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# ELEMENTARY ELECTRONICS

By the Editors of RADIO-TV EXPERIMENTER

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ALARM p. 108

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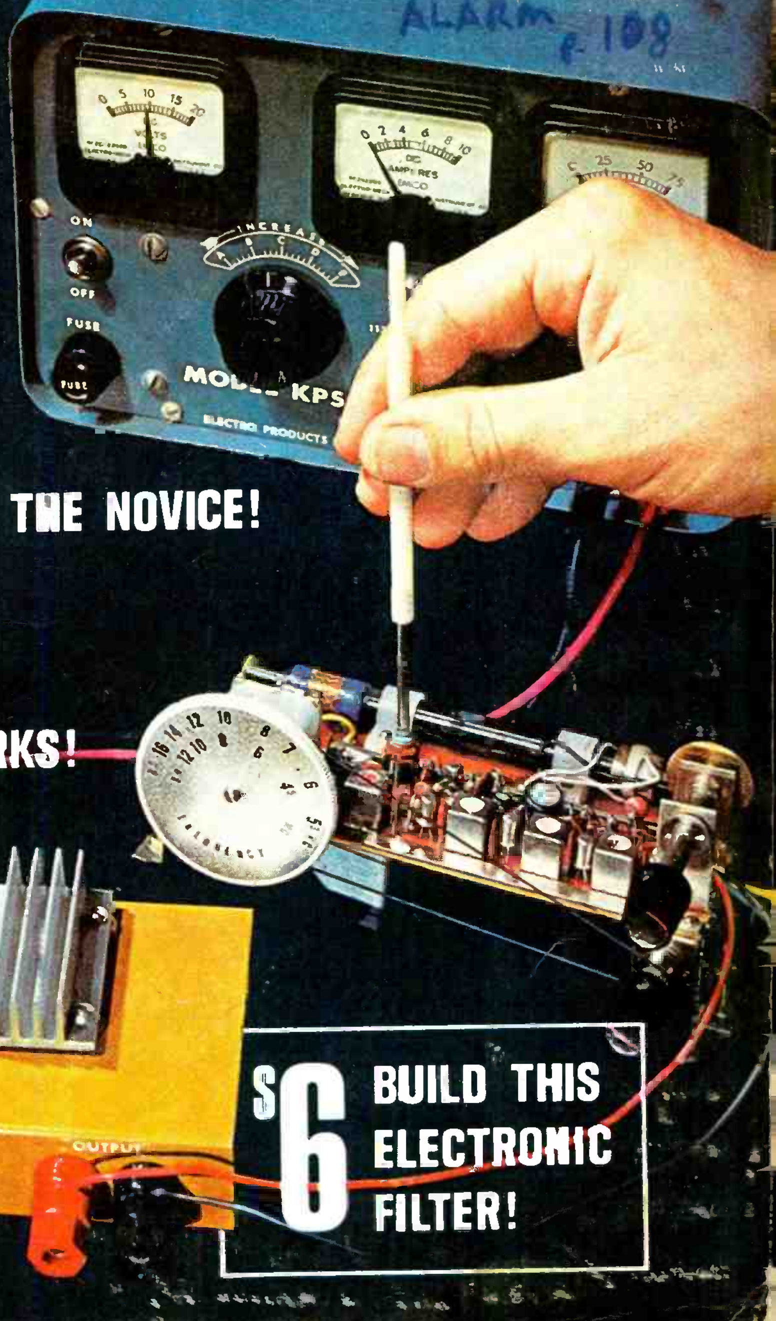

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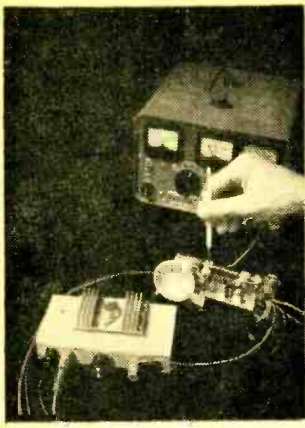
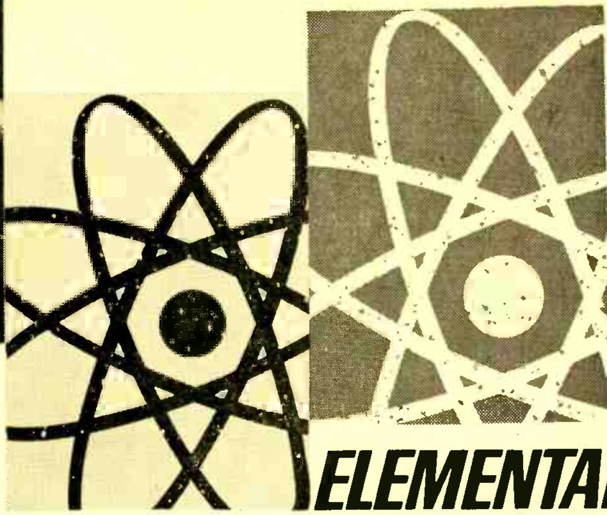


*Cover photo by Don Lothrop*

SPRING, 1965



# ELEMENTARY ELECTRONICS

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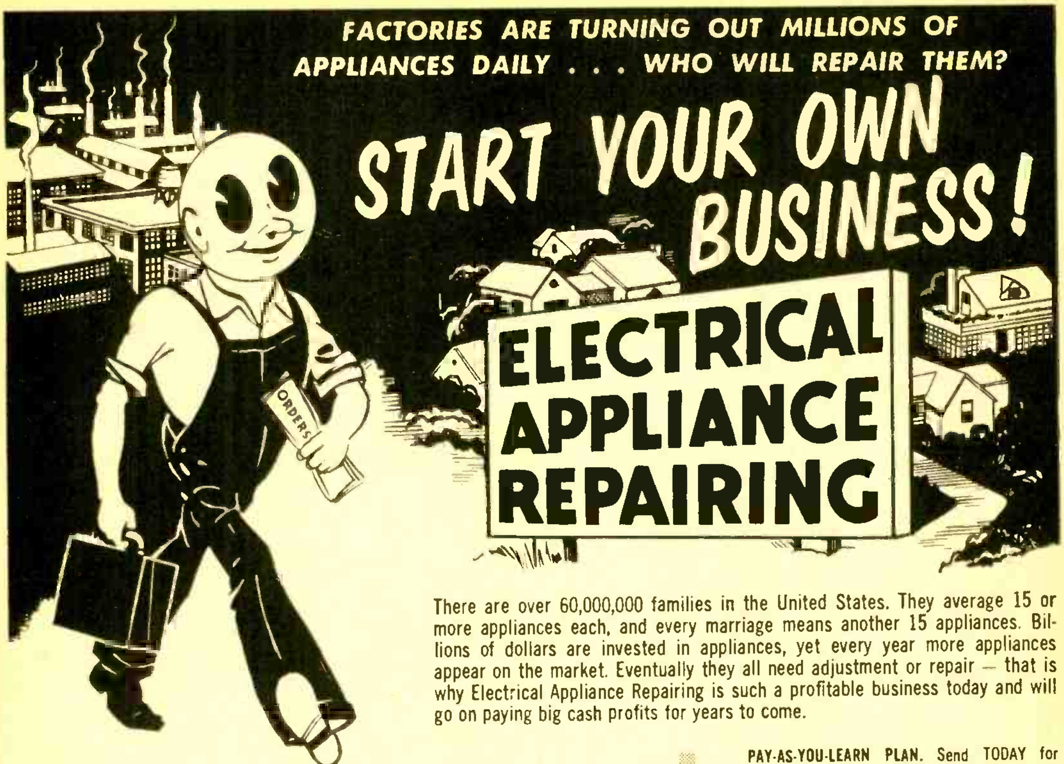


There are over 60,000,000 families in the United States. They average 15 or more appliances each, and every marriage means another 15 appliances. Billions of dollars are invested in appliances, yet every year more appliances appear on the market. Eventually they all need adjustment or repair — that is why Electrical Appliance Repairing is such a profitable business today and will go on paying big cash profits for years to come.

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No. 725 Spring 1965 Edition

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## Airborne Closed-Circuit TV

A personal entertainment system that offers passengers motion pictures and live television as well as stereophonic musical programs and in-transit pictures of the terrain, takeoffs, and landings, has been introduced by American Airlines. The system is unique in the airline industry. A survey of passenger opinion had played a large part in American's decision to provide the new service. The survey was conducted by the airline and the Opinion Research Corporation during an experiment in flight with the movie-stereo combination. The test airplane covered nearly 100,000 miles on various routes during a two-week period in May.

A special feature of this equipment is that its individual characteristics, including per-

A stewardess instructs a passenger aboard an American Airlines Astrojet in the use of Astrovision, an in-flight entertainment system. At passenger's right elbow is earphone jack and sound control knob.

*(Continued on page 10)*

# BIG MONEY

awaits **CHRISTY-TRAINED TV & ELECTRONICS TECHNICIANS** in the **4 CORNERS OF THE WORLD!**

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**YOU GET 19 TRAINING KITS!** With your complete Christy Master Shop-method Home Training Course we send you a Multi-tester, Oscillator, Signal Tracer, Oscilloscope, Signal Generator, Electronic Timer, Regenerative Radio, 27-inch Television Set (optional) and other valuable equipment. This equipment makes your training clear, simple, and easy to understand. You work with your hands . . . you learn in the most practical, thorough way possible—by *doing*. In a few months of simple home study using the Christy system you learn what used to take years of hard work to master. Just put in a few hours of your spare time each week and before you know it you're ready for a BIG-PAY job as an Electronics Technician or for a profitable TV repair business of your own.

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# Build 20 Radio and Electronic Circuits at Home

# ALL GUARANTEED TO WORK!

## YOU DON'T HAVE TO SPEND HUNDREDS OF DOLLARS FOR A RADIO COURSE

The "Edu-Kit" offers you an outstanding PRACTICAL HOME RADIO COURSE at a rock-bottom price. Our Kit is designed to train Radio & Electronics Technicians, making use of the most modern methods of home training. You will learn radio theory, construction practice and servicing. THIS IS A COMPLETE RADIO COURSE IN EVERY DETAIL.

You will learn how to build radios, using regular schematics; how to wire and solder in a professional manner: how to service radios. You will work with the standard type of punched metal chassis as well as the latest development of Printed Circuit chassis.

You will learn the basic principles of radio. You will construct, study and work with RF and AF amplifiers and oscillators, detectors, rectifiers, test equipment. You will learn and practice code, using the Progressive Code Oscillator. You will learn and practice trouble-shooting, using the Progressive Signal Tracer, Progressive Signal Injector, Progressive Dynamic Radio & Electronics Tester, Square Wave Generator and the accompanying instructional material.

You will receive training for the Novice, Technician and General Classes of F.C.C. Radio Amateur Licenses. You will build Receiver, Transmitter, Square Wave Generator, Code Oscillator, Signal Tracer and Signal Injector circuits, and learn how to operate them. You will receive an excellent background for television, Hi-Fi and Electronics.

Absolutely no previous knowledge of radio or science is required. The "Edu-Kit" is the product of many years of teaching and engineering experience. The "Edu-Kit" will provide you with a basic education in Electronics and Radio, worth many times the complete price of $26.95. The Signal Tracer alone is worth more than the price of the entire Kit.

## THE KIT FOR EVERYONE

You do not need the slightest background in radio or science. Whether you are interested in Radio & Electronics because you want an interesting hobby, a well paying business or a job with a future, you will find the "Edu-Kit" a worth-while investment.

Many thousands of individuals of all ages and backgrounds have successfully used the "Edu-Kit" in more than 79 countries of the world. The "Edu-Kit" has been carefully designed, step by step, so that you cannot make a mistake. The "Edu-Kit" allows you to teach yourself at your own rate. No instructor is necessary.

## PROGRESSIVE TEACHING METHOD

The Progressive Radio "Edu-Kit" is the foremost educational radio kit in the world, and is universally accepted as the standard in the field of electronics training. The "Edu-Kit" uses the modern educational principle of "Learn by Doing." Therefore you construct, learn schematics, study theory, practice trouble-shooting—all in a closely integrated program designed to provide an easily-learned, thorough and interesting background in radio.

You begin by examining the various radio parts of the "Edu-Kit." You then learn the function, theory and wiring of these parts. Then you build a simple radio. With this first set you will enjoy listening to regular broadcast stations, learn theory, practice testing and trouble-shooting. Then you build a more advanced radio, learn more advanced theory and techniques. Gradually, in a progressive manner, and at your own rate, you will find yourself constructing more advanced multi-tube radio circuits, and doing work like a professional Radio Technician.

Included in the "Edu-Kit" course are Receiver, Transmitter, Code Oscillator, Signal Tracer, Square Wave Generator and Signal Injector circuits. These are not unprofessional "breadboard" experiments, but genuine radio circuits, constructed by means of professional wiring and soldering on metal chassis, plus, the new method of radio construction known as "Printed Circuitry." These circuits operate on your regular AC or DC house current.

## THE "EDU-KIT" IS COMPLETE

You will receive all parts and instructions necessary to build 20 different radio and electronics circuits, each guaranteed to operate. Our Kits contain tubes, tube sockets, variable, electrolytic, mica, ceramic and paper dielectric condensers, resistors, tie strips, coils, hardware, tubing, punched metal chassis, Instruction Manuals, hook-up wire, solder, selenium rectifiers, volume controls and switches, etc.

In addition, you receive Printed Circuit materials, including Printed Circuit chassis, special tube sockets, hardware and instructions. You also receive a useful set of tools, a professional electric soldering iron, and a self-powered Dynamic Radio and Electronics Tester. The "Edu-Kit" also includes Code Instructions and the Progressive Code Oscillator, in addition to F.C.C.-type Questions and Answers for Radio Amateur License training. You will also receive lessons for servicing with the Progressive Signal Tracer and the Progressive Signal Injector, a High Fidelity Guide and a Quiz Book. You receive Membership in Radio-TV Club, Free Consultation Service, Certificate of Merit and Discount Privileges. You receive all parts, tools, instructions, etc. Everything is yours to keep.

## SERVICING LESSONS

You will learn trouble-shooting and servicing in a progressive manner. You will practice repairs on the sets that you construct. You will learn symptoms and causes of trouble in home, portable and car radios. You will learn how to use the professional Signal Tracer, the unique Signal Injector and the dynamic Radio & Electronics Tester. While you are learning in this practical way, you will be able to do many a repair job for your friends and neighbors, and charge fees which will far exceed the price of the "Edu-Kit." Our Consultation Service will help you with any technical problems you may have.

J. Stataitis, of 25 Poplar Pl., Waterbury, Conn., writes: "I have repaired several sets for my friends, and made money. The "Edu-Kit" paid for itself. I was ready to spend $240 for a Course, but I found your ad and sent for your Kit."

## FROM OUR MAIL BAG

Ben Valerio, P. O. Box 21, Magna, Utah: "The Edu-Kits are wonderful. Here I am sending you the questions and also the answers for them. I have been in Radio for the last seven years, but like to work with Radio Kits, and like to build Radio Testing Equipment. I enjoyed every minute I worked with the different kits; the Signal Tracer works fine. Also like to let you know that I feel proud of becoming a member of your Radio-TV Club."

Robert L. Shuff, 1534 Monroe Ave., Huntington, W. Va.: "Thought I would drop you a few lines to say that I received my Edu-Kit, and was really amazed that such a bargain can be had at such a low price. I have already started repairing radios and phonographs. My friends were really surprised to see me get into the swing of it so quickly. The Trouble-shooting Tester that comes with the Kit is really swell, and finds the trouble, if there is any to be found."

## PRINTED CIRCUITRY

At no increase in price, the "Edu-Kit" now induces Printed Circuitry. You build a Printed Circuit Signal Injector, a unique serving instrument that can detect many Radio and TV troubles. This revolutionary new technique of radio construction is now becoming popular in commercial radio and TV sets.

A Printed Circuit is a special insulated chassis on which has been deposited a conducting material which takes the place of wiring. The various parts are merely plugged in and soldered to terminals.

Printed Circuitry is the basis of modern Automation Electronics. A knowledge of this subject is a necessity today for anyone interested in Electronics.

# NOW! TRAIN AT HOME IN RADIO AND ELECTRONICS

ORDER DIRECT FROM AD . . . . USE COUPON ON NEXT PAGE

## RECEIVE FREE RADIO & TV PARTS JACKPOT

NEWSCAN

*(Continued from page 6)*

sonalized closed circuit television monitors and earphone headsets, assure privacy for those passengers who wish to work or read. The passenger may watch his monitor for a movie, short subject, live television or a picture being made at that moment by a camera installed in the nose of the airplane—but only one of these will be shown at any one time. Or he may decide in favor of a musical program available on the stereo channel. If he wants no entertainment, electing to work or read, he may do so and not be disturbed —even though his seatmate may be watching or listening.

Each airplane in American's fleet will be equipped with nine-inch monitors, one for each two passengers in the first class section,

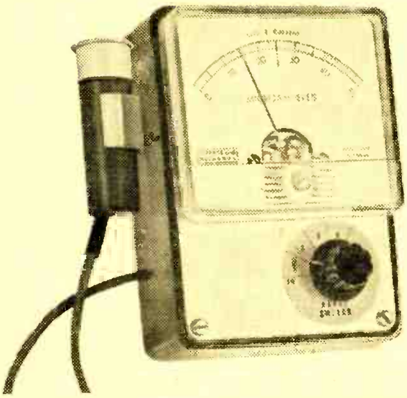
Motion pictures are transmitted from the Sony video tape machine located in cockpit of American's 707 and 720 Astrojets. Astrovision, a four-part in-flight entertainment system, also features stereophonic classical and popular music, live and tape TV, and in-flight photos.

and one for each nine coach passengers. The sets in the first class compartment will be installed between the backs of the two seats ahead. Additional privacy is afforded because each pair of American's first class seats is separated by a built-in table. The coach cabin monitors will be attached to the overhead service consoles.

Each passenger will have his own ear-

*(Continued on page 12)*

# Here is the NEW S&M Supersensitive PHOTO METER



NOW complete with carrying case

Every photographer knows that the high quality of his photos depends on the accuracy of his equipment. Here is a precision instrument that meets the highest standards of any meter available. **Modern Photography** says "This is certainly one of the most unusual, most versatile and most sensitive exposure meters at any price today." **U. S. Camera** wrote "It is as sensitive as anything on the market. It's so adaptable—those 4 separate ranges of sensitivity have the effect of spreading the meter's scale."

Now, the S&M Supersensitive Photo Meter is better than ever! A new plastic cap protects the probe and permits diffused light to be read with the cap on. The probe can still be used to read direct light with the cap removed. A new positive meter-lock in the OFF position protects the meter's needle.

The S&M Supersensitive Photo Meter uses the newest cadmium sulfide light cell to measure light levels from 0 to 10,000 foot lamberts at ASA speeds of 3 to 25,000. It is successfully used with movie or still cameras, microscope, telescope—as well as a densitometer. The computer gives F stops from .7 to 90 and lists exposure time from 1/15,000 sec. to 8 hours. 43° angle of acceptance; 4 range selection; EV-EVS-LV settings; weighs only 10 ounces.

And yet—this all-inclusive kit can be assembled with soldering iron and screw driver in less than 2 hours. Step by step instructions make it easy—or, order your S&M Supersensitive Photo Meter, fully assembled and fully tested. Complete with attractive carrying case.

**$24.95** in kit form No. 101

**$29.95** assembled No. 102

**$2.00** carrying case only No. 103

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**SCIENCE and MECHANICS—Kit Division**/505 Park Avenue, New York 22, N. Y. 69

Please send the new S&M Supersensitive Photo Meter as checked below, complete with carrying case. I understand that if I am not completely satisfied, I may return the meter within 10 days for a complete refund.

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Add 10% for Canadian and foreign orders. New York City residents add 3% for N.Y.C. sales tax.

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(Please print)

Address __________________________________________

City ______________________ Zone ________ State ________

☐ Check or money order enclosed, ship prepaid

☐ Enclosed is $3 deposit, ship COD for balance, plus postage and COD charges

*(Continued from page 10)*

phone headset with individual volume control. Convenient jacks will make it easy to select either the picture sound track or the music channel. Each monitor will have the conventional controls for regulating brightness, contrast, and vertical and horizontal line adjustment.

