the resultant resistance value, 32,000 ohms, on the Rt scale. In comparison, the correct answer, using slide rule and/or pencil and paper, of 31,950 ohms certainly will take much longer to calculate than if you use the Equivalent Resistance Nomograph. ■

Frequency Fundamentals

☐ It was 4:00 A.M. and the thermometer read 15 degrees below zero. The squad car had to deliver the package without delay! Thanks to the flashing red light and the 2-kHz note screaming from the siren, the three miles from the bus terminal to police headquarters were covered in only 2½ minutes. The chief rushed out to get the package. He likes his coffee hot.

So the siren gave out a 2-kHz note. Is that anything like say, the 60-Hz current which lights a table lamp or, maybe, the 27.155-MHz carrier a CBer sends out from his 5-watt rig? The answer is yes—and no! No, because the siren note is actually a *disturbance of the air* which surrounds the whirling siren. The 60-Hz current which lights the lamp is actually a *disturbance of electrons* in the lamp cord. And the CB carrier is actually a *disturbance in the electro-magnetic field* which surrounds the transmitting antenna. But the answer is also yes because, in spite of their apparent differences, the siren note, the 60-Hz current, and the 27.155-HMz signal all have something in common—the characteristic way each of these "disturbances" go through their vibrations.

Bouncing Air. If analyzed scientifically, each type of disturbance is seen to be a repetition of identical actions. When the siren gives out a constant howl, tiny air particles are forced to collide and spread apart—in steady rhyhm. If the howl is a 2-kHz note, the colliding and spreading takes place 2000 times a second. Although the individual air particles move hardly any distance at all in their back and forth motion, the rhythmic collisions of these particles radiate from the siren in all directions, from particle to particle. This radiation is, of course, "sound" and travels through air at a speed of about 1100 feet per second.

Bouncing Electrons. Alternating current flows back and forth through a wire because electrons, in varying quantities, are made to push one another first in one direction and then the other—in steady rhythm. If this AC is 60-Hz current, such back and forth motion takes place 60 times a second. The individual electrons don't move very far along the wire in either direction but their "bumping" travels through the wire at a speed of almost 186,000 miles per second. Naturally, this bumping action is made to change directions in step with the electrons that cause it.

Bouncing Fields. Basically, a radio signal is a disturbance in which the electric and magnetic fields surrounding a transmitting antenna are distorted, first in one direction and then the other—in steady rhythm. If this signal is a 27.155-MHz CB carrier, these fields are forced to change direction 27,155,000 times a second. This rhythmic, field-reversing action radiates from the antenna at the speed of light, 186,000 miles per second.

Feel the Vibrations. Now—it's the changing nature of these three types of disturbances that we are really interested in! Aside from what is actually and physically happening, all three seem to follow the same pattern of change while going through their vibrations. True, the 27.155 MHz signal does its vibrating much, much faster than the other two but its vibration pattern is much the same.

Instead of using a lot of words to describe how each disturbance goes through its vibrations, let's use a helpful mathematical tool—the graph. The ancient Chinese said that *a picture is worth a thousand words* and that's exactly what a graph is and it's worth. More important, a graph provides us with a *lasting* picture, a permanent record, of how these vibrations change their speed and direction.

Our graph is set up in the usual manner. First there are the two reference lines, the "vertical axis" and the "horizontal axis." In our graph, the horizontal axis is made to show the *passage of time*. How the vertical axis is used depends on which type of disturbance we are portraying. For the 2-kHz siren note, the vertical axis is made to measure *how far* each air particle moves during its back-and-forth motion. For the 60-Hz AC current, the vertical axis measures *how many* electrons are in mass movement along the wire during their forward-and-reverse motion. As for the 27.155-MHz signal, this axis tells *how much* and in what direction the electric and magnetic fields are being distorted.

So much for the preliminaries. Next comes the most important item. It doesn't matter which disturbance we are graphing—for each *instant of time* that is represented on the horizontal axis, there is a *point* above or below the axis which measures how far the vibration is displaced from its resting position. If all these individual points (and there are an unlimited number of them) are "plotted" on the graph, a continuous curve will appear. The amazing thing about this curve is that its shape looks pretty much the same for the 2-kHz note, the 60-Hz current and the CB carrier.

Study the special shape of this curve. While examining the curve (and this must be done from left to right, never from right to left!), notice that it rises abruptly, gradually tapers off, levels out for an instant, starts to fall, picks up downward speed, and falls below the horizontal axis only to repeat the process in upside-down fashion. The 2-kHz note will make 2000 of these waves in just one second while the 60-Hz current goes through only 60 of them. But the CB carrier will turn out 27,155,000 of these double swings during each second.

You Had Better Believe. This curve we have been discussing is something very special! It is fundamental to many different areas of science and engineering. It is the famous *sine curve*. The current leaving a simple AC generator varies according to a sine curve. So does the output of a vacuum-tube or transistor oscillator in an AM radio. Even the pendulum on a grandfather's clock swings back and forth in accordance with a sine-curve pattern.

But it must be understood and understood well! The sine curve is only a graph which shows the changing character of sound waves, alternating currents, and radio transmissions, etc. To be sure, a sine curve is a picture but it *is not* a picture of sound waves, currents and radio signals as they really look (if, in some way, we could actually see them).

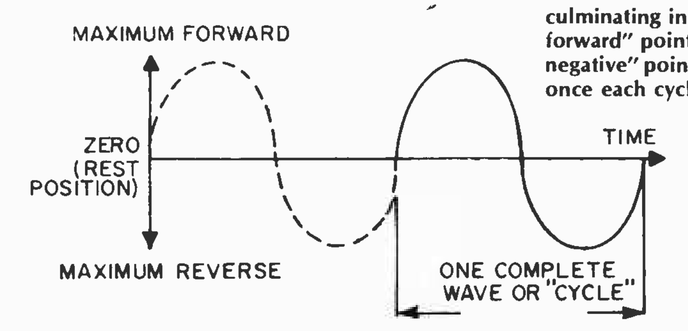
Ironically (and students of electronics must not be misled because of this), there are sine-curve relationships in other fields of science where the physical occurence actually looks like a sine curve. If a pebble is drooped into a calm pond, for example, ever-enlarging circles (ripples) will be seen leaving the splash. However, if these ripples are viewed from the side, at water level, a train of honest-to-goodness sine curves will be observed as they leave the splash area. As another example of real-life sine curves, if two persons suspend a rope between each other and one of them whips it up and down, a beautiful sine wave will run along the rope. Nevertheless, sine curves *don't* travel through electrical circuits, they *don't* travel through air as sound waves, and they *don't* radiate from transmitting antennas! Radio signals, AC currents and sounds vibrate in unison with sine curves but they *don't* look like them! However, a check of their graphs indicate they do!

Discovering Frequency. At this point, the true meaning of "frequency" should become clear. It doesn't matter if we are talking about sound waves, AC current, or radio carriers. Frequency is the number of times these various disturbances repeat their vibrations during *one second*. From a graphical standpoint, frequency is the number of times *each* complete cycle of sine curve is repeated during *one second*. Either way you look at it, frequency can be classified by its number of "cycles per second." As everyone should now know, however, this once common designation for frequency has been replaced by, simply, "hertz" (Hz) in honor of that great German scientist of the Nineteenth Century, Heinrich Hertz.

To Sum Up. The 2000-Hz sound energy from the police-car siren, the 60-Hz AC from the wall outlet, and the 27,155,000-Hz carrier from the CB rig are three different scientific phenomena. But they have the common property of being able to be described by sine curves and, because of this, all can be measured by a common yardstick—frequency.

But hold on! Are these three so-called disturbances really so different from each other? (After all, electronics wouldn't be electronics without sound and radio signals!) They are different, but not as much as you would think. With the aid of a "transducer," one type can be *transformed* into another! Thus, a *microphone* will change 2-kHz sound waves into 2-kHz alternating current in a wire. A *loudspeaker* will change the AC back into sound waves. A *receiving antenna* will change 27.155-MHz electromagnetic energy into 27.155-MHz alternating current (AC) in a wire (the antenna feedline, that is). A *transmitting antenna* will make the opposite change.

That's it. If the interrelation between sound, electrical, and electromagnetic frequencies now makes sense to you, you've learned a tremendously important bit of electronics theory. And don't forget the almighty sine curve. The sine curve can be used to explain theory in many fields of science, not just electronics. Nevertheless, keep clear in your mind just how the sine curve fits into electronics—what it is and what it isn't. Maybe you don't care whether your coffee is hot but you better stay *hot* on the *sine curve*. ■



Whether you're trying to graphically picture ripples on a sylvan pond, or the unmodulated carrier of a Citizens Band RF voltage, the familiar sine wave is all you need to draw. All sine waves have peaks culminating in "maximum forward" points and "maximum negative" points, each occurring once each cycle.

Coils and Capacitors

☐ The lowly resistor is the solid citizen of electronics. It can be relied upon to behave with the same, predictable performance, whether confronted with AC or DC. Unruffled by excursions into the higher frequencies, it continues to live by the guiding rule—Ohm's law—and declares that, no matter what, the current (I) it permits to flow shall depend solely on the applied voltage (E) divided by its own resistance (R).

However, the resistor's component cousins—the inductor and the capacitor—are by no means so stolid in the face of changing frequencies. The inductor, for example, grouchily shuts off more and more of the current flow as the applied frequency gets higher and higher, while the capacitor reacts to higher frequencies in just the opposite manner—it happily allows more and more current to flow as the frequency rises.

Fortunately, the reactionary behavior of these components is just as predictable as is the single-mindedness of their resistive cousin. If we study the strange conduct of these apparently erratic citizens, we not only discover the rules which govern their odd behavior, but also perceive that ultimately, they too, are faithful to Ohm's law—in their fashion—just as are all electronic components and circuits.

Reactionaries in the Lab. To begin our study, let's set up the lab experiment shown in Fig. 1.

Here, we have an audio oscillator set to produce an output of 60 Hz, and a power amplifier to amplify that signal to the 100-volt level. The power amplifier drives a load consisting of a large (25-watt) 390-ohm resistor connected in series with an ordinary 1½-volt (0.25-amp) flashlight bulb. An AC meter reads the output voltage from the power amplifier.

Turning on the equipment, we set the audio oscillator to 60 Hz, and gradually turn up the amplifier gain till 100 volts appears at the output. (Note: The ordinary hi-fi amplifier won't do this—you will need a public address amplifier with a high-voltage (70-volt, or 500-ohm) auxiliary output if you actually want to carry out this experiment.) At this point, the bulb will light to its normal brightness, indicating that the 100 volts is pushing about 0.25 ampere through the combined resistor/light-bulb circuit. Using Ohm's law, we can easily check this:

$$I = E/R$$
$$= 100 \text{ volts}/(390 \text{ ohms} + 6 \text{ ohms})$$
$$= 0.252 \text{ amperes}$$

Note that the light bulb's resistance, R, is

$$R = E/I$$
$$= 1\tfrac{1}{2} \text{ volts}/\tfrac{1}{4} \text{ ampere}$$
$$= 6 \text{ ohms}$$

Please also note that it's the 390-ohm resistor, not the bulb, which is the chief authority in establishing the current. The lamp current will change very little, whether the bulb is 6 ohms, 12 ohms, or zero ohms.

Next, let us vary the frequency of the audio oscillator; first, down to 30 Hz, and then, up to 120 Hz. We notice that the bulb stays at the same brightness, indicating that the 390-ohm resistor is behaving in its normal, stolid fashion—that is, it is steadfastly ignoring frequency changes, and permitting its current flow to be determined solely by Ohm's law. Even if the frequency were zero (which is another way of saying DC), the bulb's brightness would remain the same, if we applied 100 volts to it.

Enter the First Reactionary. Now, let's go to our parts supply bin, pick up a 1-henry inductor, and make a few preliminary measurements on it. Using an inductance bridge, we discover that its real value is 1.05 henry. We next connect it to an ordinary ohmmeter as shown in Fig. 2, which informs us that the inductor has a resistance of 45 ohms.

Now, let us replace the 390-ohm resistor of Fig. 1 with this 1-henry inductor as shown in Fig. 3, and predict what will happen when we turn on the equipment. Since the ohmmeter said "45 ohms" we can predict that the current will be

$$I = E/R$$
$$= 100 \text{ volts}/45 \text{ ohms} + 6 \text{ ohms}$$
$$= 1.96 \text{ amperes!}$$

With this large current—nearly 8 times normal—the light bulb should burn out almost instantly! However, when we apply 100 volts of 60 Hz to the inductor-plus-bulb, we are surprised to see that the bulb lights to normal brightness! This means that the inductor is behaving like a 390-ohm resistor, and is establishing a ¼-ampere flow of current—not the nearly-2 amperes calculated from the above ohmmeter measurement.

To compound the mystery, let us now vary the frequency of the oscillator: first, up to 120 Hz—and the bulb gets dimmer!—and then gingerly, down, just a little, to 50 Hz—and the bulb gets uncomfortably brighter. Here, in the lab,

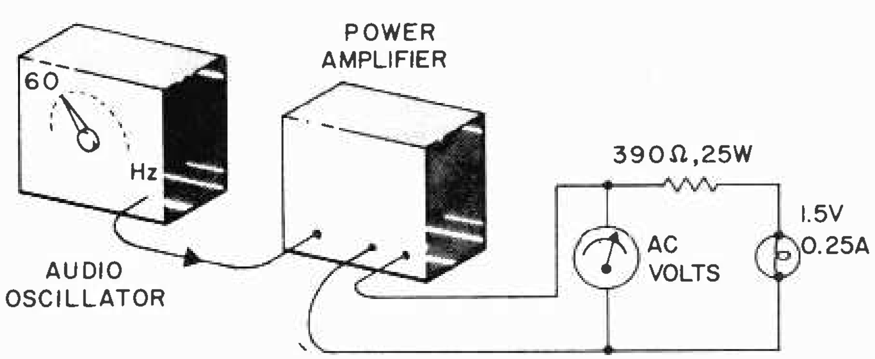


Fig. 1. Practical laboratory setup to demonstrate Ohm's law. Power amplifier must have a 70-volt output or a 500-ohm output transformer tap.

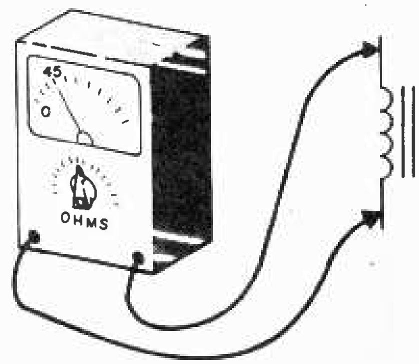


Fig. 2. Measuring the DC resistance of a one-henry inductor (choke coil) shows it has 45 ohms of resistance.

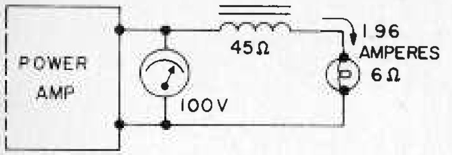


Fig. 3. Substituting the one-henry inductor in place of the 390-ohm resistor of Fig. 1 lowers the opposition of the circuit to AC, hence more current flows.

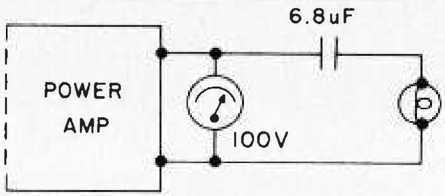
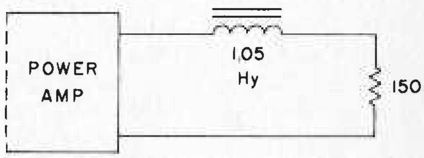


Fig. 4. A 6.8 uF capacitor substituted in the test circuit for the inductor. If the capacitor acted as an open (as it would for DC) no current would flow.

Fig. 5. Test circuit load is now combination of inductor (1.05 henry) and resistor (150 ohms). As the text explains, their combined reactance is computed by adding them at right angles!



is the actual behavior forecast by theory —the inductor grouchily shuts down the current flow for high frequencies, causing the bulb to go dim at 120 Hz, but it is willing to let low frequencies through, thus allowing the bulb to get brighter for 50-Hz input.

A Little Compassion for the Reactionary. To understand this "reactionary" behavior, we must understand how an inductor "feels" about an alternating current. An inductor is, after all, an electromagnet. If a steady direct current flows through it, it fills the space in its vicinity with a magnetic field. If we attempt to cut down the inductor's current, it reacts, quite understandably, by collapsing its magnetic field. But this collapsing field moves across the inductor winding in just the same way that a dynamo or generator field moves through the generator windings to make an output voltage. The inductor, then, reacts to any attempt to change its current by *acting as its own generator*, generating a new voltage of the correct polarity *to try to keep its own current from changing*. So, in its own way, the inductor is a solid, but *conservative* citizen—a citizen who tries to maintain the status quo.

Furthermore, the faster we try to change its current, the harder the inductor works to keep the current from changing. Therefore, the inductor sees a high frequency as an attempt at rapid changes—a threat to the status quo—so it works very hard to generate an opposing voltage (a 'counter-EMF' or 'counter-electro-motive-force') to keep its current from changing. This internally-generated voltage opposes the applied voltage more and more as the frequency rises; hence the actual current which flows drops lower and lower as the frequency rises. *This means that the apparent resistance of the inductor rises with frequency.* But this apparent resistance is not called *resistance*—since it is the inductor's reaction to the frequency applied to it, it is called *inductive reactance*.

A Resistance by Any Other Name. But whether you call it "apparent resistance" or "inductive reactance", it is still measured in ohms, and can be used as a part of the familiar Ohm's law formula. Where a simple resistive circuit answers to the expression

$$I = E/R$$

A similar circuit with resistor replaced by an inductor (coil) is described by the formula:

$$I = E/X,$$

where X is the symbol for reactance. But, since the amount of reactance (X) changes according to frequency, we must have a way to calculate its value at the frequency we are using. The following simple formula does that for us:

Inductive Reactance = 2 × π × frequency × inductance or, in the familiar algebraic shorthand,

$$X_L = 2\pi fL$$

where L is the inductance in henrys, and the subscript L following the X indicates we are talking about *inductive* reactance. Therefore, the current in an inductive circuit is:

$$I = E/X_L,$$
$$= E/2\pi fL$$

For Example. Let's take the 1.05-henry inductor and calculate its reactance at 60 Hz:

$$X = 2\pi fL,$$
$$= 2 \times \pi \times 60 \quad \times 1.05$$
$$= 395.8 \text{ ohms.}$$

which, as you can see, is very close to the 390 ohms of the resistive circuit of Fig. 1. This explains why the bulb lit to about the same brightness for the inductor as for the resistor.

When we cranked the audio oscillator up to 120 Hz, the inductive reactance became

$$X_L = 2\pi fL,$$
$$= 2 \times \pi \times 120 \quad \times 1.05$$
$$= 791.7 \text{ ohms.}$$

The new current becomes, ignoring, for the moment, the 6-ohm bulb:

$$I = E/X$$
$$= 100 \text{ volts}/791.7 \text{ ohms},$$
$$= 0.125 \text{ ampere.}$$

which is about half the rated current of the bulb. Hence, it would be dim at this frequency. You can easily calculate that at 50 Hz, the X becomes 329.9 ohms and the current rises to the excessive value of .303 amperes; any further lowering of frequency could burn out the bulb!

Reactionary No. 2: The Capacitor. Returning to the parts-supply bin, we now take a large, *oil-filled* (—Don't try this with an electrolytic!) capacitor, and, measuring it on a capacitance bridge, find that its true value is 6.8 mfd. An ohmmeter placed across the capacitor's terminals registers an upward 'kick' of the needle as the ohmmeter's internal battery charges the capacitor, but the ohmmeter then settles down to indicate that, as far as *it* is concerned, the capacitor is—as it should be—an open circuit

We now replace the 390-ohm resistor of Fig. 1 with the 6.8 uF capacitor, as shown in Fig. 4.

Again set the oscillator to 60 Hz, and turn on the equipment. Since the capacitor is really an open circuit—according to the ohmmeter—one might expect no current flow at all. We are surprised, then, when the light bulb blithely ignores our oil-filled open circuit, and proceeds to glow as serenely and confidently as it did for the inductor and resistor! When we *drop* the frequency to 30 Hz, the bulb goes dim—when we gingerly raise the frequency to 70 Hz, the bulb gets brighter. This is just the opposite of the inductive effect, where the bulb got dimmer for higher frequencies.

Capacitive Reactance. We are obviously dealing with another type of reactance, this time arising from the presence of the capacitor in the circuit, and known as *capacitive reactance*. Its behavior in the face of changing frequency is exactly the opposite of that shown by inductive reactance. A capacitor's apparent resistance goes *down* as frequency goes up, and goes *up* as frequency goes down. This inverse relationship is seen in the expression for capacitive reactance, which is

$$X_C = \frac{1}{2\pi fC}$$

where X is *capacitive* reactance, and C

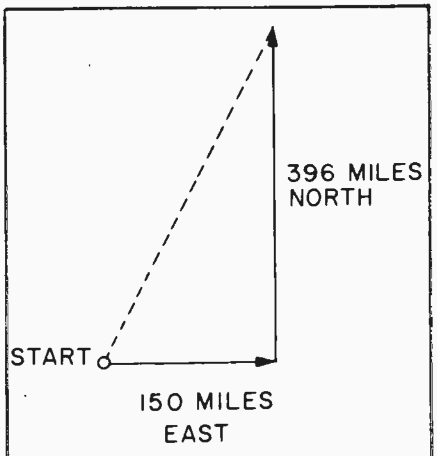


Fig. 6. Adding traveling distances in different directions yields resultant which is the diagonal (the shortest distance between the two points), also a right triangle. Back to the Pythagorean theorem!

is the capacity in *farads,* (not microfarads.)

Mathematically speaking, by placing f (frequency) in the *denominator* (bottom) of the fraction, we are saying that as f gets *larger,* the answer (X) gets *smaller,* which is exactly what we observed in the lab experiment above.

Just as in the inductive case, we can plug X right into the Ohm's law formula and have a way to calculate current or voltage for a capacitive circuit:

$$I = \frac{E}{X}$$

More Examples. As examples of how the above formulas can be used, let's calculate reactances and currents of our 6.8-uF capacitor at various frequencies at 60 hz,

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{2\times\pi\times60Hz\times6.8uF}$$

$$= 390.1 \text{ ohms.}$$

(Note that 6.8 *micro*farads must be expressed as 6.8×10^{-6} farads, since the formula is always written for C in *farads.* Alternately, you could write 6.8 microfarads as 0.000 006 8 farads, but that's a little more awkward to handle.)

At 30 Hz, a *lower* frequency, the capacitive reactance *increases:*

$$X_C = \frac{1}{2\times\pi\times30 \text{ Hz } (6.8\times10^{-6})} \text{ farads,}$$

$$= 780.2 \text{ ohms,}$$

and at a *higher* frequency, say 70 Hz, the capacitive reactance becomes *less:*

$$X_C = \frac{1}{2\times\pi\times70 \text{ Hz } (6.8\times10^{-6})} \text{ farads,}$$

$$= 334.4 \text{ ohms.}$$

The current, in any case, can be found by Ohm's law. At 70 Hz, the current is

$$I = E/X,$$

$$= 100 \text{ volts}/\ 334.4 \text{ ohms,}$$

$$= 0.299 \text{ ampere,}$$

while at 30 Hz the current is:

$$E/X = 100 \text{ volts}/780.2 \text{ ohms,}$$

$$= 0.128 \text{ ampere.}$$

So, in their way, both inductors and capacitors are obedient to Ohm's law. Their reactances—X_L and X_C, respectively—can replace the R in the familiar Ohm's law expression, $I = \frac{E}{R}$ enabling us to calculate current flow for ac circuits which include inductors or capacitors.

Adding Apples and Oranges. But, what of circuits which *combine* an inductor and a resistor? Or an inductor and a capacitor? Can we simply add the two 'ohms' together? Do resistance and reactance add like apples and apples?

Unfortunately, this is not the case. Consider, for example, the circuit of Fig. 5. Here, our 1.05-Henry inductor and a 150-ohm resistor are connected in series across the 100-volt, 60-Hz source. What is the current flow?

Obviously, we need an Ohm's-law-like expression—something like:

I = E, divided by the apparent "resistance" of R and L, combined.

We know from our previous work that a 1.05-henry inductor has an X inductive reactance of about 396 ohms. We wish that we could simply add the 396 ohms of reactance to the 150 ohms of resistance to get 546 ohms—but reactance and resistance simply don't add that way. *Instead, they add at right angles!* And how, you ask, does one *add* at *right angles?*

A Journey at Right Angles. To understand how resistance and reactance can add at right angles, consider another type of problem: If I travel 150 miles due east, and then 396 miles north, how far am I from my starting point? See Fig. 6.

You obviously cannot get the answer to this problem by adding 396 to 150, because you're certainly not 546 miles from home. But notice that the figure is a right triangle—a shape which that old Greek, Pythagoras, solved long ago. He said that if you *square* 150, and *square* 396, add the squares, and then take the square root, you will get the length of the longest side:

$$\sqrt{(150 \times 150) + (396 \times 396)},$$

$$\sqrt{179{,}316},$$

$$432.3 \text{ miles.}$$

This, then, is a way of adding two quantities that act at right angles to each other. Since inductive reactance is a kind of "north-bound resistance", operating at right angles to the "east-bound resistance" of an ordinary resistor, we combine the two by adding at right angles, just as the two right-angle distances were added in the above mileage problem. The effective resistance of the 396-ohm reactance and the 150-ohm resistor is therefore:

$$\sqrt{(150 \times 150) + (396 \times 396)},$$

$$= 432.4 \text{ ohms.}$$

What do we call this combination? It is obviously neither resistance nor reactance, but a combination of both. Since it represents a *general* way that a circuit can impede the flow of electrons, it is called *impedance,* and is represented by the symbol Z. The general formula for impedance is, therefore:

$$Z = \sqrt{R^2 + X^2}$$

Another Candidate for Ohm's Law. Impedance is measured in *ohms,* just as are reactance and resistance. If we know the impedance and voltage in a circuit, we can find the current by plugging Z into the familiar Ohm's Law expression:

$$I = E/Z,$$

$$= E/\sqrt{R^2 + X^2}.$$

Using this expression we can calculate the current in the example of Fig.5:

$$I = E/Z,$$

$$= 10 \text{ volts}/423.4 \text{ ohms,}$$

$$= 0.326 \text{ ampere.}$$

Southbound Capacitors. The knowledge that inductive reactance adds at right angles to resistance leads immediately to the question, "What about *capacitive* reactance? Does it also act as a 'northbound' resistance?"

As you might except, two circuit elements as different as inductance and capacitance could never agree on the 'direction' of their reactances. If inductive reactance is 'northbound', the capacitor obstinately declares that *its* reactance is *'southbound',* acting in direct opposition to the inductive direction, as shown in Figs. 7 and 8.

However, this makes no difference in the equation for impedance, which is still given by

$$Z = \sqrt{R^2 + X^2},$$

where X is, in this case, X_C, capacitive reactance.

As an example, let's calculate the impedance of the circuit of Fig 9.

$$Z = \sqrt{R^2 + X^2}$$

$$= \sqrt{(150)^2 + (200)^2}$$

$$= \sqrt{62{,}500} = 250 \text{ ohms}$$

As a further calculation, let us determine the current which will flow if 50 volts is applied to the terminals at the circuit in Fig. 10:

$I = E/Z,$
$= 50/250$
$= 0.2$ ampere.

All Together, Now. The final question is this: If a circuit includes resistance, inductance and capacitance, all at once, what is its total impedance?

An example of such a series circuit is shown in Fig. 10.

Here, 100 volts at 70 Hz is applied across a series circuit of 150 ohms resistance, 1.05 henry inductance ($X_L =$ 462 ohms), and 6.8 uF capacitance ($X_C =$ 334 ohms).

As a first step in determining the total impedance, we can draw the 'directions' of the resistance and the two reactances, as shown in Fig. 11.

The first thing that strikes us about this figure is that the figure is that the effect of the 'northbound' (inductive) 462 ohms is partially cancelled by the 'southbound' (capacitive) 334 ohms. The *net reactance* of this circuit is:

$X = X_L - X_C,$
$= 462$ ohms $- 334$ ohms,
$= 128$ ohms.

This combining of X_L and X_C by simple subtraction reduces the problem to a simpler one, resembling a problem we've already solved. This is graphically shown in Fig. 12.

Applying the formula for impedance

$Z = \sqrt{X^2 + R^2},$
$= \sqrt{(128)^2 + (150)^2},$
$= 197.2$ ohms.

The current flow is:

$I = E/Z,$
$= 100$ volts/197.2 ohms,
$= 0.51$ ampere.

North vs. South. In the above problem, we saw that the 'northbound' inductive reactance (462 ohms) was very nearly cancelled by the 'southbound' capacitive reactance (334 ohms). It's pretty obvious that by changing some values, or by changing the frequency, we could make *X_L exactly equal to X_C*, and they would cancel each other completely, leaving the circuit with no net reactance whatsoever—just 150 ohms of simple resistance. This condition, where $X_L = X_C$ exactly, is called resonance. When a capacitance and inductance are in series there will be one frequency for which their net reactance will be zero. A parallel capacitance and inductance present a high impedance to a current. By using these circuits you can make filters that will pass or block certain frequencies. But that's another story altogether. ■

Circuits which include capacitance and inductance as well as resistance are only slightly more complicated than circuits with just pure resistance. Once the AC frequency is known the reactance of inductors and capacitors is figured, added (subtracted) and inserted into the formula for impedance (see text).

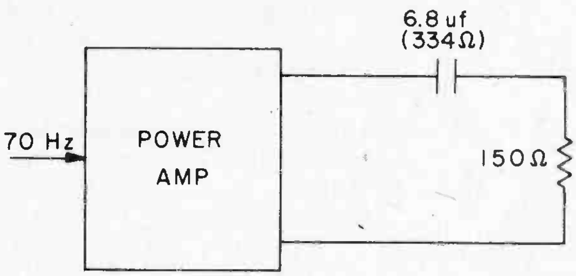


Fig. 7. The reactance of the capacitor at this frequency (70 Hz) is 334 ohms. This may be combined with the pure resistance, 150 ohms, by using the formula discussed in the text of this article.

Fig. 8. This drawing shows how the two reactances are added, as also shown in Fig. 6 and, described in the text.

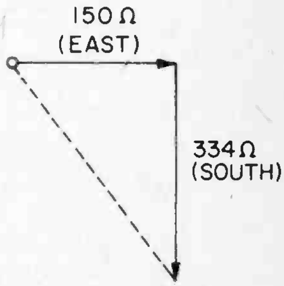


Fig. 9. Schematic showing reactance of capacitor. The two reactances add according to the formula, to yield a combined reactance (at the particular frequency used) of 250 ohms.