The motion pictures will be transmitted from tapes in a Sony Corporation Videocorder located in the cockpit. Sony is also providing the individual receivers. Motion pictures, which will run for a two-week period—one title on westbound trips and another on eastbound flights—will be provided by Movies Enroute.

The remote nose camera may be used for terrain observation. It can also be used to view approaches, landings and takeoffs. It will have a wide angle telescopic lens making a picture taken from 35,000 feet appear to be about 5,000 feet away. Local television may be used on the ground and during holding operations as long as the airplane is in range of local television stations.

Light beam from laser welder is aimed by holding the compact ophthalmoscope-like instrument to doctor's eye.

## Laser Retina Welder Developed For Mayo Clinic

Honeywell's Ordnance Division has delivered a compact laser ophthalmoscope to the Mayo Clinic, Rochester, Minn., for experimental use with animals as a retina-welding instrument. The new instrument, called a Laser Coagulator, was described by Honeywell as much smaller than conventional arc-lamp systems and equal in size to the smallest competitive laser systems yet developed. A unique optical feature which continuously indicates laser direction permits precise aiming of the beam by the operator. The Honeywell system, designed to repair certain types of torn or detached retinas, "spot welds" the damaged membrane to the eyeball with 500-microsecond bursts of coherent light. As the burns heal, heat scars form a bond.

The hand-held segment of the Mayo system is only slightly larger than a conventional opthalmoscope, yet it packs a ¼-inch by 2-inch ruby crystal, two flash lamps, trigger transformer and associated optics into its 1½-inch x 7-inch handle. The portable 115-volt power supply containing a 230-microfarad, 1,500-volt capacitor bank in parallel fits into a counter-top cabinet. The power supply, regulated by an AC phase-controlled switch on the primary of the step-up transformer, provides maximum flash lamp input of 288 joules. In normal operation, 250 joules produces the desired 0.1-joule laser output (at 6943 angstroms).

For accurate aiming of the beam into the patient's eye, a fiducial mark, consisting of a secondary lamp and condenser lens, has been built into the system to provide continuous indication of laser direction. The illuminating beam passes through the ruby rod, allowing focus of both the fiducial mark and the laser beam in the same plane. Other laser ophthalmoscopes employ a less accurate aiming method using a cross-hair projected into the viewing system.

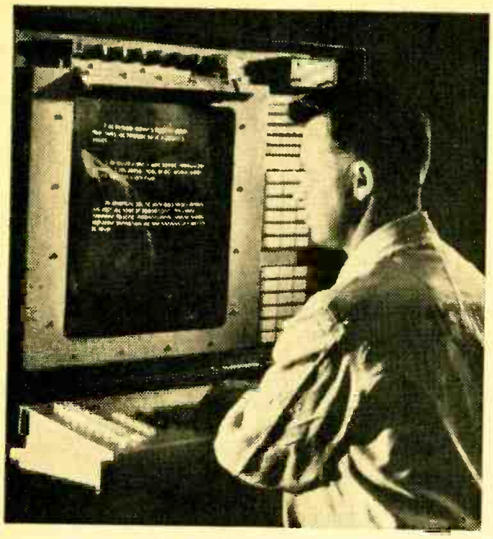
While laser beams have been successfully used in retinal operations on both animals and humans by researchers elsewhere in the United States, the Mayo unit will be used only with animals during the initial test phase which may last up to a year.

## New Query Response System Works Like Human Editor

An electronic "editor" that takes the paperwork out of a computer's answer has been developed by Raytheon Company for the

*(Continued on page 14)*

*(Continued from page 12)*



Engineer-operator composes messages for Raytheon's electronic "editor" that takes the paperwork out of computer's answer.

U. S. Air Force. Called a QRCC—query response communications console—the "editor" can compose, read, or edit material stored in the computer's data files. The first two units, now being field tested by the Air Force, were integrated by the Univac division of Sperry-Rand into the data processing portion of an intelligence system being developed by the Air Force Systems Command, (Research and Technology Division) Rome Air Development Center at Griffiss Air Force Base, New York. Cost of these two units, including development, was about $500,000.

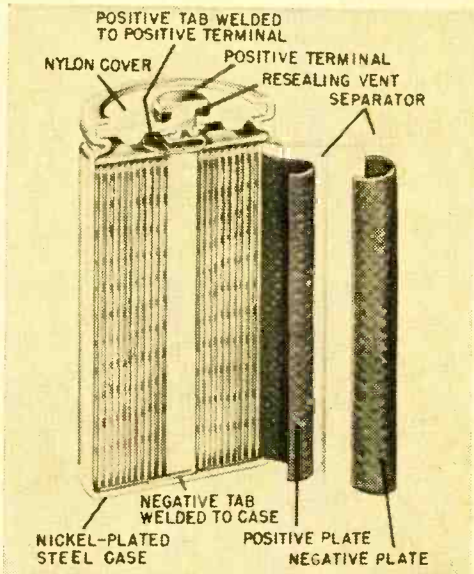
Linked to a computer, a QRCC serves as the interface between man and the machine. It translates the digitalized binary bits stored in the computer into a conventional language or formula that has meaning for the user. Not only does the QRCC "read out" the stored data, but it can "read in" new information as well. The new inputs are consolidated quickly to provide an updated answer moments later. These answers are flashed onto the "editor's" 24-inch television type tube in less than a third of a second. The flicker-free data can be displayed indefinitely or wiped off at will. Should a written record also be desired, the QRCC will provide it simultaneously. Otherwise, paperwork is eliminated.

An infinite variety of messages can be flashed on the screen. The 24-inch picture tube has 2,720 positions on which up to 120 different characters can be spotted. These characters are drawn from a built-in store or font which can be readily changed. Among the characters used in the present models are the capital and lower case English alphabet letters, the Greek alphabet, the numerals 1 through 9, and mathematical symbols, such as square root signs, triangles, etc.

In commercial use, the units would be invaluable for rapid retrieval and editing of all kinds of processed data. For example, insurance policies, purchasing orders, hospital records, servicing instructions, bank statements could be reviewed and updated quickly.

## Safety Vent Built Into NI-CD Battery

A new resealing safety vent that makes nickel-cadmium battery power more practical for a variety of household and electronic products has been developed at General Electric's Battery Product Section, Gainesville, Florida. Resulting from hundreds of hours of laboratory testing, the new unit is now standard on all G-E sealed,




Cutaway of General Electric's nickel-cadmium battery with new safety vent. The vent assures a continuous safe power source for cordless appliances by acting as a guard against inadvertent cell and battery abuse.

cylindrical-cell batteries. A guard against the results of inadvertent cell or battery abuse, the vent assures a continuous safe power source for cordless appliances.

Misuse, such as applying too high a current surge for too long a period when recharging a cell, may cause excess internal gas pressure to build up within the cell or battery. The resealing safety vent relieves the pressure buildup and thus prevents cell rupture or escape of large amounts of gasses. This breakthrough in battery seal design adds life and important safety features to the nickel-cadmium battery. Unlike other commercially available battery seals, General Electric's safety vent automatically reseals itself after opening. By resealing, the vent prevents reductions in battery life or performance due to evaporation or outgassing of the electrolyte. Once internal pressures are relieved, the vent closes again and the cell functions normally without noticeable effect on performance.

Radio and television interference inspector Graydon Bailey inspects a Tacoma City distribution sub-station in a residential area with an ultrasonic sound detector. By pointing directional probe at 110-kilovolt lines overhead, Inspector Bailey checks and logs readings to pinpoint possible troubles.

## Transmission Line Electronic Noise Located With Ultrasonic Device

A reduction in man-hours needed to pinpoint electric transmission line "noise" creating radio and TV interference in patrons' homes has resulted from use of an ultrasonic detection system by Tacoma City Light. The city-owned utility, which serves 68,000 meters over a 48 square mile area, responds to an average three calls per week from householders (usually those living near 52.5 Kv lines) complaining of radio and/or TV interference.

Without four hours of a complaint, one of seven men trained by the department as radio and television interference inspectors is dispatched to the customer's residence. The inspector's house call equipment includes a transistor AM radio, a portable battery-powered TV receiver, and a two-pound instrument known as the Delcon Model 117 Ultrasonic Translator detector.

Within the household, the inspector quickly determines whether the interference emanates from within the domestic circuitry by disconnecting main service momentarily and noting reception on his portable radio or TV. Characteristics of internal noise sources are generally recognized by the inspector as originating in such common devices as electric blanket controls. If the cause is not immediately apparent, the inspector often uses the ultrasonic system to pinpoint sources of interference on the premises which involve bimetal actuated contacts, including heating pads, doorbell transformers and many other devices.

When preliminary test indicates external interference, the inspector, using his transistor radio, patrols nearby transmission lines. Reaching the vicinity of particular noise, he employs the ultrasonic system.

Consisting solely of a miniaturized 35-ounce instrument containing electronics and volume control plus a hand-held directional probe, and earphone, the Delcon Ultrasonic Tranlsator detector system is compact enough (six pound total weight) to be carried along the steepest right-of-way. As he walks along, the inspector merely points the probe along the course of the conductors and hardware overhead. When the detector's earphones emit a hiss similar to that heard on an ordinary AM radio receiver when detuned from a transmitting station, the inspector zeroes in on the precise trouble spot by coordinating the direction of the probe with the intensity of the sound. To simulate windy day conditions, he strikes the structure with an eight-pound sledge hammer to produce vibration in pole, conductor, hardware and guy wires and then notes the intensity of the interference.

During his surveillance with the Delcon unit, the inspector is actually "listening" for sonic energy in the 36,000 to 44,000-cps range. Far beyond human hearing and far beyond ambient masking noises, such sonic energy, caused by arcing on 52.5, 105 and 230 Kv lines, can be detected by the Ultrasonic Translator from ground level at distances up to 60 feet.

The Delcon detection unit, which does not respond to audible frequencies, translates ultrasonic energy into immediately recognizable audible counterpart sounds. Since corona sounds are familiar to all utility service men and normal eye-hand coordination can pinpoint the source of energy, training requirements are minimal. Tacoma City Light's seven-man crew became expert in the location of noise interference with eight hours training.

Four times more light and lower current consumption resulted when a 40-watt fluorescent lighting unit was installed over a sofa-bed in the main cabin of this 38-foot cruiser.

## Fluorescent Lighting System For Small Boats

Electric lighting on pleasure craft falls far short of the quantity and quality to which boat users are accustomed at home. Reason for this lies in the fact that, except when shore power is available, lighting is powered by the same batteries employed to start the boat's engine. And the importance of keeping battery drain at a minimum is abundantly clear to every boater.

Relief in the form of better lighting for less battery drain is on the horizon as a result of the development by General Electric of a tiny electronic circuit which makes practical the operation of fluorescent lamps on battery power. The new, transistorized circuit overcomes equipment problems involving power drain, cost, size and weight, which have limited the use of efficient fluorescent lighting on boats in the past, and promises to revolutionize boat lighting.

First boat to have an installation of the new lighting system is the 38-foot cabin cruiser of Frank E. Carlson, special lighting applications supervisor for General Electric's Large Lamp Department. As a result, Carlson's boat, which operates out of the Sandusky, Ohio, Yacht Club, could be the best-lighted pleasure craft of its size in the nation. The prototype installation was made by Robert L. Henderson, G-E transportation lighting engineer, for test, evaluation and demonstration purposes.

The boat's 12-volt battery powers six fluorescent lamps—a 15-watt reading light over each berth in the forward cabin; and eight-inch, 22-watt circline lamp in the galley over the sink; a 40-watt reading lamp over the sofa-bed in the main cabin; and a 20-watt reading light over each twin bed in the aft cabin. The six fluorescent lamps produce a total of approximately 7200 lumens, or units of light. Their combined drain on the battery is only about 11 amperes. Eight 50-watt, 12-volt incandescent bulbs would emit 6800 lumens, yet create a battery drain of 33 amperes.

Possible future uses for the new fluorescent lighting system, in addition to pleasure boats, include lighting for automobiles, trucks and trailers; emergency lighting for hospitals, telephone exchanges and fallout shelters; lighting for campers, patios, fishermen; hand lanterns, flashlights, and miners' helmet lights; portable lighting for construction sites; portable lighting for still and motion picture photography; sign lighting for taxicabs and trucks; insect light traps; marine buoy lights; and space capsule lighting.

## Automated Credit Control

Using special telephone facilities in conjunction with high-speed data processing equipment, Hooper-Holmes Bureau, Inc., nationwide commercial reporting firm, has established an automated credit-checking service that is specifically designed to level the $30 million bad debt loss currently absorbed by the mail order industry each year. Called the Credit Index, the new service provides for the transmission of customer listings and similar credit files by telephone from distant collection points directly to the firm's data processing center in Morristown, N. J. There, the information is automatically screened by a computer and the results returned to the inquiring company within 24 hours.

Credit checks on subscription lists transmitted by telephone line facilities from distant centers are automatically processed by computer and transmitted back.

The service has been formed primarily to provide direct mail merchandisers with a more scientific method of checking the credit status of prospective customers faster than previously possible and at a reasonable cost. Incidence of mail order fraud and other bad debt activity has been rising increasingly throughout industry and traditional credit-checking methods have been unable to stem the tide. Through the application of advanced information handling facilities, however, the restriction, and perhaps eventual elimination, of this problem is now possible.

Key facilities in the new system are Bell Telephone System Data-Phone data sets, enabling the transmission of information on punched cards between distant transmission offices and the firm's computer center over regular phone lines. At headquarters, a Minneapolis-Honeywell computer system, containing credit delinquency data gathered from the records of major mail order houses throughout the country, is being used to evaluate inquiries.

The economic advantages of this automated system are considerable. While most procedures in use today cost users approximately two dollars per credit inquiry, the average cost to search a record through the Index is about eight cents, provided the information is supplied in punched card form. If not, the cost is slightly higher to cover the expense of converting the data to a form compatible with the computer system's input requirements.

While initially designed for direct mail merchandisers, such as book and record clubs, the Index has been found to be of considerable value to other types of businesses as well because of the "delinquency crossover" factors encountered in almost all credit operation.

Individuals delinquent in payments for "low ticket" items such as books and records also frequently repeat the practice on more expensive purchases or in credit card programs. Thus, a significant number of the same delinquents are found in the files of credit card holders as in direct mail and catalog credit programs.

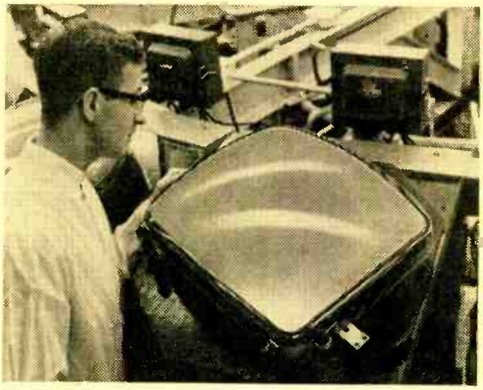
For this reason, the service is now being seriously considered by a number of firms outside the direct mail field. For example, a group of major oil companies is now testing the service as a means of reducing losses on credit card holders. In addition, the U. S. Post Office is using the service and may contribute its records on mail fraud to the file. Other subscribers to the system include Doubleday & Co., Grolier, Inc., Capitol Records and Reader's Digest, all of whom have also contributed their bad debt records to the file.

In its study of credit operations, Hooper-Holmes has found that delinquents follow a well-defined pattern to escape detection. By minor changes in the vowel structure of the last name, or by the substitution of various first names, they can successfully defeat most alphabetical filing systems.

To overcome this problem, the Index's computer system has been programmed to search orders by street address or box number first, next by city and state, and finally by name. The computer then focuses on money owed to one or more companies, printing the name, address, date and dollar amount due. Moreover, the company is now considering the inclusion of available social security numbers to the system in an effort to increase its accuracy.

## 25-Inch 90-Degree Rectangular Color TV Picture Tube

Color TV is finally shaking free from the fetters of the 90-degree round color TV picture tube. The Rauland Corporation, a Zenith cathode ray tube subsidiary, has developed and is now manufacturing a new rectangular TV picture tube. Zenith's 25-inch, rectangular color tube is the three gun,



Zenith engineers new 25-inch three-gun color picture tube with 90-degree deflection.

shadow mask type. Compared to the 21-inch, round screen tube with a 70-degree deflection angle and 265 square inches of rectangular picture area, the new tube has a projected viewing area of 300 square inches, a 90-degree deflection angle, and is 4 inches shorter than the 21-inch tube, making possible slimmer and more pleasingly proportioned cabinet shapes. Zenith expects the conventional 21-inch color sets to continue to dominate industry production for the rest of this year and some time to come because the more costly rectangular tube and other factors make the 25-inch sets considerably higher in price than the 21-inch receivers. However, your editor believes that volume production due to public demand plus improved production techniques will combine to reduce the overall cost of the new color TV tube. Eventually, the round picture tube will join its black-and-white counterparts on the scrap heap.

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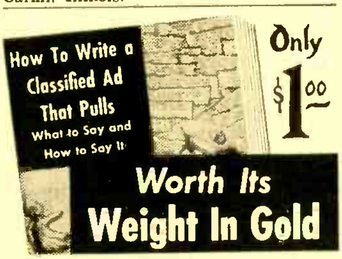


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**Electronic projects you engineer from top to bottom need not—should not!—look home-made—not if you use the following tips**

By Howard S. Pyle, W7OE

# HOME-BREW NEED NOT BE HAYWIRE

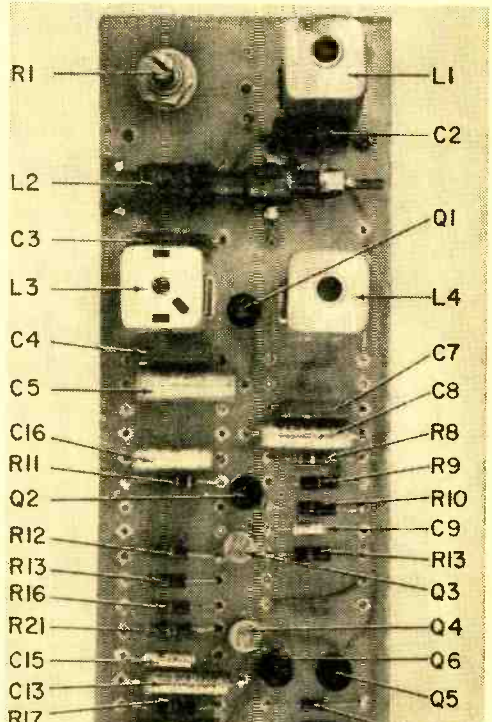
**Despite** the tremendous popularity of the "kit" type of electronic construction, there are still many, many thousands of experimenters in this field who prefer to build *from scratch* or as amateur radio enthusiasts term it, *home-brew* their projects. Even the confirmed kit builder reaches a stage eventually where he would like to try his construction skill. Maybe it is a piece of stereo/hi-fi equipment, ham radio gear or just some "odd-ball" gadget which appeals to him. Perhaps he has dreamed up a *brain-child* of his own which he can only prove up through building it himself. Other enthusiasts enjoy a great sense of satisfaction through actually creating something workable with their own hands. Whatever the reason, *home-brew* projects occupy a very large portion of amateur electronic construction.

**Mechanical Construction.** Initially the actual physical steps will be mainly mechanical; the electrical portion and perhaps a bit of *spit and polish* will appear in the final stages. If the builder proposes to work from a magazine or handbook description of a piece of gear, he will most generally find dimensioned drawings as well as wiring and schematic diagrams, incorporated in the article. If, on the other hand, he chooses to depart somewhat from the printed offerings or is going to rely solely on his own design for a particular piece of equipment, he should most certainly prepare detailed drawings showing the mechanical layout with dimensions as well as a wiring schematic.

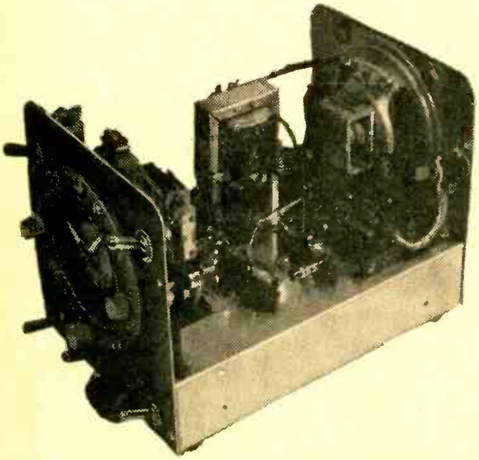
Such drawings need not be of professional drafting status; pencilled drawings are adequate as long as they are clear, legible and accurate. Use of a drawing board, "T" square, a *45* and a *30/60* degree plastic triangle and an accurate rule or a draftsmans' scale, are all desirable in order to turn out neat and workmanlike drawings, however an accurate, simple rule if carefully used, will suffice. Whenever possible, make such drawings in full size but if smaller drawings are dictated, make them to a definite scale; half or one quarter size are about as small as you will find convenient to work from. Letter all dimensions and other details right on the face of the drawing; values of capacitors, resistors and similar parts and components should likewise appear on the schematics. Once the layout has been completed in pencil (or ink if you like), the actual physical construction can begin. We assume of course, that you have previously procured all necessary components and small parts before commencing work and that you possess the necessary tools with which to accomplish a workmanlike job.

**The Chassis.** Inasmuch as almost without exception, electronic parts and components are mounted on a metal pan or "chassis," this then will be the first consideration in starting your work. Right here we want to offer you a tip. Unless you are skilled in sheet-metal work and are equipped with a

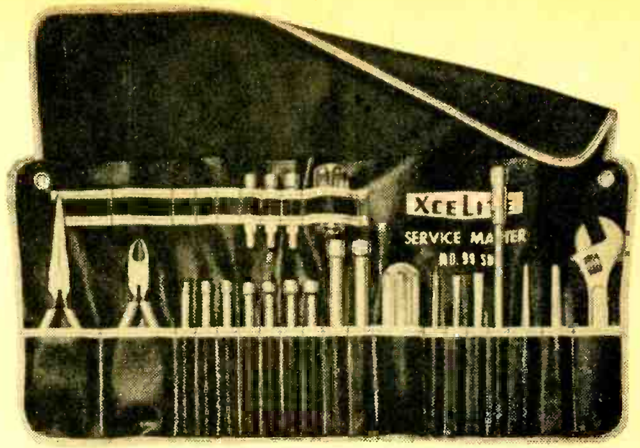
Commercial or military electronic gear? It may appear to be, but it's a unit that was smartly home-brewed down to panel markings.




Top view of circuit board that holds almost all the components for an SCA-FM adapter project; rat's nest wiring is eliminated.



Orderly component layout characterizes this unit built around clock-timer mechanism.




Lack of or inadequate tools as you've probably experienced at least once, can render the novice or the expert home-brewer equally helpless.

metal-brake, do *not* attempt to bend up a metal chassis yourself! You will find steel difficult to work and aluminum has an annoying tendency to develop a partial break at every bend. Factory formed chassis are readily available at all electronic supply houses and come in a wide variety of sizes and in various finishes. None of these are expensive and they are accurate in dimensions and very rigid. Play smart and *buy* the chassis!

**Punching Holes.** Once you have the chassis on the bench, you are ready to drill and punch the numerous holes and openings which your project will call for. Do *not* however lay out the position of these directly on the chassis surface. Go back to your drawing board and prepare a paper "template." This is nothing more than a drawing of the exact size of the chassis dimensions and on which you can mark the center of each hole and opening which you intend to make in the metal chassis itself. Mark each center with the size drill or punch to use or the size of the screw which it should pass. For large, irregularly-shaped openings such as those for top-mounting or half-shell transformers, indicate the dimensions of such. Be careful that all positions are *accurately* shown; remember that it is pretty difficult to 'erase' a hole incorrectly located once it is drilled or punched!

With the layout template finished, trim it to exactly fit the chassis and fasten it in place. So-called "rubber cement" is excellent for this purpose as the drawing may be readily peeled from the metal after the drilling is accomplished. You are now ready for the actual drilling process but first mark the center of each hole with a sharp center punch, to accurately start your drill. If the chassis is large and the top rather thin, place a block of wood under the points you are going to drill; this will avoid creating 'dimples' in the chassis top.

You will no doubt have a number of holes of the same size. Select the proper drill and make all of these before changing drill bits. Whether you use the common garden variety or "egg-beater" type of hand drill or a quarter inch electric drill, is immaterial. Hand drilling is relatively slow and tedious, especially in a steel chassis; the electric drill will cut almost as if in cheese and in a fraction of the time.

Once you have completed all of the holes up to the largest size which your drill will accommodate, you can concentrate on those which will require enlargement to accommodate the screw or item which will be used at these points. Those whose finished sizes will be from about 3/8" to 5/8" inches can be enlarged with a metal twist drill held in an ordinary carpenter's brace. If necessary they may be reamed out to an even larger size. For holes from about 3/4" up, a chassis punch will make the cleanest, neatest hole in less than a minute and is very easy to use. These come in round, square as well as some special formations and a set of these will provide for just about any opening you will require. For oddly shaped openings for which neither drills nor punches will serve, a sheet metal "nibbling tool" is ideal; you can cut just about any shape hole you may desire using a simple, round pilot hole as a starter.

Once you have finished all drilling and punching operations on your chassis, double-check your work and, if satisfied, you can peel the paper template from the chassis top and you are ready to commence assembling components and parts in position. Before you do this however, turn the chassis over and remove any burrs which the drilling has caused on the inside of the chassis. This is easily done with a small metal countersink or they can be carefully removed with a knife blade or an over-sized drill. Assemble all parts to the chassis with the appropriate size screws. Do not neglect placing a lock washer of either the split or 'star' type over each screw before placing and tightening the nut.

If your project calls for a panel on which to mount various controls and indicator lights, this should next be prepared. Draw up another paper template the exact size of the panel you will use and accurately mark thereon the positions of the various holes and their sizes and cement it to the panel face the same as you did with the chassis. Even if you use a lacquered or a wrinkle finished panel, the rubber cement won't hurt it; the adhesive can be readily removed after peeling the template by lightly scrubbing with a cloth or even with your finger. After drilling the panel, attach it to the chassis; you are then ready to proceed with the wiring.

**Wiring.** Generally speaking, a good grade of electronic hook-up wire, preferably tinned and of a size about #20, will be adequate for most circuits. For voltages of 300 or more, a good wire to use is what is known to the trade as 'primary automotive ignition wire' and is available at any auto parts supply house and at many automotive repair shops and service stations. This provides the best safety factor in high voltage circuits as it is heavily insulated although relatively small in diameter. For any circuits which will carry audio frequencies such as microphone, loud-speaker and headphone leads, use a wire with a closely braided shield; this is readily available at electronic parts stores. Route such audio runs insofar as is possible, as remote from wiring carrying alternating current, such as filament supply leads, transformer wires and similar, as your chassis will allow. This will minimize any undesirable 'hum' effects which you might otherwise encounter in your finished equipment. Otherwise, how you route your wiring back of the panel and beneath the chassis you will have to determine by the nature of the project possibly supplemented by some routing hints in the magazine or handbook article if that is what you are working from.

**Chassis punches are available in many shapes; above is "key" punch for keyed radio sockets.**

**Tied Up.** Whether you choose to 'cable and lace' your under-chassis wiring runs, is your choice. Forming it into laced harnesses below the deck and back of the panel will produce a more workmanlike job than to merely allow the wires to straggle from point to point. Just be careful not to include the shielded audio wiring in the same harness with AC and other wiring; make a separate harness for audio runs. Where wires must pass through chassis holes, *always* bush such holes with rubber grommets to avoid the possibility of the insulation being frayed where the wire passes through the hole.

**Soldering.** It should not be necessary to discuss the soldering operation, many of which will be required. You are already familiar with soldering techniques no doubt, particularly if you have previously built one or more kits. We will stress a few points here however, which should be kept in mind:

**A.** Make sure that the wire and terminal at each point is *clean*.

**B.** Heat the joint from the bottom up (heat rises).

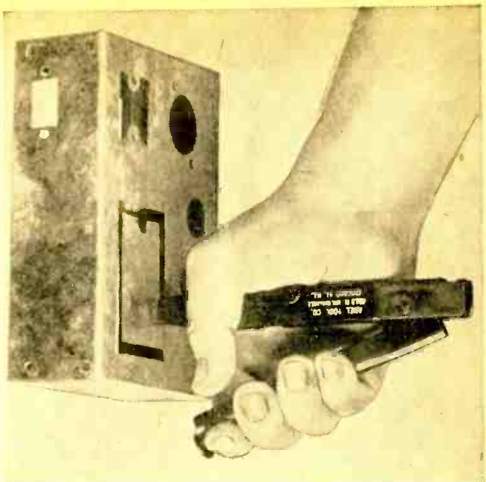
**C.** Use a hot iron of small size; 35 to 75 watts is about right.

**D.** Use the iron to heat the *joint* . . . *not* to melt the solder and 'dribble' it on the connection!

E. Before applying solder, be sure the joint is mechanically tight.
F. Apply the solder to the *joint; not* to the tip of the iron.
G. Keep the iron clean by frequently wiping with a rag.
H. Keep the iron on the joint until the solder flows freely and evenly; after removal of the iron the solder should appear smooth and bright with a polished silver appearance; not coarse and granulated.

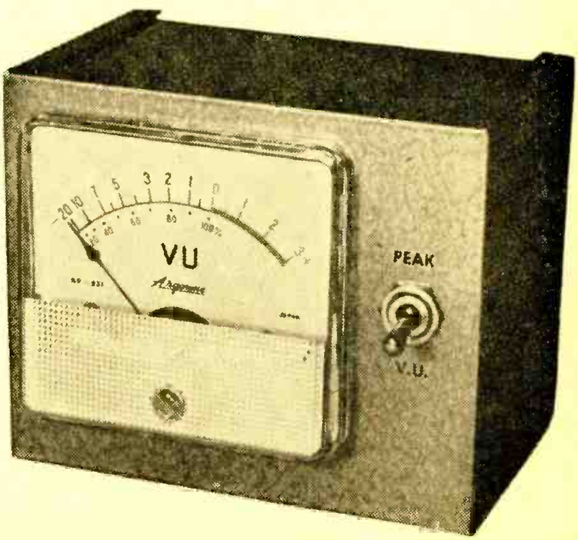
Bear all of these points in mind and you will come up with a good job.

**Tools.** We have, as previously mentioned assumed that you have provided yourself with an adequate assortment of tools before starting any electronic home-brew building project. Like in any other craft work, to accomplish a workmanlike job calls for two major things: (1) choice of the proper tool for the operation to be accomplished *and* (2) the ability of the builder to properly *use* it! Pliers, both long-nose and diagonal, an assortment of screw-drivers and socket wrenches, a good soldering iron, a hand or small electric drill, drill bits, center punch, reamer, flat and triangular files, a jackknife and possibly a small (½″) metal countersink, will pretty well fulfill your tool requirements. Add a set of socket punches; possibly a nibbling tool if you anticipate very many odd-shaped openings. You can of course, expand this tool list to whatever extent you desire. Your electronic parts dealer will have a wide assortment of tools for various electronic applications; examine his stocks and make your choice.

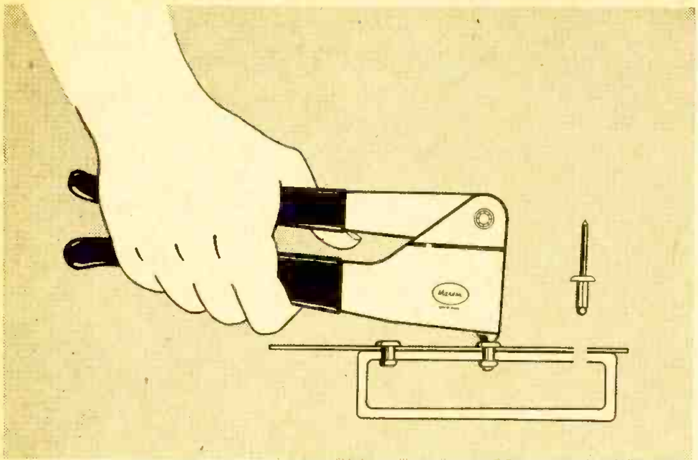


"Nibbling" tool cuts any shape hole in steel or aluminum chassis; costs about four dollars.

**Dressing It Up.** Finally, if you really want to approach a professional appearing construction job, there are a number of little niceties which you can add. Lettering the panel for example, can be accomplished neatly and attractively by several means. The little paper decals sold in book form at electronic stores is one method and are easy to apply with reasonable care. Separate stamped or engraved name-plates can be used or you can make your own with a Dymo Labelmaker tool. If you can do neat lettering with a pen and India ink, all components and parts above and below your chassis and on the



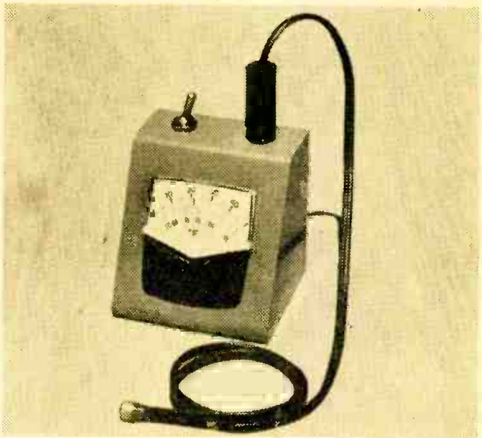

Unless you are an experienced and equipped metalworker, you will do best buying the chassis you need for the job. Careful advance figuring is necessary to come up with the optimum size for your purposes. Aluminum miniboxes, as shown here, are very versatile for a great number of applications. Their 3-sided opening design makes working easy.



If you really turn out your projects in mass production, you'll save a lot of time by not fooling around with nuts and bolts with this riveting tool. It's quick, easy, and makes a lasting joint.

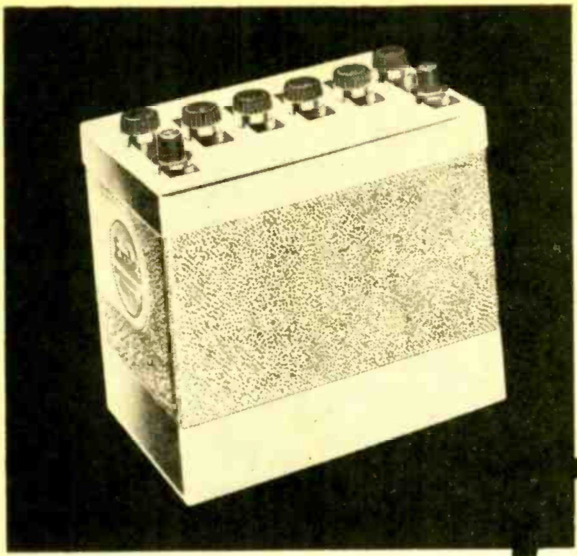
back of your panel can be so identified. After the ink dries, a spot of clear finger-nail lacquer over each designation will prevent the ink from wearing off. Colored finger-nail lacquer is a neat manner by which to mark your soldered connections below the chassis; just put a spot of red on each soldered connection. Such application will often indicate a joint which you had forgotten to solder or one which has been poorly done.

**The Final Touch.** And last, but by no means of least importance if you want your project to reflect the ultimate in final completion, by all means make up an instruction manual for it! This can be an inexpensive, 9"x12" loose-leaf, ring-binder type of notebook, and the material should preferably be typed. Include all descriptive matter which is pertinent to the unit you have built. If the design has been taken from a magazine or handbook article, clip or duplicate the essential portions and paste them to the pages. If the design is from your own ideas, make sure that schematic wiring and the values of parts and components is shown. Show all voltage readings which represent normal at essential points. Lastly, include a parts list indicating thereon every item you have used in the assembly and wiring, including manufacturer's name and catalog number wherever possible. This will give you or a possible future owner of your home-brewed gear an intelligent key from which to order similar parts for replacement if and when this may prove necessary. Such an instruction book is a considerable asset when it comes to possible sale of such equipment and will also favorably impress a prospective purchaser with the probable thoroughness of your work throughout. Remember too, to correct such instruction book text and drawings to indicate any modifications and changes which you may have occasion to make from time to time.



Meter cases are home-brew favorites; this one holds meter scaled for temperature readings. The sensor, plugged into the circuit housed in the meter case, is immersed in photographic fixing baths to monitor their temperature.

If you have followed the above suggestions conscientiously, you should turn up with an attractive and well-performing piece of home-brewed electronic gear which will pretty well approach professional factory-made equipment and which you can proudly display to anyone. Good "brewing"! ■



Electricity is generated in many ways and places—from dam-driven generator to orbitting solar cell—but the ol' "black box" still maintains its potential from pole to pole

John Potter Shields

# STORAGE BATTERIES

ONE of the most widely used, yet perhaps the least understood, sources of electrical energy is the common lead-acid storage battery. Used in a myriad of applications ranging from the central point of your car's electrical system to the most advanced aircraft, the lead-acid storage battery represents one of the most efficiently known converters of chemical energy to electrical energy. While recent developments have resulted in a number of "improved" types of storage batteries, the old reliable lead-acid battery still holds its own.

Although capable of long, trouble free service, the lead-acid storage battery must be properly treated if it is to perform at top efficiency over an extended period of time. Let's take a look at the basic operation of this battery, and how to best care for it to receive maximum trouble free performance.

**Battery Basics.** As is the case with most devices, a good understanding of their basic operation is a great help when maintaining and servicing them. So, lets begin matters by seeing just how chemical energy can be converted into electricity . . . and vise versa.

The whole thing began back around 1780 when an Italian scientest by the name of Luigi Galvani caused a frog's legs to contract when lightly touched it with two dissimilar metallic wires. Galvani concluded that this action was the result of an electric current generated by the presence of the two disimilar metals against the moist body of the frog. Indeed he was quite right in his assumption . . . to this day, *Galvanic current* is the term used to describe the minute electrical currents generated during muscular activity.

Somewhat later, another Italian by the name of Alessandro Volta discovered that a more intense electric current could be generated by stacking up a number of dissimilar metal discs—copper and zinc for example—between moistened paper discs. This first "battery" was known as *voltaic pile*. Volta subsequently found that two dissimliar metal strips immersed in a weak acid "electrolyte" would generate still more current. He is credited with this fundamental discovery that electrical energy is produced in a battery as the result of the electro-chemical reaction between two dissimilar metals immersed in a suitable chemical electrolyte.

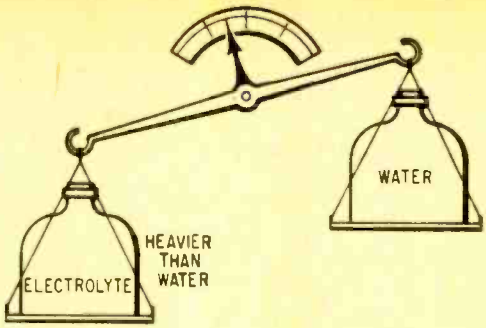



**Fig. 2. Specific gravity of sulphuric acid-water electrolyte is greater than that of pure water.**

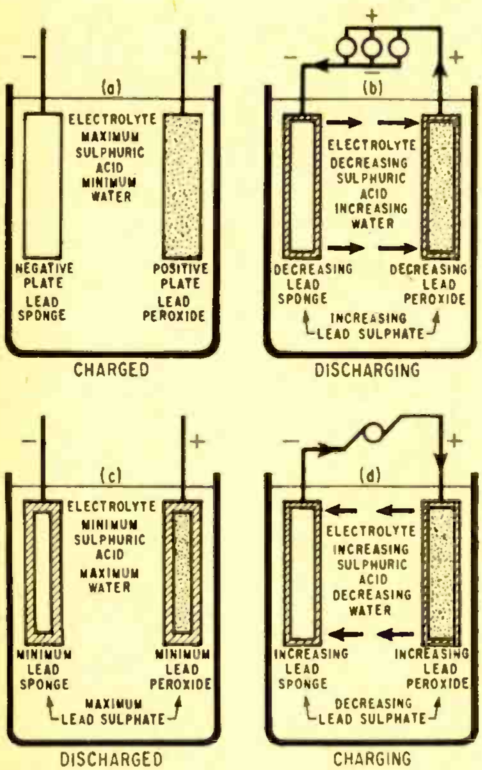



**Fig. 1. These graphic illustrations trace the cycle of chemical reactions in storage batteries. Sulphuric acid, $H_2SO_4$, breaks down to water $H_2O$, during discharge; lead forms $PbSO_4$.**

The fruits of Volta's efforts have been improved and refined and have resulted in the various types of highly developed "dry batteries" which are available today.