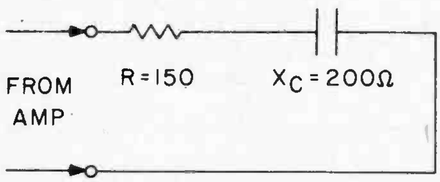
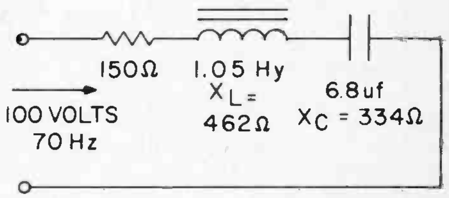


Fig. 10. Combining capacitive reactance and inductive reactance is also handled. Reactance of each at 70 Hz is computed, they are added together, and the difference is put into the formula with the pure resistance value.

Fig. 11. The relative "directions" of capacitive and inductive reactances along with that of the pure resistance. Z (the diagonal) is the resultant of the 150-ohms resistance plus the difference between the two reactances.



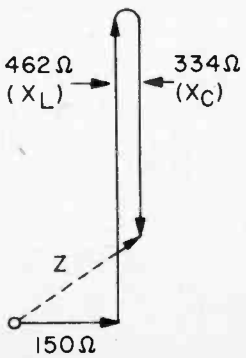
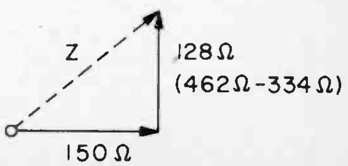


Fig. 12. Combining the reactances leaves a difference of 128 ohms and provides a directional diagram similar to that of Fig. 6. Such directional drawings are called "vector" diagrams.



The Cause and Cures of TVI

☐ Remember the time when radio interference consisted solely of "static" caused by wandering electrical storms? And how the invention of near-magical FM radio appeared to have solved all interference problems for good? During those halcyon days, few if any visionaries were around who could foresee the complex interference problems that would accompany the fantastic proliferation of such diverse communications systems as television, CB radio, AM/FM broadcasting, ham radio, radiotelephone and satellite communications, to mention only a few.

FCC Book. Interference problems relating to television usage have become especially bothersome. So much so, in fact, that the Federal Communications Commission has issued a special booklet to aid John Q. Public in his frantic efforts to identify and resolve the peskier kinds of interference problems. You can purchase the booklet, titled *How to Identify and Resolve Radio-TV Interference Problems* by sending $1.50 to the Consumer Information Center, Department 051F, Pueblo, Colorado 81009. It contains much the same information we have abstracted for this article, plus an appendix listing the names and addresses of companies that can provide additional guidance if you have especially sticky TVI problems. Use the following information first, and send your buck fifty to "Uncle Charlie" if you need additional assistance.

Most interference problems can be traced to one of four basic conditions: (1) characteristics of your TV or radio receiver, its antenna systems design and manner of installation, (2) environmental features including obstructing terrain features and the presence of a nearby radio transmitter, (3) characteristics of Citizens Band (CB) radio or other transmitters operating in your area, (4) practices of radio transmitter operators, especially the illegal use of overpowerful transmitters and/or associated accessory amplifiers.

Remedial action involves first the identification of the cause of interference, next the application of "Home Remedies" that anyone can try, and thirdly resort to more involved procedures that may require the assistance of a professional radio-TV repairman if your expertise in electronics is too limited. Primary emphasis is on the correction of television interference.

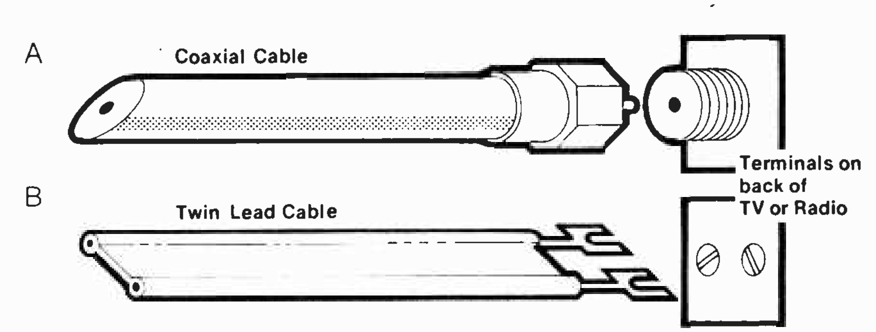
TVI Identification begins with comparison of your TV image with the photographs in this article. Note that very similar interference patterns can be caused by wholly different factors.

For example, parallel dark lines across the screen, sometimes accompanied by high pitch tones, may result from misadjustment of the horizontal control. So first check the horizontal control knob at the rear of the TV set. Or the horizontal hold problem may be caused by a bad tube or other defective component in the internal horizontal control circuitry of the set.

Radio transmitter interference (from CB, Amateur, Police or other transmitters) produces similar patterns, but only on VHF channels. You may also notice that the interference pattern changes or moves as the operator of the radio transmitter talks; this can be an important clue to differentiating radio interference from horizontal hold problems.

Electrical interference and poor TV signal problems can also be confused. Dancing bright spots on the TV screen usually indicate the presence of nearby spark-producing equipment, including such common items as hair dryers, electric shavers, mixers, blenders, power saws and vehicle ignition systems. You may hear a sizzling or buzzing sound along with the sound of the TV program.

If the picture looks washed out, and the sound is not affected (usually) the problem may be caused by a weak TV signal rather than by electrical inter-



Two types of antenna cable and their connectors—Coaxial cable at the top and 300-ohm twin lead at the bottom. Be sure that all connections are tight.

FCC District Offices

Alaska, Anchorage
Area Code 907 265-5201
California, Los Angeles
Area Code 213 426-4451
California, San Diego
Area Code 714 293-5460
California, San Francisco
Area Code 415 556-7700
Colorado, Denver
Area Code 303 837-4054
District of Columbia
Area Code 202 632-8834
Florida, Miami
Area Code 305 530-5541
Florida, Tampa
Area Code 813 228-2872
Georgia, Atlanta
Area Code 404 881-3084
Georgia, Savannah
Area Code 912 232-4321
Hawaii, Honolulu
Area Code 808 546-5640
Illinois, Chicago
Area Code 312 353-0195
Louisiana, New Orleans
Area Code 504 589-2094
Maryland, Baltimore
Area Code 301 962-2728
Massachusetts, Boston
Area Code 617 223-6609
Michigan, Detroit
Area Code 313 226-6078
Minnesota, St. Paul
Area Code 612 725-7810
Missouri, Kansas City
Area Code 816 374-6155
New York, Buffalo
Area Code 716 842-3216
New York, New York
Area Code 212 620-3437
Oregon, Portland
Area Code 503 221-3098
Pennsylvania, Philadelphia
Area Code 215 597-4411
Puerto Rico, San Juan
Area Code 809 753-4567
Texas, Beaumont
Area Code 713 838-0271
Texas, Dallas
Area Code 214 749-1719
Texas, Houston
Area Code 713 226-5624
Virginia, Norfolk
Area Code 804 461-6472
Washington, Seattle
Area Code 206 442-7653

ference. The TV receiver may be too far from the TV transmitter, large buildings or hills may be blocking the TV signal, or your antenna may be defective, improperly oriented, or may have broken or disconnected lead-in wires. Corrective methods include installation of a more powerful antenna, putting it on a higher mast, using a directional antenna, addition of a signal amplifier, or simply repairing the lead-in wire.

Herringbone patterns on the screen can be caused by FM interference or by a fine tuning problem. If the pattern changes with the sound of the TV program, you probably have a tuning problem; so start by readjusting the fine tuning control.

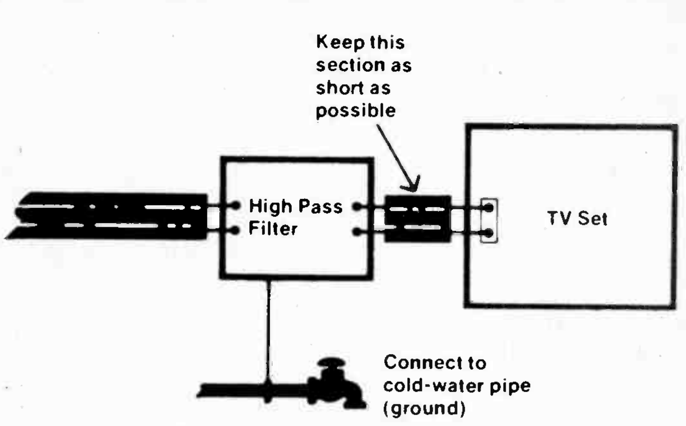
FM interference caused by a nearby FM broadcast station normally affects only TV channel 6, although one additional channel in the channel 2 to 13 range may also be affected. Sometimes both the picture and sound are affected, and the interference pattern may change with the sound of the FM broadcast station program, but not with the sound of your TV program.

Ghosting and co-channel interference problems are also look-alikes to the uninitiated, but easily differentiated by informed TV watchers. Co-channel interference occurs when your set displays two different TV signals simultaneously. You thus have two different programs superimposed. This type of interference can be caused by atmospheric disturbances, about which you can do nothing except wait for them to clear; fortunately such problems are usually very temporary. If the problem persists, look for a solution by switching to use of a highly directional antenna.

Ghosting is readily recognized because the same TV program is superimposed on itself. This problem can be caused by reflection of the TV signal by such things as large buildings, or by use of defective TV antenna or lead-in wire. Try rotating your TV antenna to a new position, and/or install shielded lead-in wire. If these measures fail, consider replacing the antenna.

Home Remedies. Home remedies for TVI involve corrective procedures that any home handyman should be able to do for himself, even if he has limited knowledge about TV troubleshooting.

If you have diagnosed your problem as one caused by radio transmitter interference, begin by installing a high-pass filter. Purchase a filter that matches the type of antenna lead-in wire in use. A round coaxial cable requires a filter having 75 ohms impedance while a flat twin-lead wire calls for a filter of 300 ohms impedance. Install the filter as near the TV set antenna terminals as possible. Disconnect the antenna wire from the TV set terminals and attach to the input terminals of the filter. In a twin-lead (flat cable) system, connect a short (1″ to 2″) jumper wire to the TV set terminals and to the filter output. For a coaxial system, buy a ready-to-use jumper cable having the proper fittings.



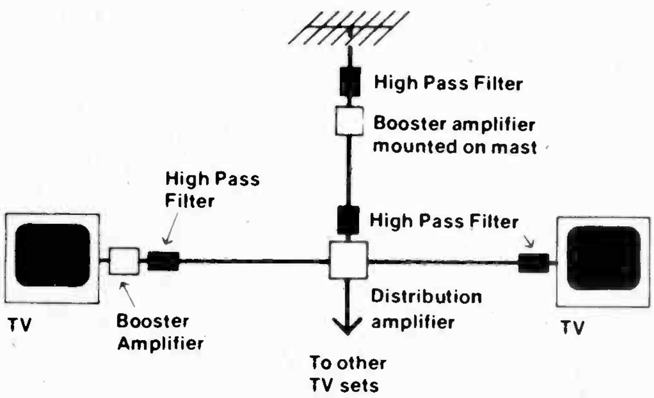
A high-pass filter helps eliminate radio transmitter interference. Connect the filter to the set with a short length of cable of the same type as used for the lead-in. Connect antenna lead-in to input filter. A ground wire may be advantageous.

If your system already has an antenna amplifier, you should install a filter ahead of the amplifier and a second filter at the TV receiver input terminals. If the amplier is close to the receiver, install a filter only before the amplifier.

A booster amplifier may be mounted near the back of the TV set, or may be out-of-doors, on the TV antenna mast. Somewhere in your antenna system there also may be a *distribution* amplifier that sends signals to two or more TV sets. In such case add a high pass filter before the distribution amplifier as well as before any booster amplifiers that may be used.

Add a ground wire from the filters to a cold water pipe or ground rod if the instructions that come with the filters so specify. Use bell wire that is readily available from any hardware store. If the filters do not entirely solve the radio transmission problem, have a TV repairman install another high-pass filter inside the TV set, at the tuner.

Auto Interference. Vehicle ignition system interference, caused by autos, lawn mowers, snowmobiles and other gasoline operated engines, is recognized by the "dancing dots" in the TV picture and by the "popping" noises that speed up as the offending engine is accelerated. If your own engine is the troublemaker, install a commercially-available kit to the vehicle to reduce ignition noise. If the engines are owned



Several high-pass filters may be needed to eliminate strong radio transmitter interference. Put one on line ahead of each TV set and one ahead of any booster or distribution amplifiers that you may be using in your TV antenna system.

by other people, the best solution may be to relocate the antenna (moving it away from or higher up from the source of noise) and by installing a shielded lead-in antenna wire.

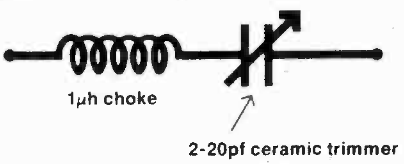
Electrical Interference. Interference from electrical devices calls for locating the specific device causing the problem. If you have a portable, battery-operated radio, use it as a detection instrument. Move from room to room and note where the radio interference ceases. If a portable radio is not available, or if your radio is not affected by whatever is causing TV interference, remove one fuse at a time from your fuse box, or punch circuit breakers off, until you find the house wiring circuit to which the offending appliance is connected. This helps zero in on the troublemaker.

If you are unable to find the cause of interference in your own home, seek the cooperation of your neighbors to track down a possible source of interference in one of their homes. If this fails, ask your power company to check the power lines in your area.

Electrical modifications to the interfering appliances should be attempted only by qualified personnel. It may be best to simply "live with" tools (electric drills and saws, for example) that cause only short duration interference. Refer to the check list of typical interference-causing devices to speed your search for an offending appliance.

FM Interference. FM interference calls for the installation of an inexpensive FM band rejection filter of the appropriate type as determined by the nature of the antenna lead-in cable (75-ohm coaxial or 300-ohm twin lead cable). Follow installation directions that come with the filter and that are virtually identical to directions concerning the installation of high-pass filters already discussed.

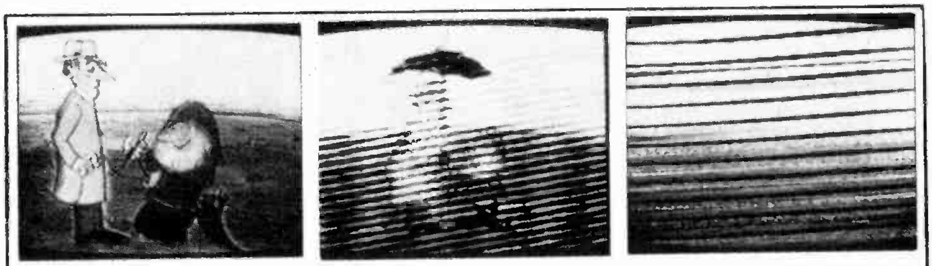
Incidentally, if you have a cable TV system you can install an FM band rejection filter or high-pass filter at the antenna terminals of your TV set. However, do not attempt any modifications to the cable system if the problem persists; contact the cable company repair service for assistance.



Interference on channel 2, from harmonics produced by some CB sets, can often be eliminated by this filter across the set's antenna terminals.

More Complex Cures. When home remedies fail you have no choice but to take more elaborate steps which may require the assistance of a professional TV repairman. If a high-pass filter does not solve a radio transmitter interference problem, proceed as follows.

First contact the operator of the radio transmitter that is identified as the source of interference and seek his cooperation to determine if the transmitter is operating properly. Is the transmitter properly grounded by means of a good radio frequency (RF) ground? (A single piece of wire to a ground rod may be an open circuit to RF.) Are harmonics and/or spurious emissions present? Is the transmitter cabinet radiating energy? Connecting the chassis to good earth ground with large diameter wire or copper strap should eliminate radiation of energy



NORMAL PICTURE — RADIO TRANSMITTER INTERFERENCE — HORIZONTAL CONTROL PROBLEM

When your TV set is picking up interference from CB, Amateur, Public Service or other radio transmitters it will normally affect only VHF channels. The center photo is interference, but if your screen looks like the one on the right, adjust the horizontal hold or call a qualified service representative.

NORMAL PICTURE — ELECTRICAL INTERFERENCE — POOR TV SIGNAL

Household tools, appliances and auto ignition systems can cause this type of pattern on a TV screen, often accompanied by a hissing or buzzing sound. Don't mistake this for a weak signal. If your set looks like the one on the right you might try a better antenna or a signal booster. Check all connectors.

NORMAL PICTURE — CO-CHANNEL INTERFERENCE — GHOSTING

Co-channel interference is interference by another TV channel on the same frequency. Two different pictures are on the screen. A directional antenna that points at the desired station is the cure here. Ghosting, on the other hand, is receiving the same signal at two different times and getting a double image.

NORMAL PICTURE — FM INTERFERENCE — FINE TUNING PROBLEM

A nearby FM broadcast staton can often cause the kind of picture shown here, particularly on channel 6. Tune in the suspected station and see if the picture wiggles along with the FM station's audio. The right-hand photo is of a fine tuning problem—here the picture will wiggle along with the TV's audio signal.

from the cabinet. Next install a low-pass filter on the transmitter antenna circuit. If a change occurs in the TV interference pattern, it's an indication of harmonics and/or spurious emis-s'ons from the transmitter. If no change ' ccurs, look for trouble in your TV re-ception system.

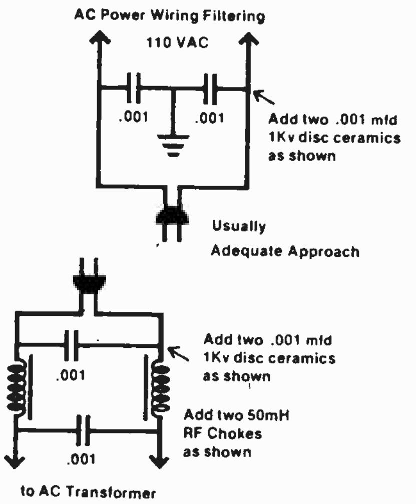
Begin your check of the TV reception system by conducting a visual inspection of the TV antenna, lead-in wire, and lightning arrestors. Repair or replace badly corroded components, clean and tighten loose connections.

Line amplifiers are highly susceptible to radio frequency (RF) energy. Remove any antenna line amplifier from the circuit. If the interference disappears, reconnect the amplifier but protect it by (1) grounding, (2) enclosing it in a metallic rf-proof housing and grounding the housing, or (3) installing a high-pass filter at the input to the amplifier. If one filter improves the condition, but does not eliminate all interference, install a second filter in series with the first.

To check the TV receiver system, add an AC power line RF filter to determine if the RF from the transmitter is entering the TV set through the power cord. Buy the RF filter ready-made, or make your own according to the schematic shown in this article. If this filter has no effect, and the antenna is disconnected, the set itself is obviously responding to RF energy. Caution! Very dangerous voltages exist inside a TV set, that could cause electrocution even when the set is off. The most likely internal circuit to be affected by RF energy is the tuner. Disconnect the antenna input lead inside the set where it is attached to the tuner; if the interference is eliminated, install a high-pass filter at the tuner. If the interference persists after addition of the filter, each stage of the TV set will have to be checked for RF sensitivity.

Second Harmonics. CB second-harmonic interference to channel 2 may exist even when the transmitter meets FCC specifications for harmonic radiation. In such case, a tuned filter placed across the antenna terminals of the TV set should help. The filter may be an inductor and capacitor in series, and tuned for minimum interference.

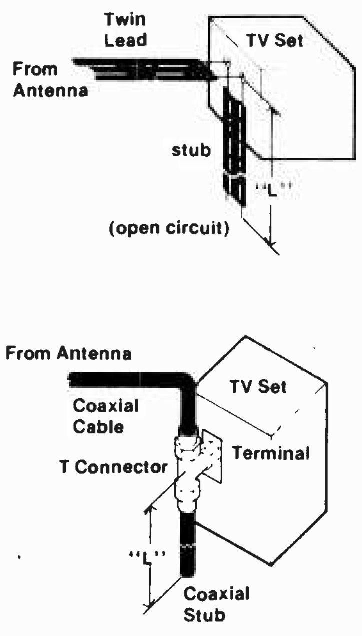
A second method of coping with CB intereference is to place an open circuit, quarter-wave, tuned stub across the antenna terminals. Make the stub from the same kind of wire as is used at the antenna input terminals. The initial stub length should be 37 inches for RG-59/U coax cable, and 48 inches for 300-ohm twin lead. One end of the cable is attached to the antenna terminals, along



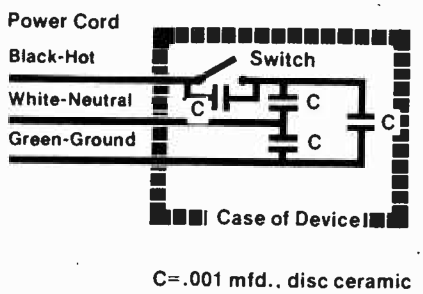
To prevent a power line from feeding unwanted RF into a TV, insert either of these filters into the power line, or use a commercially made filter.

with the regular antenna cable. A T-connector is required with coaxial cable (see diagram). The other end of the stub cable remains unconnected, but is gradually cut shorter, in ⅛-in. to ¼-in. increments, until the TV interference is eliminated.

If the harmonics fall on other TV channels (for example, 5, 6, or 9) the length of the stub may be shortened according to the following formula in which V is the velocity factor of the line (for 300-ohm twin lead V=0.82;



CB interference can be minimized by adding a stub trap to the terminals. Note the "T" connector used with coax cable. The text explains how to determine L.



Electrical interference caused by tools and other appliances may require modification of the device rather than the TV set. Spark damping capacitors must be put inside the appliance.

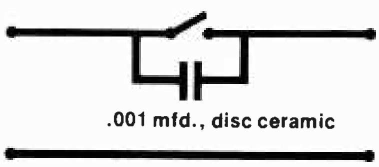
for RG-59/U, V=0.66) and f is the frequency in megahertz:

$$\text{Length in inches} = \frac{2952V}{f}$$

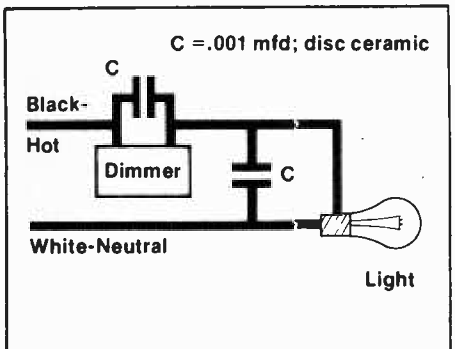
Amateur radio interference to channel 2 can be caused by the 6 meter band (50-54 MHz) because this frequency range is adjacent to channel 2 (54-60 MHz). Addition of an open circuit, quarter-wave, tuned stub at the TV antenna terminals should be effective. If the antenna lead-in wire is RG-59/U coax cable, make the stub 42 inches long. If 300-ohm twin lead is used, the length should be 53 inches. Again, clip off ⅛-in. to ¼-in. increments from the free end of the stub until interference is eliminated. If this procedure reduces, but does not wholly eliminate, the interference, add a second stub to the input terminals of the tuner. The theoretical final length of the stub can be calculated using the equation given in the preceding section dealing with CB interference.

Electrical interference problems may call for modifications in the circuitry of the offending appliances. However, you should check local electrical codes to determine if the device may be modified, and whether a licensed electrician must modify the device.

Caution! All bypassing of devices



Replace worn or pitted breaker points on troublesome controls. Add a small value disc capacitor across the switch.

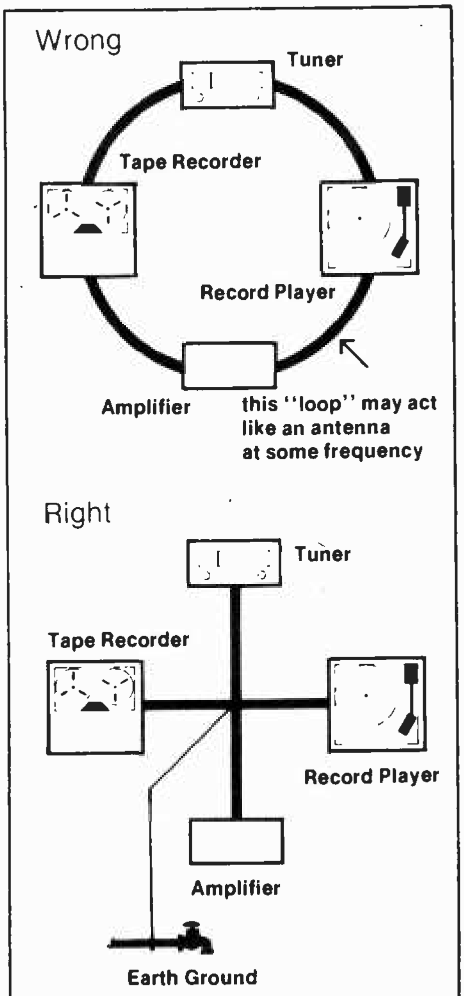


Dimmer switches can be particularly troublesome. Use disc capacitors to bypass the switches and across AC.

with capacitors should be done with extreme care to be sure that the AC line is not shorted. Dangerous voltages exist, and can cause electrocution if mishandled! Also, avoid any power wiring which can cause the full AC line voltage to appear on the case of the device, and use a tester to be sure that the case of the appliance is properly grounded after making any alterations.

Electric drills and saws are best left alone unless interference from them is of long duration. Arcing between the brushes and commutator is controlled by bypassing each side of the line to ground with a capacitor, as well as bypassing each side to the other (see drawing). Also bypass the switch. All such bypassing should be made inside the case of the tool.

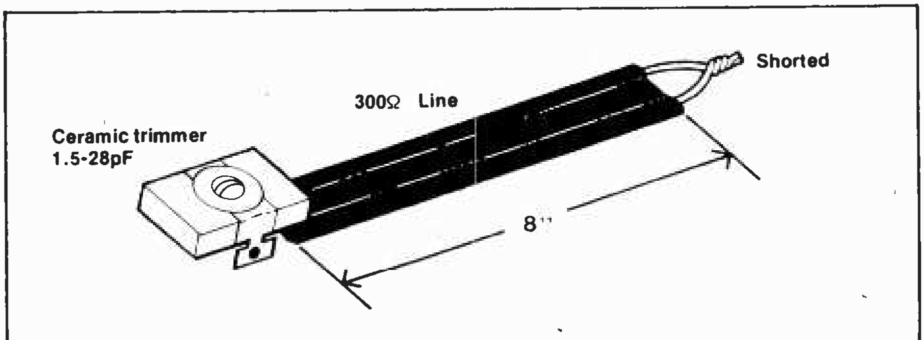
Electric blankets, fish tank heaters, and other thermostatically controlled appliances that have worn or pitted contacts can cause interference. Eliminate the problem by bypassing the contacts with a 0.001 mfd capacitor or by replacing the worn or pitted contacts. Defective devices such as doorbell transformers should be replaced. Dimmer switches that utilize SCR or triac can produce tremendous intereference that is very hard to eliminate because of the approximate square wave output that is produced by the switching at the SCR or triac. However, capacitor-bypassing, as shown, may be helpful. When by-



The correct way to ground several audio components is to feed ground wires to a common point which is then connected to earth ground by one wire. Avoid ground loops that can act like antennas to pick up interference.

passing AC circuits, use ceramic capacitors.

The elimination of FM interference may require the use of several procedures, so leave any modifications in place when you proceed to the next step. First see if an FM band rejection filter has been installed on the TV set antenna terminals, and add one as described in the "Home Remedies" section if it is missing. Next try a tuned stub trap which is constructed as shown in the diagram. Place the trap on and parallel to the lead-in and tune for minimum interference; then slide the trap long the line to further reduce interference. Finally, tape the trap to the lead-in where it is found most effective.



An FM interference trap can be added to a TV antenna cable, tuned, then repositioned on the cable to provide minimum interference. See text for details.

An open circuit, quarter-wave type stub may also be used. Make it from the same type of cable used for the antenna lead-in. The initial length of the stub should be 24" for RG-59/U coaxial cable and 29" for 300-ohm twin-lead wire. If "F" type tee connectors are not available for the coax cable, use a BNC type connector. If connecting the stub to the antenna terminals is not completely effective, add a second stub of the same length directly to the input terminals of the tuner, inside the TV set.

Audio Interference. Audio Interference to such devices as tape recorders, record players, electronic organs, telephones and hi-fi amplifiers is caused when the equipment responds to transmissions of a radio transmitter. Usually, the transmitter is nearby—but not always. For example, the author, in southern Connecticut, once received clear broadcasts from a Canadian radio station with a tape recorder that was completely disconnected from all other audio equipment. Audio interference (also called audio rectification) may also affect the sound portion of TV and AM/FM radio.

This type of interference is recognized two ways: (1) you hear the voice transmissions of the radio transmitter and/or (2) the volume level of the audio device you are using may decrease.

The correction of audio interference usually requires internal modification of the affected equipment, but there are steps you can take before calling in a professional repairman. For audio devices other than a telephone, replace unshielded wire between the amplifier and speakers with shielded wire. Next ground the affected equipment to a metallic cold water pipe or ground rod using bell wire. DO NOT under any circumstances ground "AC-DC" type devices. If the equipment has no clearly marked grounding terminal, consult a qualified serviceman before adding a ground connection.

If these treatments don't bring about a cure you will have to resort to some of the internal modifications described in the FCC booklet mentioned at the beginning of this article.

Local Television Interference (TVI) Committees are available to assist in the resolving of interference problems. Contact the nearest FCC district office or either of the two following organizations for information about the TVI committee in your area: International CB Radio Operators Association (CBA), P.O. Box 1020, Roanoke, VA 24005; of the American Radio Relay League, Newington, CT 06111. ■

Line-of Sight Antenna Theory

☐ The TV, FM, or Action Band DXer is constantly concerned with the line-of-sight (LOS) limitations imposed by the curvature of the earth and the combined antenna heights of the receiver and transmitter.

The figures presented here represent only the actual line-of-sight distances. This is because we can generally ignore refraction effects in this discussion. It's possible to do this because the wavelengths we encounter are very short when compared to the size of the earth. Also, the angle of incidence with the horizon is practically zero. There will be some diffraction due to man-made obstacles and terrain variations. This usually works in favor of increasing propagation distance, but typically account for less than a 10% increase in overall range. The antenna heights calculated here will guarantee reception of a clean signal which is caught "on the fly."