So far, we've been talking about "one way" batteries; that is, batteries that will continue to deliver electrical energy only as long as the electro-chemical reaction within them continues; after it ceases, the electrical output of the battery drops to zero. The only way to restore this type of battery is to replace its active chemicals. This type of battery is known as a *primary* battery.

**The Storage Battery.** When the active chemicals of a primary battery are exhausted in the production of electricity, the battery must be discarded as it is not practical to replace its chemicals. On the other hand, a storage, or *secondary* battery's electro-chemical action can be "reversed." An electric current is passed through the battery to restore its elements to their original chemical state. Basically, that's the action of the storage battery. A closer look will reveal how this electro-chemical process works.

Fig. 1a represents a very simplified form of storage cell in its *charged* state. The negative plate consists of sponge lead and the positive plate of lead peroxide. These two plates are immersed in an electrolyte of sulfuric acid and water.

Fig. 1b shows the same cell as it is being *discharged* by a light bulb load connected across its terminals. In this state, the dilute sulfuric acid electrolyte reacts with both the positive and negative plates to form a new chemical—lead sulfate. This lead sulfate is furnished by the sulfuric acid solution (electrolyte) which becomes weaker in concentration as the discharge process takes place. As this discharge continues, the negative plate's sponge lead and the positive plate's lead peroxide both gradually change to lead sulfate.

Fig. 1c illustrates the cell in its totally *discharged* state. At this point, both positive and negative plates have been largely converted to lead sulfate. Also, this same chemical process has resulted in the dilution of the sulfuric acid by the generation of water.

Fig. 1d pictures the cell in its *charging* condition. In this case, direct current is passed through the cell in a direction opposite to that of the discharge current. This charging current causes an exact reversal of the discharge process to take place. The lead sulfate from the plates is converted back to electrolyte,

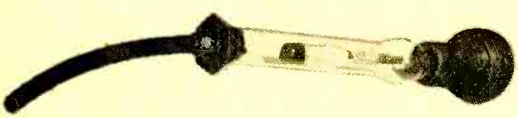


**Fig. 3. Hydrometer checks specific gravity of sample of liquid drawn into its glass barrel.**

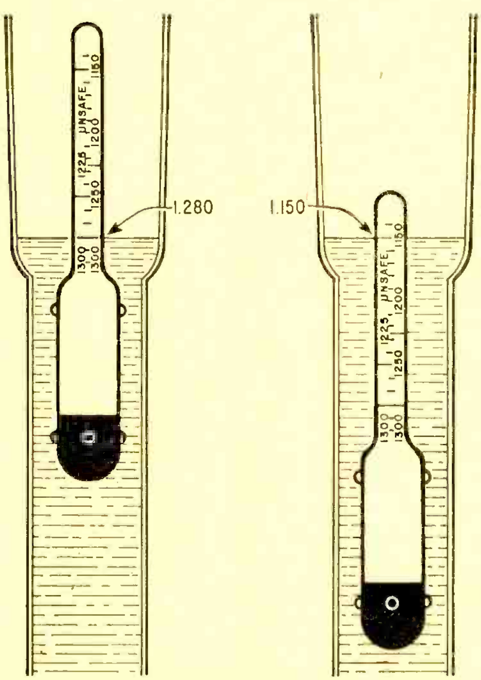



**Fig. 4. Hydrometer float in barrel displaces more electrolyte when battery is dead (1.150).**

| Specific Gravity | Battery Condition |
|---|---|
| 1.260—1.280 | 100% Charged |
| 1.230—1.250 | 75% Charged |
| 1.200—1.220 | 50% Charged |
| 1.170—1.190 | 25% Charged |
| 1.140—1.160 | Very little useful capacity |
| 1.110—1.130 | Discharged |

**Fig. 5**

restoring the electrolyte to its original strength. When this charging process is continued for a sufficient length of time, the plates are restored to lead spong and lead peroxide.

If the charging current continues after the battery is fully charged, the negative plate releases hydrogen gas, while oxygen is given off by the positive plate. These two gases are produced as a result of the decomposition of the water in the electrolyte caused by the charging current.

**Specific Gravity.** Earlier we said that water was released during the discharge of the storage battery as a result of the electrochemical reaction. The amount of water (weakening of electrolyte) is directly proportional to the state of battery discharge. Thus, by measuring the strength of the electrolyte, we can conveniently determine the battery's state of charge, or discharge.

Let's take a look at Fig. 2 which shows a jug of water and a jug of electrolyte placed on a simple balance scale. Note that the electrolyte is heavier than the water. The electrolyte in a fully charged storage battery is 1.260 times heavier than pure water, when both are at the same temperature. During battery discharge, the electrolyte becomes diluted and hence its weight or *specific gravity decreases*. Therefore, the state of charge may be accurately determined by measuring the specific gravity of the electrolyte.

Since it would be impractical to actually weigh a battery's electrolyte, a device called a *hydrometer* is used to determine the weight or specific gravity of the electrolyte. A typical hydrometer is pictured in Fig. 3. As you can see, it consists of a small calibrated float contained in a syringe. In operation, the syringe is dipped into the battery electrolyte to draw electrolyte up into its barrel. Depending on the specific gravity of the battery's electrolyte, the float will either ride high or low in the syringe barrel—high for high specific gravity, and low for low specific gravity. This is illustrated in Fig. 4; and in Fig. 5. A table gives specific gravity vs percentage of battery charge. When using a hydrometer to measure specific gravity, it's important that the water and acid be thoroughly mixed. For this reason, don't take hydrometer readings immediately after adding water to a battery.

**Battery Capacity And Ratings.** The current capacity of any lead-acid storage battery depends on the number and size of its plates as well as the amount of electrolyte. A storage battery's electrical capacity is roughly proportional to the area of its plates. For this reason, automotive batteries are manufactured with thin plates of large area. Amount of acid used is a compromise between battery performance, weight, and life.

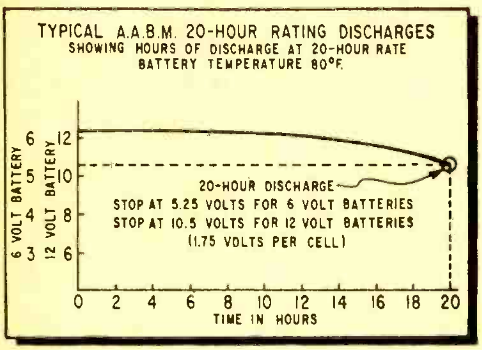



**Fig. 6. Association of Automobile Battery Manufacturers established the 20-hour yardstick.**

Several sets of battery performance standards have been adapted by the industry. Perhaps the most important is the "20 hour ampere-hour" rating. This rating, which applies to the automotive lighting ability of the battery is defined as follows. A fully charged battery is discharged at a rate equal to 1/20th of its rated 20-hour capacity in ampere-hours, until the terminal voltage drops to 5.25 volts (in the case of a 6 volt battery). The number of hours required for this discharge times the rate of discharge is equal to the 20 hour ampere-hour rating of the battery. See Fig. 6.

Another important battery rating is its automotive engine cranking ability. This is important since this is when the battery is called upon to deliver very high current over a short

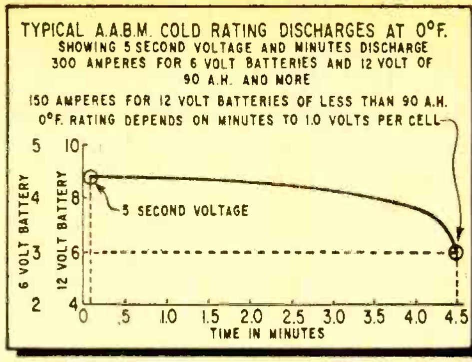



**Fig. 7. Another important criterion for rating a battery is its auto engine cranking ability.**

period of time. The accepted method of determining the performance of batteries under this condition are as follows

1. The battery's terminal voltage 5 seconds after a discharge rate of 300 amperes (for 6 and 12 volt batteries of 90 ampere-hour ratings or more), or 150 amperes (for 12 volt batteries of less than 90 ampere-hour ratings).
2. The number of minutes it takes the battery to reach a voltage of 1.0 volts per cell when discharging at the rates indicated above.

During these measurements, electrolyte temperature is maintained at O degrees F. These measurements are known as the battery's "cold rating at 0 degrees F." Fig. 7 is a curve showing typical "cold ratings" dis-

**TYPICAL CURRENT LOAD OF MODERN CARS**

| | 12 Volt System | 6 Volt System |
|---|---|---|
| Head Lamps . . . | 8.0 Amps | 13.5 Amps |
| Ignition . . . . . . | 3.0 Amps | 3.3 Amps |
| Instrument Lights | 1.5 Amps | 1.2 Amps |
| Tail Lights . . . . . | 1.0 Amps | 1.5 Amps |
| License Light . . . | 0.4 Amps | 0.6 Amps |
| Heater . . . . . . . | 5.0 Amps | 8.7 Amps |
| Radio . . . . . . . . | 1.8 Amps | 5.5 Amps |
| | 20.7 Amps | 34.3 Amps |
| Summer Starting | 100-225 Amps* | 125-300 Amps* |
| Winter Starting | 225-500 Amps* | 300-700 Amps* |

*Values vary with engine size and oil viscosity.

Fig. 8

charges for 6 and 12 volt batteries. Fig. 8 is a table, showing typical current loads in modern cars.

Storage battery efficiency is quite dependent upon temperature. Low temperatures impede the electro-chemical reaction necessary for the generation of electrical energy. As shown in the graph, Fig. 9, only 2/5ths of the battery's working power at 80 degrees F is available at 0 degrees F. Add to this the fact that a cold engine is much harder to crank at low temperatures and you can see why cold weather plays havoc on your car's battery.

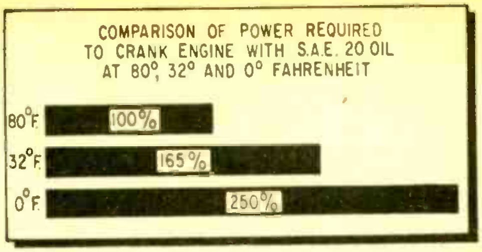



Fig. 9. During winter engines are harder to crank and less battery energy is available.

**Storage Battery Construction.** Fig. 10 shows the various component parts of an automotive lead-acid storage battery and how they are assembled. The *grid* of the storage battery, Fig. 11, consists of an electrically conductive framework in which the active chemicals (sponge lead for the negative plate and lead peroxide for the positive plate) are deposited. The thus formed positive and negative plates, Fig. 12, are formed into respective positive and negative *plate groups* as as shown in Fig. 13. A positive and negative group, insulated from one another by *separators*, Fig. 14, from a complete *cell* as shown in Fig. 15. These cells, plus the electrical connectors are placed in the battery container which is shown in Fig. 16. Addition of vent plugs and covers, (Fig. 17), sealer, and electrolyte form the completed battery seen in Fig. 18. All these parts can be seen assembled into place in the cut-away illustration of Fig. 10.

**Storage Battery Installation And Maintenance.** Now, let's take a look at the proper method of installing the storage battery. When replacing your car's original battery with a new second one, several precautions should be observed. The following procedure is suggested.

1. Before removing the original battery, note whether its positive or negative terminal is grounded to the car's frame.
2. Disconnect the battery's grounded terminal first. This will eliminate any possible short circuit caused by the other terminal accidentally contacting grounded parts of the car's frame.

*(Turn page for Figs. 11 through 18. Text continued on page 36)*

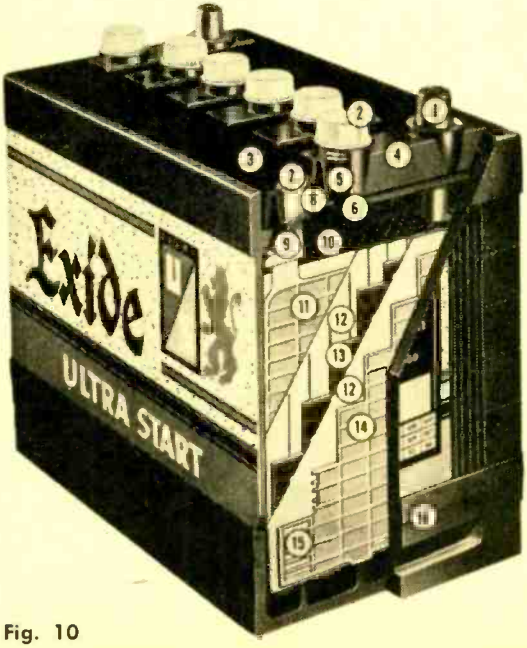
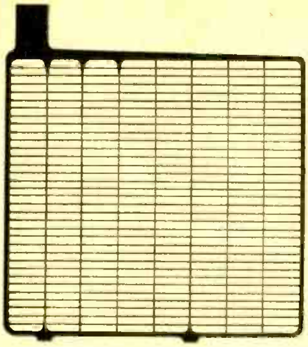



Fig. 10

1. TERMINAL POST
2. VENT CAP
3. SEALING COMPOUND
4. CELL COVER
5. FILLING TUBE
6. ELECTROLYTE LEVEL MARK
7. INTER CELL CONNECTOR welded to . . .
8. LEAD INSERT in cover and . . .
9. PLATE STRAP
10. SEPARATOR PROTECTOR
11. NEGATIVE PLATE
12. SEPARATOR
13. POSITIVE PLATE
14. NEGATIVE PLATE with active material removed to show . . .
15. PLATE GRID
16. CONTAINER

*(See previous page)*



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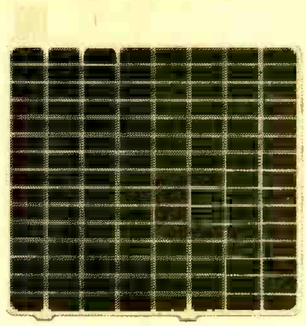

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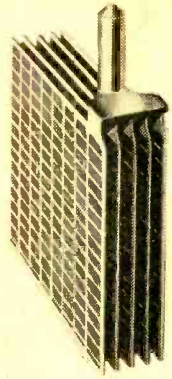

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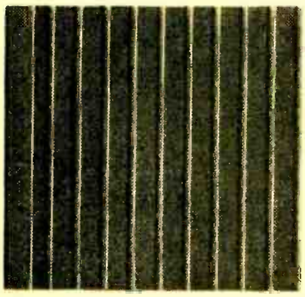

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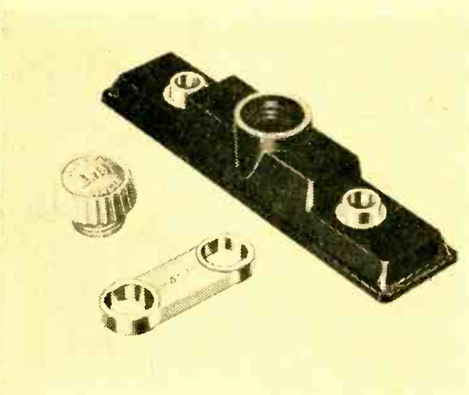


17


18

The construction of a battery, shown in Figures 11 through 18 (see text), is a precision operation requiring close tolerances. Not only are the individual grids, plates, and separators thin and delicate, but they must be secured rigidly enough to withstand years and miles of rough road shock which is a reality despite our modern shock absorbers and smooth highways. Note the complete cell in Fig. 15; its many plates and separators are separated from each other by only fractions of an inch. These details of battery construction are often startling when we are used to visualizing the internal battery with the explanatory simplicity of the cell in Fig. 1 on page 28. Fig. 18 shows completed battery.

## Storage Batteries

(*Continued from pages 31 & 32*)

| Specific Gravity (Corrected to 80° F.) | Freezing Temperature Degrees Fahrenheit |
|---|---|
| 1.280 | —90° F. |
| 1.250 | —62° F. |
| 1.200 | —16° F. |
| 1.150 | + 5° F. |
| 1.100 | +19° F. |

**Fig. 19**

3. Disconnect the other battery lead.
4. Remove old battery from its compartment or straps.
5. Clean cable clamps and battery compartment. A solution of baking soda will neutralize any acid that may have spilled in the compartment.
6. Place new battery in compartment or straps.
7. Reconnect battery terminals to cables —the ungrounded terminal first.
8. Start engine and note if battery is charging.

So-called "dry-charged" batteries have become popular of late, since they contain no electrolyte; therefore they do not deteriorate during storage. The installation of this type of battery is the same as regular batteries, except that the proper electrolyte must be added to the dry-charged batteries. Normally, no additional charging is required after installing a dry-charged battery. An exception is when the battery is to be installed in cold weather, and its temperature is low. As a rule of thumb, if the battery temperature is 40 degrees F or lower, it should be given a "pre-charge" after the addition of electrolyte.

Earlier, we mentioned that the battery cable terminals should be thoroughly cleaned before installing a new battery. Corrosion can increase resistance between the cable connectors and battery terminals. The major cause of terminal corrosion is the action of the electrolyte's sulfuric acid on the metallic parts of the cable and its connectors. This corrosion can be effectively removed by the vigorous use of a wire brush, after which a coating of clear petroleum jelly should be applied. The battery cables are subject to wear, and should be checked for any sign of chafing.

**Battery Life.** Overcharging represents one of the major causes of early battery death. Overcharging, generally caused by a fautly voltage or current regulator in the automotive ignition system, can result in:

a. Excessive decomposition of electrolyte's water into hydrogen and oxygen gases. Gas bubbles thus formed tend to remove active material from plates.
b. Excessive internal heat which is harmful to both positive and negative plates in separators.
c. Buckling or warping of plates which can puncture the separators and cause the plates to short.

By the same token, undercharging, caused by faulty generator or regulator, can greatly shorten battery life. Continual battery undercharging can result in:

a. Excessive sulfate formation on the plates which cannot be electro-chemically converted back into active material during recharging of the battery. This formation can stress the plates, causing them to buckle. This in turn,

(*Concluded on page 127*)

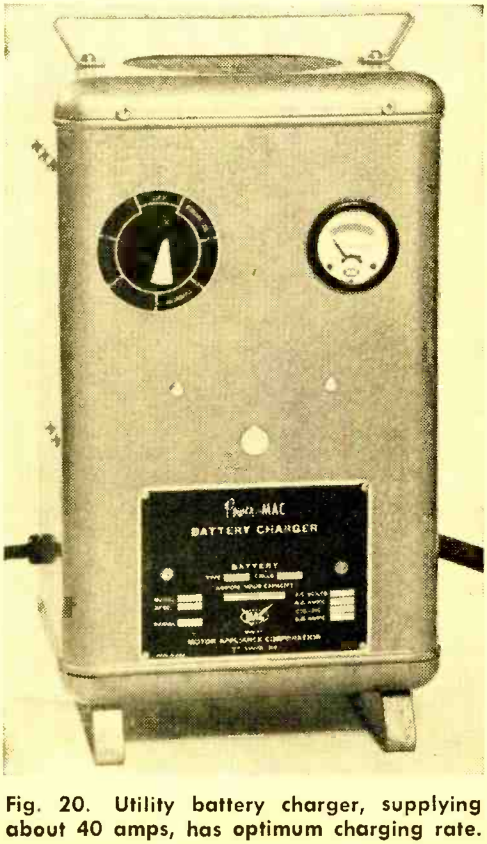
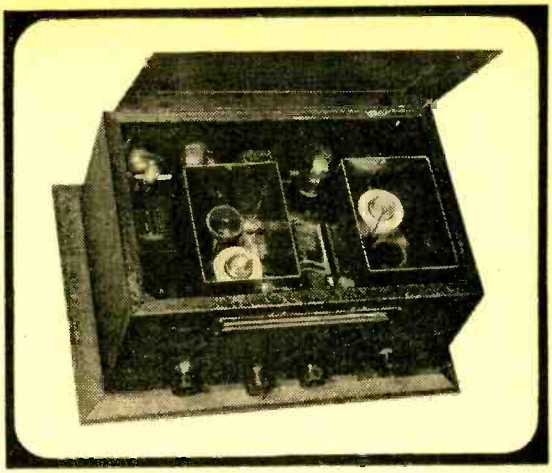



**Fig. 20. Utility battery charger, supplying about 40 amps, has optimum charging rate.**



# TRF RECEIVERS

**Just as knowledge of history enhances understanding of the present, knowledge of the earliest radio receiver increases understanding of our contemporary receivers**

**By Leo G. Sands**

**The** first radio receivers were of the so-called TRF (tuned radio frequency) type, the simplest type consisting of crystal detector D1 (diode), a headset, antenna and ground, as shown in Fig. 1. This receiver's selectivity is very poor since its only tuning circuits consist of the antenna which is broadly resonant at some frequency. When used with an outdoor antenna about 50 feet long, and with a good ground connection, it will pick up AM broadcasting stations nearby. You may hear several stations at once unless there is only one local station on the air.

A more selective crystal set circuit is given in Fig. 2. Here, coil L1 and capacitor C1 form a series resonant circuit which determines the frequency at which the receiver is most sensitive. The antenna is a part of the tuned circuit and its length as well as its height above ground has an effect on tuning. The RF current flowing through L1 will cause an RF voltage to develop across L2 which is rectified by crystal diode D1. When receiving an AM signal, the audio modulating current will flow through the headset. Capacitor C2 bypasses any RF getting past the diode.

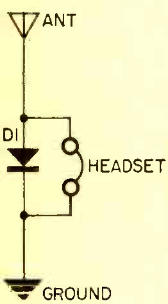
A parallel resonant tuning circuit is shown in Fig. 3. The circuit is tuned by adjusting variable capacitor C1. The length of the antenna affects the sensitivity and selectivity of the receiver, but has little effect on tuning.

**The Triode.** The sensitivity and audio output level can be made higher by replacing the crystal diode with a triode tube (V1) as shown in Fig. 4. This circuit is known as a *grid leak* detector. When no signal is being received, the bias on the control grid of V1 is zero unless grid leak resistor, R1, is of high value in which case a small negative bias voltage may exist due to space charge.

# TRF Receivers

When an RF signal is intercepted, grid bias is developed by the signal. During positive signal excursions the grid and cathode form a diode through which current flows causing capacitor C2 to become charged in the polarity shown in the diagram. When the RF signal swings negative, the charge in C2 is in series—aiding with the signal. Thus, the stronger the signal, the more the plate current is reduced by the negative voltage on the grid. The charge in C2 leaks off slowly through grid leak R, but is continually replenished as long as a signal is being received.

An AM signal is demodulated by the grid leak detector since the positive halves of the RF signal cycle have less effect on plate current than the negative halves. Capacitor C3 bypasses the remaining RF getting through the tube and the variations in amplitude of the negative half-cycles of the RF signal become audio signals. The grid leak detector actually consists of a shunt diode detector and an audio amplifier.



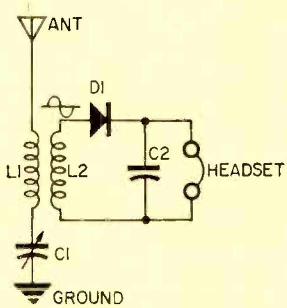




**Fig. 1. (left) Selectivity of basic TRF is low. Fig. 2. (right) More selective tunable circuit.**

The RF signal has the opposite effect on the plate detector shown in Fig. 5. Here the grid is biased highly negative by cathode resistor R which is bypassed for RF and AF signals by C2. The negative excursions of the RF signal cause only a small decrease in plate current since the grid is already biased to near cut-off. Positive signal excursions, on the other hand cause a sharp rise in plate current. Hence, the variations in amplitude of the positive RF half-cycles of an AM signal are transformed into an audio signal.

The circuit of an *infinite impedance* detector is given in Fig. 6. Here, the plate is essentially at RF ground potential since it is connected directly to the battery supply without a plate load. The audio signal is developed across cathode resistor R1 which is bypassed for RF, but not for AF, by C2. To prevent shunting of the DC bias voltage across R1, capacitor C3 is connected in series with the headset. C2 could be in the order of a few hundred micromicrofarads whereas C3 may be about 0.5 microfarad.

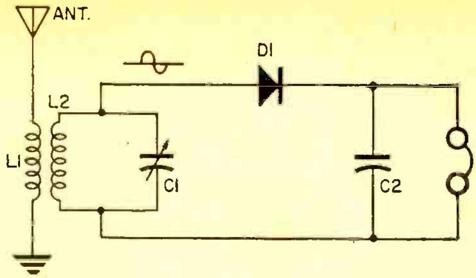



**Fig. 3. Parallel resonant tuning of this receiver is effected by adjusting capacitor C1.**

The most commonly used AM detector circuit, given in Fig. 7, employs a diode which may be a tube or semiconductor diode. Here the rectified RF signal (audio) flows through the headset with C2 acting as an RF bypass. Close examination of this circuit reveals that it is almost identical to the dwell circuit shown on Fig. 2.

In place of the headphones shown in all of the above diagrams, the audio signal may be developed across a resistor or reactor (audio choke) or primary winding of an audio transformer when an audio amplifier is to be connected to the detector output. In all of these diagrams a B battery is shown as the plate voltage source and the tube heater has been omitted for the sake of simplicity.

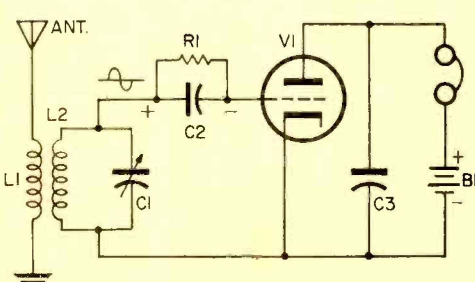



**Fig. 4. Triode tube replaced the crystal diode combining detection and audio amplification.**

The selectivity and sensitivity of the above circuits is relatively poor. Both can be improved by adding a tuned RF amplifier ahead of the detector. The audio level can be raised sufficiently to permit use of a loudspeaker by also adding one or more audio amplifiers as shown in Fig. 8.

**Oscillation.** Before screen grid tubes (tetrodes and pentodes) were developed, triodes were used in RF amplifier stages. Triodes are still used in special circuits such as grounded-grid and cascode amplifiers. When used in conventional RF amplifier circuits, such as the one shown in Fig. 9, the amplifier is apt to oscillate. This happens because of the feedback path between the plate and grid which form a low value capacitor, as indicated by Cgp in the diagram.

When tuning capacitors C1 and C2 are tuned so that their circuits are resonant at almost exactly the same frequency, the phase relationships between the grid and

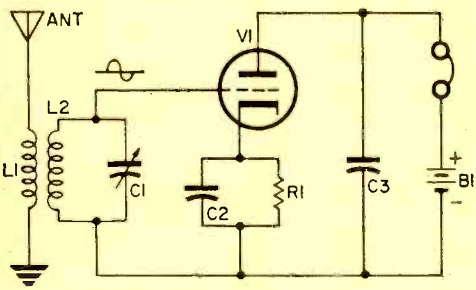



**Fig. 5. Detection of audio signal from RF carrier in this triode is termed plate detection.**

plate are such that *positive* feedback occurs (due to Cgp). The circuit acts like a tuned plate-tuned grid oscillator.

**The Neutrodyne.** This problem was overcome by the late Professor Hazeltine who invented the *neutrodyne* circuit shown in Fig. 10. Some of the signal developed across L3 at the output of first RF stage is fed back to the grid through neutralizing capacitor C4. The operation of the neutrodyne circuit relies on introducing a signal feedback from the bottom half of L3 and C4 to counterbalance the feedback effect caused by capacitor Cgp inside the triode. The signal tapped off the bottom of L3 is the exact opposite of that seen at the plate. Hence, when C4 is adjusted so that the signal supplied to the control grid of V1 is equal in magnitude to the signal supplied by

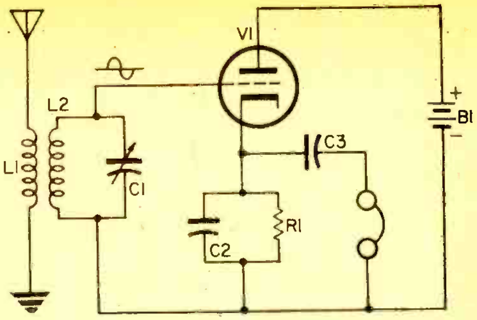



**Fig. 6. The audio signal in the infinite impedance detector is developed across resistor R1.**

internal capacitance Cgp, the signals cancel and the triode is said to be neutralized. Under these conditions the triode amplifier stage cannot oscillate.

It was Prof. Hazeltine's neutrodyne circuit that gave the radio industry its biggest boost and made it possible for Philco at that time to quickly become the world's largest radio manufacturer. Earlier, the neutrodyne circuit brought fame to Fada and other radio manufacturers.

The neutrodyne TRF receivers generally employed two tuned RF stages ahead of the detector. But, the introduction of the 222 and later the 24, 35 and 51 screen grid (tetrode) tubes spelled the end of the neutrodyne era. Still later, a suppressor grid was added to the screen grid tetrode and the pentode tube became king as an RF amplifier.

**Multi-element Tubes.** The effect of the screen grid is illustrated in Fig. 11. The screen grid is an element within a tube between the control grid and the plate, which is usually at a positive DC potential and bypassed to ground (through C4 in Fig. 11).

The screen grid essentially isolates the

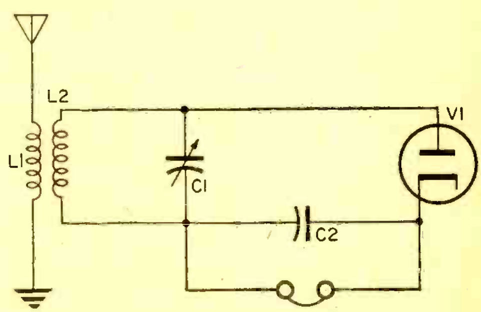



**Fig. 7. In this AM detector circuit, capacitor C2 functions as an RF bypass for the headset.**

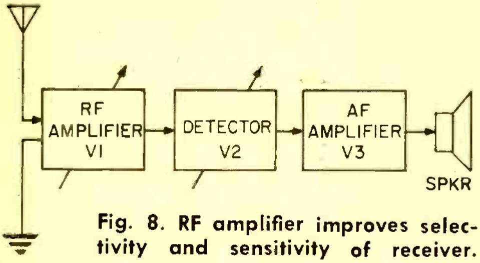


**Fig. 8. RF amplifier improves selectivity and sensitivity of receiver.**

plate from the control grid as far as capacitance is concerned, but allows electron flow. In the circuit given in Fig. 11, L2-C1 and L4-C2 may be tuned to the same frequency without causing the RF amplifier to oscillate.

The pentode provides much higher gain than a triode. Also, it is easier to control its gain. In Fig. 12, two possible gain controls are shown. Control grid bias voltage is controlled by R1 and screen grid voltage is controlled by R2. Both have a large effect on gain, but only one is used. Screen control is often used when a sharp cut-off pentode is employed. Cathode or other control grid bias control is used when a remote cut-off type pentode is employed.

**Typical TRF's.** The circuit of a typical TRF receiver of the type that was popular in the early 30's is shown in Fig. 13. It is similar to the circuit used in Peter Pan, Melotone, Remler and other popular radios of the depression era. These four-tube sets employed a tetrode or pentode tuned RF amplifier, a tetrode or pentode plate detector, a pentode AF power amplifier and a dual-diode full-wave power supply rectifier.

The radios of that era employed field coil type loudspeakers. In the diagram, L5 may be either a filter choke or the speaker field coil.

Volume is controlled by R2 which varies the control grid bias of the RF amplifier and the degree of shunting of the antenna coil (L1) by the potentiometer. The detector tube, V2, screen grid voltage is determined by the values of R4 and R5 and is fairly critical.

There is only one audio stage since the tetrode or pentode detector delivers enough audio signal to drive a pentode or beam audio power amplifier. For good, clean reception of local stations, the circuit of Fig. 13, is hard to beat even with the more sophisticated circuits of today. While it may not be as selective as a super heterodyne receiver, it is adequate in most areas and free from *birdies* and other ailments of superhets.

This circuit employs manual gain control. The gain of the RF amplifier is controlled by R2 which requires frequent resetting as determined by the RF level of the station being received. Automatic volume control (AVC) may be employed in TRF receivers, as shown in simplified schematic Fig. 14.

The level of the DC voltage developed across R1 and R2 in series depends upon the level of the incoming RF signal. Capacitor C6 and C7 are RF bypasses, and R1 is a part of the RF elimination filter. The audio signal is fed from volume control R2 through C8 to the audio amplifier.

The minimum bias at the two RF amplifier stages is determined by their respective

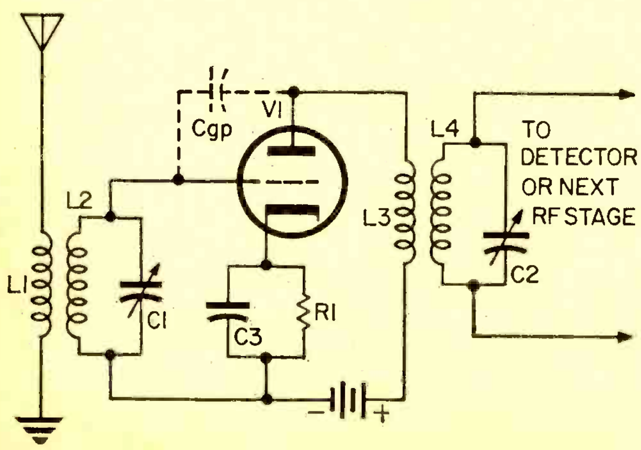


**Fig. 9. Feedback from plate to grid through the effective capacitance, Cgp, in this RF amplifier stage occurs easily and results in oscillation. The oscillation-producing positive feedback is actually desired in a tuned plate-tuned grid circuit.**

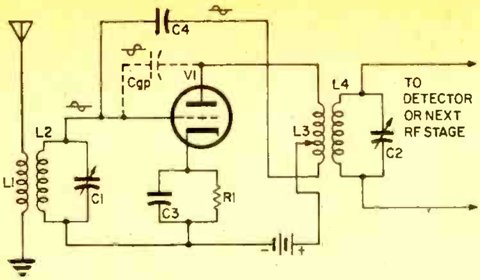



**Fig. 10. Cancelling feedback signal through Cgp with output sample prevents oscillation.**

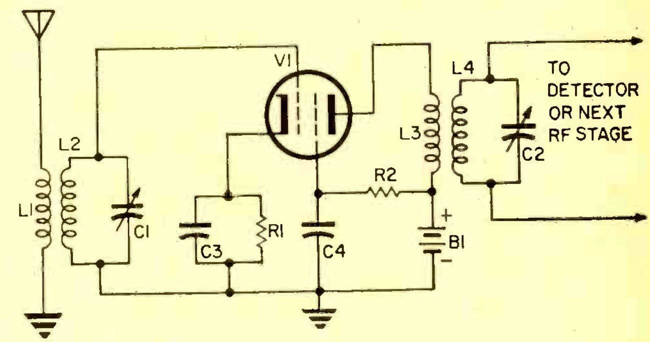



**Fig. 11. The addition of a screen grid in the tetrode isolates the plate from the control grid thereby preventing capacitance feedback and then oscillation.**

cathode resistors which are bypassed by capacitors for RF. Their tuned circuits are equipped with RF bypass capacitors (C2 and C4) which are large enough to not affect the tuning by C1 and C3 and, at the same time, to increase the AVC time constant so as to prevent too fast a change in AVC voltage.

The gain of the two RF amplifiers is automatically regulated. A strong RF signal causes a large negative DC voltage to be developed across R1 and R2 (in series) which is fed through R3 and R4 to the RF amplifier grids. This negative voltage, added to the cathode bias voltage decreases the plate current and the gain of the amplifier.

When tuned to a weaker signal, or if the signal fades, the gain of the RF amplifier is automatically increased because the AVC voltage is decreased. Under ideal conditions, the gain of the RF amplifiers is automatically regulated so as to produce the same audio output on weak or strong signals. In practice, this cannot always be achieved since some signals may be too low in level to produce adequate audio output, and some signals may be too strong, beyond the dynamic range of the AVC.

There are many variations of TRF circuits. In Fig. 15, for example, the RF amplifier plate circuit is tuned and the detector input circuit is untuned. Capacitor C5 permits grounding the rotor plates of variable tuning capacitor C2. The effect is essentially the same as when the RF amplifier plate coil is untuned and the following stage's grid coil is tuned.

The detector employs a *voltage doubler* circuit, which is shown here to illustrate various possibilities. It provides twice the output voltage (6 db) of a conventional diode detector. During the positive half-cycle of the RF signal, diode D1 conducts and C6 is charged. During the negative half-cycle, D1 does not conduct, but D2 does and C7 is

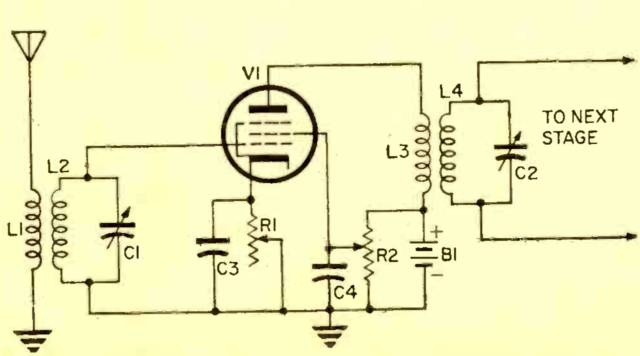



**Fig. 12. Addition of a third grid results in pentode which has improved gain over lesser element tubes, and easier control of gain. Choice of control gives remote or sharp cutoff.**

charged. Hence, the DC and audio signal voltages fed to the audio amplifier are equal to the sum of the voltages across C6 and C7.

In the circuits shown in Figs. 11 through 15, the detector and RF amplifier stages are all tuned to the frequency of the desired incoming signal. In early receivers, the tuning capacitors were indivdually tuned. Later, the tuning capacitors were mechanically ganged. Trimmer capacitors, which are usually connected across each tuning capacitor section have been omitted from the diagrams for the case of simplicity.

**Vintage.** It is not necessary to tune all stages. In early Sparton radio receivers, as shown in Fig. 16, there were several RF amplifier stages employing triodes. The amplifier was a wide band one, and selection of stations was accomplished by tuning a bandpass filter ahead of the RF amplifiers. Since the RF amplifier section was stagger-tuned, oscillation problems were eliminated. These receivers were among the best ever made.

Only the RF amplifier is tuned in the circuit shown in Fig. 17. The RF amplifier plate load is an RF choke or coil (L) which is resonant at a frequency lower than the tuning range of the receiver.

The antenna is connected directly to the grid of the first RF amplifier in Fig. 18. Potentiometer R1 serves as both the input circuit and volume control. The next stage (detector or second RF amplifier) is tuned.

A grounded grid RF amplifier circuit is shown in Fig. 19. The RF amplifier is tuned by the series resonant circuit L1-C1 and the detector is tuned by the parallel resonant circuit L4-C2. The grid of the RF amplifier triode is grounded, and the input signal is fed to the cathode. The bias is determined by R1 which is bypassed for RF by C3.

**Loops.** An external antenna system has been shown in all circuits so far. The input circuit (L1-L2-C1 in Fig. 14, for example) may be replaced by a loop antenna or ferrite loopstick (see your AM radio) to eliminate the need for an antenna or ground. The signal pick-up is not as great as that of an external antenna system and, for this reason, loop antennas are seldom used in TRF receivers. Superhets, on the other hand, are usually equipped with loops.