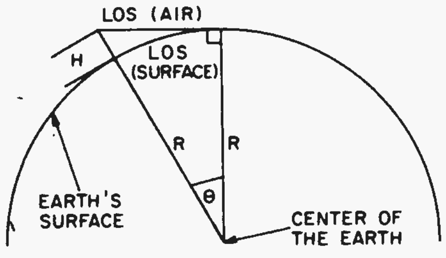
Since the triangle within the figure shown is a right triangle, the relationship $\cos \theta = r/(r+h)$ must be true. The radius of the earth (20,873,998 ft.) is r and the antenna height is h. Each degree measured along the surface of the earth is 69 statute miles therefore, the line-of-sight along the surface of the earth (as opposed to through the air) is given by 69 x arc cos θ. This information is presented in both tabular and graphic form.

This information can be used to determine what stations are within range of your antenna, or how high your antenna should be to receive a particular station. You will need to know antenna heights and geographical features in your area. Antenna information can be found in Spot Radio Guide which can be found in the business and commerce section of larger libraries, or by contacting the station involved. The best way to determine geographical features is to look them up on a topographical map either from an atlas at the library, or from some other source such as an Aeronautical Sectional Chart. The Sectional Chart sells for about $2.00, and can give you both antenna heights and topographical information if you know the location of the antenna. If you cannot obtain this information, you can make an educated guess as to the antenna height (800-1000 ft. for TV, 500 ft. for larger FM stations and 150 ft. for firehouse or police station antennas).

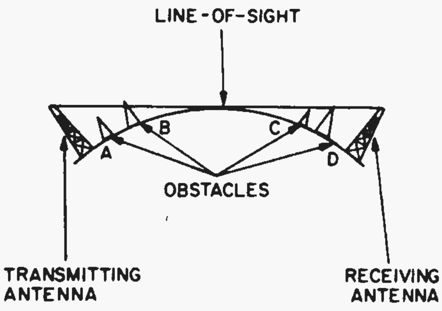
How to Work The Tables. Case I; (station and receiver at same elevation):

How high must an antenna in eastern New Mexico be to clearly receive a west Texas TV station (antenna 1200 ft.) which is 50 miles to the east.

LOS due to receiver = Distance–LOS due to transmitter; = 50 m.–42.39 (from table); = 7.61 mi



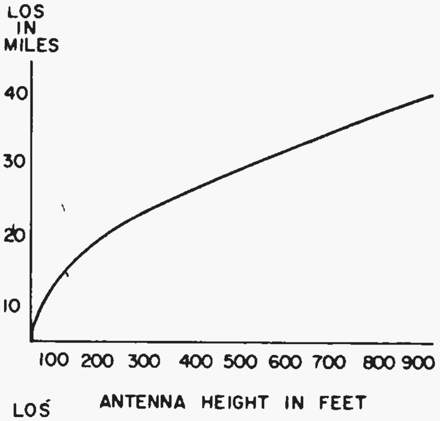
This figure illustrates the geometry on which the charts and diagrams are based. Note that r is measured from the center of the earth and H is the height of the antenna.

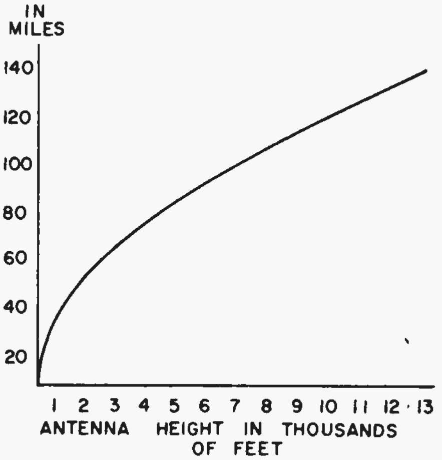


There are four possible ways obstacles may be positioned between a receiving and a transmitting antenna. Note that A and C are below line-of-sight between the antennas.

Line-Of-Sight Tables

Antenna (ht./ft.)	LOS (mi.)	Antenna (ht./ft.)	LOS (mi.)
10	3.87	1200	42.39
20	5.47	1300	44.12
30	6.70	1400	45.79
40	7.74	1500	47.40
50	8.65	1600	48.95
60	9.48	1700	50.46
70	10.24	1800	51.92
80	10.94	1900	53.34
90	11.61	2000	54.72
100	12.24	3000	67.03
110	12.83	4000	77.40
120	13.41	5000	86.54
130	13.95	6000	94.80
140	14.48	7000	102.39
150	14.99	8000	109.46
200	17.31	9000	116.11
300	21.20	10000	122.39
400	24.47	11000	128.36
500	27.36	12000	134.07
600	29.98	12500	136.84
700	32.38	15000	149.83
800	34.61	20000	172.99
900	36.71	30000	211.83
1000	38.70	35000	228.77
1100	40.59		





The table and charts show the mathematical relationship of an antenna to a flat-surfaced earth. Obstructions and depressions are not accounted for in these charts, nor is any refraction, although this would be insignificant at most radio frequencies.

Going back into the tables, we see that the required antenna height is between 30 and 40 ft. tall. We can pick off about 38 ft. from the graph.

Case II; (station and receiver at different elevations):

How high must an antenna in San Bernadino, California (elev 1000 ft.) be to receive an FM station near Los Angeles, California (combined antenna and mountain = 4000 ft.) which is 75 miles away?

Since the antenna has a 3000 ft height advantage over the receiver, we will enter the charts at 3000 ft.

LOS due to receiver = Distance − LOS due to transmitter

LOS due to transmitter = 75 mi −67.03 = 7.97 mi

Again, from the graph, we see that the antenna should be about 43 ft. tall. If the receiver has the elevation advantage over the transmitter, subtract this advantage from the antenna's required height.

Special Problems. Difficulties involving "looking over" an obstacle between you and the transmitter may not always be practically overcome, but the calculations for this problem are as follows.

If the obstacle is within the LOS of the transmitter, compare the height of the antenna to the height of the obstacle as follows:

$$\frac{\text{Height of transmitter}}{\text{LOS of transmitter}} \; ? \; \frac{\text{Height of obstacle}}{\text{Distance to obstacle}}$$

If the right hand side is greater than the left hand side, the obstacle is below the line-of-sight of the transmitter, and it is no factor.

If the left hand side is greater than the right hand side, the receiver antenna's required height must be increased by the following factor:

If the obstacle is beyond the LOS of the transmitter, calculate the required height of a hypothetical antenna located at the obstacle. If this hypothetical

$$\text{Extra ht} = \frac{\text{Distance (Transmitter to Receiver)}}{\text{Distance (Transmitter to Obstacle)}} \times \text{Ht of Obstacle}$$

antenna is heigher than the obstacle, then the obstacle is completely below the line-of-sight between the transmitter and receiver, and can be ignored.

If the obstacle is higher than the hypothetical antenna, subtract the height of the hypothetical antenna from the obstacle (since this portion of the obstacle is not a factor) and proceed using the previous formula.

The DX'er must still depend on Tropospheric bending or E-skip for those now and again catches, but knowledge of how to use these tables will help to improve his day to day reception. ■

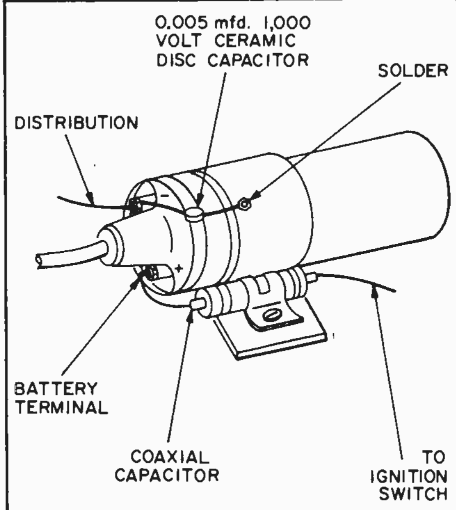
Mobile MD Cures CB Ills

□ Vehicular electrical systems have long been recognized as major sources of radio frequency interference (RFI). In recent years, the use of citizen band radios has undergone dynamic growth and is still expanding at a phenomenal rate. The vast number of CB radios, coupled with their low transmitting powers, their extremely high receiver sensitivities, and their proximity to interference sources, all combine to create a widespread and very severe RFI suppression problem.

Vehicles manufactured in the United States are suppressed at the factory to provide satisfactory reception on their installed AM and FM receivers, and to conform with suppression standards for external broadcast receivers. But for a CB radio additional and much more efficient suppression is required; even for CB radios that contain built-in noise limiters or noise blankers.

Fundamentals. The noise (RFI) you hear in your CB receiver is produced in two ways. Radiated interference comes from sources that act as miniature broadcasting stations and broadcast their interference. Most radiated noise originates in the engine compartment. Conducted interference, unlike radiated interference, is not transmitted through the air but rather travels along the wiring of the vehicle.

Three approaches may be used to suppress CB radio frequency interference. Limit the interference by turning the squelch up on your CB set. However, by "squelching out," you limit your range to only the stronger signals and "tune-out" all weaker signals. You can reduce the strength of the interference at its source. Finally, you can try to confine the interference to its source.



Those annoying popping sounds, which can be traced to the ignition system, can be readily cured. Install a coaxial capacitor at the coil's battery terminal and a .005-uF, 1,000 VDC, disc capacitor to distributor.

Preliminary Procedures. Before attempting to identify a particular source of noise, it is best to suppress some minor sources of noise and thus make it easier to identify the major sources. Make sure the antenna, transceiver, battery and hood are properly grounded. Then check to see that all connections are clean and tight. Be certain all suppression devices installed by your vehicle's manufacturer are still in place and are in good condition. Broken components will not help to suppress radio interference, but can even make it worse.

If your engine has not been tuned recently, have it done. Include new spark plugs, breaker points, and condenser. In order to guarantee optimum radio performance, your engine must be in top operating condition.

You might consider having resistor spark plugs, resistor suppression ignition cable, and ignition suppression resistors installed if they are not already. All of these devices serve to check ignition noise and thereby reduce interference.

Connect your CB radio directly to the battery if not already done. Tapping into the accessory-ignition switch or another of your vehicle's electrical systems can cause interference.

After completing the preliminary procedures, you will probably find that the noise in your CB receiver has been somewhat reduced but not eliminated. A step-by-step search will be necessary to locate and identify the remaining sources of interference, since this interference may be due to a single source or a combination of effects. Every type of noise that you hear on your receiver will give you a clue to the culprit's identity by a characteristic sound.

Alternator and Generator? Most modern vehicles employ an alternator that generates alternating current, while older cars are equipped with a direct current generator to keep the battery charged. Both will produce a *high pitched whine or whistle* which varies with engine speed. It will be louder immediately after starting your engine or after turning on your headlights. The whine will not stop instantly when the ignition is shut off at a fast idle, but will rather decrease gradually.

Ignition System? The interference caused by the ignition system is produced by the distributor (at the points) and by the spark plugs, each time a plug fires. This interference makes a *popping sound* in the CB receiver that increases with engine speed. The noise will stop instantly when the ignition is shut off at a fast idle.

Starting with 1975 models, all domestic and most import cars feature electronic ignitions as standard equipment. Electronic ignitions tend to produce more ignition noise because the major components of the system are generally widely seperated, causing the wiring for the ignition system to be interconnected with the other engine compartment wiring.

Voltage Regulator? The voltage regulator causes a *rasping sound* that occurs at an irregular rate. This irregular rate is because of changes in the generated voltage; caused by things such as an increase in engine speed or turning on the air conditioner. The rasping sound will usually be heard in conjunction with the alternator and generator whine. The interference produced by the voltage regulator will not stop instantly when the ignition is shut off at a fast idle.

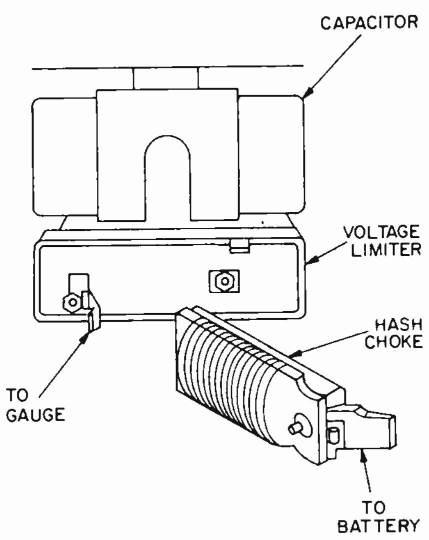
Voltage Limiter? The interference produced by the voltage limiter is a loud *erratic scraping sound* that occurs when the ignition is switched to "start" but the engine remains off. It is caused by the movement of fuel and temperature gauges and will lessen after the gauges settle down.

Electrical Accessories? Electrical accessories such as electric windshield wipers, heater and air conditioner blowers, electric window openers, and turn signals can cause interference to CB reception, most often in the form of *various-pitched whines*. To determine the offending accessory, turn each accessory on one at a time and listen for increased interference.

Instruments and Gauges? Instruments and gauges tend to produce *hissing, cracking, or clicking sounds* at irregular intervals. The noise they produce usually worsens on rough roads. To identify this source of interference; park the car and leave the engine running, hit the dash to simulate road conditions, and listen for a sudden change in hissing, cracking, or clicking.

Wheels? A less common source of CB

The Disease	The Symptom	The Cure
Alternator or Generator High Whine or Whistle	Pitch of the whining or whistle varies with engine speed. The noise is louder after starting vehicle and decreases gradually after the ignition is finally shut off.	1. Install a coaxial capacitor or a commercial noise filter. 2. Check the alternator for dirty slip rings or for worn brushes. 3. Check generator for worn commutator or worn brushes.
Ignition system Popping sound	Popping increases with engine speed, but the noise stops at once after the engine is switched off.	1. Get a major tuneup; replace worn plugs, points and condensor. 2. Resistance ignition cable should be installed (or may have been factory-installed) from the distributor to plugs and ignition coil. 3. See that ignition coil and bracket are making a good connection. 4. Make certain that your CB antenna is properly, electrically grounded. 5. Install a noise filter (coax capacitor) near coil battery terminal. 6. Install a .005-uF, 1000 VDC, ceramic disc capacitor to distributor.
Voltage regulator Irregular Rasping	Heard in conjunction with the alternator or generator noise. The rasping will not stop instantly when the ignition is switched off.	1. Install coaxial capacitors at the terminals of the regulator.
Voltage limiter Erratic Scraping	This noise occurs when the ignition is switched to start, but the engine is still left off.	1. Install a coaxial or pigtail capacitor at the terminal. (or) 2. Install a hask choke in series with the battery terminal of limiter.
Electrical Accessories Various Whinings	Operate each of the vehicle's accessories one at a time. As you do this, listen for a whining sound.	1. Install coaxial capacitors or commercial filters at terminals. 2. Avoid putting your CB on the same circuit as vehicle's accessories.
Instruments/Gauges Hissing, Clicking	Park the vehicle and, with engine running, bang the dash and listen for any occurrence of noise/static.	1. Install a coaxial capacitor in series with each accessory.
Wheels Irregular Popping	On a dry day, coast at highway speed with engine off. Apply brakes very lightly. Popping should stop.	1. Install static-collector rings against the tip of front axle. 2. Check the vehicle springs for wear and repack the wheel bearings.
Tires Regular Popping	Use same coasting test as for wheels The popping will continue even if you apply brakes as before.	1. Inject anti-static powder through the valves of each tire.



An erratic scraping noise may point to your vehicle's noise limiter. Try installing a hash filter in series with the limiter and battery; also install either a pigtail or a coaxial capacitor at the terminal.

radio interference is the front wheel axle. As the wheels rotate, a static charge is built up between the axle and the wheel bearing. This produces an irregular *popping and rushing noise* in the CB receiver. It occurs most often in dry weather at high vehicle speeds.

To identify this source of interference, accelerate to highway speed, then coast in neutral with your engine off. Apply the brakes gently. If the popping and rushing noise disappears you have wheel static.

Tires? In the case of tires, a static charge, similar to the noise generated by the wheels, can be generated by the inner tube and tire. This static produces a more *regular popping noise* in the CB receiver.

Once you have identified and located the interference, there are many methods to help remedy the problem.

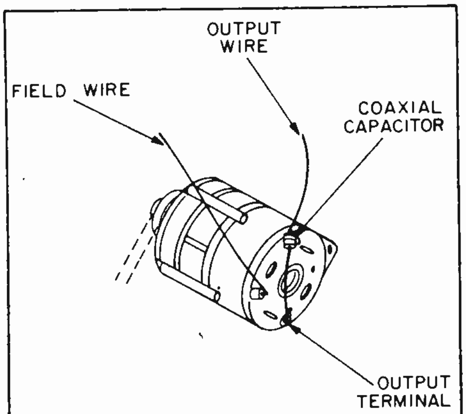
Alternator and Generator! The high pitched whine or whistle caused by the alternator can be eliminated by simply installing a noise filter or coaxial capacitor at the alternator output terminal. Care should be taken to make sure the filter or capacitor is rated to handle the maximum alternator output, and that the device is connected to the output terminal, and not the alternator field terminal. Cleaning the alternator slip rings and replacing worn brushes also helps to reduce alternator interference.

As is the case for the alternator, the high pitched whine or whistle caused by the generator can also be limited by installing a coaxial capacitor or noise filter. The generator will already have a factory installed capacitor attached to the armature terminal. If this capacitor is not already a coaxial capacitor, it should be replaced by one. The capacitor or filter is installed by connecting it to the generator output or armature terminal. Once again care should be taken to insure that the capacitor or filter can handle the maximum generator current, and the devices are connected to the output terminal and not the generator field terminal. In addiion, check the generator for worn brushes and commutator.

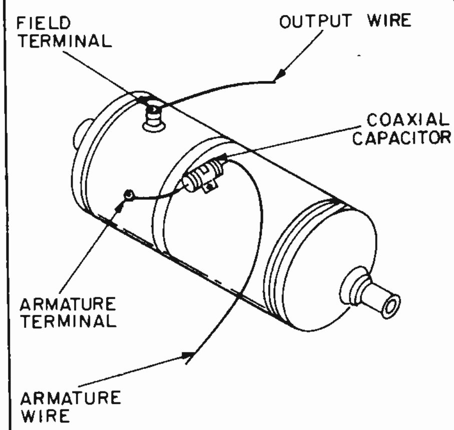
Ignition System! While most late model vehicles are factory equipped with resistance ignition cables and a minimum of radio noise suppressors, this usually will only reduce interference sufficiently for satisfactory auto radio reception. To further reduce the amount of interference and thereby increase the operating range of your CB, you should get a major tune-up and replace worn spark plugs, points, and condensor. Then make sure resistance ignition cable is installed from the plugs to the distributor and from the distributor to the ignition coil. (This is very important if your vehicle is an older model). Also make sure the ignition coil and its mounting bracket are making a good connection with the engine block and install an ignition type filter or coaxial capacitor as close to the coil battery terminal as possible. Make sure the antenna is properly grounded. Try mounting a 0.005 mfd. 1,000 volt ceramic disc capacitor at the coil distributor terminal.

To supplement these steps in limiting ignition noise, you might consider the use of one or more of the following: resistor spark plugs; ignition noise suppressors; and ignition system shielding kits.

Voltage Regulator/Limiter! The rasping sound caused by the voltage regulator can be reduced by connecting a



An alternator can often be stopped from whining by the installation of a coaxial capacitor at the alternator's output wire.



A generator's high whine can often be silenced by installing a coaxial capacitor at the armature terminal of the generator.

coaxial capacitor or noise filter as close as possible to the "armature" and battery" terminals. Some voltage regulators, particularly in late model vehicles, are solid state and thus have no contacts. Others have single or double contacts. In the case of a single contact, attach a coaxial capacitor or noise filter to the "ignition" terminal. For a double, contact, a second capacitor or filter should be attached to the "battery" terminal. Make sure the capacitor or filter is rated to handle the maximum generator or alternator current.

The radio interference from the voltage limiter, in the form of a scraping sound, can be suppressed by connecting a capacitor at the "battery" terminal of the voltage limiter, or by attaching a radio-type pigtail capacitor directly across from the voltage limiter terminals. If the interference still persists after taking these measures, install a hash choke (a small wire coil) in series with the voltage limiter battrey terminal.

Accessories, Instruments! Once the accessory that is causing the interference is identified, its interference can be silenced by installing capacitors or noise filters at the accessory's terminals. The size of the capacitor or filter will be ditcated by the accessory's maximum output. However, out of all the electrical accessories, it is really only worth suppressing the noise from the wipers and blowers since they get continuous use when turned on.

A similar source of interference can be attributed to the audible and visible safety and warning devices that have been installed in late model vehicles. Interference from these sources can be controlled by isolating the primary power circuits to your CB equipment, and avoiding circuit sharing with the buzzer and flasher systems.

The best approach to suppressing the cracking, hissing, and clicking interference produced by offending instruments and gauges is to connect a 0.5 mfd. coaxial capacitor in series with each gauge terminal.

Wheels and Tires! Wheel static, which produces an irregular popping and rushing noise, can be cured by using a pair of static-collector rings. To install these devices, simply remove each front hubcap and each axle dust-cover. Then, press the small end of the static-collector ring against the tip of the axle and replace the dustcover and hub-cap.

Additional measures to reduce the interference caused by the wheels include having your vehicle's springs checked for wear and having the wheel bearings repacked.

Eliminating the popping noises generated by the inner tube and tire is accomplished by injecting anti-static powder into each of the inner tubes through the tube valves. Kits for this contain the special tool and packets of powder necessary.

Last, Not Least! One final noise suppression measure warrants mentioning, and that is bonding. Bonding is a procedure whereby the interference generated by the ignition and charging systems are kept from traveling throughout the vehicle by assuring a common ground. This is accomplished by connecting the metal parts of your vehicle together (usually by means of a braided ground strap) to form a shield.

All of the following are strategic bonding locations: Corners of the engine to the frame, air cleaner to the engine block, coil and distributor to the engine and firewall, exhaust pipe to the engine and frame, tail pipe to the frame, both bumpers to the frame, both sides of the trunk lid, both sides of the hood, battery ground to the frame, steering column and gauge and other lines where they pass through the firewall. ■

Two-Meter Techniques

☐ Chances are, you've been hearing all sorts of predictions about the future of personal communications. But, right now, there is already a personal radio service that offers even more convenience than a telephone! The service is VHF amateur radio, and we'll center this discussion on the two-meter amateur band. You can carry a portable two-meter rig with you anywhere and, unlike operations on the citizens band, your efforts won't be cramped by overwhelming interference or sunspot predictions. The two-meter amateur band covers 144 to 148MHz, well into the VHF range and above most interefrence problems.

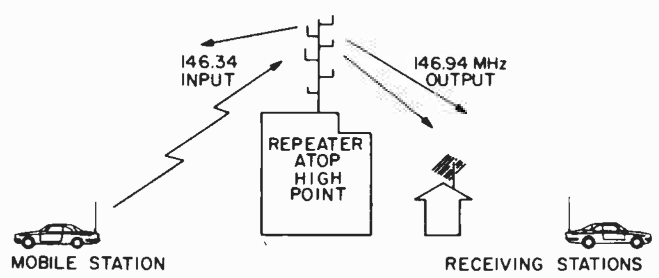
To operate a two-meter transceiver in the United States, you'll need a Technician class or higher amateur radio license. Earning an amateur radio license is a good deal more difficult than obtaining a CB license, but it's well worth the extra time and effort. For a Technician class license, you'll need to pass a five word per minute Morse code test and a written exam covering laws, operating procedures and electronics theory. Unlike some CB operating practices; call sign identification and other legalities are taken quite seriously in the amateur radio service. Most hams pride themselves on good operating procedures and respect for regulations.

The American Radio Relay League can supply you with information about publications designed to help you earn a ham license. You can write to the ARRL at 225 Main Street, Newington, CT 06111, or look for their publications at local book stores or ham radio stores.

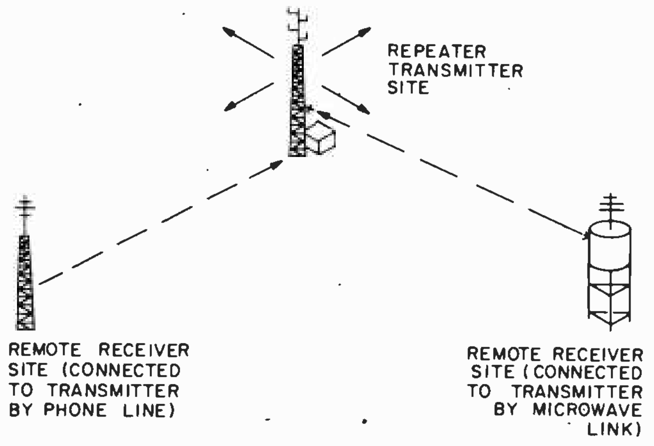
Before the current popularity of FM communications, the two-meter band was populated by a relatively few number of stations, operating with AM mode equipment. As surplus commercial FM equipment designed for the high business band (148-174 MHz) became available, enterprising hams converted these transceivers to operate on the two-meter band. Before long, two-meter FM activity was starting to spread. Surplus equipment was often large and quite hard to convert to multi-channel operation, so the introduction of moderately priced commercial solid-state two-meter transceivers soon followed.

Two-Meter FM lives! Two-meter FM activity is buzzing 24 hours a day, all across the U.S. For many reasons, two-meters is probably the most convenient amateur band to operate, and it's ideally suited to local communications. A ¼-wave antenna is only 17" long; a ⅝-wave antenna is only 40" long. Transceivers are efficient and compact as most are about the size of a mobile CB transceiver, but have power outputs of from two to twenty-five watts.

FM communication is very quiet. If you've noticed how much quieter an FM broadcast radio is than an AM



Basic repeater operation is very simple. Here we have a repeater operating 34/94. A mobile station may transmit on the input of 146.34 MHz and the repeater will retransmit on 146.94 MHz with a higher powered signal.



More complicated repeater arrangements may involve more than one repeater site. The repeaters may be twenty or more miles apart. All the remote receivers transmit their signals simultaneously to the main repeater (via the phone line or microwave). A switching device at the main site chooses, and then rebroadcasts the best signal from the remote stations.

radio, you have a feel for how much quieter it is in the two-meter FM band than on CB. There are no heterodynes and amplitude modulated noise, such as static and ignition crackling, is greatly reduced. Most two-meter FM transceivers have neither a noise limiter or blanker!

Repeaters boost range. Another outgrowth of the similarity between two-meter FM operation and business band radio is repeater operation (termed *duplex*). The repeater may be thought of as a sort of satellite station located at a high point. The repeater's sensitive receiver picks up a transmitted signal and retransmits it through a transmitter (usually at least 100 watts) having an antenna atop a high building, tower or hill and, in this way, increases the reliable range of low-power stations. Even with a low-power hand-held transceiver, reliable range through the repeater may be fifty to sixty miles. Without the repeater (*simplex* operation), reliable range of a hand-held may be only two or three miles.

When working through a repeater, a two-meter transceiver must transmit and receive on different frequencies, for when a repeater is receiving on one frequency, it is transmitting the received signal on a second frequency (usually 600 kHz higher). Most repeaters operate on somewhat standardized repeater frequencies, called "common pairs." Examples of these are 146.34 (repeater input)/146.94 (repeater output), 146.16/146.76, and 146.28/146.88. You'll commonly hear these pairs called 34/94, 16/76 and 28/88. Repeater directories that detail what repeater frequencies are used in each region are available from many ham radio stores.

Most repeaters are owned and maintained by local amateur radio clubs. Club dues pay the expenses of the repeater, but you don't have to be a member of a club to operate a repeater, though some clubs do frown on the practice.

Sometimes, in an effort to deter non-members from operating, but mostly to reduce occasional interference from distant stations using other repeater, a club will design their repeater to "turn-on" only when a proper encoding signal is received. These are called "closed repeaters." Unlike the more common "carrier access" or "open repeater" which turns on when any carrier is received, closed repeaters will retransmit your signal only if it contains the proper audio encoding signal. The encoding signal is usually a continuous sub-audible tone (commonly called "PL" or "private line") or a short audible tone burst at the beginning of each transmission. PL is most common. Accessory units are available to add these encoding features to most transceivers. Once installed, the encoder must be tuned to the PL or burst frequency used by your local repeater. This frequency can be learned by consulting a repeater directory or your local club.

A Portable Telephone. As a service to their members, some clubs offer a repeater feature known as autopatch. Autopatch allows you to patch into a phone line (rented by the club) and use your rig to make short, local phone calls. By punching up the correct numbers on a touch-tone pad, you can gain access to the patch. From there, you need only punch up the phone number you're calling. In most all cases, autopatch is a service for members only. The access codes are changed frequently to maintain the member only operation. A few, very few, clubs do have open autopatch. In such repeaters, keying the * and # opens the patch.

Many transceivers are now available with optional factory installed tone pads, and similar tone pads are available as add-on accessories. Several companies have packaged their tone pad in a microphone case for easy installation

Equipment Available. Two meter FM transceivers range in price from about $150 to close to $1000. Most are either portable units with built-in batteries or mobile style units (which require an optional power supply for home use).

The lowest priced transceivers are crystal controlled, most requiring two crystals per channel (one receive and one transmit). Except for portable units using a small number of channels, crystal-controlled transceivers may actually be no bargain. Synthesized transceivers which do not require optional crystals generally start at about $300. The purchase of twenty-two sets of crystals for a lower cost transceiver may cost over $190. Add this to the cost of the basic transceiver and it's easy to see that the cost of a synthesized rig has been met or exceeded.

From about $350 to $500 you'll find a wide selection of synthesized transceivers. Many offer full-band (144-148 MHz) coverage, though the vast majority of FM operation takes place between 146 and 148 MHz.

The Wilson WE-800 is the only portable synthesized rig now on the market. At $399, this transceiver combines all of the advantages of a mobile style synthesized unit with the size and convenience of a portable. The twelve-watt position of the WE-800 is useful when external power is available, while the one-watt position allows a full day of operation on external batteries.

The Midland 13-510 is another synthesized transceiver with full-band coverage. This mobile-style rig features a one-watt position for local repeater operation and a twenty-five watt position for simplex operation. The 13-510 also provides another popular feature, plus or minus 600 kHz transmit offset. Though most repeaters have their input frequencies 600 kHz below their output, the situation is sometimes reversed.

Two of the crystal-controlled portable transceivers available, the Drake TR-33C and the Heathkit (hand held) HW-2021, use only one crystal per channel. These units offer selectable transmitter offset or simplex operation, with the need to purchase only one crystal per channel.

Our brief sampling of transceivers is just that. Many more are available. For more information on equipment, contact the companies listed.

Once you have your Ham radio license a whole new world of fun and excitement will open up to you. Like many others, you will probably find two-meter operation to be one of the most enjoyable forms of communication. Hope to be seeing you soon—on your local repeater! ■

Manufacturers of Two-Meter Transceivers and Accessories

Amcomm, 730 West McNab Road, Fort Lauderdale, Florida 33309
Clegg Communications Corp., 208 Centerville Rd., Lancaster, PA 17603
Genave, 4141 Kingman Drive, Indianapolis, Indiana 46226
Icom West, Suite 3, 13256 Northrup Way, Bellevue, WA 98005
Midland International, Box 1903, Kansas City, Missouri 64141
Regency Electronics Inc., 7707 Records St., Indianapolis, IN 46226
R. L. Drake & Co., 540 Richard St., Miamisburg, Ohio 45342
Standard Communications, PO Box 92151, Los Angeles, CA 90009
Wilson Electronics, 4288 S. Polaris, Las Vegas, Nevada 89103
Yaesu Electronics Corp., 15954 Downey Ave., Paramount, CA 90723

Antenna Manufacturers

Antenna Specialists, 12435 Euclid Avenue, Cleveland, OH 95037

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 3¢ per kilowatt hour—which means you can operate a plugged-in table radio for about 100 hours on a penny.

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

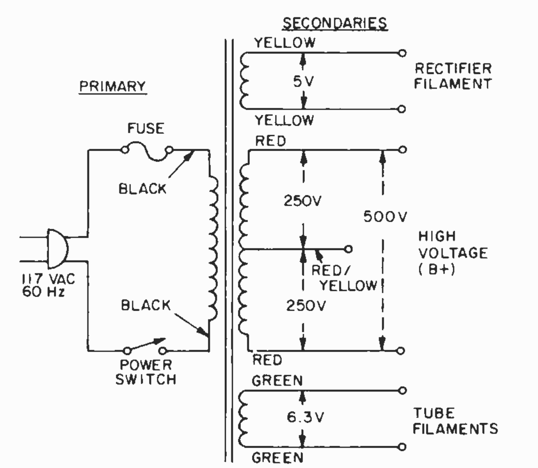


Fig. 1. Schematic of typical power transformer, showing voltages and EIA color-coding of windings.

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.

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.

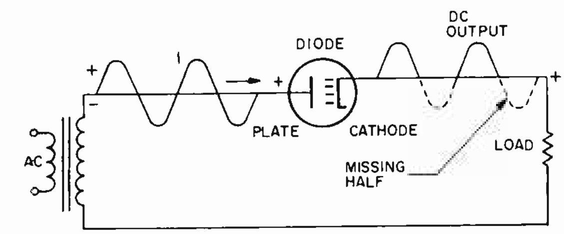


Fig. 2. Half-wave rectifier, showing how diode produces pulsating DC output by repelling electrons when plate is driven negative.

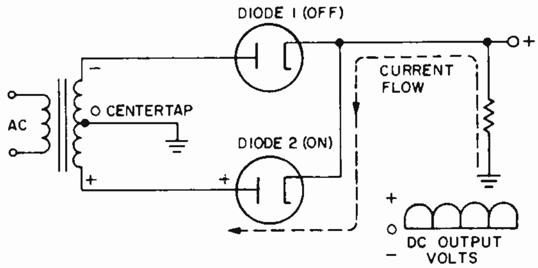


Fig. 3. Full-wave rectifier is a pair of diodes driven alternatively to take advantage of both halves of AC input voltage.

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-

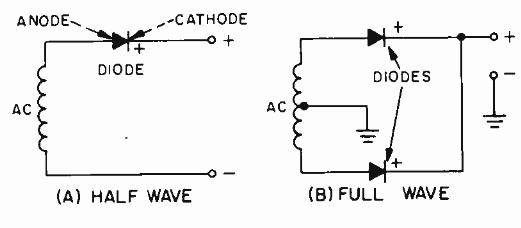


Fig. 4. Solid-state selenium or germanium diodes in similar half- and full-wave rectifier circuits are better than tubes since they don't need filaments or heaters for rectifying action.

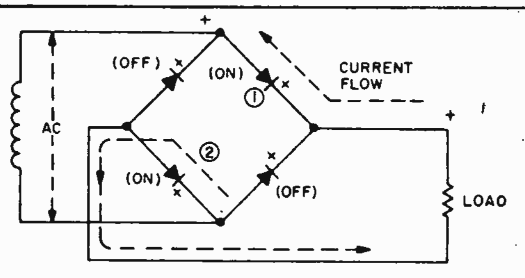


Fig. 5. Solid-state bridge rectifier provides full-wave rectification with center-tapped transformer by using four diodes.

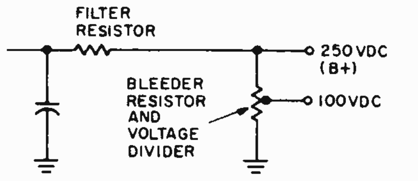


Fig. 7. Choke can be replaced by filter resistor. Also shown is bleeder resistor that serves both as output regulator as well as voltage divider.

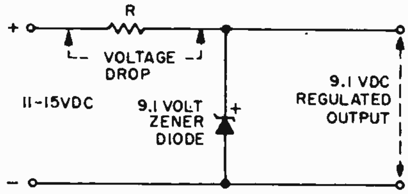


Fig. 8. For more efficient regulation than produced by bleeder resistor, zener diode shunted across DC output will hold voltage to specified limit.

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.

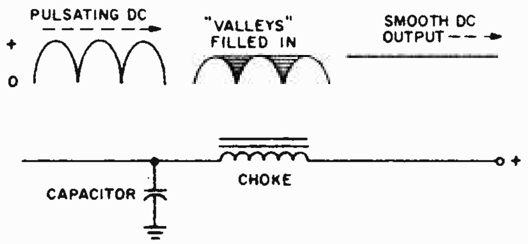
Yet we see 9.1 volts indicated at the output. Secret of the zener's ability to hold at 9.1 is that it detours part of the supply current as the voltage increases. Since a resistor is in series with that current flow, a voltage drop (as shown) appears across the resistor. Thus, any increase in supply 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.



The Uses of Negative Air Ions

☐ Do negative air ions exist? Are they beneficial or harmful to human beings and other living organisms? Are most of us suffering less than perfect health because we are deprived of adequate amounts of negative air ions? Is it desirable to install negative air ion generators in homes, offices and even in our automobiles? About the only generalization you can safely make concerning these and other questions relating to negative air ions is that it is very difficult to be positive about negative ions.

For decades, most scientists appear to have dismissed negative air ions as the stuff of which medical myths are created. Back in the early 1960s, the Food and Drug Administration confiscated hundreds of commercial negative ion generators that were being sold as near-magical cure-alls for countless human ailments including asthma, hay fever, allergies, lung cancer, high blood pressure, impaired sexual activity and even suicidal tendencies. To this very day the FDA prohibits generator marketers from making health or therapeutic claims for their equipment. For this reason, all negative air ion generators, including those described in this article, are sold purely for "experimental" uses.

Biological Effects. On the other hand, there are scientists who claim that there is sufficient experimental evidence concerning the biological effects of air ions on both plants and animals to justify further research in this area. Later in this article we shall discuss some of this research and indicate where you can obtain additional information. But first let's find out what air ions are and how they are generated in nature.

Atmospheric electrical effects are created several different ways. There's a "dynamo" effect wherein air moves across the magnetic field of the earth to create an electric field. This is more important in relation to lower regions of the ionosphere than with respect to air near the earth's surface where other generating effects are more prominent. In the lower atmosphere, electrical generation and the separation of positive and negative charges depend on the relative motion of air and other particulate matter in the air, including dust, smoke, snow, ice and water. There's also a "turbulence generator" factor such as the vertical movement of air masses caused by heating of the earth's surface by the sun. This turbulence can aid significantly in the separation of electrical charges.

Storms can be powerful charge-separating phenomena, as a lightning bolt adequately demonstrates. But even a gentle rainstorm can produce electrical effects, and it's known that when large water drops in a waterfall break up in air, the resulting droplets become positively charged while the surrounding air becomes negatively charged. It has even been suggested that the feelings of elation and well-being that people seem to experience near waterfalls may in part be due to the biologic effects of increased negative ion concentrations in the air. Of course, proving such a presumed cause-and-effect relationship would be extremely difficult.

Ill Winds. So-called "ill winds" that appear to have strong, adverse effects on people occur in many parts of the world. For example, in the Middle East a meteorological phenomenon known as the *sharav* is blamed for widespread ill effects including irritation syndromes such as migraine, nausea, vomiting, amblyopia, irritability, hyperperistalsis, edema, and inflammation of the respiratory tract. It's claimed that the affected people become ill from 12 to 36 hours before there are detectable changes in wind speed, temperature, humidity or solar radiation; the only change appears to be a measurable increase in the ratio of positive to negative ions in the air. Some consider this as evidence that an overabundance of positive air ions can have adverse effects on plants and animals. Sharav-like atmospheric conditions occur in many parts of the world, but have different name. There's the *foehn* of Switzerland, Germany and Austria; the Argentine *zonda;* and the *chinook* of our own Rocky Mountain states.

Some investigators of air ion phenomena are firmly convinced that man's activities do much to alter positive and negative ion ratios in the wrong direction because negative ions are constantly being destroyed by air pollutants in our homes, offices, factories and especially in closed, air-conditioned cars. However, it is one thing to speculate about possible adverse effects on people, and quite another to prove that people are suffering the effects of negative air ion depletion.

Displaced Electrons. As already noted, air ions can be produced in nature by the shearing action of water droplets, the flow of air masses over

The old wives' tales about "ill winds" may not be so far from the truth. Observations tend to indicate that psychological depression may be effected by the presence of positive ions that frequently accompany some wind storms. Some say this is fact—some fiction.

land and by air turbulence; but ions are also produced by radioactivity and cosmic rays and any other form of energy that can knock electrons off air molecules. When an electron is displaced, the molecule of course becomes positively charged. The freed electron is normally captured quickly by another air molecule which thus becomes negatively charged. Water molecules in the air then tend to aggregate around the charged ions—usually from one to eight water molecules per charged gas molecule—to produce variations in ionic compositions. However, the unit charge is said to be, uniformly, about 1.6 x 10^{-19} coulombs with a mobility of up to two centimeters per second, per volt, per centimeter.

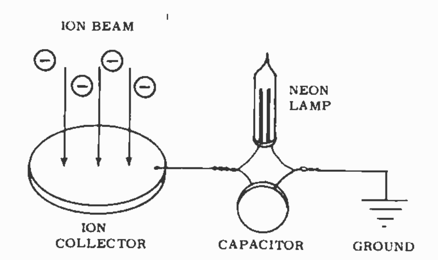
Negative air ions can be generated experimentally in a number of ways. One means is through high-voltage (but low current!) electric arcs. A Van de Graaff generator could fill the bill.

Two different Van de Graaf generators are currently available from Edmund Scientific Company (for more information circle number 69 on the reader's service coupon or write directly to Edmund Scientific at 91 Edscorp Building, Barrington, NJ 08007). The deluxe unit runs at 200,000-volts and is priced at $79.95—catalog number 70264. They also offer a cheaper version which runs at 75,000-volts and must be handcranked; the price being $30.00 and catalog numbered 70070.

You can try varying means of directing the negative ions produced by these devices. One simple method might be to arrange a paper cone at the output of the device with the spark drawn in such a way that the air within the cone becomes negatively ionized. You could also try installing a room fan behind the generator so as to direct a stream of negative ion-enriched air to the experiment site.

Of course, both Van de Graaff generators may be used for many other things. There are all sorts of electrical experiments (detailed in accompanying instruction manuals) which the experimenter may perform after having used the generators as simple ion producers.

Ion Detectors. Homebrew ion detectors are easy to construct. A conventional electroscope serves well and if you cannot borrow one from a school physics lab, make your own. Fit a 250-ml flask, empty food bottle or even a glass milk bottle with a cork holding a length of hollow curtain rod. The ball at the upper end of the rod serves as an ion collector. Fasten a brad, horizontally, to the lower end of the rod to support a folded strip of metal foil measuring about ⅝ by 4 inches. Ordinary



The presence of ions may be demonstrated with a simple detector made from a neon lamp, a capacitor, a coin and a length of wire. The ions cause the lamp to blink at a rate determined by the value of the capacitor.

kitchen aluminum foil is too stiff, but you can obtain suitably limp foil by taking apart a tubular type capacitor. A metal ball or metallized plastic ball added to the curtain rod can increase ion capture somewhat, but is not really necessary.

When the electroscope is placed into a stream of ions, the foil leaves spread apart to indicate the accumulation of an electric charge. The charge can be dissipated by touching the collector ball with a fingertip, as is evidenced by the collapse of the spread foil leaves.

But how can you know whether the charge is negative or positive? Rub a hard rubber comb or other hard rubber article with wool to generate a negative charge on the rubber. Touch the rubber to the electroscope ball. If the leaves remain apart or spread even more, you obviously have a like (negative) charge in the electroscope. If the foil leaves droop, it indicates that the electroscope is positively charged.

Another type of ion detector is made by wrapping the leads of a disc capacitor to the leads of an NE-2 neon lamp. Crimp a small alligator clip to one pair of terminals to hold a coin (quarter) or any small piece of scrap sheet metal. Connect a length of wire to the other pair of capacitor/lamp leads and run to any earth ground. Place the collector plate (coin) in an ion stream and the neon lamp will blink softly if ions are present. The glow is faint, so view the lamp in a dark room. Start with a 0.001 mfd capacitor; however, the rate of blinking can be varied by using higher or lower capacitor values.

A third way to demonstrate the presence of ions is to position the two probes of a vacuum tube voltmeter (VTVM) in the ion stream, keeping the tips a millimeter or so apart. The air gap results in an infinite resistance reading, when the instrument is used as an

Negative ions are said by some people to cause positive effects by making people and plants happy. As the text explains falling water and other natural energy systems generate negative ions—perhaps this explains the popularity of waterfalls for honeymoon couples, or the elation some people feel before and during a rainstorm.

ohmmeter, if no air ions are present. When the ion generator is turned on, the air gap resistance will drop noticeably, probably to about 200 megohms.

Room for Research. Clearly, the broad area of ions offers very interesting and challenging opportunities for original research. Anyone entering into such research projects must become familiar with the research work done by professional scientists over the past decades, and in particular with the work of Dr. Albert Paul Krueger, Professor Emeritus of Bacteriology and Lecturer in Medicine at the Department of Biomedical and Environmental Health Sciences at the University of California in Berkeley. Special thanks go to Dr. Krueger for his generous assistance in in the acquisition of background information for this article.

Dr. Krueger and his associates have published countless reports in various scientific publications concerning negative air ion research during the past two decades. An excellent review of the subject and a summary of Dr. Krueger's views can be found in a lengthy article published in the September 24, 1976 issue of *Science*. The article includes a valuable 46-item bibliography. The following general comments concerning air ion research have been drawn from Dr. Krueger's publications and lecture material.

Serotonin (also known as 5-hydroxytryptamine or 5-Ht) is a powerful neurohormone that can induce profound neurovascular, endocrine and metabolic effects in the body. The neurohormone is concerned with the transmission of nervous impulses relating to such patterns of life as sleep and to subjective evaluations of how we feel and our moodiness.

Tests on Animals. Almost twenty years ago Dr. Krueger's team found, by direct measurement, that negative air ions reduce the amount of serotonin normally present in the trachea of mice and rabbits, and that there was a considerable increase of a chemical called 5-hydroxyindoleacetic acid in the urine of animals exposed to negative ions; that's significant because the acid is an inactive end product of the oxidation of serotonin and an increase in concentration indicates that negative ions tend to reduce serotonin in animal tissues.

To obtain more direct evidence of this observation, the researchers performed other extensive tests in vitro that are too complex to detail here. But two fundamental conclusions emerged from the experiments that included spectrofluorometric analysis of over 12,000 brain and 36,000 blood samples from controls and ion-treated mice: (1) high concentrations of negative air ions decrease serotonin concertrations while (2) high concentrations of positive ions have exactly the opposite effect of increasing serotonin concentrations. Related studies by other scientists led to another conclusion: negative ions reduce the amount of serotonin in the mid-brain to produce a *tranquilizing effect* similar to that produced by the well-known drug reserpine.

Dr. Krueger and his associates have also investigated the role played by air ions in determining the course of influenza infection in mice. The most significant findings: high concentrations of positive ions (or ion-depleted air) increased the cumulative mortality rate due to influenza; on the other hand, high concentrations of negative ions decreased the cumulative mortality rate.

Considerable work has been done by Dr. Krueger and others concerning the effects of air ions on the growth of microorganisms. It appears that negative air ions are more effective than are positive ions in retarding bacterial growth, although both types of ions tend to be lethal to bacterial cells. On the other hand, air ions of either charge produce "statistically significant increases" in the growth rates of plants as measured by stem length, integral elongation, fresh weight and dry weight. Dr. Krueger advises that air ion effects on plant growth are readily demonstrated with barley or oat seedlings.

Controls. Controlled Conditions are Vital to meaningful research in this area. In fact, much published information must be used with caution because some researchers neglected to observe important experimental safeguards. Dr. Kruger points to the following examples in particular: (1) failure to use pollutant-free air led to ion loss through combination with aerosols, particulates and other pollutants, (2) conditions of exposure (temperature, humidity, shielding from stray electrical fields) were not controlled, (3) subjects were not held at ground potential, (4) concentrations of air ions delivered to subjects were not monitored, (5) considerable amounts of ozone produced by corona-discharge type ion generators produced effects that were wrongly attributed to air ions.

Anyone who is attracted to this field of research should make every effort to work under controlled conditions, exercising the best possible scientific discipline. In light of the wild and unsubstantiated claims that have been made about the supposed benefits of negative air ions by hucksters of medical "miracle machines," you must anticipate and accept considerable skepticism on the part of other scientists. Probably, much valuable research has been bypassed because of the bad name given negative air ions by the money-grubbers.

On the other hand, it certanly appears within the realm of possibility that air ions can affect our behavior and general health since much body chemistry, and in particular the nervous system, operates by means of complex electro-chemical processes. The studies of Dr. Krueger and others seem to have moved that possibility at least a little closer to probability. But much more needs to be learned about negative air ions before any hard conclusions can be drawn. Some of those vital discoveries could just as easily result from the work of independent investigators, even science studnts, as from the sophisticated probings done by professional scientists. ■

Op-Amps-How to Use Them

☐ Few linear (non-digital) ICs have achieved the wide popularity of the op amp in hobbyists projects of every description. Combined with few other circuit components, the op amp circuit vastly outperforms the multiple transistor circuit of yesteryear. Because you will encounter the op amp time and time again in many circuit applications and may desire to work up your own op amp circuits, it is essential to become familiar with the device.

This will introduce you to the basics of op amp circuits and applications. Four simple rules of operation are logically applied to trace and deduce the operation of the basic linear op amp circuits. Test circuits are included for "hands on" familiarity. Only a few mathematical relationships are listed to effect a comparison of the several circuits.

Some Basics. As shown in Fig. 1a, the op amp has two input terminals and one output terminal. A plus sign at one input identifies the *non-inverting* or "follower" input. When this input goes positive (with respect to the other) the output voltage VOUT also goes positive, thus "following" the polarity of the input. The minus sign at the other input identifies the *inverting* input. When this input goes positive (with respect to the other), VOUT goes negative, thus "inverting" the polarity of the input. In technical terms, the input stage of the op amp is a balanced "differential input" amplifier and is one which responds to the *difference* between the voltages.

Output voltage VOUT equals VIN times AVOL (AVOL equals the open-loop voltage gain as listed on spec sheets). Input impedance (AC resistance) *Zi* and output impedance *Zoi* are shown in Fig. 1b. These are the primary characteristics of the op amp. If a perfect op am could be constructed, AVOL and *Zi* would be infinitely large and *Zoi* would be zero. Actually, for a general purpose 741 op amp, AVOL equals 200,000, *Zi* equals 2 megohms, and *Zoi* equals 75 ohms.

Important Concept. In linear applications such as an AC or DC amplifier, the op amp is operated closed-loop with negative feedback. To do this, the loop is "closed" by connecting a feedback circuit from the output terminal to the *inverting* input; this results in negative feedback. That porton of the output voltage fed back to the input tends to negate, or oppose, the applied input signal voltage. As will be shown later, the resulting closed-loop gain, AVCL, is very much smaller than the open-loop gain. Also, the closed-loop gain now depends on the particular feedback circuit itself and not on the actual value of the open-loop gain. This makes it possible to build amplifiers with precise closed-loop gains. Among other beneficial effects, negative feedback imparts high linearity and stability to the amplifier.

Rules Of Operation. A few basic facts of op amp operation will be stated as rules and applied to the operation of several circuits. The implications and meanings of these rules will become clear as you apply them to the circuits.

1. The *difference* in voltage between the + and − input terminals is always small and can be assumed to be zero. (This fact is a direct reuslt of very high AVOL.)

2. The current entering the + and − input terminals is small and can be assumed to be zero. (This rule is a direct result of a very high *Zi*.)

3. If the + input terminal is at ground voltage or zero, the − input terminal can be assumed to be virtually at ground voltage or zero. (This rule is also a direct result of high AVOL.)

4. When an op amp is connected in a negative feedback configuration, a voltage change at the + input must result in an equal voltage change at the − input terminal. (This is a description of rule 1 in operation.)

Fig. 1A

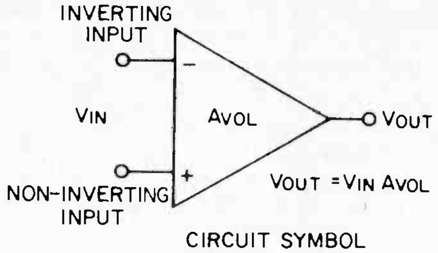
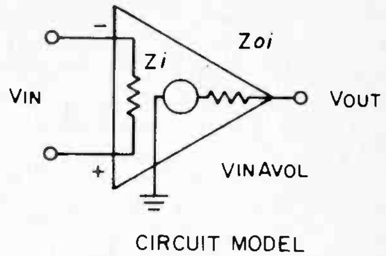


Fig. 1B



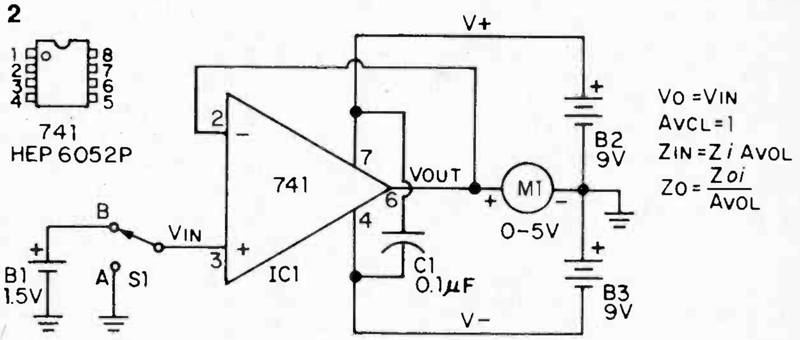
Think of an op amp as a high gain amplifier capable of boosting a minute signal many thousand times. With a little trick called inverse, or negative, feedback, you hook a resistor between the input and output which, in effect partially shorts out the gain.

Setting Up. Breadboard the op amp circuit shown in Fig. 2. You can use perforated board and flea clips to assemble the circuit. Better still, use a breadboarding kit such as the Vector 38X solderless breadboard kit or similar. Use only the 741 or the HEP 6052P op amp for IC1. These are short-circuit proof and are internally frequency compensated to prevent oscillations. Switch S1 may be simulated by a clip lead.

Install disc capacitor C1 as close as possible to the IC. Use either a common tie point for all ground connections or a heavy ground bus. Keep the input lead wires well separated from the output lead wires. The prototype breadboard uses a 50 uA DC meter (Radio Shack 22-051) connected in series with a 100,000-ohm, 1% resistor for meter M1. Alternately, you can use your VOM (1000 ohms/volt or better) to measure output voltage. Use two fresh nine-volt transistor batteries for B2 and B3 and 1½ volts (an AA cell) for B1.

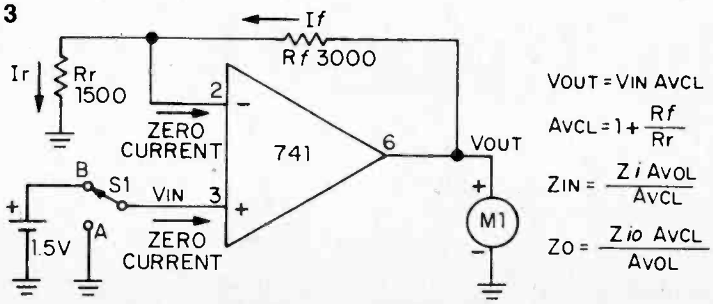
● **Unity Gain Follower.** Simplest of the op amp circuits, the unity-gain follower shown in Fig. 2 has a direct connection from output to the inverting input. This provides one-hundred percent negative feedback. With switch S1 at position A, the + input is grounded and meter M1 indicates zero. By rule 3, the − input is at virtual ground. There-

Fig. 2



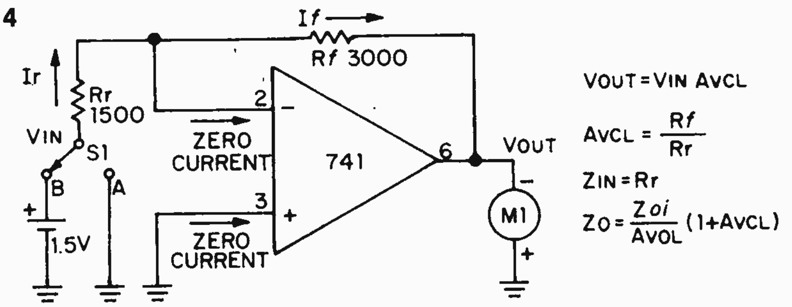
Unity-gain voltage follower.

Fig. 3



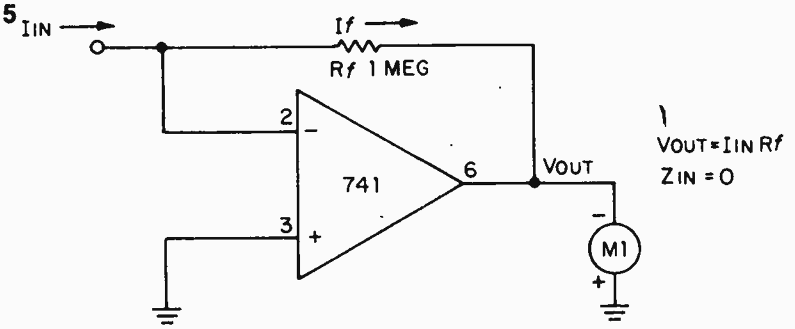
Non-inverting voltage amplifier.

Fig. 4



Inverting voltage amplifier.

Fig. 5



Current to voltage converter.

fore, VOUT is also at virtual ground. With S1 set to position B, the meter now indicates the voltage of battery B1, near 1.5 volts. By rule 4, the 1.5 volt increase at the + input must be accompanied by a 1.5 volt increase at the – input. Hence, VOUT must rise to 1.5 volts.

The resulting closed-loop gain, or AVCL, is unity (one unit out for one unit in). However, the high AVOL inside the IC itself is still present, enforcing close compliance with the several rules. As noted on Fig. 2, actual input and output resistances ZIN and Zo are much improved due to feedback. The resultant input resistance now equals *Zi* times AVOL or 400,000 megohms for the 741 op amp! The resultant output resistance now equals *Zoi* divided by AVOL, or .0035 ohms! Consequently, the unity gain follower can duplicate the input voltage at its output without loading down the input voltage source due to the high input resistance and with high accuracy due to the low output resistance. Actually, input and output resistances are degraded somewhat by secondary factors. Nevertheless, this unity gain follower offers the highest input resistance and lowest output resistance of the several basic circuits.

● **Non-Inverting Voltage Amplifier.** Stable op amp voltage amplification is obtained by feeding back only a portion of the output voltage. Alter your breadboard circuit to include feedback voltage divider resistors R*f* *and* R*r* as shown in Fig. 3. With R*f* equal to 2R*r*, only one-third of the output voltage is fed back to the inverting input.

With S1 at position A, the + input is at ground voltage and the meter indicates zero. By rule 3, the – input is at virtual ground or zero. With zero voltage across R*r*, current I*r* is zero. In view of rule 2, I*f* always equals I*r* and is zero in this case. With zero current in R*f*, the – input and the output voltage must be equal and zero in this instance.

With S1 at position B, the + input is raised to 1.5 volts and the meter indicates 4.5 volts. By rule 4, the – input must rise to 1.5 volts matching that at the + input. The op amp does this by forcing a current into the feedback voltage divider as shown. With 1.5 volts across R*r*, current I*r* equals 1.5 volts divided by 1500 ohms, or 1 mA. Also, the voltage across R*f* equals 1 mA times 3000 ohms or 3 volts. Thus, VOUT equals 1.5 plus 3 or 4.5 volts.

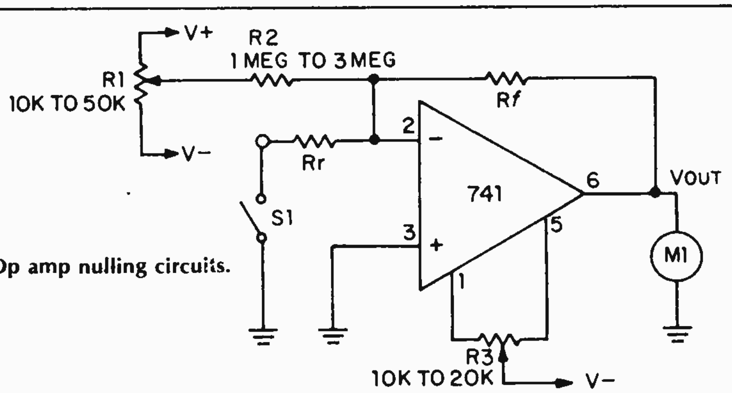
Closed-loop voltage gain AVCL equals 1 + (R*f*/R*r*) or 3 in this case. Compared with the unity gain circuit, actual output resistance Zo is three times greater and input resistance ZIN is one-third that of the unity gain circuit. This reflects the effect of feeding back 1/3 of the output voltage. To obtain a closed-loop gain of ten, resistor R*f* must equal 9R*r*, and so forth.

● **Inverting Voltage Amplifier.** Alter the breadboard circuit to that of Fig. 4 including reversal of the meter. With S1 at position A, the meter indicates zero. The proof of this result is identical to that of the non-inverting voltage amplifier with switch at position A. With S1 at position B, the meter indicates 3 volts (actually, minus 3 volts since the meter is now reversed).