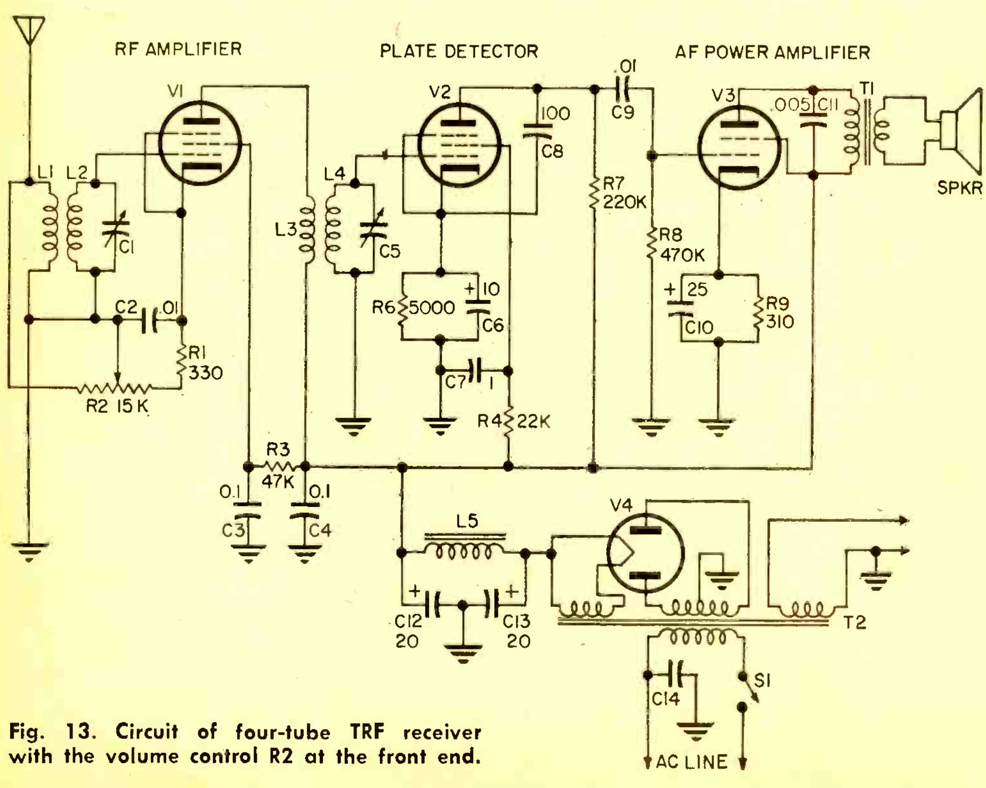



**Fig. 13. Circuit of four-tube TRF receiver with the volume control R2 at the front end.**

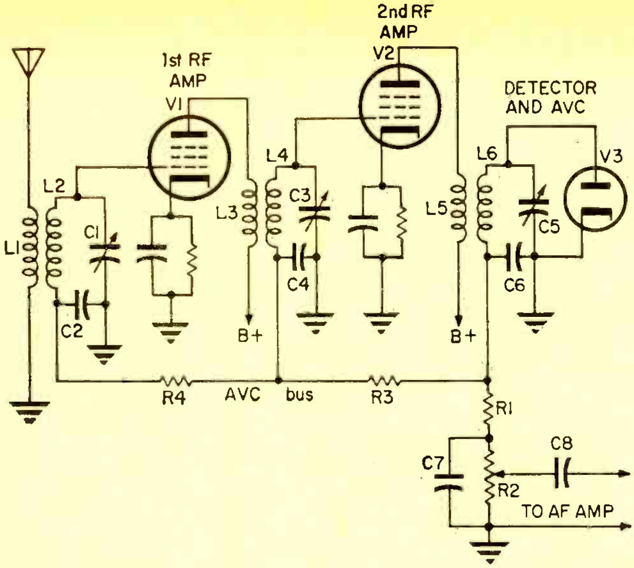



Fig. 14. Tuned radio frequency stage employing an automatic volume control circuit. The circuit maintains constant signal strength to AF amplifier despite strength of incoming RF.

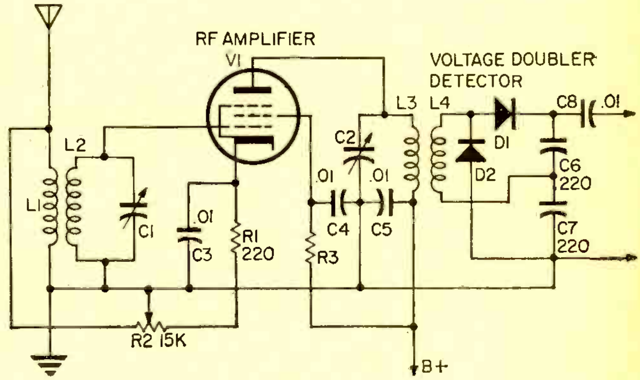
In receivers not equipped with loop antennas, an indoor or outdoor antenna is required. If the set is battery operated, a ground connection is also required. In AC-operated sets, the antenna system is grounded through the power line. A ground connection, however, may help reduce noise and increase sensitivity.

**Special Applications.** TRF sets may be designed for operation in the low frequency bands as well as in the broadcast and higher frequency bands. Early amateur and short wave broadcast receivers employed a TRF stage ahead of a regenerative detector. The TRF stage added selectivity and sensitivity and at the same time reduced radiation from the detector when it was set to oscillate for reception of code (cw) signals.

A very sensitive and relatively selective receiver for use at all frequencies from VLF (very low frequency) to VHF (very high frequency) consists of a TRF stage and a regenerative detector, as shown in Fig. 20. The audio amplifier is not shown.

The receiver is tuned to the frequency of the desired signal with C1 and C3. RF am-

Fig. 15. Detector of this TRF circuit also doubles the signal voltage; it detects both the negative and positive half-cycles of incoming signal. The two voltages are combined and then fed to the audio amplifier circuit.



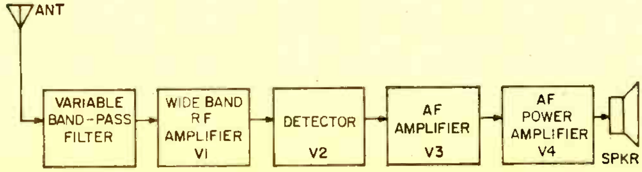




Fig. 16. In this receiver, the desired station frequency is tuned with the variable band-pass filter; the RF amplifier receiver stages are untuned.

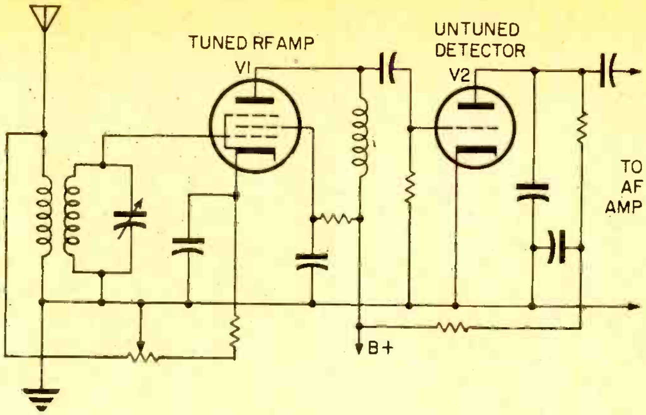



**Fig. 17. Another circuit illustrating operation without all stages tuned. Here only the RF amplifier need be tuned to select and detect the desired frequency.**

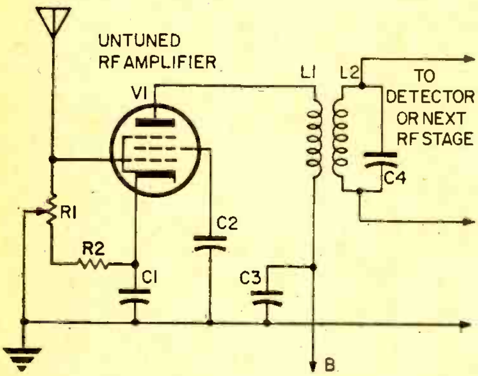



**Fig. 18. The RF amplifier of this circuit is untuned—the signal from the antenna is fed directly to the control grid of the pentode. But the detector stage is tuned, however.**

plifier gain (and volume) are controlled with R3 which varies RF amplifier bias. R2 prevents adjustment of R3 for zero bias, and R1 applies a positive potential to the cathode to prevent high maximum bias.

The RF signal from the plate to the detector is fed back *in phase* from L4 to L3. The amount of positive feed back (regeneration) is determined by the turns ratio of L4 to L3, the value of C5 and detector plate voltage, which is adjusted by R6.

To receive CW code signals R6 is advanced just beyond the point where the detector starts to oscillate. When the detector is oscillating, its own signal is *heterodynal* with the incoming signal and a beat note is heard which is equal in pitch to the sum or difference of the incoming signal frequency and the frequency at which the detector oscillates.

To receive AM voice signals and radio programs, R6 is set just below the point where oscillation starts. At this point, maximum sensitivity and selectivity are obtained. Selectivity is increased because of *negative resistance* effect which increases the "Q" of L3-C3.

By increasing the value of grid leak R5 and connecting it between the grid and plate, instead of grid and cathode shown, the detector can be made *superregenerative.* The detector switches in and out of oscillation at a rate determined by the time con-

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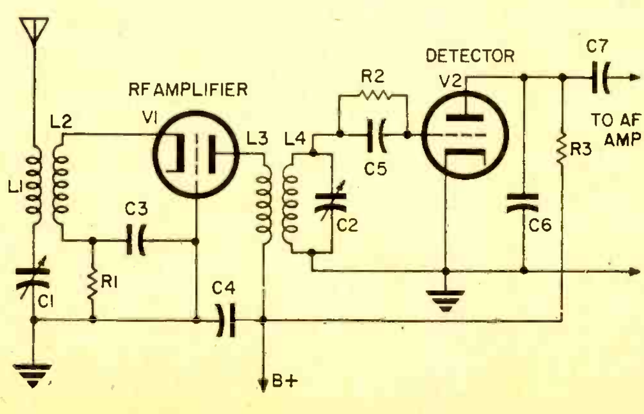



**Fig. 19. The grounded grid amplifier shown here is tuned by series combination of L1 and C1. The detector is tuned by parallel resonant circuit L4-C2.**

# SUPERHETERODYNE RECEIVERS

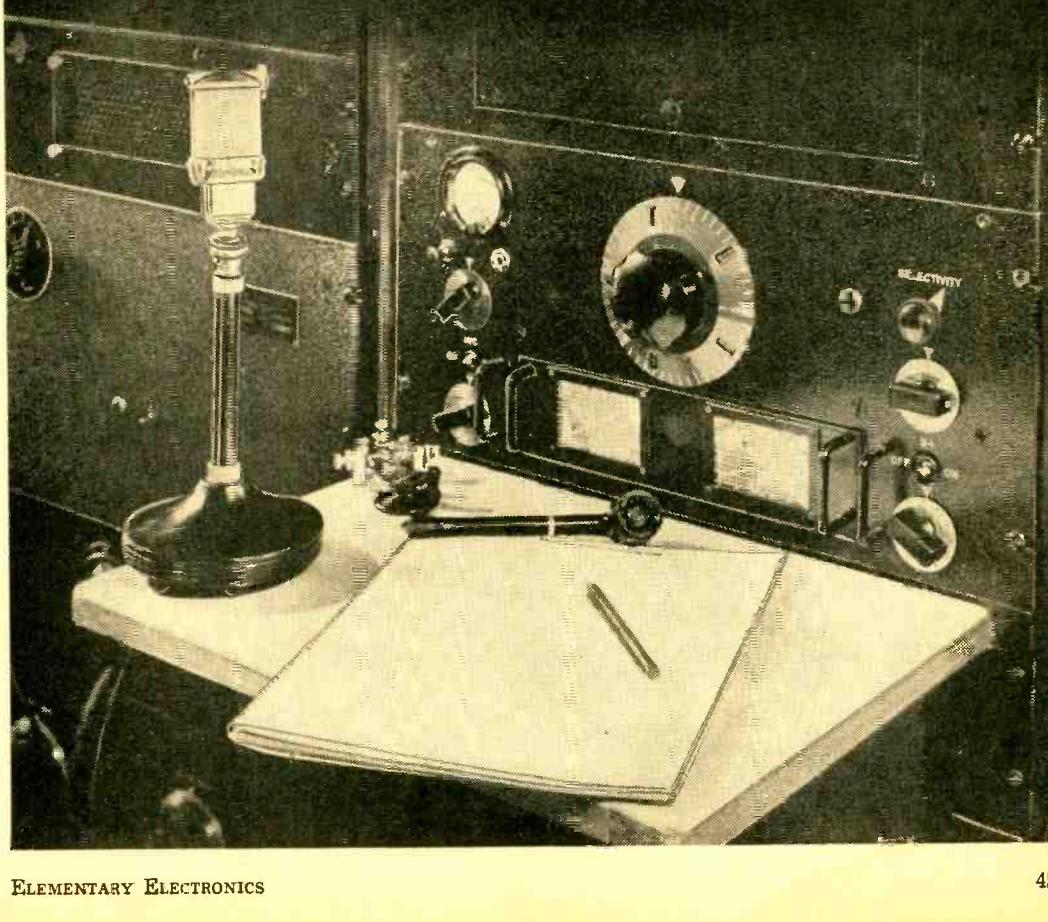
By Leo G. Sands

## The radio design for modern-day communications

The superheterodyne receiver is the most popular type of radio receiver in existence, by far. It makes possible the design of very compact receivers with great sensitivity and selectivity. Even pocket transistor radios employ the superheterodyne circuit.

It derives its name from *heterodyne*, a technique for mixing two signals at differing frequencies to produce a third frequency which is equal to the *sum* or *difference* of the two original frequencies.

A *heterodyne* receiver, as opposed to a superheterodyne, employs a *local* oscillator whose output signal is mixed with an incoming radio signal in a stage called a mixer, converter or detector. In a heterodyne receiver the resulting beat signal is usually at a frequency low enough to be heard, and is fed directly to a headset or an audio amplifier



# Superheterodynes

If the incoming radio signal (f1) fed to the receiver circuit shown in Fig. 1 is at 500 kc and the local heterodyne oscillator is tuned to 499 kc (f2), a 1000-cycle audio beat (f1−f2) note will be fed to the audio amplifier and will be heard through the loudspeaker. This makes it possible to hear the dots and dashes of a CW (code) signal in the form of a keyed audio tone. The beat note is equal to the *difference* between the local and intercepted signals. Their sum (f1 + f2) is equal to 999 kc, but this beat signal cannot be heard and is blocked by an RF bypass capacitor from entering the audio amplifier.

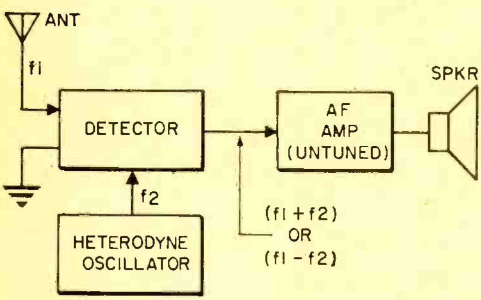



**Fig. 1. In the heterodyne receiver, detected signal is passed directly to audio amplifier.**

The pitch of the beat note can be varied by changing the frequency of the local oscillator. When both signals are at exactly the same frequency, a *zero beat* condition exists. The local oscillator may be tuned to a frequency higher or lower than the incoming radio signal. For example, when tuned to 501 kc, a 1000-cycle beat will be produced as will a 1001 kc beat which is rejected by the bypass filter.

**The Superhet.** A superheterodyne receiver employs one or more *frequency converters* or mixers. A frequency converter may be an *up-converter* whose output beat signal is higher in frequency than the incoming signal. Or, it may be a *down-converter* which produces a beat at a frequency lower that the incoming signal.

*Down-converters* are usually employed in superheterodyne receivers. If the incoming signal (f1) fed to the receiver circuit shown in Fig. 2 is a 1000 kc, for example, and the local oscillator is tuned to 1465 kc (f2),

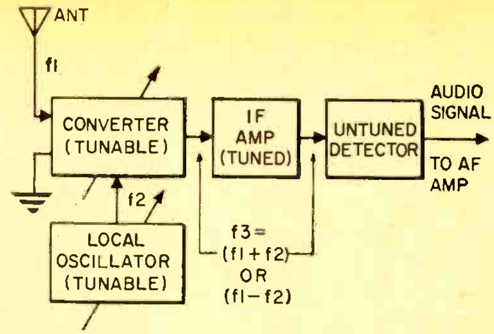



**Fig. 2. The superheterodyne receiver is characterized by its one or more IF amplifiers.**

beat signal (f2 − f1) will be produced at 465 kc and utilized. But the 2465 kc signal (f1+f2) is rejected by a tuned circuit at the output of the converter.

The desired 465-kc signal is the IF (intermediate frequency) signal which is fed through a fixed-tuned IF amplifier to the detector, sometimes called the *second detector,* which demodulates the signal and converts it to audio.

The converter input and local oscillator are usually tunable by means of a ganged tuning capacitor. This is shown in Fig. 2 as arrows through the blocks. There may or may not be a TRF (tuned radio frequency) stage ahead of the converter.

**First Detector.** The converter stage used to be called the *first detector* because it is a non-linear stage, whether it is an amplifier or a simple diode detector. Triode tubes are sometimes used as converters as shown in Fig. 3. The incoming signal (f1) is fed into L1 and is inductively coupled into L2 which is tuned by C1 to the frequency of the incoming signal.

The locally generated oscillator signal (f2) is inductively coupled, in this particular circuit, to L3 which is in series with the

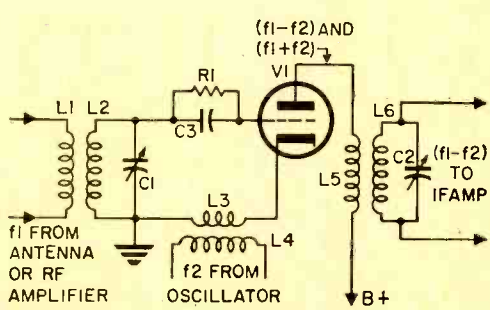
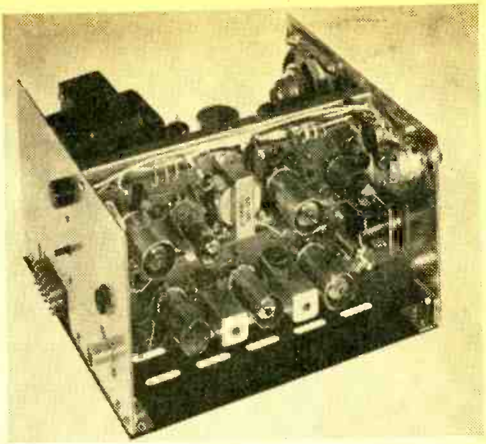
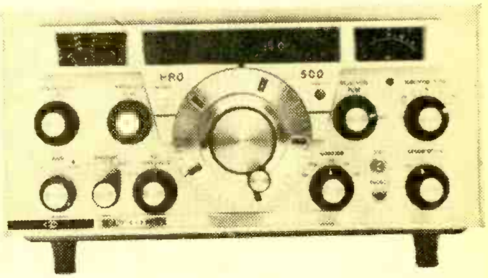
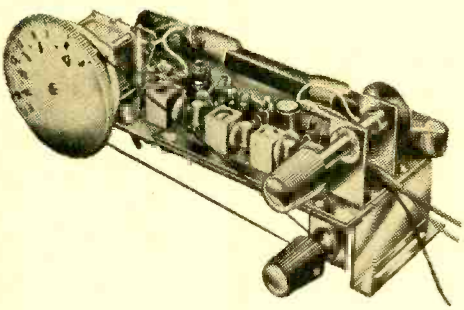



**Fig. 3. In this circuit, triode V1 is the converter where frequencies f1 and f2 are mixed.**





These photographs show an array of superheterodyne equipment that covers much of the radio spectrum, and several decades in the history of radio. Top left is a popular ham receiver of 1933 vintage—the National FB-7, a 7-tube superhet. Top right is a contemporary CB set—an International Crystal double conversion transmitter. Above left is a short-wave receiver of the early 1940's. Above is a modern high-quality ham receiver—the National HRO-500. At left is Lafayette transistorized broadcast and combined short-wave tuner.

cathode of the triode. Even if the junction of L2 and L3 is grounded, both signals are actually applied to the grid since the cathode is above RF ground potential. The oscillator circuit itself is not shown in the diagram.