In this case, the – input does not rise to 1.5 volts. By rule 3, with + input grounded, the – input must remain at virtual ground. Therefore, and quite importantly, the voltage across R*r* equals the input voltage, or 1.5 volts. Current I*r* equals 1.5 volts divided by 1500 ohms, or 1 mA, flowing in the direction shown. Since I*f* equals I*r*, the voltage across R*f* equals 1 mA times 3000 ohms, or 3 volts. With the – input at virtual ground, the output voltage must be minus 3 volts as indicated on the reversed meter.

The closed loop voltage agin, AVCL, is simply R*f*/R*r*, or 2 in this case. Quite unlike the previous cases, actual input resistance ZIN equals R*r*, the input resistor. Compared with the unity gain non-inverting amplifier, actual output resistance Zo is greater by a factor of (1 + AVCL) or three times as much, still acceptably small at this (and even much higher) gain.

By connecting additional input resistors to the – input and upon applying several input voltages, the amplifier will sum the several input voltages at the output. For this reason, the amplifier is often termed a summing amplifier



Op amp nulling circuits.

and the — input is termed the summing node or input.

● **Current to Voltage Converter.** A variation of the inverting amplifier, the current to voltage converter shown in Fig. 5, omits input resistor R*r*. Because the — input must remain at virtual ground for linear operation, this circuit cannot accept an input voltage. Instead, it accepts an input *current* and is used to measure very small currents. If IIN were 1 *u*A, the output voltage would be 1 *u*A times 1 megohm, or 1 volt. By making R*f* very large, the circuit can measure extremely small currents. The input resistance of this circuit is zero. The output voltage, VOUT, equals IIN times R*f*.

If you breadboard this circuit, you may observe a small output voltage at zero input current. This output "offset" voltage is caused by the flow of a small bias current from output to input through the large feedback resistor, R*f*. Unless special op amps having very low bias currents are used, it is necessary to include a nulling circuit to reset.

● **Input Bias and Offset.** Although rule 2 assumed zero input currents, an op amp does require a small input current I*b* to bias the input stage into linear operation. For the 741, I*b* may range up to .5 *u*A. The difference between the input bias currents at the two inputs is the input offset bias current I*io*. This current is usually much smaller than I*b*. Both I*b* and I*io* cause an objectionable output offset voltage when R*f* is very large. To restore the output voltage to zero, add the nulling circuit potentiometer R1 and resistor R2 as shown in Fig. 5. With S1 open, adjust the control until meter indicates zero.

If R*r* is small, and upon closing S1, you may observe that the meter again loses its zero. This is caused by the input offset voltage V*io* resulting from slight mismatches of the input transistors. Input offset voltage V*io* is defined as that input voltage required to restore VOUT to zero. It is measured under open-loop conditions with very low value resistors at the input. For the 741, V*io* may range up to 6 millivolts. Conveniently, the 741 includes terminals allowing compensation for input offset voltage. Add potentiometer R3 and adjust the control with S1 closed, until the meter indicates zero. If both circuits are included, adjust the controls several times in succession.

Conclusion. Having become acquainted with the basic operation of the op amp, and with some knowledge of the six primary op amp specifications, you will now be able to experiment with op amp circuits with some degree of confidence rather than apprehension. With some appreciation of how and why the circuit functions as it does, how the performance of the several circuits compare with each other, and how negative feedback plays its part, you will find that op amp literature and circuits are more easily understood. ■

Computer Questions

☐ It's been less than a year since we heard the first rumors that both Heathkit and Radio Shack were working on personal computers for the electronic hobbyist, yet in the few short months since the rumors were proved correct *personal computing* has become the hottest thing going for the electronic hobbyist and experimenter.

It has also become the most confusing, with each manufacturer and distributor inventing new terminology to prove, or imply, his computer, system, or accessory is the best. Even trained computer and data-handling experts with advanced degrees in computer science are often at a loss to explain what in heck many computer dealers are talking about. Personal computing has become a Tower Of Babel; and as yet there is no Rosetta Stone the average hobbyist can use to unscramble *computerese*—a foreign language even more complex than French.

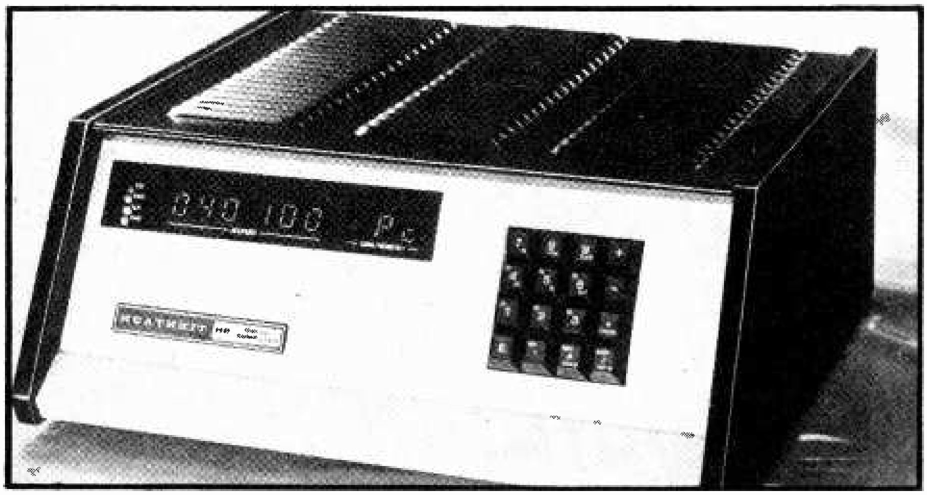
In fact, because ELEMENTARY ELECTRONICS is one of only a few national consumer publications providing extensive coverage of personal computing on the experimenter and hobbyist level we are literally drowning in a sea of reader mail, and can no longer answer each individual letter about personal computing equipment.

Instead, we have compiled the most frequently asked questions and hope the answers meet your particular needs and interests.

For some, the answers will appear simplistic; but keep in mind we are trying to avoid *computerese*. Our primary purpose is to provide you, our reader, with concrete information you can put to work. We are not going to try to impress you with anyone's expertise. We know computer equipment represents a substantial investment so we aim to present our information in the most useful manner—and that means straight English.

Question—*Since some computer kits are priced almost the same as complete computers having built in BASIC and*

Complete computer systems for the home can be bought off the shelf from various companies. Shown here is the Radio Shack TRS-80 micro computer system. It features an ASCII keyboard-equipped computer that can be mated to numerous peripherals.



Another popular home computer is the Heathkit H8. This unit can be purchased assembled or in kit form. Building a kit is a great way to gain an in-depth understanding of how the computer is put together. The computer has an octal keyboard.

a keyboard, what is the advantage in building a kit?

Answer–The complete computers such as the Apple, OSI, and Radio Shack generally need a TV monitor for output display, or the computer's output signal is fed through an *RF Modulator* to an ordinary TV set which serves as the display. At present, the complete computers have no peripherals for providing "hard copy" (a printout). The computer kits, on the other hand, permit almost unlimited expansion, though it does get costly when you add in the cost of a complete terminal: either TTY (teletype), CRT, or Selectric typewriter.

Q–*I don't care for the print quality of a TTY terminal, nor do my teachers, who don't accept my homework printed all in capital letters. Can I connect a Selectric typewriter terminal to my SWTP 8600 computer?*

A–It depends. Most of the rebuilt Selectric terminals you find advertised in computer magazines are for the IBM *correspondence* and EBDC codes, and they won't work with a personal computer. Some surplus outfits, however, build in an ASCII converter with an RS-232 output. If you can find one of these ASCII/RS-232 Selectrics (about $900) you simply connect it to a personal computer's serial RS-232 I/O. (Just plug it in.)

Q–*I would like to get my child started in computing. Which of the beginner's kits in the $100 range do you suggest?*

A–There is no such animal. Firstly, if your child is ready to enter High School, or already there, the school probably has an introductory course in either Data Processing or Computer Math. If your child wants to get into the design end, and has shown previous interest and ability in electronics, and really wants to play and experiment with the electrons, the Heathkit 6800 trainer is probably the only kit of practical value. (On a college level it's a whole different game.)

Q–*Which of the computer kit CPUs do you recommend for a beginner: 8080, 6800, 6502, or whatever?*

A–Tough question. The 8080 and its relative, the Z-80, often use the S-100 bus, for which there are many accessories. Unfortunately, the I/Os (inputs/outputs) are under software control and it can get somewhat expensive if you need ports for several peripherals. The 6800 I/Os are memory-mapped and it's cheap and easy to add peripherals. For example, the SWTP 6800 computer can handle up to ten peripherals and you simply purchase an inexpensive I/O card whenever you add another printer, terminal, recorder, etc. Also, the 6800 system allows a good intermix of serial and parallel I/O ports. You can do the same with the other CPUs but at much higher cost. Unfortunately, there are more "gadgets" for the S-100 bus than for any other bus or system, so you'll have to plan ahead.

Some personal computers using the 6502 are extremely powerful, but at the time this article was prepared there was little in the way of I/O equipment or even ports for peripherals.

Q–*What is meant by an integer BASIC?*

A–It means it cannot handle decimals. For example, the statement "PRINT 2/4" would return an answer of "00" instead of "0.5". Similarly, "PRINT 5/2" would return "2" instead of "2.5". Integer BASICS can be powerful in terms of graphics, etc., but they are useless for any school work involving even simple arithmetic. One exception to our rule of "No integer BASICs" is the Apple II computer, whose 4K resident integer BASIC is used to load Apple's notably good 16K BASIC.

Q–*How much memory would I need for a computer kit?*

A–12K will handle most BASIC interpreters running on an 8 bit system (8080, 6800, Z-80, etc.), though Apple requires 16K for their BASIC. The Heathkit LSI-11 system is a 16 bit system so you get the same results with half the memory: we would suggest at least 8K on the "Big Heath." Few computer kits come with enough memory to handle BASIC, or even an editor/assembler, so be sure to add in the cost of extra memory to the basic kit price.

Q–*What is meant by an "ASR Terminal"?*

A–ASR means **Automatic Send/Receive** and refers to a paper tape reader and punch accessory mounted as part of a teletype terminal. A used ASR TTY–the model 33–sells for about $900. Without the reader and punch you can get one for about $500 to $600; so if you have no need for paper tape you can save a bundle by getting a TTY without ASR. Just the printer part of the TTY, known as an RO33 for **Read Only,** sells for under $300, less than the cost of most "computer printer peripherals."

Q–*What is meant by "Hardware," "Software," and "Firmware"?*

A–**Hardware** *is* any equipment; computer, printer, even an individual integrated circuit. **Software** means a program, or instructions for the computer. **Firmware** is some form of program or instruction-set already in the computer, usually called a *resident monitor,* that makes it easy for the user to enter, or write programs. Firmware is ready as soon as power is applied.

Q–*What is a "Monitor"?*

A–See **Firmware** in the previous question.

Q–*What is meant by "Boot" and "Boot strap"?*

A–You have probably heard of the expression "Picking yourself up by your bootstraps."; meaning, getting yourself started by moving yourself. Same thing with computers. A computer can only sit there and do nothing until programmed; but you can't just shove a program into the computer; something must tell the computer what's going on when you start to enter your program. A boostrap program is a very small program that sets up the computer to load a larger, complex program. To boot a program means to use a program (generally in a resident monitor or operating system) to program a larger program, or to set up something like a disk operating system.

Q—*An accessory I/O I'm planning on adding to my home computer has a feature called "handshaking." Exactly what is a computer's handshake?*

A—**Handshaking** is electronic confirmation that some piece of computer equipment is ready to execute operations. For example, before a computer transmits to a mass storage device such as a recorder it might send out an electronic signal to find out if the recorder is ready. On receipt of the signal the recorder, if ready, will transmit a signal back to the computer that it is ready. The computer will then transmit the start signal, followed by the data transmission. If the computer does not get its "handshake" from the recorder it doesn't transmit data. Handshaking can also work the other way: The recorder might send out its handshake signal, and automatically feed data to the computer only if a handshake is received from the computer.

Modems also generally use handshaking (see next question).

Q—*What's a modem?*

A—A **modem**—a term derived from **mod**ulator/**dem**odulator—is a device that connects both computers and terminals through telephone or other remote-wired circuits. A modem converts the electrical impulses from terminals and computers into audio tones which can be easily handled by voice-grade telephone circuits. Some modems, used on private lines, work at extremely high speeds; the common voice-grade modems operate at TTY speed (110 words per minute) or 300 words per minute. Modems used at terminals are called *originate* modems. Those used at the computer are *answer* modems. Each responds to different audio tones: the originate modem transmits low tones and receives high tones from the computer. The answer modems transshigh tones and receives low tones.

Q—*A group from school would like to set up a computer we could use from each home. Is this possible?*

A—Yes. You will need an answer modem at the computer, and each of you will need a terminal with an originate modem. Some means must be provided, if there is no one to attend the computer, to automatically answer the phone at the computer, connect the modem, and then "hang up" when the terminal signs off. This is easily accomplished through a modems handshaking signal. (We hope to have a construction project on such a device in an upcoming issue.) Answer modems, and combination originate/answer modems, manufactured by Omnitec—perhaps the most respected name in modems—are available from some surplus dealers from time to time. You have to keep looking because answer modems don't come cheap—even used.

Q—*Is there some reason paper tape (teletype) recordings made on my own computer cannot be fed into my school's computer, or the time-share system available through my school?*

A—Yes. Even though computers might use the same CPU there are minute variations in the encoded signals. It is more common than not that recordings from one type of computer cannot be fed to another, even when using the same type of recording system. For example, one of the most popular personal computers uses four nulls and a control signal at the end of each line of a BASIC program; this encoding precludes its acceptance by other personal computers. Similarly, it cannot accept recordings from a time-share system. It's a common problem. Some day there might come about a common recording or encoding standard.

Q—*What is an "acoustic coupler"?*

A—An acoustic coupler is a modem that is connected to the telephone circuit by placing a telephone's handset in the modem's sound-absorbing cradle —which contains a speaker and microphone to couple sounds from the modem to the phone and vice-versa. This contrasts with a "hard wired" modem that is wired directly to the telephone line(s).

Q—*What would cause intermittent recordings from my computer? I'm using a Kansas City interface and a Panasonic cassette recorder. Sometimes I load a program and find there's errors, even on the safety dump.*

A—If you can get good recordings occasionally it's a sure sign both the interface and recorder are okay. Most likely you are using a really cheap tape, and dropouts—which normally go unnoticed with sound recordings—are dropping bits out of your dumps. Even at 300 baud you need decent tape such as TDK-AD, Maxwell UD, and AVDEX, all of which are excellent to at least 4800 baud. When recording baud rates above 4800 a special data cassette is recommended.

Q—*What is the difference between audio and data cassettes, and why are data cassettes at least twice the cost of audio cassettes?*

A—The primary difference between an audio and data cassette is the pressure pad. The one on the data cas-

The Apple II computer features color graphics and high resolution graphics in addition to the normal alpha-numeric features of most computers. This ability to create three-dimensional forms makes it popular with many experimenters and computer artists.

sette is oversize, generally made of a special low-friction material, and often costs more than the tape itself. In addition, the tape (supposedly) has a more uniform coating, is less prone to oxide flaking, and most important, is certified for a specific minimal baud rate. It is claimed the shell and internal construction is better but we haven't noticed construction having any effect when it comes to personal computers.

One advantage of the personal computing data cassettes such as those from AVDEX is they have short tape loads; you don't pay for 30 minutes worth of tape when you need about thirty seconds worth. (Data cassettes often come in several "short" lengths.)

Q—*What is meant by "serial" and "parallel"?*

A—In **serial**, each bit of the seven bits (or eight with parity) making up an ASCII character, or binary information, is transmitted to or from a computer in sequence, one bit after the other. Special timing and encoding tells the computer which bits make up a character. In **parallel** form all bits are simultaneously transimtted, so no timing or special encoding is required. TTY uses a serial format. An inexpensive tape reader such as the Oliver uses the parallel format, thereby allowing you to feed the tape as fast as you can pull it through the reader. All you must be certain of is that the computer's I/O matches the terminal or peripheral: serial for serial and parallel for parallel. You cannot mix the two, such as feeding a serial TTY through a parallel I/O port. (Note. Though a TTY feeds and receives in serial unless specially modified, a TTY punched tape is recorded parallel—the TTY makes the "conversion".)

Q—*How much memory can be installed in a personal computer?*

A—The maximum amount of memory is determined by the particular CPU and the size of the power supply. Some kits provide for something like 16K, 20K, or 24K in the main cabinet, with an extra cabinet and power supply needed for additional memory. Other kits have a heavy-duty power supply, usually a cooling fan, and can accommodate up to 48K of memory. New memory ICs draw relatively little current and you can now get 8K of memory in less space than you needed for 4K, and the 8K takes less current. As a general rule, 6K to 8K of available memory—in addition to the memory needed for your higher language such as BASIC —is more than enough for 99% of the average personal computer's programs. You need a lot more memory —upwards of 20K—when you start getting into filing systems, or FORTRAN. But if you're into files and/or FORTRAN you really need a disc system.

Q—*What is a "Header"?*

A—A **header** can be several things, but it generally refers to a code, often a single letter, placed in front of a program when several programs are recorded on the same tape. The computer can be programmed to search for the header and load only the program that follows the specified header. Basically, it's a simplified filing system for cassette storage. Some BASICs make provisions for headers, or more commonly, "files"; others don't, and the BASIC loads everything coming off the tape.

• Well, that about wraps up those questions most frequently asked by our readers. We would like to answer your letters individually but it has become physically impossible to do so. But we will keep track of your letters and comments and from time to time cover those questions most frequently asked. Meanwhile, each issue of e/e will keep you up to date on the latest in personal computing hardware, some software, and most especially, those oddball gadgets with particular appeal and value to the hobbyist and experimenter. So keep those letters and cards coming. ■

Computing With Kansas City

☐ You've just spent a couple of hours loading your personal computer with a long, complex program such as Lunar Lander, Wumpus, or Hammurabi, or maybe a school project; you have spent perhaps another hour debugging the program to get the so-called "universal BASIC" into your computer. Your fingers are sore from typing on the terminal, and all that effort can be wiped out by a sudden powerline interruption. Similarly, if you turn the power off after a computer session, the program is cleared and that requires another long session of typing and debugging the next time you need to run the program.

The plain truth is, after you've typed out a small twenty line program for the fourth time you have probably *had it up to here* with personal computers. Imagine what it's like reloading a hundred, two hundred, or 500-plus step program!

Fact is, anyone who wants to use a personal computer for more than a toy must have some means of recording and reloading programs. The problem with recording, however, is that the marketplace is jam-packed with personal computer recording equipment. Few of these are compatible with each other, or different hobby computers. The prices for the hobby-quality recorders range from budget to astronomical, with price not necessarily reflecting either reliability or ease of use.

Since your selection of personal computer recording equipment can make or break your bank account, as well as your interest in hobby computers, we're going to describe a few of the moderately priced equipment that provide a good balance between price, performance, and, most important, convenience. Keep in mind we will be covering only hobby-grade personal computing accessories. Please don't write in that we overlooked an IBM Selectric terminal with computer interface, or surplus magnetic tape or disc devices from a discarded commercial system. We will be talking only about equipment specifically made for what is essentially the *entry-level* to hobby or personal computing.

A warning before we get started: Take notice that virtually all of the personal computing recording equipment we've used have come with instructions setting a new low for clarity. They barely suffice for getting power into the equipment; they are worse than useless if you run into problems, so be certain you can get assistance from someone who knows or has used the equipment you're planning to purchase. If you're a college level technology student or a flaming technical genius you can probably go it alone. (Don't forget, when it comes to computers proper grammar is not a substitute for the ability to express an idea or instruction clearly. Do not be fooled by slick, well edited instructions: they are probably beyond intelligent comprehension. Get some skilled back-up before you tackle a recording system.)

Paper Tape. The basic recording medium is *paper tape*, the type with up to eight holes representing each character and parity—called 8-level ASCII (see ELEMENTARY ELECTRONICS Sept.-Oct. 1977). It can be punched and read under computer control by an ASR 33 teletype or similar equipment being used as a computer terminal. The chief advantage of paper tape is that, unlike magnetic storage systems which are subject to accidental erasure by strong magnetic fields, paper tape is virtually destruction-proof. Short of setting fire to the tape, the recording will last for years and years. Should the tape be damaged it can be easily repaired by a Mylar patch similar to a movie film splice, which is applied by an editing/splicing device also similar to a movie film editor.

You can even use the editor/splicer to remove sections of the recorded programs, or splice in new additions.

Many of the personal computer BASIC interpreters (compilers) are available on TTY paper tape, as are core-sident assembler/editors and some game programs. Naturally, it might not be worth several hundred dollars for a tape reader you might only use a few times, so you can consider a manual tape reader that sells for less than $80. You simply pull the tape through the reader by hand, or jury-rig some form of winder. (Check your local computer store for an Oliver tape reader.)

If you're thinking of swapping programs with friends or using them on a school or time-share computer system, paper tape is the easiest way to get a reliable, essentially universal format.

To make tapes you'll need a punch. A combination punch and reader used to run many hundreds of dollars; now you can build one yourself for a moderate price. The Heathkit H10, priced at $350 in kit from, can be easily adapted to most personal computers having a standard parallel I/O port.

Though the H10 is somewhat more inconvenient to load and operate than some other punch/read devices, it has several advantages for the hobbyist. Firstly, there's reader speed. Paper tape is punched at the standard rate of 10 characters per second, which represents a theoretical maximum of 110 wpm (words per minute) at the TTY standard 9.09 mSec character rate. Now this might look fast on paper, but when being read into a computer it's a crawl; some 8K BASIC programs take as long as 18 minutes to load at 110 wpm. But the Heathkit reader operates at five times the punch speed, and the tape is read in 20% of the normal time. The same tape that would take 18 minutes to read at 110 wpm takes only 3.6 minutes with the H10 reader.

The punch/reader of an ASR-type teletypewriter is one of the more common systems. It's very easy to use; just push a button to transmit a signal from the computer and it will punch or read a tape or do both.

The H10 will also directly copy a paper tape, and it's punch and reader can operate independently under computer control if needed.

In combination punch/readers the H10 is about the best buy, even though it can be a little troublesome to load, or reload if you want to pick up from a stop.

Kansas City. Though paper tape is essentially indestructible, under normal handling it is prone to spill, leaving yards and yards of curling, twisting ribbon on the floor. Besides, until the Heathkit H10 came along, hobbyists had to put up with a slow read of 110 wpm, or an ASR TTY terminal. At a computer fair in Kansas City several years ago, *Byte* magazine proposed a tape recording system operating at 300 baud (about three times TTY paper tape speed) using audio tones of 1200 and 2400 Hz on standard Philips cassettes. The system came to be known as the "Kansas City" standard. It's primary advantage is that an ordinary, inexpensive cassette recorder can be used to record the audio tones which result from conversion of the computer's digital data.

Unfortunately, the originators were "digital designers", and there probably wasn't an audio engineer in the room. No self-respecting audio engineer would ever use two harmonically related frequencies for information storage. How the Kansas City proponents ever got tangled with what we will show is the weakness of harmonic relationships we'll never know, because the telephone Touch-Tone frequencies, which are non-harmonic, have been around for many years, and just about everyone but the Kansas City designers use Touch-Tone frequencies for encoding, signaling, etc.

To use Kansas City you need an interface such as the SWTP AC-30, which also uses computer signals to control up to two associated recorders. We spent four weeks trying to "repair" a working AC-30. The problem was that the distortion in the tape recorder was providing sufficient harmonic energy from the 1200 Hz signal to interfere at 2400 Hz. It is somewhat *tricky* to get the recorder's output level and tone control properly set for reading. It is one hell of a job to get the record level correct with some small recorders; too much signal and the distortion confuses the read of the tape. Too little level and the inherent tape/electronic noise confuses the read of the tape.

For those with SWTP 6800 computers there is a small Kansas City interface that plugs right into the computer—taking up an I/O port simply for

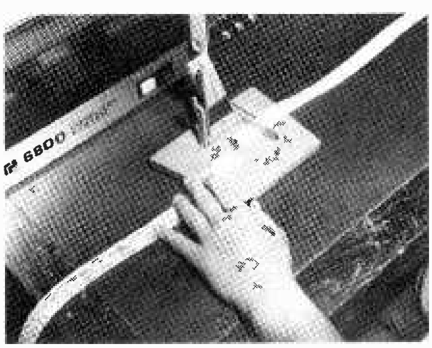
Where to Find More Info

Info on the products shown in this article is available from: H10 paper tape punch/reader from Heathkit, Benton Harbor, MI 49022; AC-30 cassette interface from Southwest Technical Products, Inc., 219 W. Rhapsody, San Antonio, TX 78216; PCC Model 33 cassette interface from Personal Computing Company, 3321 Towerwood Drive, Dallas, TX 75234. CC8 Cassette Data Recorder from National Multiplex, Corp., 3474 Rand Ave., South Plainfield, NJ 07080; BFD-68 Floppy Disc System from Smoke Signal Broadcasting, Box 2017, Hollywood, CA 90028.

power—that provides for easy level adjustments. This device, the Personal Computing Company's model 33, is the easiest-to-use Kansas City interface we have yet to see. It becomes part of the computer, doesn't require a separate power cord, is easy to set up because of an L.E.D. level indicator, and best of all, the PCC Model 33 is sold completely wired and tested.

National Multiplex. The name tells you absolutely nothing about this firm's products, which are essentially hobbyist versions of commercial digital tape recorders. Their model CC8 digital cassette recorder is really an ordinary cassette recorder with all new electronics that provides for NRZ (none return to zero) data recording. There are no audio tones to get distorted; the system always works. The only audio is a monitor tone(s) that lets you know a signal is being fed into or out of the recorder. It can operate virtually error-free with a good quality audio cassette tape such as TDK-AD, AUDEX, and Maxell UD up to 1200 baud, and similarly error-free to 4600 baud with data cassettes. In plain terms, 4600 baud means you can load a program that would take 18 minutes with paper tape (at 110 baud) in only 26 seconds. Fact is, we load a SWTP computer with 8K type 2.0 basic in less than 20 seconds using a CC8 recorder at 4600 baud. In months of operation we have had only one error when recording/reading programs.

The CC8 has an RS-232 or TTL I/O—as selected by the user. It is best used on computers with Motorola 6800 CPUs, such as the SWTP 6800 computer. Problem is, it cannot piggyback the control port. You need some program that switches from the control port to a recorder/reader port (we use #3 port) and back to the control port when loading BASIC. We use a *Linzer Loader* program—a short program that permits dumping any section of memory to the recorder, or reading of the recorder's output, and then return to the control port. The Linzer Loader checks every bit for parity and indicates a correct load on the control treminal. If the load is defective it is indicated by a special code and a readout of the memory location where the failure took place. If the location remains the same on three successive attempts to load you know you have a defective tape. If the load fails at different locations you know heat and/or humidity has affected the drive speed and you either correct the ambient conditions (not unusual for computer installations) or adjust the recorder's drive speed.



Damage a paper tape? Or, do you want to splice two program parts together? Never fear, it's as easy as splicing film.

You don't need a special interface for the CC8 "Computer Aid" recorder.

(Note: The Linzer Loader for SWTP 6800 computers is available to readers of e/e for $5 from Harry Linzer, 12 Crafton Ct., Malverne, NY 11565. It comes complete with listing for SWTP 8K type 2.0 BASIC in 12K of memory and a TTY tape with the dump and loader programs. In combination with a CC8 recorder it permits loading BASIC in less than 20 seconds.)

The CC8 recorder is the fastest, most reliable we have seen in personal computing cassette recorders. The only problem we have run across is speed drift during very hot and humid weather. At 4600 Baud the speed tolerance is 1%. National Multiplex supplies a speed alignment tape but you'll need a counter. Otherwise, use a Linzer Loader program, load BASIC, and slowly change the setting of the speed adjustment so the loading failure occurs at progressively higher memory locations.

Mass Storage and File Handling. When you need to handle mass storage and files, the equipment to use is the floppy disc. These floppy discs are a rather expensive recording medium for the hobbyist. A more practical, certainly less expensive disc system, is the so-called *Mini-Floppy*, or *discette*, such as the Smoke Signal Broadcasting BFD-68 floppy disc system. Though intended for computers with Motorola 6800 CPUs, similar systems are available for the S-100 buss (8080 and Z-80 CPUs).

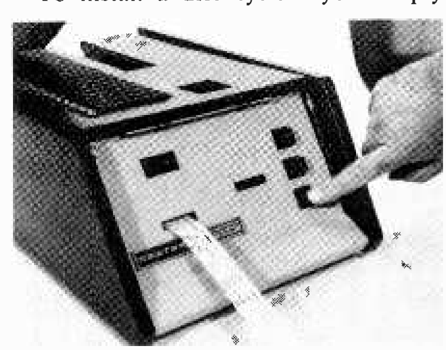
The Smoke Signal disc system is available fully wired and adjusted with one, two, or three floppy disc drives. It uses the 5-inch mini-floppy (discette) shown in the photographs. Each discette has upwards of 80,000 (80K) bytes of storage (the exact amount depending on the particular drive system). The primary advantage of the disc system in addition to its mass storage and relatively rapid retrieval is the ability to assign names to files, the renaming of files, the transfer of computer memory to disc and from disc to memory, and a direct jump to the starting location of any location loaded from disc to memory. All operations are under direct software control.

By using a disc system with at least two drives data can be easily and continuously updated. For example, assume you are the secretary of a bowling league. All previous information is on disc storage, along with a program for handling the bowling scores, averages, standings, handicaps, etc. The program is loaded from disc to the computer's memory. It combines previous file data on the league members with input from their latest games and creates a new, updated file. You can either save or erase previous files

You can even transfer your BASIC interpreter to disc. This way, you simply call for the disc operating system to list the files on the tape, load the file which contains BASIC, usually named "BASIC", and in seconds rather than minutes your computer is loaded. (Fortran is now also available on disc for some S-100 buss computers).

Some disc systems provide the BASIC—usually the 8K extended variety—pre-recorded on disc along with a disc operating system. The Smoke Signal BFD-68 provides no BASIC, you dump your favorite version of BASIC to the disc.

To install a disc system you simply



Need paper tape equipment without a TTY? The H-10 from Heathkit is an economical punch/reader. The punched tape comes out one of the front panel slots.

plug the supplied board into your computer, connect the disc unit's line cord to the nearest outlet and press the power switch. Just slip a disc into the drive, *initialize* the computer to the disc system's address and you're running.

Similar to audio and data cassettes, a discette (mini-floppy) can be protected against accidental erasure. There is a small notch in the discette, which, when covered by tape, prevents the drive being placed in the record mode.

Summing Up. We have illustrated some of the most common and popular computer storage equipment. Unquestionably you'll find other devices advertised for direct mail sale, or in your local computer store. We will keep you up to date on the equipment most requested by our readers. If there is a particular storage system – generally available from coast to coast—that you believe is suitable for the personal computing hobbyist just call it to our attention. If it appears to have general interest you can be certain it will be considered for a future article. ■

Computers Dial the Future

☐ Even if you now haven't the vaguest interest in personal computers, within a year or two you will likely be up to your neck in personal computing whether you like it or not; and by *personal computers* we don't mean a Hewlett-Packard or TI programmable calculator—though they are, in fact, personal computers.

Personal computer means a full blown computer you can use to keep and process business and family records; one your children can, and probably will, use for their math, science and social studies—at all levels from grade school up; a computer your preschool children might use to play games such as *Star Trek* and *Klingon Capture;* a computer you could use for adult education courses taken in the comfort of your own home.

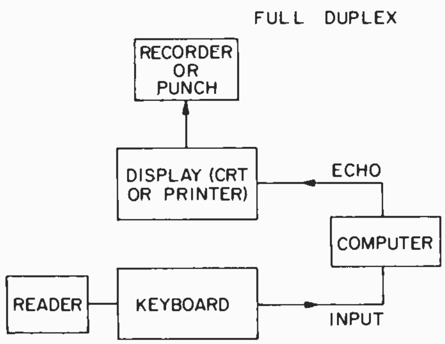
For less than the cost of a decent hi-fi system, or a console color TV with remote control, you can have a computer in your own home as powerful as some of the big IBM jobbies, and the whole computer won't take up much more space than a couple of shoeboxes. If you don't have room for two shoeboxes worth of electronic hardware you can rent computer time from regional and national companies. For example, did you ever wish you had an hour or so of computer time to finish a school problem? *Call Data* will charge you as low as $6 per hour (educational rate) for using their computer. If all you need is a couple of hours on their computer per month the bill could be less than your phone company charges you for the privilege of having a telephone.

Whether you opt for a personal computer in your own home, or a connection through your telephone to a time-share computer service you are going to need a *terminal,* the device that lets you communicate with the computer.

Trouble is, the surplus market is loaded with *computer terminals* that are really worthless for general use, so this article is going to serve as both an introduction to computer terminals and a guide as to what's available and really worthwhile.

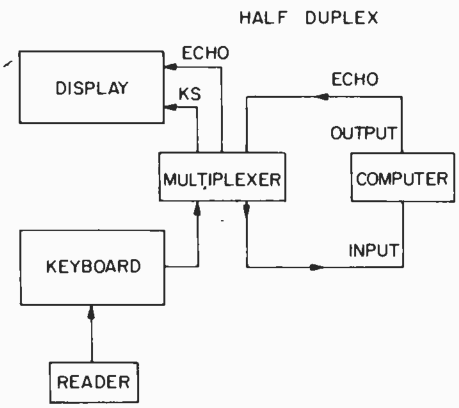
Because of space limitations we cannot cover every type of terminal used to communicate with computers. Since the average reader will have access to a time-share dial-up computer, (via the telephone) or a personal computer in the home, we are going to cover only the terminals that work with both systems. There is no reason to spend several hundred dollars for a terminal that works with a personal computer only to find that if someone offers you free time on a giant time-share system your terminal can't be used

Two Piece Terminals. At the very minimum a computer terminal consists of two separate devices: a typewriter style keyboard that transmits information to the computer, and a display de-



For computer use a terminal—whether TTY or electronic with CRT—is generally arranged in the full-duplex mode, meaning the keyboard and display are independent of each other. In some instances the keyboard will have an associated reader that can provide output from a punched tape (or other player), while the display has an associated recorder, or a punch for paper tape. If there is an associated reader and punch the complete terminal is an ASR (Automatic Send and Receive).

The keyboard sends the characters to the computer which in turn sends back an instantaneous echo to the printer/display. It appears to the user that he is typing directly to the display though there is, in fact, no direct connection between the keyboard and display.



In the half-duplex mode a form of multiplex device somewhere in the overall system—it can be a simple wire from the keyboard—sends the keyboard signal to the display even if the computer's echo is turned off. If the echo is left on the display will show each character twice, once from the direct connection from the keyboard followed by the echo. Half-duplex is generally used when the terminal operates at baud rates too fast for the printer to follow the echo, or too fast for the computer to handle the incoming character plus the echo. In time-share and hobby personal computer systems the echo is usually turned off at baud rates higher than 300.

vice that "prints" the information coming from the computer. The display can either be some form of printer that "types" a written record—called "hard copy"—on paper; or a CRT, which can be a TV monitor, a modified TV receiver, or anything else using a CRT.

As à general rule the two sections—keyboard and printer—are totally independent even though you might have used, or observed, a working computer and seen that whatever was typed on the keyboard was printed out on the display. The keyboard transmits information to the computer, which then *echoes* back to the display so the user can check the entry. If the user types the word *ready* the computer echoes back the word and the display shows the word *ready*. Without the echo the user would have no idea whether he was transmitting correct data into the computer. The condition of separate keyboard and display is termed *full-duplex*, meaning two things can occur at the same time—you can transmit and receive simultaneously.

Another condition is termed *half-duplex*, and there appears to be several versions of what is meant by half-duplex. The most common use feeds the keyboard character to the display and the computer. When the computer echoes back, the display shows both the original keyboard entry and the echo. In full-duplex, a keyboard entry of ABCD is displayed via the echo as ABCD. In half-duplex the display shows AABB CCDD. In full-duplex the word *ready* is displayed as READY; in half-duplex it appears as RREEAADDYY Half-duplex transmission is commonly used when time cannot be allowed for the computer to echo back. There are certain conditions when this is necessary, and the half-duplex mode, at the least, allows the user to check *spelling* and codes as they are entered into the computer.

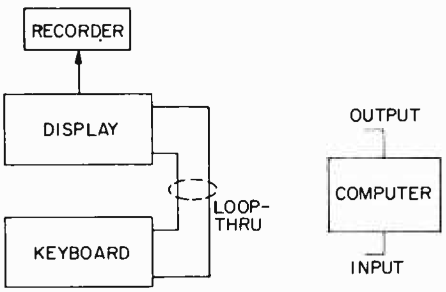
Local is a term meaning the keyboard is connected directly to the printer so that keyboard entries are fed only to the display and any recording device attached to the display. In this manner a tape can be prepared for transmission to the computer at a later time.

If the terminal is in the vicinity of a computer it can be connected directly to the computer via multiple wires—this is termed *hard wired*. On the other hand, it is possible to use the telephone to "converse" with a computer on the other end of town, or even the country. The terminal is connected to a device called a *modem*, an acronym for *Mod*ulator-*Dem*odulator. Some modems can be hard wired directly to the telephone line; others can be acoustically coupled by simply placing the telephone's handset into a built-in receptacle. The modem takes the signal from the keyboard and converts it into audio tones which are fed to the computer through the telephone line. At the receiving end, a different type of modem converts the audio tones back to an electrical signal for the computer. Each modem is a two-way device. The modem at the computer takes the computer's output electrical signal and converts it into audio tones for transmission to the terminal. At the terminal the modem converts the audio tones back into electrical signals needed to drive (produce) the display. To avoid a mix-up on the telephone line the audio tones from the computer systems is the model 33 teletype, and the terminology for the model 33 has become, more or less, the accepted terminology for all I/Os. A model 33 printer (no keyboard) is called an RO for *R*ead *O*nly. CRT displays, or any other type of printer without an associated keyboard are usually termed ROs.

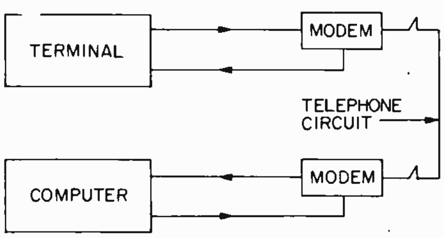
A model 33 teletype which consists of a printer and keyboard is termed a KSR for *K*eyboard *S*end and *R*eceive. Any other type of TTY or CRT terminals with a keyboard and display is termed a KSR.

Then there is ASR for *A*utomatic *S*end and *R*eceive. This is a model 33 TTY with an attached paper tape punch and a reader to read back the paper tape. The tape can be punched either from the keyboard in the *local* operating mode, or by the computer via the echo. The punch is mechanically attached to the printer so whatever the printer receives (with some exceptions programmed through a "stunt box") gets punched out on the tape. The reader feeds out as does the keyboard. If the tape is played (or *read*) by the reader, the output from the TTY is just as if it was sent from the keyboard. Both the punch and reader can be controlled from the computer by special signals, hence, this type of TTY is termed Automatic Send and Receive, or ASR Any similar terminal device is known as an ASR.

Though the model 33 TTY, and its designations such as RO and KRS, is



When a terminal is switched to the local mode the keyboard is connected directly to the display via a loop, and the computer is disconnected. In this way the keyboard entries are fed directly to the printer and tape punch of an ASR TTY, and tapes can be prepared for feed to the computer at a later time. It also permits characters such as control functions to be added to a punched tape that has been previously made from a feed by the computer using the full or half duplex modes. (In half-duplex the computer can feed the display if the keyboard is not in use. This is usually accomplished by sending special control signals to the computer.) In electronic terminal systems with CRT display the recorder might well be a digital tape recorder rather than a TTY-type tape punch.



A terminal can be connected to a computer through voice-grade telephone circuits using a device termed a modem, an acronym for modulator-demodulator. The modem converts the terminal's electrical pulses to tones in the approximate 1000 to 2000 Hz range. When the tones are received by the computer's modem they are converted back to electrical signals. Each modem is a two-way device: the computer's modem converts the computer's signal to audio tones and feeds it to the terminal's modem where it is converted back to an electrical signal for the printer or display. To avoid confusion between the terminal and computer the tones from the terminal are completely different from the tones generated by the computer's modem.

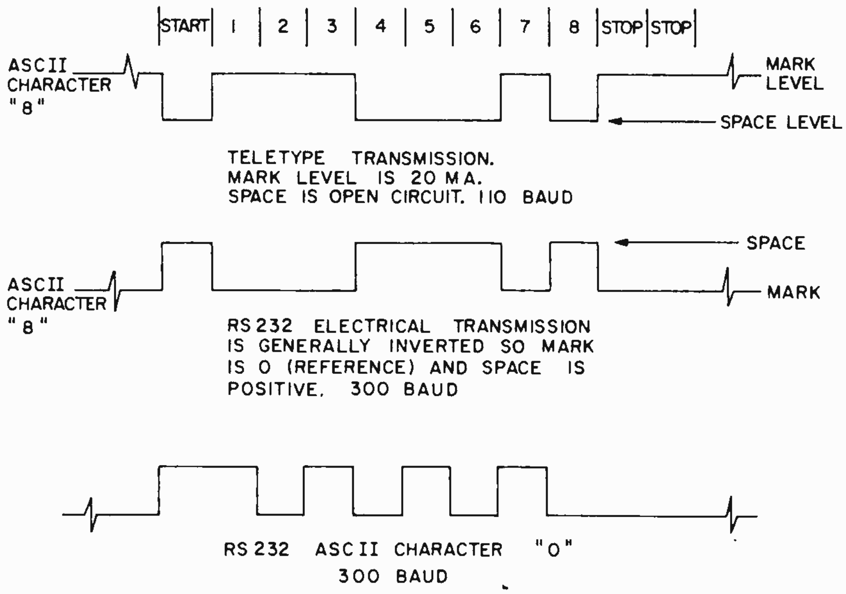
terminal are at a different frequency than those from the computer.

The basic input/output device for both time-share and most personal the common standard of reference for most hobby and time-share computer systems there are other keyboard-printer devices that provide similar functions. Other straight TTY equipments are available as ASR and KSR equivalents of the model 33; and there are special *line printers* that print an entire line of copy at high speed, in contrast to the TTY's one-letter-at-a-time printout.

Smart and Dumb. Another variation is the "dumb" CRT terminal. This is a keyboard and CRT display made to function exactly as a KSR TTY. Though all-electronic, it puts out exactly the same type of signal as a TTY and responds to the same input signal, printing one letter at a time at TTY speed on the CRT. A slightly different version of the KSR electronic TTY puts out something called an RS-232 signal, an industry-wide TTL (transistor-transistor logic) compatible signal used for direct connection to computers and some modems; but it's still a "dumb" terminal.

What's a "smart" terminal? An electronic terminal with a built in minicomputer. A smart terminal allows the user to type a full page into storage, examine the page for errors, make corrections, and then transmit the signal. In some smart terminals additional information can be typed into storage as the previously entered information is sent out. On the receiving end, a smart terminal can often store several pages of transmission, allowing the user to electronically roll back to previous pages. (A full screen is usually a page.) Some smart terminals are actually full computers with built in KSR and can store thousands of words, but this is esoteric equipment. The typical hobbyist and time-share user is more likely to use an inexpensive, dumb KSR electronic terminal such as the highly rated Micro-Term ACT-1, which has 300 *baud* (we'll explain *baud* later) RS-232 output that can be fed directly to a hobby computer or into a modem such as the Omnitech 701A (the industry "work horse" available used for about $150) that has both a TTY and RS-232 connection.

For those who need both a direct RS-232 output and a modem, but who don't want the modem as an extra piece of gear with its required wiring there is the ACT-2 terminal shown in the photographs. The one shown is a prototype sent to ELEMENTARY ELECTRONICS for test and evaluation. It is essentially the ACT-1 with a built in modem.



All time-share and most of the larger personal computers use an electrical character code termed ASCII, short for *A*merican *S*tandard for *C*ommunications *I*nterchange of *I*nformation, and pronounced "as-key."

The 8-level ASCII code presently in use was designed for teletype so the associated terminology refers to TTY operation even if the entire communications system is electronic with a CRT for the display.

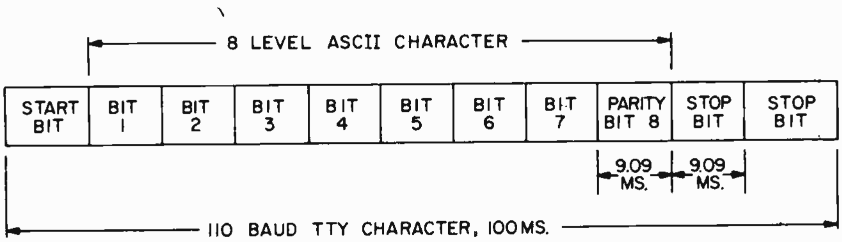
The TTY terminology in turn goes back to the days of the telegraph when one or a series of magnetic sounders was connected in a battery powered loop through the telegraph keys. Since everything was in series, the normal *off* condition was for current to flow in the loop and this condition was called *mark*. When the key was open to send a character the current loop was broken, the sounders made a "click" and the open current loop condition was called *space*. We still use the terms *mark* and *space* today. When a computer's TTY is connected to its associated equipment and it is not receiving a character signal it is fed 20 mA of current for the printer—the *mark* condition. To send characters the current is interrupted—the *space* condition. (You might have to read this over a few times to get the sense because it appears to be the opposite of what's needed. As we'll show, in electronic systems we invert the signal so *mark* is generally zero current or voltage and *space* is some amount of current or voltage.)

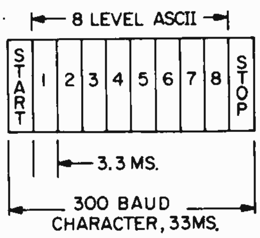
On to the next confusion. The 8-level ASCII character code really uses only seven *bits* to transmit the character; the eighth bit is for something termed *parity*, and even here we don't stop because there must be signals to synchronize the sending and receiving equipment. After all, something has to tell the printer that the electrical pulses to follow are a character and not line noises. So we add a *start* bit in front of the character. Now we must turn off the printer so it doesn't generate "garbage" sensing line noises as character bits. For this we follow the parity, or eighth bit, with two stop bits. Now we have a total of 11-bits making up the 8-level ASCII TTY character, as shown in our earlier diagram.

Note that each bit is 9.09 msec wide, making a total character length of 100 msec. The start bit turns on the printer, the first seven bits represent the character—either letter, numeral, control function, etc.—and the stop bits insure the printer stops and resets for the next character.

The parity, or eighth bit, is used to "test" the transmission when there is the possibility noise can obliterate, or add, a bit. The keyboard can be programmed so the parity bit is added to provide odd or even parity; that is, the *total number of character bits* from one to eight is even or odd.

Assume the keyboard is programmed for even parity and the letter Q is transmitted. The letter Q uses three bits—Numbers 1, 5 and 7. Three is an odd number so the eighth bit is automatically added, making the





total number of bits transmittted four, an even number. At the receiving end only the first seven bits are processed, giving the character Q. A *parity* detector, however, counts all the bits; if it's not an even result the printer might indicate an incorrect character has been received, or the parity detector might light a lamp or sound a bell to indicate something is wrong with the transmission. If the character originally had an even number of bits, such as the letter V which uses bits Numbers 2, 3, 5 and 7, the eighth parity bit is not added since the transmission has an even number of bits for the character, and the parity detector "sees" an even count. Both the keyboard and parity detector can be programmed for even or odd parity. Where there is a direct connection to the computer, or a circuit with little likelihood of noise, the parity detector is usually disabled or simply not used.

Though a TTY requires a bit length of 9.09 msec. the resultant 110 words per minute printer speed is too slow for most users. 300 WPM is the standard for electronic terminals used by time-share (with echo) and personal computers. We get the higher speed by simply reducing the time of each bit to 3.3 msec., and by eliminating the second stop bit.

The actual TTY transmission of the No. 8 is shown in the topmost figure. Note that the reference is *mark*, and the transmitted bits are *start*, 4-5-6, stop-stop. The middle figure shows the electrical equivalent as would be transmitted by an electronic keyboard using the EIA's RS-232 standard. Note that *mark* is now "O" (zero) and the waveform appears as a conventional waveform with the bits positive-going. (Yes, RS-232 provides for a negative-going waveform resembling the TTY waveform shown in the topmost figure). Note that the RS-232 character shown is 300 *baud* so the second stop bit is eliminated.

In both the top and middle figures bit number 1 is not used so the start bit stands alone. The bottom figure shows what occurs when bit 1 is part of the character. The letter "U" has alternating bits starting at bit 1, so bit 1 combines with the start bit to form a "pulse" double the reference bit length of 3.3 msec. The receiving device senses the leading edge of the start bit, times out for 3.3 msec. and since it "sees" a signal at the start of the next 3.3 msec. interval it "counts" bit 1. It is through the timing that the receiver counts bits. For example, in the top figure bits 4, 5 and 6 run together and "appear" as part of a square waveform. In actual fact the TTY doesn't recognize a square wave; its timing mechanism simply counts three contiguous bits followed by a space.

In both TTY, modem, and most personal computer use each ASCII character is transmitted *serially*, meaning one bit follows the other. There are special circuits, however, that require a *parallel* transmission, that is, all bits are transmitted through at least seven wires at the same time (eight wires if parity is used). This is generally done electronically with each bit represented by a *high* (logic 1).

The subject of the ASCII code and its transmission is rather extensive. We have featured the general highlights you'll need to know as you get started in using computers. A more complete explanation geared for hobbyist use can be found in the Sam's publication **TV Typewriter Cookbook** by Don Lancaster. If possibe, avoid the TTY service manuals and handbooks; you need a whole set to find out what's going on and the Cookbook is faster and more easily understood.

Baud. Whether you go into personal or timeshare computer systems you're going to hear and read much about something termed *baud* or *baud rate*. Very simply, *baud* is expertese for something we used to term *pulse width*, or *time;* it's sort of like when the experts decided to upgrade electronics by deciding we must all call cycle-per-second *hertz*.

In order for electronic systems to communicate there must be some form of synchronization; each character or command must be transmitted and received in a specific time interval. If a printer was programmed to receive a character in say, 100 milliseconds (msec.), and it received one and a half characters in 100 msec., obviously it would be confused and display incorrect information, just as it would if it received only half the character information in 100 msec.

As you might have guessed, we achieve synchronization by transmitting any character in a specific time interval. If you refer to the illustration of an ASCII TTY signal you'll note it consists of 11 bits—the start bit, 7 character bits, parity, and two stop bits—with each bit being precisely 9.09 msec. in width for a total of 100 msec. Now *baud*, or *baud rate* is very simply the reciprocal of the pulse width of each bit. Since the pulse width of each ASCII TTY bit is 9.09 msec the *baud rate* is 1/.00909, or 110. That's all there is to it. We could just as easily have called it the "Irving rate," the "Gloria rate," or the "9.09 rate." We call it *baud rate*, and a 110 baud rate is always 8-level TTY speed.

Trouble is, the TTY is capable of printing a maximum of 100 words per minute typing rate, which is fine for someone typing away, but slow when getting information back from a computer.

Though there are printers capable of displaying more than 100 words per minute they cannot print faster than the information is transmitted, and the limitation remains the speed at which the ASCII characters are transmitted. But, the ASCII format applies to the sequence of the eight bits making up the character and parity (a self-checking feature). If each bit were shortened each character would take less time to transmit, and that's exactly what is done. By general convention, for most personal and time-share *high speed* terminals the character bit rate is shortened from 9.09 msec to 3.3 msec., Almost three times as much information may be transmitted within a given time interval as compared to a 110 baud TTY. If we find the reciprocal of 3.3

msec. (1/.0033) we get an answer of 300, meaning a 300 *baud* rate. You will find most hobby CRT terminals such as the ACT-1 and ACT-2 to be 300 baud.

The fact that 110 baud means 100 words per minute and 300 baud means 300 words per minute doesn't mean there is a direct relationship between baud rate and words per minute. The close relationship is purely accidental. (If you get out the calculator and start multiplying you'll probably claim a 300 baud rate should produce less than 300 words per minute. The "error" comes in because the TTY signal has two stop bits which take up a total of 18.18 msec. The complete TTY signal is 11 bits; start, 8 characters with parity, 2 stops. The 300 baud system has only one stop bit—ten bits total for the character—so the stop is 3.3 msec, which is less than one-third the time of the 110 baud stop bits.)

Baud rates can be intermixed for storage. Assume you have a Southwest Technical Products MC6800 personal computer such as the one E/E will use for our personal computing series. You might type in your program using a 110 baud model 33 teletype. Allow for corrections, proofing and changes and assume you have worked one hour loading the program. The final program —error free—if punched out on paper tape through the TTY might take 10 or 15 minutes to load it back in the next time you want to use it. But you can have a "hobby standard" 300 baud recorder connected to the computer, and instead of dumping the program out to the TTY you dump to the recorder at three times the TTY speed. The recording will take only some 3 or 4 minutes to save and reload into the computer. Some personal computing hobby recorders run 1200 baud, and that 10 or 15 minute program can be saved and loaded in a few seconds. (There are even higher baud rate recorders.)

Summing Up. Your first requirement for both personal and time-share computers is the terminal. With the personal computing marketplace growing at a rate exceeding Jack's beanstalk there are more and more ads from more and more companies offering surplus TTYs and CRT terminals, both kit and wired. Like the early days of anything, many won't be around tomorrow when you need service or parts, and some of what will be sold won't work too well. In selecting a terminal, stick to the well-known brands from companies that have deserved reputations. For example, you can always get parts and service for a model 33 TTY at reasonable prices. This is not necessarily true of any other TTY. If you're purchasing a used model 33 (which is about the only way to get one, because the waiting list for a new one direct from Teletype is months and months) make certain you get it from a company specializing in rebuilt models, such as National Teletype.

If you opt for a CRT terminal the proven one is the ACT-1; if you want to go the build-it-yourself route Southwest Technical Products is probably your best bet at this time.

The age of personal computing is upon us so you might as well climb aboard at the beginning. ■

Microprocessor Revolution

☐ 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.

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!

The whole area of applications is so broad that we need more than one article to begin to cover it. This issue will address microcomputers in business, transportation systems, and the home. But the home applications will only be touched on at this time. The next issue will dive into electronic games for the home—which is a fantastic voyage in itself. So stick with me as we weave our way through.

Computers In The Office. The use of computers in business—a subject many of you have asked me about in your letters—can be broken up into the 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 our last Computer Readout article 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 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.

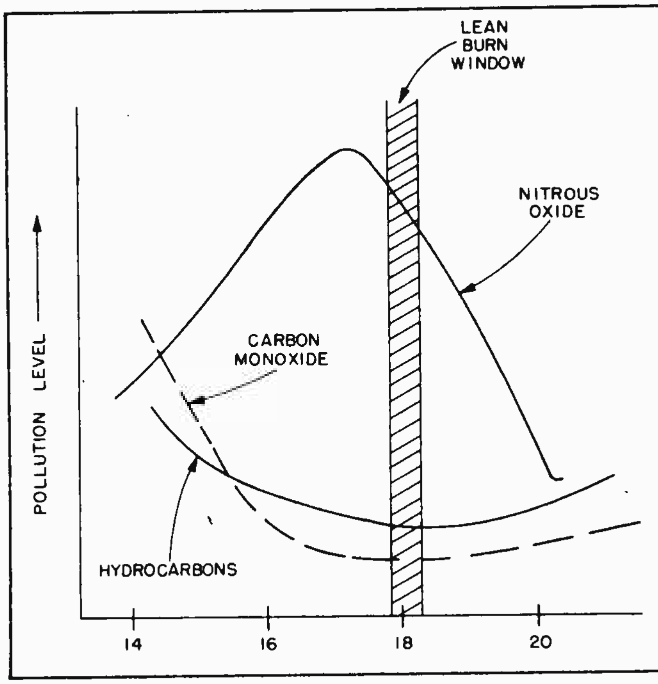
That is a bit astray from pure inventory control, but that kind of leapfrogging is exactly what is making small computer businesses take off to big things today. Inventory control is very much in demand, and every case has to be nearly custom tailored to the client. Through software control, that customizing 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, ni-



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.

trous 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. ■

Cut the Cost of TV Repairs

☐ 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.

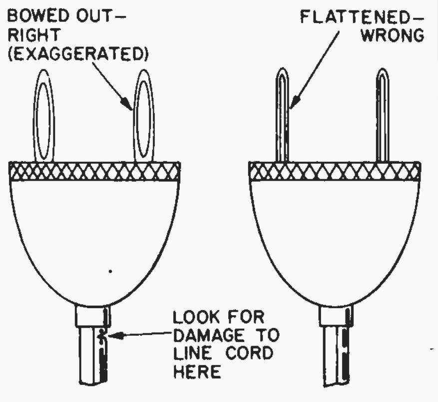


Fig. 1. Prongs of the line plug should have "spring" to make good contact. If they don't, bend them apart with a knife blade.

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 twinlead." 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

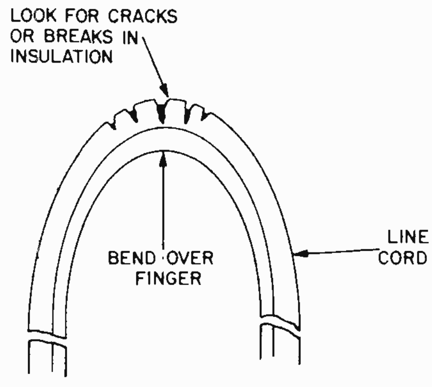


Fig. 2. Bend the line cord sharply between your fingers and look for cracks in the insulation. Don't forget to pull the line plug!

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'll see a pattern that looks like Fig. 5. You won't be able to see a picture at all—nothing but 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.) 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.

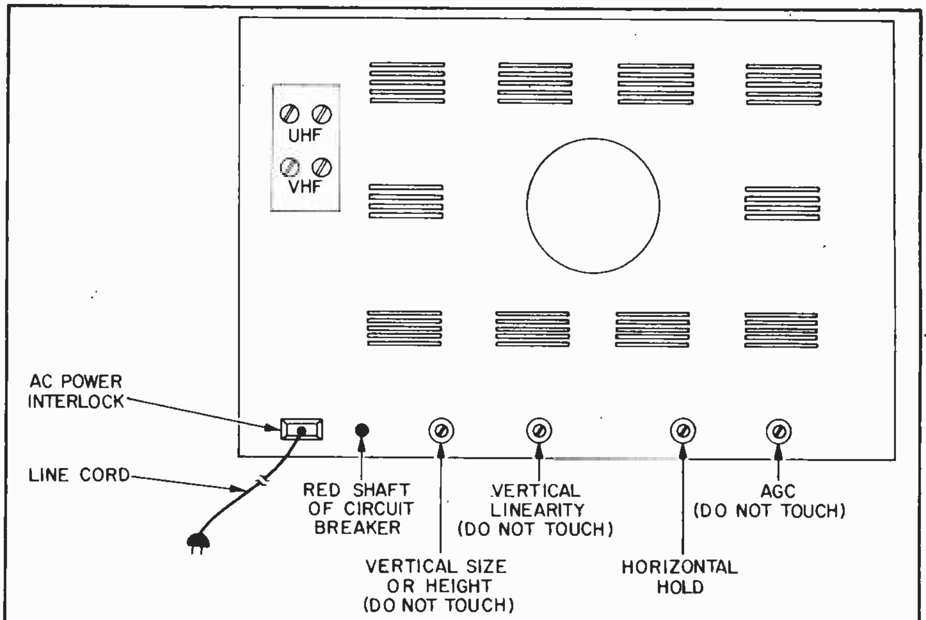


Fig. 3. Back view of TV set showing those controls you should not move.

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.

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. If you can readjust the controls, and the set works normally, fine! You don't need to call a service technician. ■

Crystals and How They Work

☐ 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 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

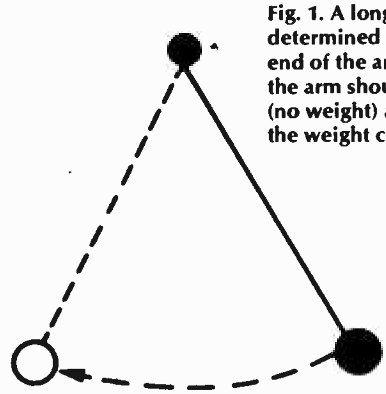


Fig. 1. A long pendulum swings at a rate determined by its length and weight at the end of the arm. To experiment at home, the arm should be made of light thread (no weight) and a small heavy mass (all the weight concentrated at one point).

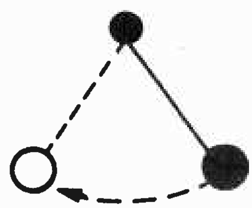


Fig. 2. A short pendulum swings at a faster rate no matter what the weight is. The heavier the weight, the longer the pendulum will swing at the faster rate.

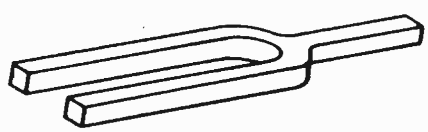


Fig. 3. The geometry of the tuning fork produces a continuous pure tone for a long time when struck gently. It is favored by piano tuners as a convenient way to carry a source of accurately-known tone or pitch.