**Pentode Converter.** The circuit of Fig. 4 is typical of a pentode converter stage. The incoming signal is inductively coupled from L1 to L2, which is tuned to the desired frequency by C1, and is fed to the control grid of pentode V1. The local oscillator signal is also fed to the pentode's grid through C8, a very low value capacitor.

A separate tube, triode V2, is used in the local oscillator circuit. It is tuned by C3 to a frequency that is higher than the incoming signal frequency, usually 465 kc higher in most AM broadcast receivers. Capacitor C4 in series with C3 is a series padder which reduces the total capacitance across L3 in order to make C1 and C3 track with each other, when mechanically ganged, at frequencies 465 kc apart. Sometimes, the tuning condenser gang employs a smaller section for the oscillator, in which case C4 may not be required.

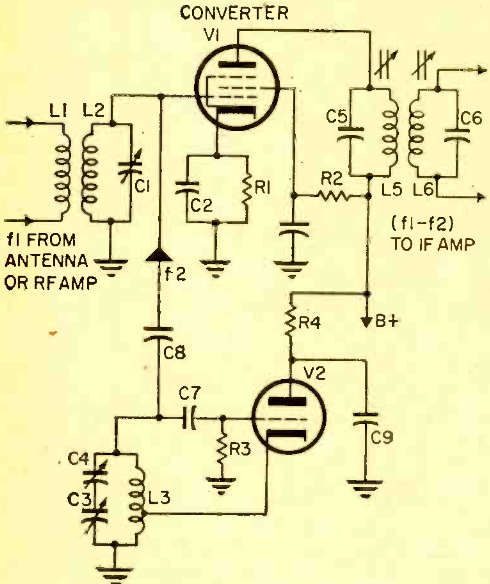



**Fig. 4. This converter stage utilizes pentode tube V1 and the local oscillator triode V2.**

The plate circuit of the converter is fed to an IF transformer (C5-L5/C6-L6) which is tuned to the 465 kc (f1-f2). This transformer is a filter which passes the 465 kc signal but rejects the *sum* beat signal (f1+f2) and the incoming and local oscillator signals which would otherwise be present.

Many receivers employ a single tube as a combination converter and local oscillator. The circuit of Fig. 5 employs a *pentagrid converter* tube. The grids are numbered—No. 1 is closest to the cathode, No. 2 second closest, etc. Grids 1 and 2 are employed by the oscillator, grid 2 functioning as the oscillator plate which is operated at a steady, high DC voltage.

The incoming signal is fed to grid 3 which is isolated from the plate by grid 4, a screen grid which is connected internally to grid 2. Grid 5 is the suppressor grid.

The local oscillator signal modulates the electron stream reaching the plate. The incoming signal applied to grid 3 also modulates the electron stream. Hence, plate current is modulated at the incoming signal frequency (f1) and the local oscillator frequency (f2). These signals plus sum and difference beat signals all would appear across the plate load (L4). But, because L4-C5 and L5-C6 are resonant at only one frequency, the difference frequency, only it is passed and the other are rejected.

The desired IF signal is then fed to one or more IF amplifier stages. Fig. 6 is the circuit of a portion of a typical AM broadcast receiver employing a loop antenna or ferrite core antenna, often called a loopstick.

**Working Together.** The incoming radio signal is picked up by the loop, which is tuned to the signal frequency, and is fed to grid 3 of the pentagrid converter tube (V1). If the signal frequency is 1000 kc, the local oscillator is tuned to 1465 kc and the resulting 465-kc IF signal is fed through an IF amplifier, V2, with tuned input and output transformers, to the detector.

The IF signal, when rectified by the detector diode, V3, produces a DC voltage across R1 and R2 in series, which is negative with respect to ground, and whose amplitude is proportional to signal voltage. The audio signal is also developed across R1 and R2 (C3 and C5 are RF bypasses) and is fed through C4 to the volume control whose output is connected to the audio frequency amplifier (not shown).

The audio signal across R1-R2 is filtered out by C5 and R3, and a pure DC voltage is developed across C6. This DC voltage, whose level varies with the strength of the incoming signal, is applied as a variable bias voltage to the grid of the IF amplifier tube through the secondary winding of T1, and to grid 3 of the converter through isolating resistor R4.

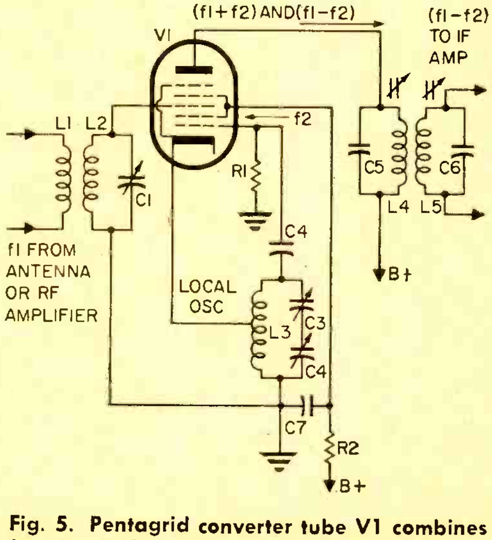



**Fig. 5. Pentagrid converter tube V1 combines functions of converter and local oscillator.**

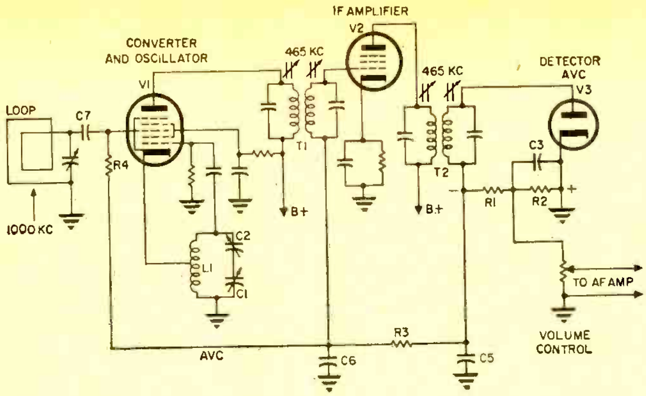



**Fig. 6. "Front end" of a standard AM broadcast receiver is shown here in schematic diagram. The circuit combines the individual elements that have been discussed: the converter and local oscillator, the IF amplifier, and the detector. But note the addition of the feedback circuit, marked AVC, which maintains automatic volume control of receiver.**

When there is no signal, this AVC (automatic volume control) voltage is near zero and the gain of the converter and IF amplifier tubes is maximum. When a signal is tuned in, the AVC voltage automatically controls the receiver gain so that the audio voltage across the volume control will not rise above a certain value. Hence, the audio signal level remains fairly constant whether the receiver is tuned to a weak or strong signal. Of course, very weak stations will not sound as loud as strong stations if the weak signals require more gain to produce normal audio output than the receiver's capability.

**Picking the IF.** Early superheterodyne receivers employed 175-kc IF amplifiers, some even lower. Today, most AM broadcast receivers employ 465 kc IF amplifiers. Some shortwave receivers have a 1600-kc IF amplifier and FM broadcast tuners and receivers employ a 10.7-mc IF amplifier.

A low IF is desirable since it is easier to get high gain and selectivity than at medium and high frequencies. It is necessary for the IF amplifier to pass the IF signal and its modulation sidebands to reject all other frequencies. At 175-kc, for example, when a 10-kc IF bandwidth is required, the IF transformers are required to pass signals as low as 170 kc and as high as 180 kc, and to attenuate signals above and below these frequencies. This 10-kc band represents a substantial amount with respect to the 175-kc center frequency. At 456 kc, a 10-kc band is small percentage-wise to the IF center frequency.

**Images.** The industry moved their IF amplifiers from 175 kc to higher frequencies in order to eliminate or at least reduce *image* signals. For example, when the receiver is tuned to a 100-kc signal and the local oscillator is tuned to 1175 kc to produce a 175-kc IF signal, a radio signal at 1350 Kc/s signal mixing with the 1175 kc local oscillator sig-

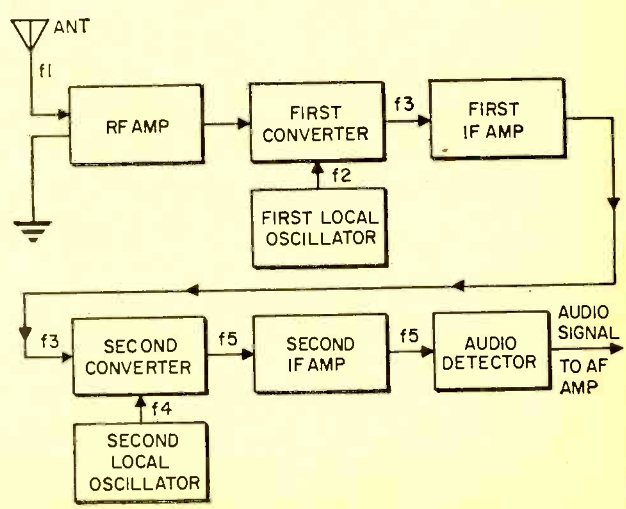



**Fig. 7. The dual-conversion superheterodyne receiver has two frequency converters. Two IF frequencies, f3 and f5, are produced, f5 being an even lower frequency than f3 to minimize possibility of image problems.**

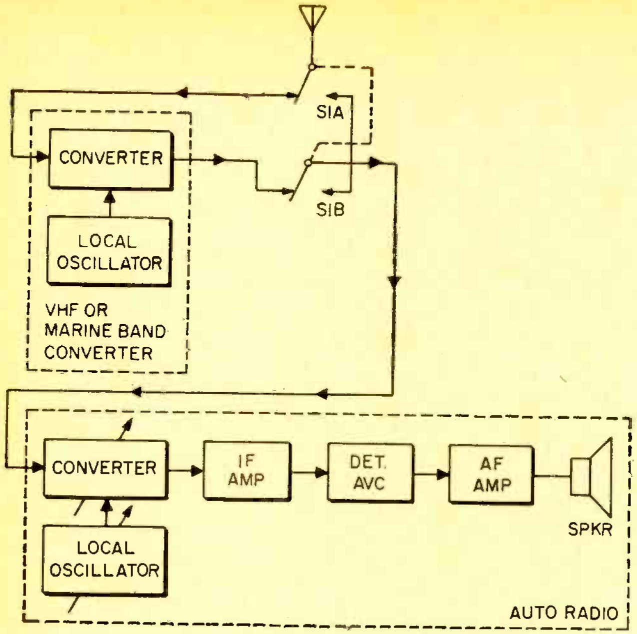



**Fig. 8. Dual-conversion in a superheterodyne has many applications. Here a short-wave or marine band converter is used with an automobile broadcast band radio to give listener choice of either band.**

nal will also produce a 175-kc IF signal. In order to eliminate image interference, it was necessary to employ one or more RF stages ahead of the converter. The tuned circuits of the RF stages and the converter, when tuned to 1000 Kc/s would greatly attenuate the 1350-Kc/s signal.

To make it practical to build receivers without an RF stage ahead of the converter, it was necessary to raise the IF to higher than 400 kc. The image, when the receiver is tuned to 100 kc (local oscillator to 1465 kc), is at 1930 kc, out of the broadcast band. Since the image is 930 kc away from the frequency of the desired 1000-kc signal, the simple tuned circuit at the input of the converter is usually adequate to reject image interference. Even higher frequency IF amplifiers are used in receivers that can be tuned to the high frequency and very high frequency bands.

**Superhet Advantages.** The main advantages of superheterodyne receivers include (1) the requirement for a minimum of tunable circuits (usually oscillator and converter), (2) the ability to get gain and selectivity at relatively low frequencies where they are easier to achieve, and (3) more uniform gain throughout the tuning range because most of the gain is achieved in the fixed-tuned IF amplifier.

**Dual Conversion.** Some so-called all-wave amateur and shortwave receivers employ dual-conversion superheterodyne circuits, as do many citizens band and commercial FM mobile receivers. As shown in Fig. 7, a dual-conversion superheterodyne has two frequency converters. The signal frequency is down-converted twice. For example, in a CB receiver tuned to 27.125 mc (f1) the IF beat at the output of the first converter is at 1650 kc (f3) when the first local oscillator is tuned to 26.96 mc (f2).

The 1650 kc IF signal is fed directly or through a 1650-kc IF amplifier to the second converter. Here the 1650 kc (f3) signal is mixed with a 1387.5 kc (or 1912.5 kc) second local oscillator signal (f4) to produce a 262.5 kc second IF signal (f5). This signal is amplified by one or more IF stages and then fed to the audio detector. This technique further reduces the image problem and allows getting the required gain and selectivity at quite a low frequency.

In CB receivers, the first local oscillator may be tunable and the RF amplifier (if there is one) and converter input may be broad-banded to cover the entire citizens band. Or, the second local oscillator may be tunable over a 290 kc spread and the first local oscillator may be crystal controlled.

**Specialized Circuits.** In fixed-tuned FM communications receivers, both local oscillators are usually crystal controlled. Some even employ triple-conversion superhetero-

*(Continued on page 129)*

# TUNING UP THE ALL AMERICAN 5

***Superiority of the 5-tube superhet resulted in the obsolescence of the old TRF, but a superhet must still be tuned!***

**By Mannie Horowitz**

**Modern** radio as we know it today, is due to one great invention—namely the superheterodyne receiver. Sure people used radios before the circuit was widely adapted. The multi-dial TRF (tuned radio frequency) set was quite popular in the '20's —especially if you could afford one. However, commercial five tube radios as we know them today, originated with the low cost superheterodyne circuit. This circuit has proven itself so fine and effective that it has been adopted for use in practically every FM receiver as well as for the popular five-tube, AM radios flooding this country.

Before proceeding with the discussion of the superheterodyne receiver, it is convenient to review the old fashioned TRF type of unit.

**The TRF Receiver.** The radio signal transmitted by the radio station, is intercepted by the antenna and is induced into a circuit consisting of an inductance and a capacitor. A circuit consisting of these two components connected as shown in Fig. 1, is known as a resonant circuit. A resonating circuit selects the desired radio signal while rejecting all other stations.

The sizes of the inductance and capacity in the circuit determine just which station the circuit is tuned to. One of these components is made to a fixed value while the other is variable; the value of one of these components can be changed at will by rotating a knob on the front panel. By changing the value of either component, different radio stations can be selected. It has been accepted pretty much as a standard throughout the industry that the variable will be the capacitor rather than the inductance. This convention has been used in Fig. 1, as can be seen by the arrow through the plates of the capacitor, indicating a variable item.

The desired radio signal which has been selected by the first resonant circuit, is amplified by a transistor or vacuum tube radio frequency (RF) amplifier. Following this amplifier is a second resonant circuit which must also be tuned to the frequency of the desired radio signal. This signal is in turn amplified by a second RF amplifier, which is followed by a third resonant circuit to be tuned to the same RF frequency.

It should be recalled that all of these circuits were tuned by individual dials on the front panel of the radio. Actually, the mechanics could have been arranged so that one knob could operate all capacitors simultaneously. This is being done in the modern superheterodyne. It was not done here because all circuits must resonate perfectly at the proper frequency for the radio to work properly. The tracking of all three capacitors must be perfect. In the superheterodyne circuit, this requirement is not as stringent, although the condition is highly desirable.

Of course, the question arises, why did they need more than one resonant circuit to receive the station properly. Actually, the more resonant circuits tuned to the same frequency, the better the rejection of stations broadcasting at adjacent frequencies. This principle has been carried over to the superheterodyne receiver where more than one intermediate frequency (IF) transformer is used.

Continuing to trace the path of the signal in Fig. 1, the signal is detected after the final resonant circuit. Here, the audible signal is separated from the radio frequency signal which carried this audio signal from the radio station through the RF stages of the receiver. The radio frequency is then discarded. The audio intelligence is amplified by audio voltage and power amplifiers. These power amplifiers are used to activate the speaker. The stages from the detector through the power amplifier and speaker may be identical to those found in the superheterodyne receiver.

**The Superheterodyne.** Keeping in mind the description of the TRF receiver, the block diagram of the superheterodyne does not look like a radical change. As a matter of fact—it is *not* a radical change, only the results are far superior.

As was the case with the TRF receiver, the RF signal is selected by varying the capacitor in the resonant circuit. This signal is fed to the first tube, known as the mixer, converter, first detector, or anything else you may wish to call it. Along with this RF signal, a second signal, which is generated in the receiver, is fed to the mixer. The frequency of the signal generated by this local oscillator in the receiver, is 455 kc *above* the frequency of the radio station. Thus, if the radio station broadcasts on a frequency of 1100 kc, the oscillator frequency is set to 1100 + 455 or 1555 kc. If the radio station broadcasts on a frequency of 880 kc, the frequency of the oscillator is set to 880 + 455 or 1335 kc. The frequency generated by the local oscillator is varied by a capacitor in the oscillator circuit, as shown in Fig. 2.

It is quite simple to accomplish the variation of the oscillator frequency with the variation of the frequency of the resonant circuit in the RF section. The capacitors which tune the oscillator and the RF signal are actuated by one knob. Thus, when a specific station is selected by the RF section

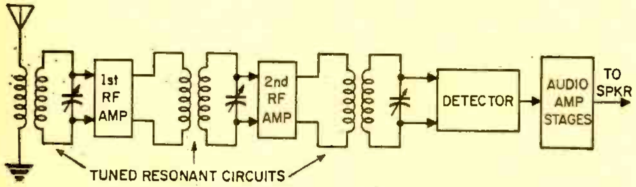



**Fig. 1. Each stage of the TRF receiver is tuned individually to ensure the selectivity of the receiver. After RF stages, signal is detected and amplified.**

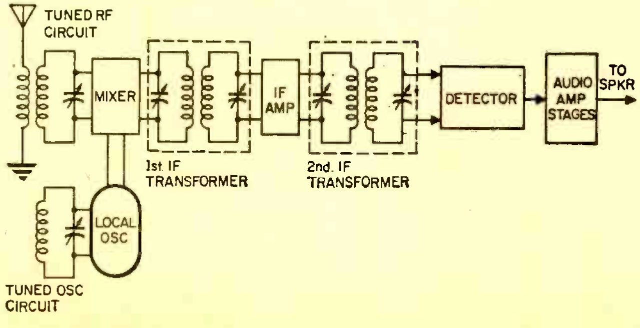
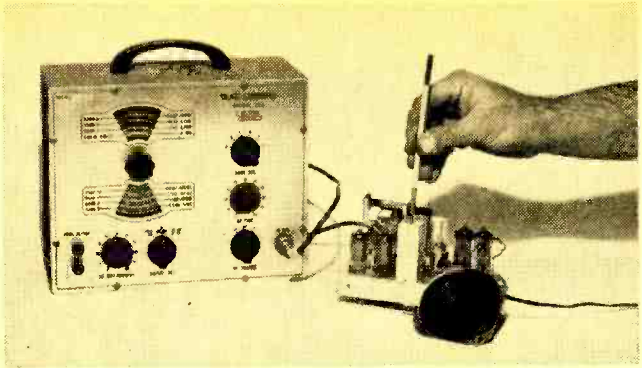



**Fig. 2. In the superheterodyne receiver, the incoming RF signal is reduced to an intermediate frequency in the mixer.**



With the signal generator set to internal modulation, good alignment is achieved by peaking the IF amplifiers for maximum signal output heard.

of the capacitor, the corresponding oscillator frequency is selected by the oscillator section of the capacitor.

The two signals are combined in the mixer stage. The output from this stage is the 455 kc difference between the two signals. The 455 kc difference in frequency is maintained between the oscillator and radio station; thus the difference frequency is available for all radio stations over the tuning range. It should be noted that the audio signal, which was received by the antenna as intelligence riding on top of the RF signal, is now transferred to the 455 kc signal. It rides on top of this 455 kc IF or *intermediate frequency* signal.