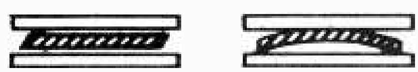


Fig. 4. Depending on how the crystal is cut or sliced from the mother crystal, some crystals warp or bend as in A and others shear as shown in B. Each of the many cuts have special characteristics.

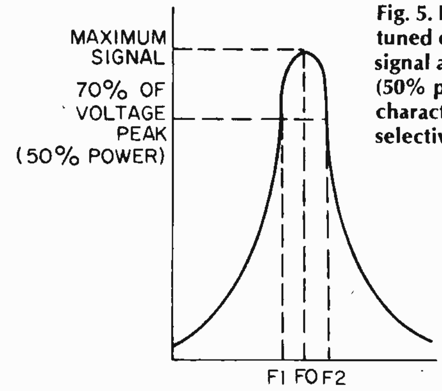


Fig. 5. Bandwidth characteristic of a typical tuned circuit shows the peak or maximum signal amplitude and the 70% voltage peak (50% power) points. This is the characteristic that determines overall selectivity.

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.

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.

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.

Pieozelectricity. The 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 multipication 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.

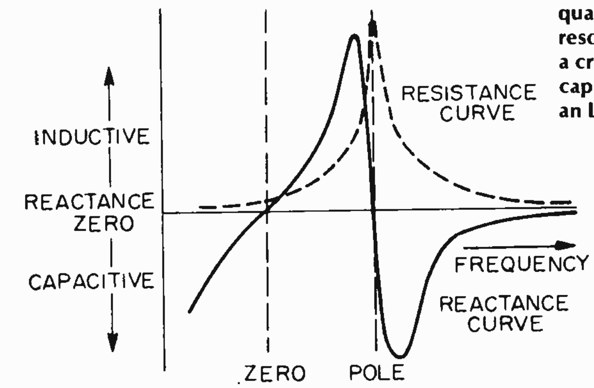


Fig. 7. Some characteristics of a quartz crystal. When slightly off resonant frequency (at the pole) a crystal exhibits inductive or capacitive reactance—just like an LC circuit.

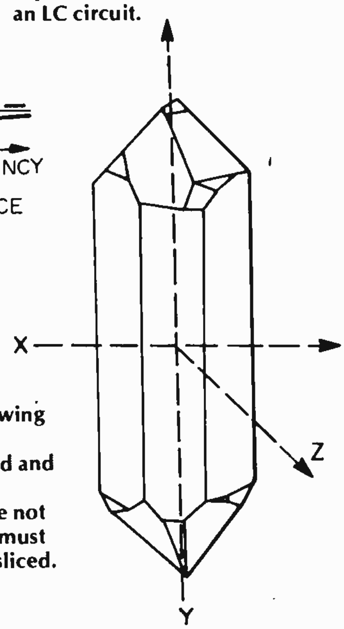


Fig. 8. A view of a mother crystal showing X, Y, and Z axes. Crystal is sliced into blanks, ground to frequency, polished and plated (on facing sides) to make permanent electrodes. All crystals are not made perfect by Mother Nature and must be examined optically before being sliced.

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. 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 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, microscopic 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 fre-

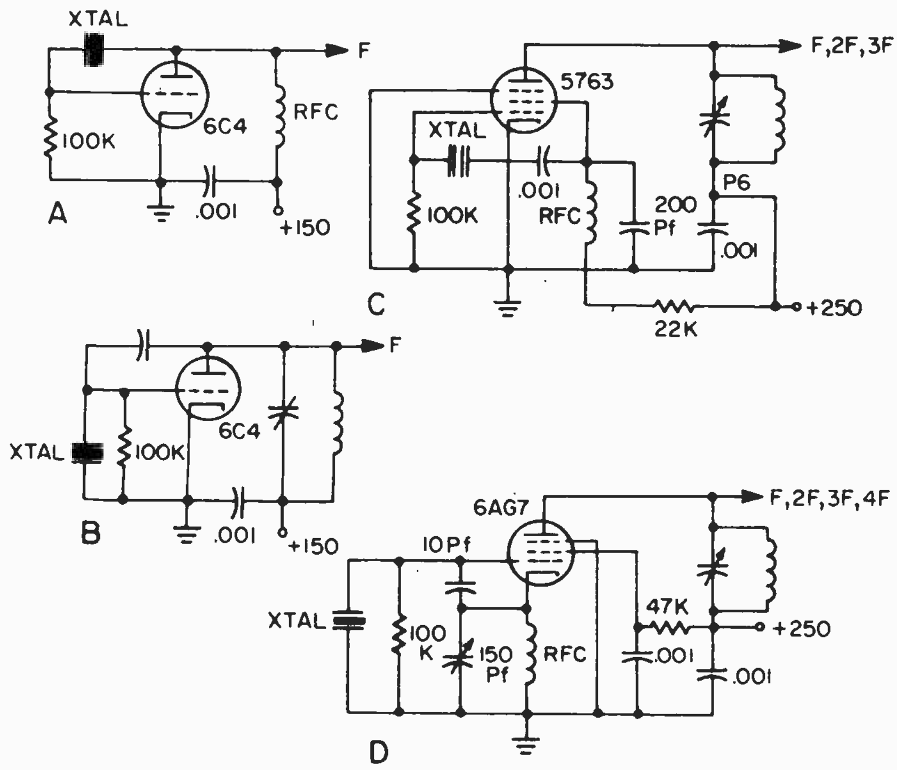


Fig. 9. The simplest crystal oscillator circuit (A) has no tuned circuits. To change frequency it is only necessary to change crystals, although a small variable capacitor across the crystal will cause some small frequency change. Miller oscillator (B) is nearly as simple as Pierce type shown in (A). 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.

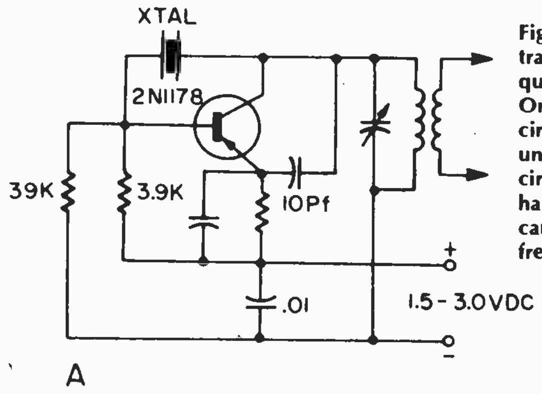
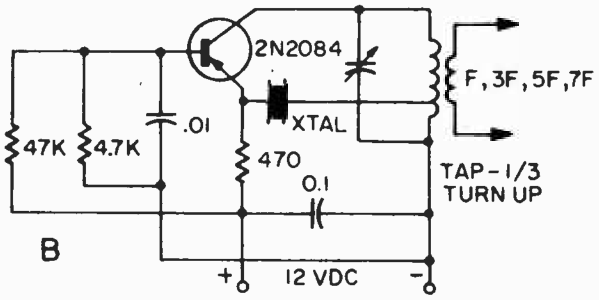


Fig. 10. Fundamental frequency transistorized oscillator (A) is quite similar to that in Fig. 9A. One difference is that tuned circuit in output replaces RFC unit. The overtone (harmonic) circuit (B) uses crystal for odd harmonic feedback. Either circuit can be used for fundamental frequency operation—just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



quency (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.

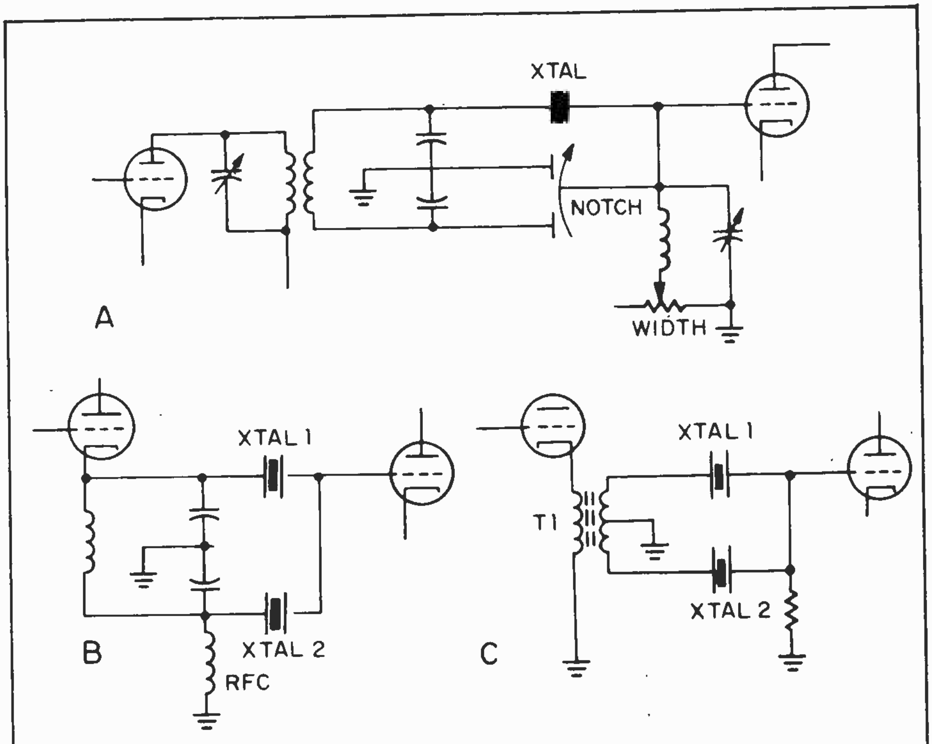


Fig. 11. Crystal filter used in the IF amplifier of a receiver sharpens the selectivity. Circuit in A uses special variable capacitor to adjust notch frequency. Potentiometer varies width (selectivity) of notch. Adding resistance lowers Q of crystal circuit which increases bandwidth. Two-crystal circuits (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.

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. While all circuits shown use vacuum-tubes, transistors may be substituted without modification of the filter circuits themselves if the impedances are right.

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. The only absolute critical requirement of the transformer, however, is that it have no resonant frequencies. ■

Amplifiers that Oscillate

☐ As any slightly cynical experimenter can tell you, if you want an oscillator, build an amplifier—it's sure to oscillate. Conversely, if you want an amplifier, (this same cynic will tell you), build an oscillator—it's sure to fail to oscillate, and you can then use it as an amplifier! This is well known as a corollary to Murphy's famous law, "If anything *can* go wrong—it *will!*"

Our informed cynic must have had long and unhappy experience with negative-feedback amplifiers, which are known to have at least two outstanding characteristics:

1. They function beautifully if carefully designed and built.

2. Otherwise, they oscillate!

Why do they oscillate? Or, more basically, how does a feedback amplifier differ from an oscillator?

The fundamental block diagrams of an oscillator and an amplifier with feedback bear a strong resemblance to each other, as you can see from Fig. 1. From a block diagram viewpoint, both diagrams are *very* similar. Both contain some type of amplifying device, and both have part of their output signal fed back to their input. There are only two major differences between them:

1. The amplifier with feedback contains an *inverting* amplifier; the oscillator contains a *non*-inverting amplifier.

2. The oscillator doesn't have an input.

The circuit action obtained from these two circuits is entirely different. In the amplifier with feedback, the output waveform is upside down with respect to the input, so when it is fed back to the amplifier input, it cancels a portion of the input waveform. The output is therefore less than it would be without feedback. See Fig. 2.

The feedback signals from inverting amplifiers are not "in phase" with the input signal and subtract (or reduce) the input signal level to the amplifier. When a feedback signal does this, it is called *negative feedback*.

So Why Negative Feedback? Of course, if you merely want the biggest possible gain for your money, negative feedback's not your game. However, negative feedback offers other advantages, which can be summed up by saying that the amplifier's output, though smaller, is always nearly constant for the same input signal. For example, if the amplifier weakens with age, and the output tries to drop, there is less signal to be fed back; hence there is less cancellation, and the output is restored almost to its former level. Similarly, if you feed a high-frequency signal through the amplifier—so high in frequency that the amplifier can barely amplify it—the resultant drop in output reduces the fed-back voltage, produces almost no cancelling feedback signal, and keeps the output nearly the same as it was at lower frequencies. Moreover, any clipping or other distortion of the waveform inside the amplifier produces an output waveform which does not match the input; hence the non-matching part is not cancelled, and the distortion is removed, or at least greatly reduced. Without this action, hi-fi amplifiers would not exist.

So the loss in output you obtain from negative feedback repays you by providing less distortion, better long-term stability, and better frequency response —that is, the best and most uniform output in response to *all* input frequencies.

On the Flip Side. The oscillator, on the other hand, is not supposed to give the best output from all input frequencies, but is instead made to give an output at a *single* frequency—with no input at all. It's not surprising that the opposite type of internal amplifier (non-inverting) is used to obtain this opposite result. See Fig. 3.

In the oscillator, any output at all (probably the result of some random noise in the internal amplifying device) is fed back, non-inverted, to the input, where it does not cancel but instead serves as the signal at the input. This feedback signal causes an even larger output, which results in an even larger signal fed back, further reinforcing the input signal, and so on.

You guessed it—this type of feedback signal is commonly referred to as *positive feedback*. In theory, the output waveform should continue to get larger

Fig. 1

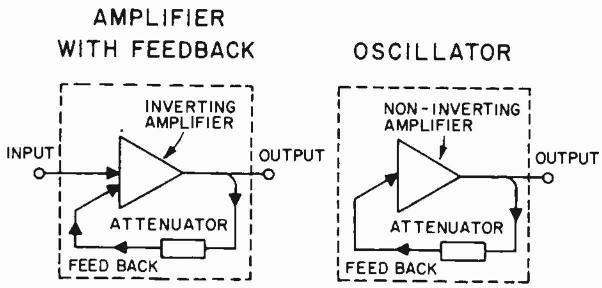
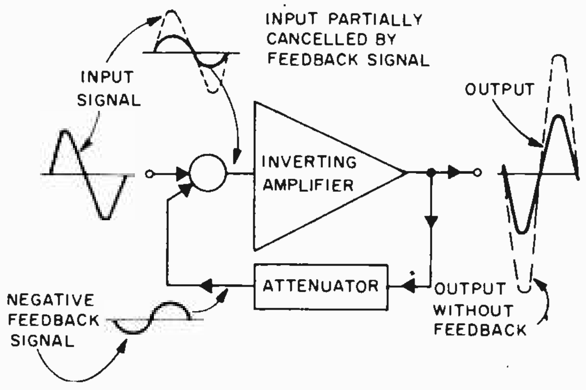


Fig. 2



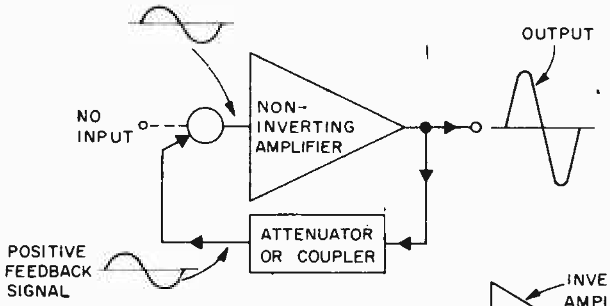


Fig. 3

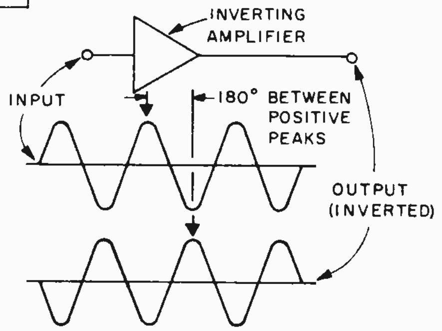


Fig. 4

forever. In practice, the amplifier is limited in the maximum size of the signal it can deliver, so the output waveform stops growing in this amplitude. As it stops to grow, so does the positive feedback signal. Now the signal reduces rapidly and the positive feedback signal lends a hand until the signal can get no lower. This is the beginning of the first cycle of many to follow.

All well and good, you say, but if the major difference between feedback amplifiers and oscillators is the inverting or non-inverting nature of their internal amplifiers, why does an amplifier sometimes oscillate? What turns an inverting amplifier into a non-inverting one?

To answer this question, first observe that an inverting amplifier, in passing a sine-wave signal, *effectively* shifts the signal's phase by 180° as shown in Fig. 4. We say *effectively*, because it doesn't really shift the timing by delaying the signal (which is what a real phase-shifter does) but, by turning the signal upside down, the amplifier makes it look like a signal which has been delayed (phase-shifted) by 180°.

A real phase-shifter, on the other hand, is normally nothing but a fistful of judiciously connected resistors and capacitors (and sometimes inductors) which can be designed to give a 180° phase shift *at a single frequency*, such as 1,000 Hz, for example. In contrast to an inverting amplifier, it provides this phase shift by actually delaying the signal. See Fig. 5.

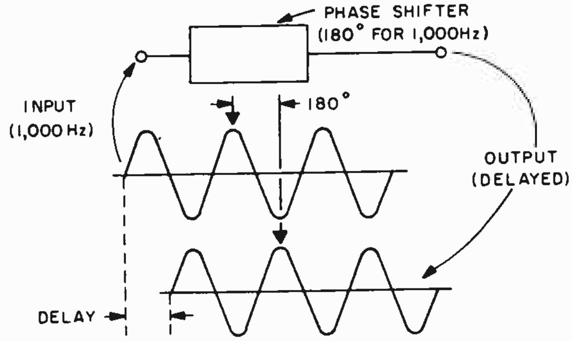
What happens if we combine an inverting amplifier and a 180° phase-shifter? Take a look at Fig. 6.

This combination will shift the phase of a given frequency by a total of 360° (an entire cycle) so the output is identical to the input. In effect, this combination (at 1,000 Hz) *will behave the same as a non-inverting amplifier*. See Fig. 6.

Therefore, if we build a feedback amplifier which contains the normal inverting amplifier but also (inadvertently) contains a 180° phase-shift network, the resultant circuit will oscillate at the particular frequency, (1,000 Hz in the figure) for which the phase-shifter provides 180° phase shift. See Fig. 7.

How can one "inadvertently" make a phase-shifter? It's easier than you might think. The circuit shown in Fig. 8A will provide 60° phase shift at 1,000 Hz. Three such networks connected in a "ladder" (see Fig. 8B) will proved 3 x 60° = 180° of phase shift. (But not at 1,000 Hz. Because of the way the networks load each other, the 180° shift occurs at 707 Hz. However, if an amplifier were located between each net-

Fig. 5



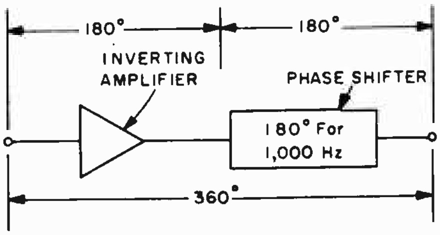


Fig. 6

Fig. 7

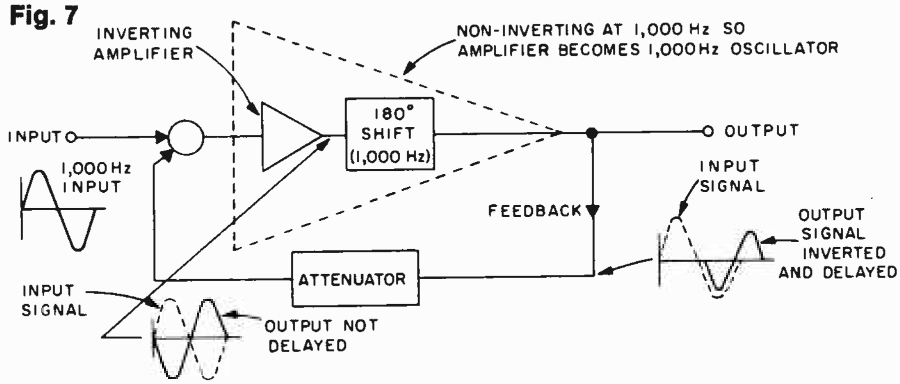


Fig. 8

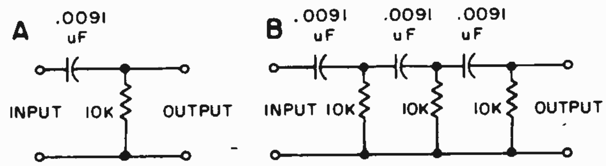


Fig. 9

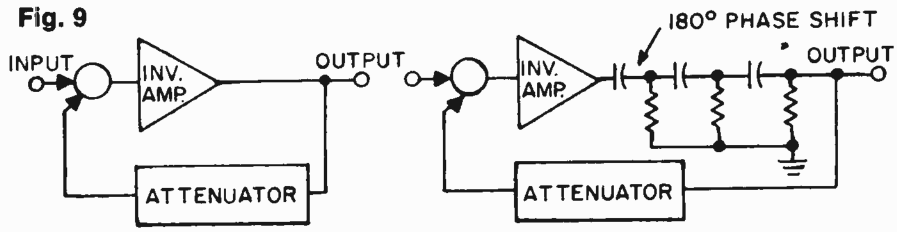
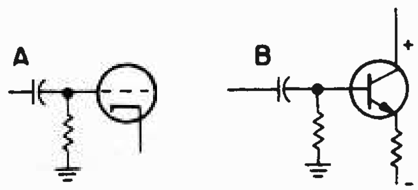


Fig. 10



work, then the amplifier will oscillate at 1,000 Hz.) This network, if dropped into a normal feedback amplifier circuit, will convert it to an oscillator.

This circuit (Fig. 9) is known as a *phase-shift oscillator* and is widely used in electronics.

Of course, when you set out to build a phase-shift oscillator, you *deliberately* insert a phase-shifter to make the circuit oscillate. How could one ever *inadvertently* place such a circuit in a feedback amplifier, thereby producing unwanted oscillations?

Phase-shift circuits can "hide" within an amplifier, posing as other circuits. For example, vacuum-type amplifiers often have grid circuits arranged as shown in Fig. 10A. Does that resistor/capacitor circuit look familiar? In form, it's just like the phase-shift circuit above. And transistor amplifier circuits often take the form shown in Fig. 10B.

Again, the coupling/biasing network looks just like the basic phase-shifter network. At some frequency, this network will provide 60° of phase shift. If we use three such identical networks in a three-stage amplifier we have a 180° phase-shift network "buried" inside the amplifier, masquerading as three normal coupling networks. If this three-stage amplifier is used as part of a feedback amplifier arrangement, the amplifier will oscillate at some frequency, and be quite useless for the purpose for which it was intended.

More Trouble. This is not the only way an amplifier can get into trouble. There are other types of phase-shifters than can creep into amplifiers, unrecognized, and drive the unwary experimenter up the nearest wall. This circuit (shown in Fig. 11A) can also produce a phase-shift of 60° at 1,000 Hz. Three of them, can produce the 180° phase-shift required for oscillation. See Fig. 11B. This particular network can invade amplifiers in an even more insidious fashion. The "masquerading" part of the circuit is shown heavy in Fig. 11C. The dotted capacitor doesn't appear physically in the circuit, because it is the so-called "stray capacity" associated with wires, sockets, terminals, etc. Three of these circuits hiding in an amplifier, can produce an unwanted oscillation. See Fig. 12. Since the stray capacities are so small, this "osc-plifier" will oscillate at a very high frequency; often so high that it is undetected as an oscillation. However, such oscillation can make an amplifier behave erratically; sometimes distorting, sometimes not; sometimes overheating, sometimes not. Fig. 7 and Fig. 12 have a lot in common.

Are feedback amplifiers the only culprits in this oscillating-amplifier business? Absolutely not! Often, so-called "straight" amplifiers—with no *intentional* feedback—will gaily oscillate away. But watch that word *intentional*. Close inspection of these misbehaving circuits usually uncovers an *unintentional* feedback path hiding within the amplifier. Consider the innocent-looking circuit in Fig. 13. This is an ordinary two-stage amplifier, obviously assigned the task of converting a small, positive-going signal into a large, positive-going signal. To help it along, the designer has even provided a decoupling network, R1 and C1. At high frequencies, C1 acts like a short circuit, effectively isolating (de-coupling) the amplifier's power bus, Ecc +, from the main power bus, Ecc + +. But, at low

Fig. 11

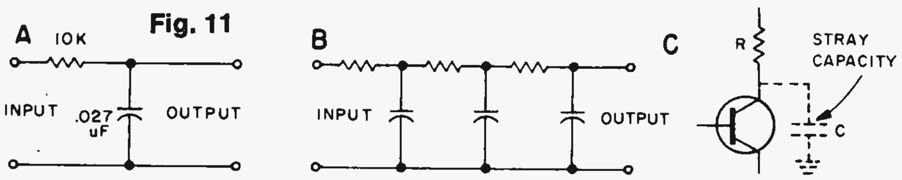
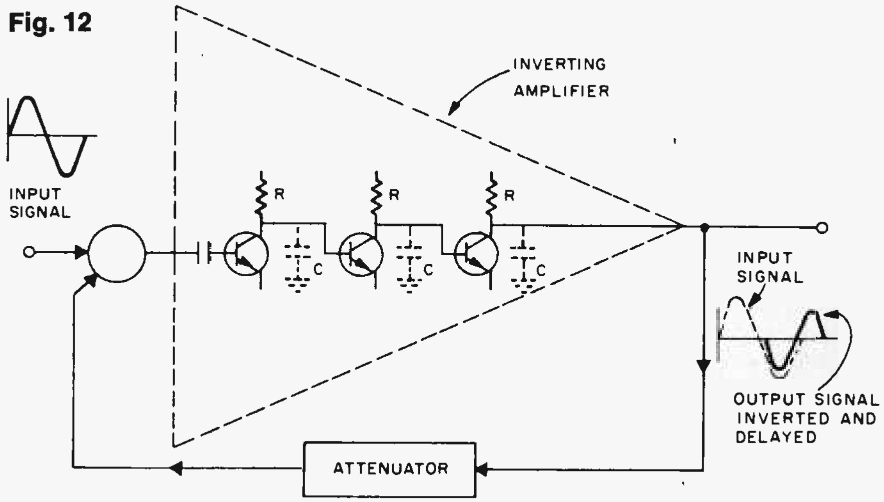


Fig. 12



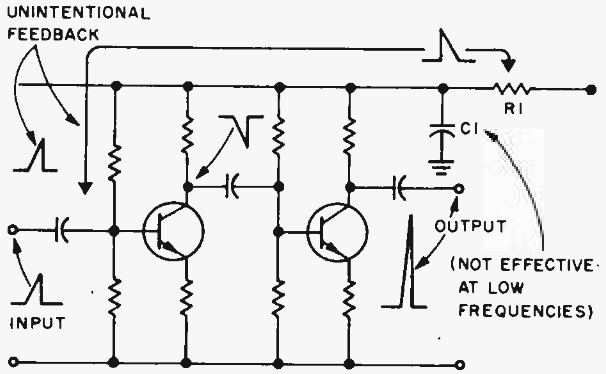
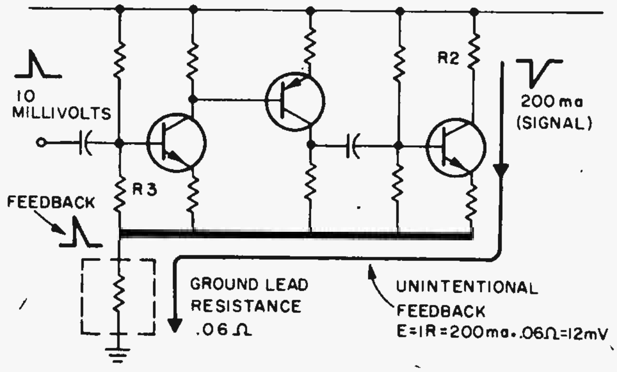


Fig. 13

Fig. 14



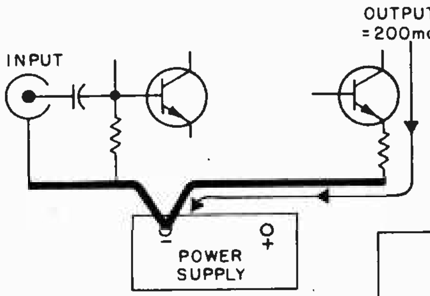


Fig. 15

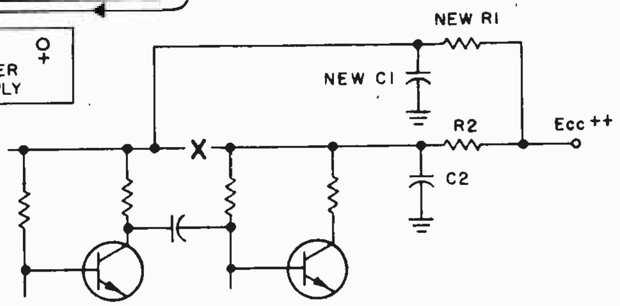


Fig. 16

frequencies, the capacitor acts like an open circuit—it just isn't there! A small part of the output voltage now appears across R1, and is coupled through the amplifier's power bus back to the input, arriving there with the same polarity as the normal input. True, the signal unintentionally fed back isn't very large, because the unintentional feedback path provides substantial losses for this stray signal. For example, the signal may arrive back at the input 100 times smaller than it was at the output. However, if the amplifier has a gain of 101, it makes an even larger output signal out of the fed-back signal, which then is fed back as an even larger voltage and oscillation begins.

Careless construction can get you into trouble, too. The amplifier shown in Fig. 14 is trying to convert a 10-millivolt input into a 200-ma signal needed by the load, R2. The builder has tied all ground returns to a heavy ground bus, and returned this bus to ground at only one point. Unfortunately, that single ground wire has to carry both the tiny input signal and the large output current. And, since every wire has *some* resistance, the actual circuit includes an 0.06-ohm resistor that does not appear in the original construction schematic diagram, but must be considered and is shown in Fig. 14.

Again, an uninvited, unintended feedback path has appeared, coupling the output back to the input. In the sketch, the large output current, flowing through the tiny ground-lead resistance, produces a voltage which is even larger than the original input voltage. And, since this voltage is also connected to the input (through the bias resistor R3), the fed-back voltage appears uninverted (and uninvited!) at the input, and will cause the amplifier to oscillate. What is to be done to convert these oscillators back into well-behaved amplifiers?

The general rule is *divide* and *conquer*. In the example just above, we can conquer the oscillation by dividing the ground returns, making sure that the high-current output circuits and the sensitive input circuits have their own private and individual paths to the power supply. See Fig. 15.

Short leads to the input connector are also helpful in squashing oscillations.

The misbehaving decoupling network, R1 and C2 in Fig. 13, can also be brought under control by dividing the network into *two* decoupling networks as shown in Fig. 16

The stray capacities causing the unwelcome phase shifter to hide in the best divide-and-conquer approach to this amplifier are harder to exorcise. Your amplifier is to put feedback around only a pair of stages instead of three or more. This way, there are only two pairs of stray Rs and Cs lurking in the amplifier, and it takes at least three such pairs to make an oscillator.

The coupling capacitors, which combined to make a phase shifter in the very first example, can be prevented from ganging up on the amplifier and making it oscillate by making the product of each capacitor times its associated resistor (called the "RC product") 5 or 10 times larger or smaller than the other RC products. For example, in a three-stage feedback amplifier which has all its base resistors the same values, you could make the three coupling capacitors 2 *u*F, and 10 *u*F, and 50 *u*F, respectively. Again, you have divided the coupling capacitors into three widely-separated values, and conquered the oscillation.

All three problems and solutions are by no means a comprehensive list of all the ways an amplifier can get into trouble, nor of all the tricks of the trade that can be used to bail them out. For that matter, we've said nothing at all about the opposite problem—how to persuade a balky oscillator to "take off" and do its thing. But we've said enough to indicate that the cynic mouthing Murphy's law would be well-advised to look to his basic theory and construction, because both amplifiers and oscillators answer to certain basic circuit laws, and will behave themselves impeccably if those laws are not violated. ■

Morse Code Can Be Easy

☐ Even though the storm had passed, Dave, WA6RGJ, stayed close to his radios. He knew that local flooding can short underground cables, interrupting power and telephone service. If that happened, two-way radio might be the only link to safety. But the bands remain quiet. Just a single carrier on Channel 9, without modulation. Probably some kid playing with the family CB rig. Dave politely asks the station to stop blocking the emergency channel which is continuously monitored by Dave and other REACT volunteers in this coastal town.

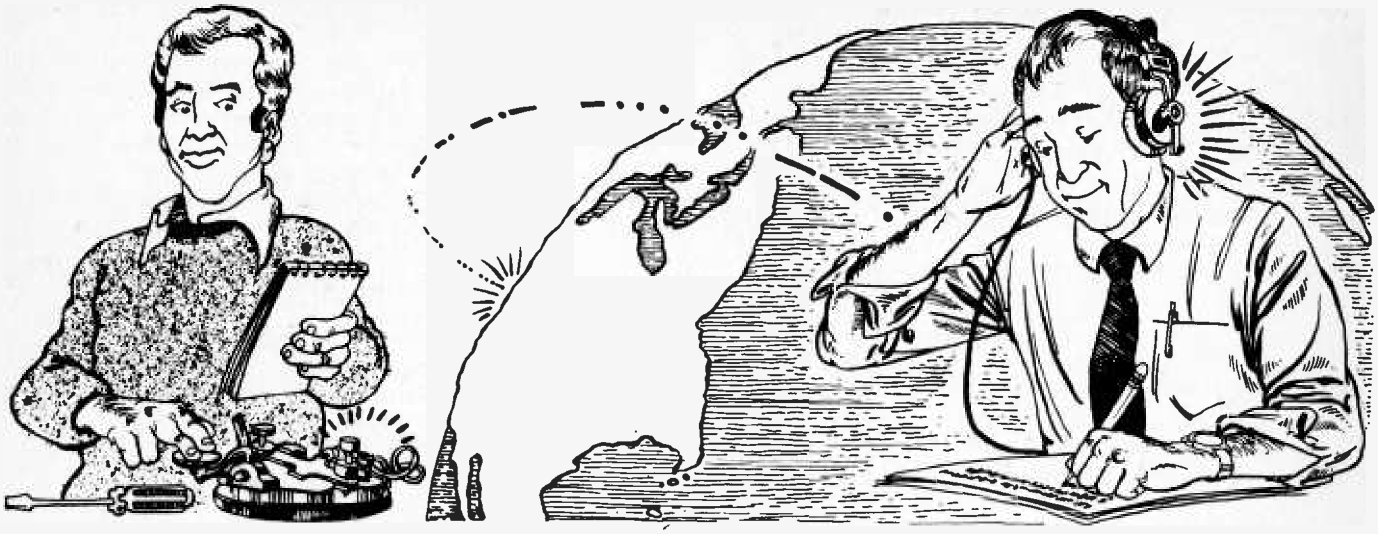
Suddenly the carrier flicks on and off rapidly! Always alert, Dave asks, "Are you in trouble? Do you need assistance?"

Again the carrier flicks on and off. "Use one click for no, two clicks for yes. Again, are you in trouble?" Two clicks. "Do you need help?" Two clicks. "Are you in a car?" One click. "A boat?" Two clicks, and another two clicks, faster this time.

Before Dave dials the Coast Guard, he tries a stab in the dark, "Do you know the Morse code?" Two clicks! "Standby while I hook up a system to copy code on this CB rig."

Moments later, Dave has connected a jury-rigged beat frequency oscillator, essential for copying code. "Go ahead. Describe your location and problem. I am a ham radio operator and will copy your code and relay to the Coast Guard."

Soon Dave has the Coast Guard on



the line, asking them to go to the rescue of a small yacht a few miles off the coast. Badly battered in the storm, it is leaking, engines out, and microphone smashed.

The Coast Guard dispatcher is skeptical. "How did you find out all this if his microphone is broken?"

Dave quickly explains the makeshift code transmission. Within minutes the Coast Guard cutter is on the way.

Ridiculous? Never happen? What you have just read is a dramatization of a true story. Dave McCollum is a ham who never lost his interest in CB public service work. He regularly monitors both channel 9 and the local amateur radio emergency frequencies. His ability to use Morse code often comes in handy on the ham bands, but this was his first cw contact on the 11-meter Citizen's Band! The skipper of the troubled ship learned code as an Eagle Scout; this was his first oportunity to make a contact in cw! Normally prohibited by FCC rules, cw is allowed under emergency situations to help save a life.

Ham Talk. Morse code, cw, the International code, that dit-dah stuff. By whatever name, the Morse code is an essential and valuable part of every amateur radio operator's training. It is what sets the radio ham apart from other communicators, and is the common bond between amateurs throughout the world.

To get a ham radio license in the United States, you have to pass an examination in sending and receiving code. (A code-free license has been proposed by the Federal Communications Commission, but the increased interest in CB has postponed action on this idea for at least a couple of years.) Meanwhile, a new, easier code examination and improved teaching methods have greatly simplified the once-difficult task of mastering the code. These changes and improvements have put the amateur radio license, with its worldwide range and almost unlimited freedom, within the reach of any interested radio communicator.

Is Morse Obsolete? Why code? The simplest answer is that international agreements require it. Every amateur must possess knowledge of the Morse code. But this does not really answer the question. Why does this requirement exist?

Morse code is still the most efficient method of radio communication known. The equipment needed to send code is far less complex than that needed for voice, and far less expensive. Code can get through interference and noise more effectively than any other mode of communication, which is why it is used to handle most amaetur radio messages, and is also used in weak signal work such as bouncing radio signals off the moon. Code is efficient in the use of the radio spectrum: almost 30 code signals can fit into the same band occupied by a single voice station, which helps reduce interference. Finally, code is a universal language. Hams throughout the world, from Russia to Rochester, can communicate with each other with Morse code.

More than 40% of all amateurs in the United States use code as their major amateur radio activity; many more use the code regularly. Every amateur has the ability to communicate in code; it is the common bond which ties together amateurs from all walks of life, in every country and every age bracket. Code and amateur radio have been inseparable more than 60 years. Unless you are willing to wait at least until 1980 to get your code-free ham license, you will have to spend a little time getting to know the code. It's a lot easier than you think!

First Steps. It takes only a few hours of study to reach a code proficiency of five words per minute (5 wpm), needed for the most basic amateur radio licenses: Novice and Technician. Almost everyone can pass the new comprehension-style code exams with less than ten hours of code practice, and many make do with as little as five hours. A mere 15 minutes of practice each day is all you'll need to pass that magic 5 wpm level in a few weeks, and be well on your way to higher code speeds. It really is simple, thanks to some of the new teaching aids now available.

In learning the code, you want to build up a habit, just as in learning to ride a bicycle. You learn a few motions, and pretty soon you are riding—or copying the code—without thinking about it. The trick is to start on the right foot. You can cut your effort in half by using the proper approach.

Many would-be radio amateurs have run into difficulties learning the code because they tried to tackle *two* translations at the same time. They learned it from a piece of paper, with the code written down as either dots and dashes or dits and dahs. Either way, they learned letters as combinations of dits and dahs, not as *sounds*. If you learn this way, you have to translate the sounds you hear into dits and dahs, and then translate *that* into the letters. The double translation is twice as much work and twice as difficult, especially when you are trying to learn both translations at the same time.

The right way to start is to translate the code from sounds to letters directly, skipping the additional step: half as much effort, and twice as fast! All you need is the correct training aids.

To learn the code by this sound-only system, you need someone to speak the letter and send the code. "A—didah, a—didah." Every time you hear the sound,

Slow Speed Code Practice from W1AW

	UTC	pdst	cdst	edst
Monday, Wednesday and Friday.	1300	6 am	8 am	9 am
	2300	4 pm	6 pm	7 pm
Tuesday, Thursday, Saturday and Sunday	2000	1 pm	3 pm	4 pm
	0200	7 pm	9 pm	10 pm

Frequencies: 1.835, 3.58, 7.08, 14.08, 21.08 and 28.08 MHz

think of the letter, and write it down. The letters should be sent at a fast character speed, with long spaces between them to lower the resultant speed. Using this method, you can avoid the temptation to think of code in terms of dots and dashes. A character speed of about 16 words per minute is about right to start, with long spacing between letters to reduce the effective speed down to a couple of words per minute. (A code "word" is five letters long; a speed of 5 words per minute (wpm) is 25 letters per minute, or about one letter every two seconds. Numbers and punctuation each count as two letters.) Finally, avoid learning similar sounding letters at the same time. Before long, you'll be copying code in automobile horns and whistles.

What if you don't have someone to say the letters and send the code? A good recording of an instructor talking, reading the characters and sending the code, is an adequate substitue. The recording in the ARRL *Tune in the World with Ham Radio* package uses two instructors and properly formed characters to lead you quickly through the first steps in code learning. This ssytem has been used by more than 50,000 prospective amateurs during the past few months, with unparalleled success. Heathkit Company offers the same system in their Novice training courses, and even the military training programs now use the *Tune in the World* code.

Practice—the Key to Code. Learning the letters is the first step in building code skill. The next step is practice. There is no substitute for continued, diligent practice in mastering the Morse code. Proper forms of practice, however, can smooth the path to code proficiency just as proper teaching techniques make it easy to learn the letters in the first place.

The three simplest ways to enhance your command of the Morse code are: code practice oscillators, tapes and records, and on-the-air code practice. If you're willing to devote between 15 and 20 minutes each day with one or more of these aids, you'll be on the bands with your own amateur license in weeks.

The most flexible of these is the code practice oscillator, or cpo. Even a buzzer will work for a cpo, but there are many kits and ready-made electronic cpos available from only a few dollars (see table). With the addition of a key, speaker and power supply of some nature (usually an inexpensive battery), any one of these cpos will produce a note very similar to what you will hear on the air.

Sit down with another member of the family or a friend and send to each other for a few minutes. The instructor of your radio class can provide code practice material geared to your progress through the letters, or you can use any book or magazine, sending only those letters you have learned. Try sending for about five minutes straight, and then compare what you sent with the text. Then switch roles for another five-minute session.

If you don't have someone working with you on the code, you can still use the readily available tapes and records for additional practice. Just make sure the code is sent at high character speed, with longer spacing between letters. Most of the popular brands use this system today: AMECO, 73, and the new *ARRL Code Kit*. Random letters and numbers, such as found on the *Code Kit* cassettes, make for long-lasting practice, as you cannot anticipate or memorize the code.

Another alternative for additional code practice is listening to contacts or code practice on the air. If you already own an amateur band receiver or transceiver, you can receive a wealth of code practice throughout the ham bands. The Novice bands in particular are filled with slow speed contacts, and make good practice for the comprehension code exam and future on-the-air contacts. The well-known W1AW code practice is also very useful, as many thousands of amateurs have found that its machine-produced code is excellent practice. This station recently changed its code practice schedule to include more practice at slower speeds; check the schedule which accompanies this article.

Novice Frequencies:	Code
3700-3750 KHz	21100-21200 KHz
7100-7150 KHz	28100-28200 KHz

Whatever method you use to practice the code, you should be conscientious about sticking to a regular schedule. As little as 15 minutes each day will do wonders—but an hour one day in four will leave you frustrated and disappointed. It's *daily* practice that helps the most.

Have your code practice partner send (or listen from tapes or W1AW) at a speed a little faster than you can copy perfectly. Your greatest increase in speed comes when you are pushing a little. If you get almost every letter at 3 words per minute, do most of your practice about 4 to 5 wpm: you'll get fewer letters, but your speed will increase that much faster.

If you want to spend more than 15 minutes per day on the code, break up the practice sessions in blocks of no more than 20 minutes. Do something completely different for a while, and then go back to the code for a few minutes. Hours and hours of continuous practice can be discouraging, and really isn't necessary although some people have mastered the code in less than a single day of dedicated effort! It can be done.

Off and Running. Receiving is only half of communicating via Morse code; you also must be able to send accurately. It is a lot easier to learn how to send properly than to receive, but you should spend at least a few minutes of each session working on the other half of code communications.

If you are working with someone else, you automatically get your sending practice on a regular basis. Any sending problems such as running letters together or poor character formation will stand out quickly, and be

(Continued on page 104)

Sources of Code Practice Oscillators

Supplier	part number	cost	address
Radio Shack	20-1155	$ 1.99	(local store or catalog)
	28-105	4.49	
Heathkit	HD-1416	12.95	Benton Harbor, MI 49002
G. R. Whitehouse		5.95	Newbury Drive, Amherst, NH 03031
MFJ Enterprises	CPO-555	15.95	P.O. Box 494, Mississippi State, MS 39762
Ramsey Elect.	CPO-1	2.50	P.O. Box 4072, Rochester NY 14610

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301. Get the '78 *Eico* Catalog and see their do-it-yourself kits and factory assembled electronic equipment. Specialties are test equipment, burglar/fire alarms, hobbyist and auto electronics.

302. *International crystal* has illustrated folders containing project information on radio communications kits for experimenters (PC boards; crystals; transistor RF mixers & amplifiers; etc.).

303. *Regency* has a new low cost/high performance UHF/FM repeater. Also in the low price is their 10-channel monitoradio scanner that offers 5-band performance.

304. *Dynascan's* new *B & K* catalog features test equipment for industrial labs, schools, and TV servicing.

306. Get *Antenna Specialists'* catalog of latest mobile antennas, test equipment, wattmeters, accessories.

310. *Turner* has two catalogs on their CB microphones and antennas. They give individual specifications on both lines. Construction details help in your choice.

311. *Midland Communications'* line of base, mobile and hand-held CB equipment, marine transceivers, scanning monitors, plus a sampling of accessories are covered in a colorful 18-page brochure.

312. *The EDI (Electronic Distributors, Inc.)* catalog is updated 5 times a year. It has an index of manufacturers literally from A to X (ADC to Xcelite). Whether you want to spend 29 cents for a pilot-light socket or $699.95 for a stereo AM/FM receiver, you'll find it here.

313. Get all the facts on *Progressive Edu-Kits* Home Radio Course. Build 20 radios and electronic circuits; parts, tools, and instructions included.

316. Get the *Hustler* brochure illustrating their complete line of CB and monitor radio antennas.

318. *GC Electronics* offers an "Electronic Chemical Handbook" for engineers and technicians. It is a "problem solver" with detailed descriptions, uses and applications of 160 chemicals compiled for electronic production and packaging. They are used for all types of electronic equipment.

320. *Edmund Scientific's* new catalog contains over 4500 products that embrace many sciences and fields.

321. *Cornell Electronics'* "Imperial Thrift Tag Sale" Catalog features TV and radio tubes. You can also find almost anything in electronics.

322. *Radio Shack's 1978* catalog colorfully illustrates their complete range of kit and wired products for electronics enthusiasts—CB, ham, SWL, hi-fi, experimenter kits, batteries, tools, tubes, wire, cable, etc.

323. Get *Lafayette Radio's* "new look" 1978 catalog with 260 pages of complete electronics equipment. It has larger pictures and easy-to-read type. Over 18,000 items cover hi-fi, CB, ham rigs, accessories, test equipment and tools.

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.

328. A new free catalog is available from *McGee Radio*. It contains electronic product bargains.

329. Semiconductor Supermart is a new 1978 catalog listing project builders' parts, popular CB gear, and test equipment. It features semiconductors—all from *Circuit Specialists*.

330. There are nearly 400 electronics kits in *Heath's* new catalog. Virtually every do-it-yourself interest is included—TV, radios, stereo and 4-channel, hi-fi, hobby computers, etc.

331. *E. F. Johnson* offers their CB 2-way radio catalog to help you when you make the American vacation scene. A selection guide to the features of the various messenger models will aid you as you go through the book.

332. If you want courses in assembling your own TV kits, *National Schools* has 10 from which to choose. There is a plan for GIs.

333. Get the new free catalog from *Howard W. Sams*. It describes 100's of books for hobbyists and technicians—books on projects, basic electronics and related subjects.

334. *Sprague Products* has L.E.D. readouts for those who want to build electronic clocks, calculators, etc. Parts lists and helpful schematics are included.

335. The latest edition of the *TAB BOOKS* catalog describes over 450 books on CB, electronics, broadcasting, do-it-yourself, hobby, radio, TV, hi-fi, and CB and TV servicing.

338. "Break Break," a booklet which came into existence at the request of hundreds of CBers, contains real life stories of incidents taking place on America's highways and byways. Compiled by the *Shakespeare Company*, it is available on a first come, first serve basis.

342. *Royce Electronics* has a new 1978 full line product catalog. The 40-page, full-color catalog contains their entire new line of 40-channel AM and SSB CB transceivers, hand-helds, marine communications equipment, and antennas and accessories.

345. For CBers from *Hy-Gain Electronics Corp.* there is a 50-page, 4-color catalog (base, mobile and marine transceivers, antennas, and accessories). Colorful literature illustrating two models of monitor-scanners is also available.

353. *MFJ* offers a free catalog of amateur radio equipment—CW and SSB audio filters, electronic components, etc. Other lit. is free.

354. A government FCC License can help you qualify for a career in electronics. Send for information from *Cleveland Institute of Electronics*.

355. New for CBers from *Anixter-Mark* is a colorful 4-page brochure detailing their line of base station and mobile antennas, including 6 models of the famous Mark Heliwhip.

356. *Continental Specialties* has a new catalog featuring breadboard and test equipment for the professional and hobbyist. Descriptions, pictures and specifications aid your making a choice.

359. *Electronics Book Club* has literature on how to get up to 3 electronics books (retailing at $58.70) for only 99 cents each . . . plus a sample Club News package.

362. *B&F Enterprises'* Truckload Sale catalog offers 10% off all merchandise: (military or industrial surplus) speaker kits, TV games, computer terminals, tools, TV components, lenses, and more.

364. If you're a component buyer or specifier, you'll want this catalog of surplus bargains: industrial, military, and commercial electronic parts, all from *Allied Action*.

365. *Electronic Supermarket* has a new catalog of almost everything in the field—transformers, semiconductors, tv parts, stereos, speakers, P.C. boards, phones, wire and cable, tools, motors.

366. Send for *Poly-Packs'* new catalog featuring hundreds of bargains: new Barrel Pack kits, hobby computer peripheral parts, fiber optics, solar energy chips, digital clocks, and more.

367. *Optoelectronics'* new catalog features their new Frequency Counter, a 6-digit clock calendar kit, mobile LED clock, biorhythm clock, digit conversion kit, and many others.

368. *Cherry Electrical Products* has a handbook describing their new "PRO" keyboard for personal computer, hobbyist and OEM users. Included are instructions on how to customize it on-the-spot, schematics, charts, and diagrams.

369. *Motorola Training Institute* offers a brochure on two new home-study courses: Four lessons cover semiconductors, designed for all technicians servicing electronic equipment; the 34-lesson professional FM two-way radio course is for those planning to service land-mobile equipment.

370. The 1978 catalog from *Computer Warehouse* has data on 10 different microcomputers, with used peripherals, and available for immediate delivery. Over 1,500 products are covered, new and used, from over 170 different vendors.

371. Your computer system needn't cost a fortune. *Southwest Technical Products* offers their 6800 computer complete at $395 with features that cost you extra with many other systems. Peripheral bargains are included here.

372. See how you can save with *Olson's* "Erector Kit" Computer System; also their factory wired version which includes a 2-volume Bell & Howell instruction course. Send for information.

373. *ETCO* has a Grand Opening Catalog which anyone in the electronics field shouldn't miss. Full of all kinds of products from surplus and warehouse sales, they claim everyone is a bargain.

374. *Radatron's* Catalog 1006 lists many projects from a self-contained portable lab station for an electricity-electronics course to many texts, lab manuals, and applied activities.

375. *Compucolor Corp.* has a personal computer system with an 8-color integral display, a typewriter-like keyboard, and a mass storage device. Programs are ideal for checkbook and income tax figuring.

376. *Sparkomatic* offers all the car sounds for the "travelin' man"—speakers, amplification systems, radios, speaker accessories along with CB, antennas, all presented in 4-color pics with descriptions.

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117 Services Anyone can sell by mail. 12 page report tells how. Free details. Emjay Sales, Box 27611-E. Escondido. CA 92027.

$350 weekly mailing letters. Free details. Bronxville House, Box 311-D, Bronxville, NY 10708.

JEWELRLY business, small investment, money back guarantee. Don Rose, Box 392, Pittston, PA 18640.

$480 WEEKLY! Proven Mailing Program, Guaranteed Earnings: Rasmussen DP108, 1747N. 450E., Ogden, Utah 84404.

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COLLEGE degree by mail, via resume. Education, 256D South Robertson, Beverly Hills, CA 90211.

GET INTO BROADCASTING: Become DJ, engineer. Start your own station, get free equipment, records. Free details. "Broadcasting," Box 5516-G10E, Walnut Creek, CA 94596.

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TWENTY disc, or small bar magnets, $1.00. Magnets, Box 192-AA, Randallstown, Maryland 21133.

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NEW occult products including King Tut jewelry! Free catalog! World, 7247-1 Eccles, Dallas, TX 75227.

MONEYMAKING OPPORTUNTIES

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$180.00 WEEKLY Mailing Circulars. Start Immediately. Everready, 422F Clermont Ave., Brooklyn, NY 11238.

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$300.00 WEEKLY, Mailing Circulars. Write: McGuire, Box 91054, Tacoma, WA 98491.

$83,501.00 FREEBIES WAITING! GOVERNMENT DIRECTORY $3.00. PALMER, B1244DG, Phenix City, AL 36867.

$3,000 MONTHLY stuffing envelopes. Details free. Northeast Enterprises, P.O. Box 537, Dept. IN, Laurel Springs, NJ 08021.

WIN cash prizes entering famous national million dollar sweepstakes! Free details! Contests, Box 7469-DV, Philadelphia, PA 19101.

$200/$500 every weekend organizing garage sales for others. Complete instructions $3.00. Stanley Gerard, Suite 701, 1012 Davenport Rd., Toronto, Ontario M6G 2B9.

MONEYMAKING OPPORTUNITIES—Cont'd

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EARN $1500 monthly guaranteed mailing envelopes. Details 25¢. IPPERSIEL, RR #1C, Noelville, Ont. P0M 2N0.

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JOIN North America's leading penpal club. Details from Friends Worldwide CP-95/F Anjou, Montreal, H1K 4G5.

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Ask Hank, He Knows!

(Continued from page 9)

Simpler Than You Think

I have an automatic drip coffee pot that works fine. My problem is that I took it apart looking for the heater timer and found nothing. How come?

—*L. K., Troy, NY*

Because it has none. To start the coffee maker, you pour in a measured amount of water into a reservoir. The water is channeled by gravity to a tank heater which boils (perks) the water up a shaft to the drip spout over the drip-type coffee pot. Be sure to turn the unit on after the water is in the reservoir or the tank heater will burn out! This action continues until all the water is gone which will cause the tank heater to overheat. Before damage is done, a thermostat disconnects the tank heater circuit from the power line. A warming element, in the meantime, is on providing heat to keep the coffee warm for use anytime. The heat from the warmer prevents the thermostat from cooling and recycling the tank heater. See—no timer, but adjusted thermostats that control the heating current.

Lend a Hand, Boys!

We're doing a bit of all right with this part of our column. Readers are telling me that help is coming through the mails. That's wonderful, so keep up the good work.

∆ Knight Transistor Stereo Amplifier Model KG-870, schematic diagram required: George Martin, 45-57 167th St., Flushing, NY 11358.

∆ Ballast tube 24B875 for Hallicrafters S-52 shortwave receiver urgently needed: Robert E. Musser, R.D. 1, Box 292, New Columbia, PA 17856.

∆ Metz 202 Electronic Flash, needs schematic diagram: Clayton Mitchell, 4326 Sheldon Ave., Baltimore, MD 21206.

∆ Knight-Kit R100 shortwave receiver needs info on obtaining new oscillator and RF coils: Gary Lenarz, 1424 165th Ave., San Leandro, CA 94578.

∆ Hallicrafters S-38E shortwave receiver, urgently needs schematic diagrams and service literature: Elvin Keriluke, 2337 Linsay St., Regina, Sask., Canada S4N 3C5.

∆ Normende Fidelic C Stereo V308, No. C10194 four-band receiver, urgently needs schematic diagram and service data: Clarence Pieper, 48 Homewood Ave., Hamilton, Ont., Canada.

∆ RCA Volt Ohmyst Jr., Model No. unknown, uses two 6K6 and one 6X5 vacuum tubes, circuit appears in early 1950 RCA tube manuals—can anyone help?: Theodore R. Walker, 1753 Kettering Rd., Alcoa, TN 37701.

∆ VT Grid Circuit Tester GCT-5 by SECO, info on tube location and any literature available: Steve Halvorson, 4244 Washington St., N.E., Columbia Heights, MN 55421.

∆ Chicago Industrial Instruments Co. Model 531 tube and battery tester, service data urgently requested: Robert L. Bodine, Jr., 201 W. Azalea Ave., Tampa, FL 33612. ■

Learn Morse Code

(Continued from page 101)

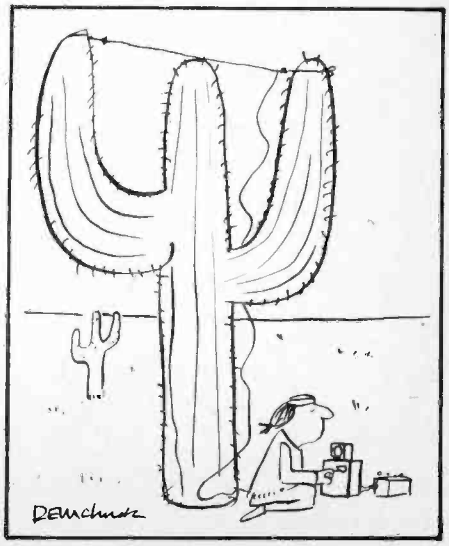
quickly corrected. If you are using a tape for practice, record a few minutes of your own sending on a blank cassette. Listen to it the next day, and see if you can copy it. Again, any slight irregularities will show up rapidly. Finally, W1AW includes some text from recent issues of the monthly ARRL journal, *QST*, every week. You can send along (not on the air!) and compare your "fist" to the code practice machines at W1AW. The booklet in the *ARRL Code Kit* contains additional hints on both sending and receiving.

The Finish Line. If you are like most of us, a few weeks of 15-minute per day, 5-6 day per week practice will bring you to the needed 5 word-per-minute proficiency level. All that remains is to take the code test itself. Any qualified amateur radio operator can give you the test; The ARRL, Newington, CT 06111, has a file of more than 4,000 instructors who regularly give comprehension style code exams.

For the test itself, the examiner will send a standard amateur contact, just like you would hear on the air, or as found on the back of the *Tune in the World* cassette tape. Then he will give you ten multiple choice questions about what was in the contact: the operator's callsign, name, location, etc. Passing grade is eight or more out of ten.

It is impossible to "fail" the code test, as new FCC rules allow you to continue to take it until you pass! It's simply a matter of concentrating on the code for a few minutes.

As thousands of new hams discover every month, the code is *not* designed to keep you from getting an amateur radio license. It's an integral part of amateur radio that opens the door to one of the most exciting avocations in the world: ham radio. ■



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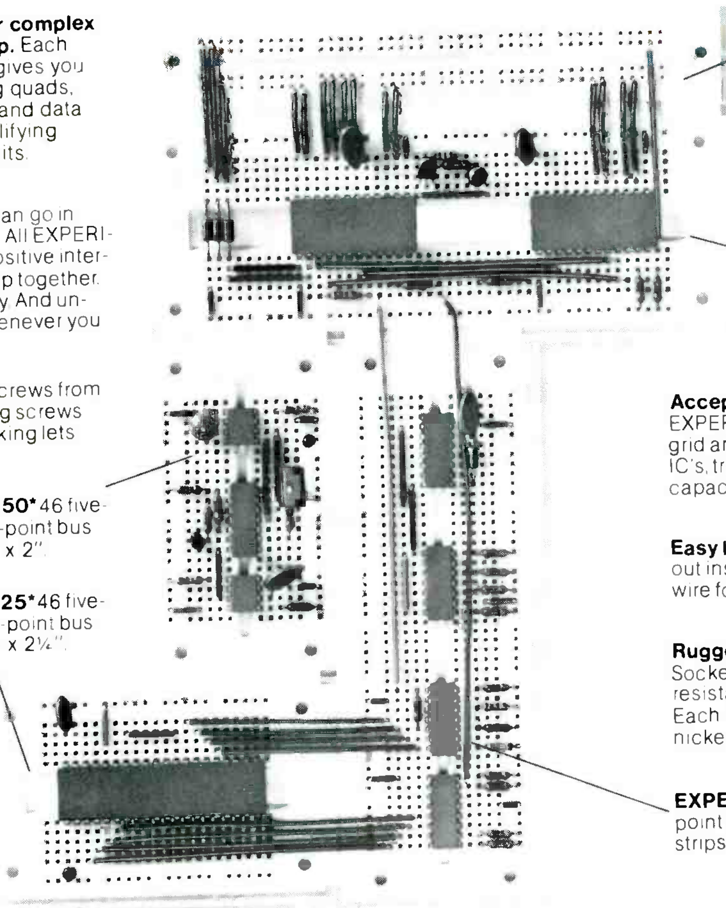

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