**IF Amplifiers.** This 455 kc signal must now be amplified. The 455 kc is carefully selected by two IF transformers. Between these two transformers is a stage of IF gain involving a vacuum tube or transistor. This is not unlike the tuned RF stage in Fig. 1, except here, only one frequency must be selected and only one frequency must be amplified. This can be done most efficiently.

In the remainder of the unit, the IF signal is detected to separate the audio from the IF carrier, the IF is discarded, the audio is amplified, and sent on to the speaker.

Two questions remain unanswered in this discussion. First—if requirements were too critical to couple all tuning capacitors to one tuning knob in the TRF receiver, why was it possible to couple the two capacitors in the superhet?

The answer becomes obvious when it is understood that the oscillator is of paramount importance in the operation of the complete superheterodyne radio. Whatever frequency was selected by the input, only the frequency that was 455 kc different from that of the oscillator, would pass through the circuit. If even a slight amount of RF were received, it would be sufficient to beat with the oscillator to pass through the IF stages. The RF stage is not tuned so sharply as to reject adjacent channels completely. Thus some signal from adjacent channels would be received, even though the circuit was tuned to resonate at some other frequency.

If the RF resonant circuit were improperly tuned, the signal passing through the IF stages would not be the signal to which the RF were tuned. A signal which was somewhat weaker than the resonant frequency, but 455 kc different from that of the oscillator, would proceed through the IF's.

The IF stages in conjunction with the oscillator are the most important factors in narrowing the band to reject unwanted signals and select desired stations. Of course, good tracking between the oscillator and RF is desirable and would lead to optimum performance. In general, this tracking between the two sections of the variable capacitor is fairly good; but it would not be good enough for the TRF type receivers.

The result of all this conversion and IF amplification results in a more sensitive receiver which tunes better, with a higher degree of undesirable signal rejection than does the TRF receiver.

The second question is why is 455 kc used as the IF frequency.

Old timers in the field, and many of us younger folk under 85, remember that old radios used 175 kc as the intermediate frequency.

Why the choice of any specific IF frequency, is difficult to determine. It seems that 450 kc or 500 kc would be a more logical choice. Is there less interference or

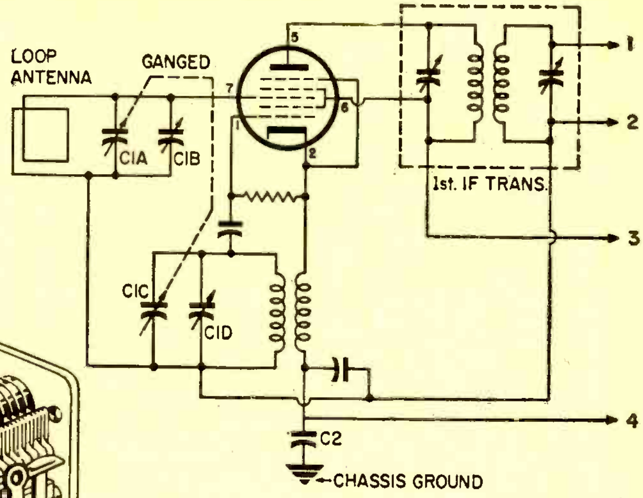



Fig. 3. Schematic diagram of superhet converter-oscillator shows the pentagrid converter.

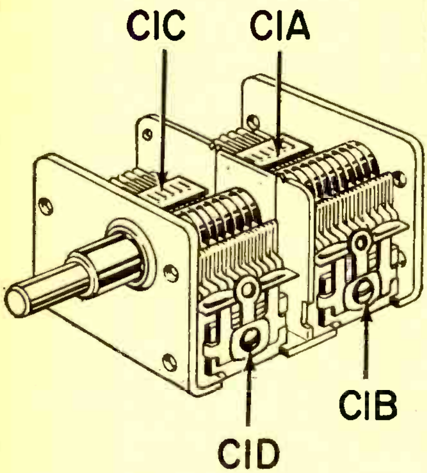



Fig. 4. Ganged tuning capacitor C1A-C1C combines oscillator-RF tuning on one control.

better sensitivity using 455 kc? Or is it just a choice someone made and the number happened to stick? Whatever the reason, the industry has accepted this as the standard. We have no choice but to use this figure when aligning a radio.

**Alignment Requirements.** Although no outline of exact procedures has been described, the above discussion of the superheterodyne radio indicates the alignment requirements. There are two precise factors which must be satisfied.

*First,* the IF transformers must be aligned so that they will pass the 455 kc IF frequency while rejecting all other signals.

*Second,* the variable capacitor must be adjusted so that the difference in frequency between the RF signal and oscillator is 455 kc over the entire broadcast band.

Exact procedures using a signal generator and an output meter will be discussed below. However, before this is done, it would be helpful to discuss the circuit of a typical superheterodyne receiver. We will consider the receiver one stage at a time. If you would hook-up the leads (with arrowheads) represented by identical numbers in two successive stages (or two successive schematic figures), you have the schematic diagram of a complete superheterodyne receiver.

**Typical 5-Tube Superhet.** The first tube of the superhet (see Fig. 3) serves several functions. First, it is the oscillator—pins 1 and 2. Then, it receives the RF signal at pin 7. Finally, the two signals mix through the maze of grids to give the final IF frequency —455 kc at the plate. The first IF transformer is tuned to this 455 kc. Other RF frequencies that happen to get to the plate circuit are bypassed to ground via the power supply by the action of the 1st IF transformer.

Because these receivers are quite sensitive, the RF signal does not have to be picked up by an antenna on the roof. Instead, a loop antenna at the receiver is usually used. This may consist of several turns of wire on a flat piece of cardboard, or several turns of wire on a ferrite rod. The ferrite material is composed of iron and other metallic oxides combined with ceramic material for rigidity. This ferrite rod is also known as a loopstick.

The loop antenna works in conjunction with capacitor C1A (see Fig. 4) to form a resonant circuit to tune to the radio station. A small variable mica capacitor, C1B, is usually mounted on C1A and connected in parallel with it by the manufacturer of the capacitor. This C1B is used in the alignment procedure. It is known as a trimmer capacitor and is used to trim the combined values of C1A and C1B so that it will resonate at the proper frequency with the loop antenna coil, and at the proper setting of the tuning dial.

The oscillator coil, in junction with C1C and C1D form the resonant circuit to determine the frequency which the oscillator will generate. Capacitor C1C (see Fig. 4) is the main tuning capacitor for the oscillator, and C1D is the trimmer, arranged very much like the combination discussed above for C1A and C1B in the RF section.

Capacitors C1A and C1C are attached to one shaft. One knob is used to turn both capacitors simultaneously. Screwdriver adjustment screws are set in the variable mica capacitors which are mounted on its respective large air capacitor.

You can usually tell which section of the capacitor refers to the oscillator and which to the RF circuit. The oscillator resonates at a higher frequency than does the RF circuit. Therefore the oscillator section usually has less or smaller plates than does the RF section. This is very much like musical instruments where higher pitched notes come from smaller instruments.

In Fig. 5, a simple IF amplifier stage using the 12BA6 and a second IF transformer, is shown. These are used to amplify the signal from the converter and first IF transformer and provide better selection of the IF frequency. These, in turn, are connected to the detector diodes in the 12AV6, the triode voltage amplifier in the 12AV6 and finally the power amplifier 50C5 which drives the speaker. All this is shown in Fig. 6.

The AC-DC power supply used to provide the necessary DC voltages to operate the radio circuit, is shown in Fig. 7, using a 35W4. Some radios used selenium or silicon rectifiers instead of a tube.

The various interconnections between sections are self-evident. Lead 1 is the link connecting the output from the IF transformer in Fig. 3 to the input of the IF amplifier tube in Fig. 5. Lead 3 in Fig. 3, 5, 6 and 7 is used to interconnect the B+ supply to all stages. Lead 4 in these figures is the common B− ground.

Lead 5 in Fig. 5 and 6 connect the second IF transformer to the detector, while lead 6 connects the audio to the volume control through a resistor.

**Introducing AVC.** Only lead 2 requires some additional discussion. This lead is used to conduct part of the detected signal back, as DC, to the earlier stages. This DC controls the gain of these stages. On strong signals, the gain of the IF and mixer amplifiers is reduced due to this DC. Thus, this lead completes an Automatic Volume Control (AVC) circuit. It sort of equalizes the strength of the final output signal for all stations. In alignment procedures, AVC action is undesirable, for it limits variations in gain at the output. During alignment, the test signal levels are kept low so that AVC action will be negligible.

One other factor should be observed in this circuit. The chassis is not used as a ground for the B−. Because B− is connected to the AC line, grounding the chassis to B− and hence the AC line, can be hazardous. To keep the chassis from floating, it is connected to B− ground through a small capacitor. This is shown as C2 in Fig. 3.

**Aligning Instruments.** Two instruments are necessary in this procedure. One is to be used as a signal source. The second is to be used to measure the output.

In the alignment procedure, three signals should be used. An audio signal should be fed to the audio amplifier section of the receiver (Fig. 6) to be certain that it is operating.

Next, a 455 kc signal modulated by an audio tone should be fed to the IF stages. The IF stages are adjusted for maximum output by monitoring the audio signal strength at the speaker.

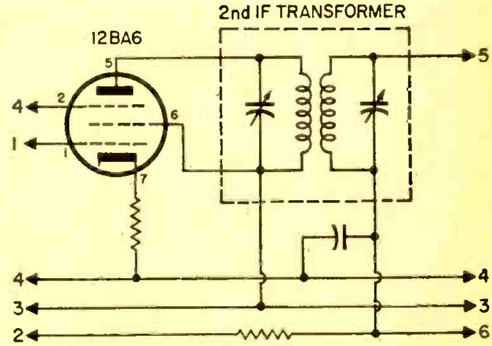



**Fig. 5. IF amplifier tube 12BA6 boosts signal; second IF transformer increases selectivity.**

Finally, two modulated RF signals are required to permit adjustment of the RF and oscillator circuits. One RF signal must be at the high end of the band and the other RF signal must be at the low end of the band.

Several signal generators are available that are capable of producing all these signals. They are shown in the photograph in Fig. 8. The switch positions given in the following text are for the EICO 324 unit which is typical of the units available.

The audio output can be gotten from the two jacks at the lower left hand corner of the unit. The Signal Selector knob is to be set at the "Int. Mod/AF Out" position to get an internally modulated audio output. The "AF Mod/Output" control is used to adjust the amplitude or strength of the modulated audio signal output from the generator. None of the other controls have any effect on the audio. They are concerned only with the RF signal.

The connector at the lower right hand corner of the unit is used for the RF and IF output. The Signal Selector knob is set at its previous position for a modulated output signal. The frequency is selected by use of the Band Selector switch and the rotary frequency control knob. Thus if 455 kc is required, the Band Selector is set at "B," for this band covers the range from 400 kc to 1.2 mc (marked near the tuning scales). The tuning knob is then rotated until 455 kc appears under the pointer in the window. A similar procedure must be followed for any RF frequency that may be required.

The amount of RF signal output is con-

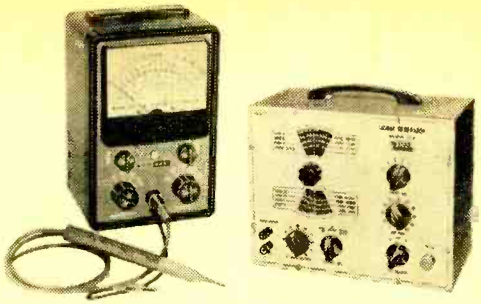


**Fig. 8. VTVM and signal generator are all you need to align superheterodyne receivers.**

trolled by the RF Course and RF Fine controls. These are usually kept near minimum during the alignment procedure.

Finally, the output from the radio must be monitored in some way or other to perform a proper alignment. The low voltage AC scale on any multimeter can be used to measure the output voltage.

If no meter is available to monitor the output, the signal level may be checked audibly by listening to the speaker and judging the levels.

**The Test Setup.** When the receiver, generator, and meter are interconnected, details and precautions should be carefully observed.

The meter should be connected to the speaker leads in Fig. 6. If one of the speaker leads is connected to a chassis of B− ground, connect the common lead from the meter to this point. If you use the instrument illustrated, it is the lead with the alligator clip.

Connect the AC probe to the remaining lead to the speaker. If the speaker has no grounded leads, the meter may be connected in either direction. If you use a meter which does not have to be connected to the AC power supply, such as a VOM, the leads

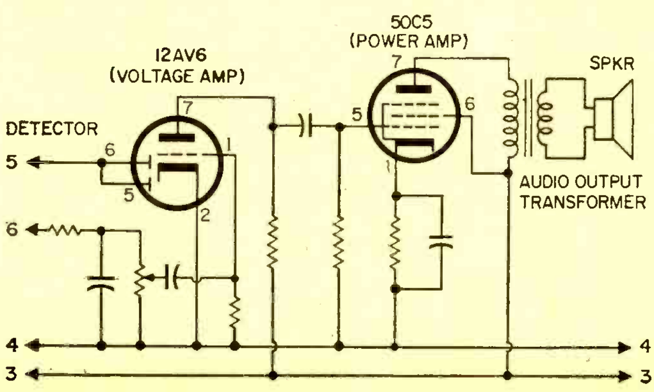
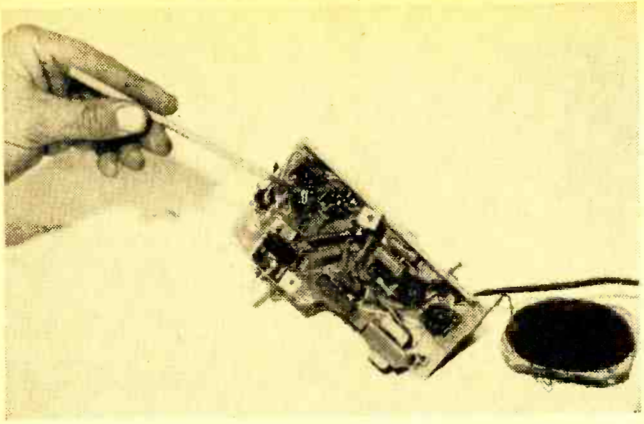



**Fig. 6. The audio amplifier section of the receiver combines detection and voltage amplification in the 12AC6 tube, and power amplification in 50C5.**



Make sure you have identified all components before aligning receiver. On some receivers, the oscillator coil looks just like the IF cans.

may be connected in either direction to the speaker.

Now set the Function switch on your meter so that it will read AC. Set the range switch to the lowest range above 1 volt. The output meter is now set up for the entire alignment procedure.

The common from the signal generator must be connected to the B− ground. During the alignment procedure, the signal will be injected from the Audio and RF outputs to various points in the radio. Just where to inject the signal will be discussed in the procedure methods.

Several precautions must be observed when making this setup.

☐ ☐ **1.** Make all connections to the receiver when it is turned off.

☐ ☐ **2.** Excess hum during test may be reduced by reversing the position of the AC power plug in its socket.

☐ ☐ **3.** Never connect an external ground (radiator, water pipe, etc.) to any point on the receiver.

☐ ☐ **4.** In conjunction with caution #3, never place the chassis on a metal bench, steam heat radiator, or any grounded object. If you must use a metal bench, be certain that the power plug is not in the socket or that there is some insulating material between the receiver with the instruments and the table. A large piece of cardboard will do. To avoid shock, do not touch the metal bench and the receiver or instruments simultaneously.

☐ ☐ **5.** To avoid shock when aligning the unit, do not touch any grounded electrical conductors.

☐ ☐ **6.** Use insulated or special aligning tools so that the alignment will not change when you remove the tool from the adjustment screws. A small insulated metal screwdriver may be used.

With this in mind, we can now proceed with the actual alignment procedure.

**Aligning the IF's.** Before touching the IF cans, you must be certain that the audio section is working properly. Connect the top (hot) lead from the audio output of the generator to the hot side of the volume control. This is the top, ungrounded end of the control in Fig. 6. Turn the volume control on the radio and the gain control on the generator to give the maximum output. Now, turn the output level control on your generator down until the sound comes through clean and undistorted to the ear. Note the voltage. During the remainder of the procedure, never let this meter read more than ½ this voltage. If it should rise above this value, decrease the output from the generator with the appropriate control. Always leave the level control on the radio set at its maximum.

Now set the generator to produce a modulated 455 kc signal. Adjust the modulation control to less than 100% modulation. This is esay with most generators, since they are either not capable of this much modulation or use fixed modulation with no front panel controls.

Connect the RF output from the generator, through a .01 mf. capacitor, to the grid of the tube preceding the final IF transformer. In Fig. 5, it would be pin 1 of the 12BA6. Adjust the trimmers in the final IF transformer for the maximum output. Keep the oscillator output low enough so that the maximum desirable output voltage level, discussed above, will not be exceeded.

Now, connect the same probe to the RF grid of the converter stage. In Fig. 3, it is pin 7 of the 12BE6. Because of impedance conditions, the level of the output from the generator will probably have to be increased to get a reading on the meter. If no reading can still be made, it will be necessary to temporarily disconnect the tuned RF circuit. This tuned circuit consists of C1A, C1B and the loop antenna in Fig. 3. Now adjust the trimmers in the first IF transformer for the maximum output. Be certain to reconnect RF circuit after alignment is complete.

**RF Alignment.** The big problem with RF alignment is to find a convenient point at which to inject the RF signal.

If there is an antenna terminal, connect the output from the generator to it, through a capacitor. If there is no antenna terminal, as is the usual case, wind several turns of wire into a small coil or "hank." The size is only important in that it should be convenient to place it a few inches away from the flat loop or loopstick antenna, without shifting its position relative to the antenna. A small hank of four loops or turns of ordinary insulated hook-up wire wound in circles of about 3 inches in diameter will do nicely for this coil. The various turns can be held together at several points with masking tape. The masking tape can be used to hold it near the antenna during alignment.

If you made the RF loop discussed, disconnect both the RF and AF generator leads from the chassis or B− ground. Connect the two leads from the hook-up wire loop to the RF leads from the generator. Should this loop stop the generator from oscillating (as noted by no output in the receiver) more turns will be required. Just how many turns can be found by trial and error.

If there is an antenna terminal on the receiver, do not disconnect the generator from ground, but connect the RF lead through a 200 mf. capacitor to the antenna terminal.

Feed a 1400 kc modulated signal to the receiver. Set the dial on the receiver to 1400 kc. Adjust the oscillator trimmer condenser, C1D, for the maximum output.

Now feed a 600 kc modulated signal to the receiver and set the dial on the radio to 600 kc. Adjust the oscillator padder condenser,* if any, for maximum output. If there is no padder condenser, there is usually a screwdriver adjustable slug in the oscillator coil. Adjust this for maximum

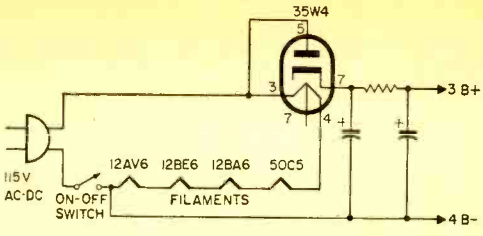



**Fig. 7. The power supply that provides the DC voltages for receiver utilizes 35W4 diode tube in filtered half-wave rectifier circuit.**

output. If there is neither a padder condenser nor an adjustable slug in the coil, skip this step.

Next, recheck the 1400 kc adjustment. Repeat both adjustments (the one at 1400 kc and the one at 600 kc) until you get the maximum output and best tracking at the two frequencies.

Now that the oscillator section has been adjusted, the RF circuit must be adjusted. Once again, feed a 1400 kc modulated signal to the receiver. Tune the radio to 1400 kc. Adjust the RF trimmer condenser (C1B in Fig. 3) for maximum output.

Next, feed the 600 kc signal to the receiver and set the dial to 600 kc. Adjust the padder condenser or slug in the antenna coil, if either exists. In some units, it is possible to adjust the position of the coin on the loopstick for maximum output signal. In other units, where no padder facilities exist, the trimmer must be adjusted to give the best maximum output compromise at 600 kc and 1400 kc.

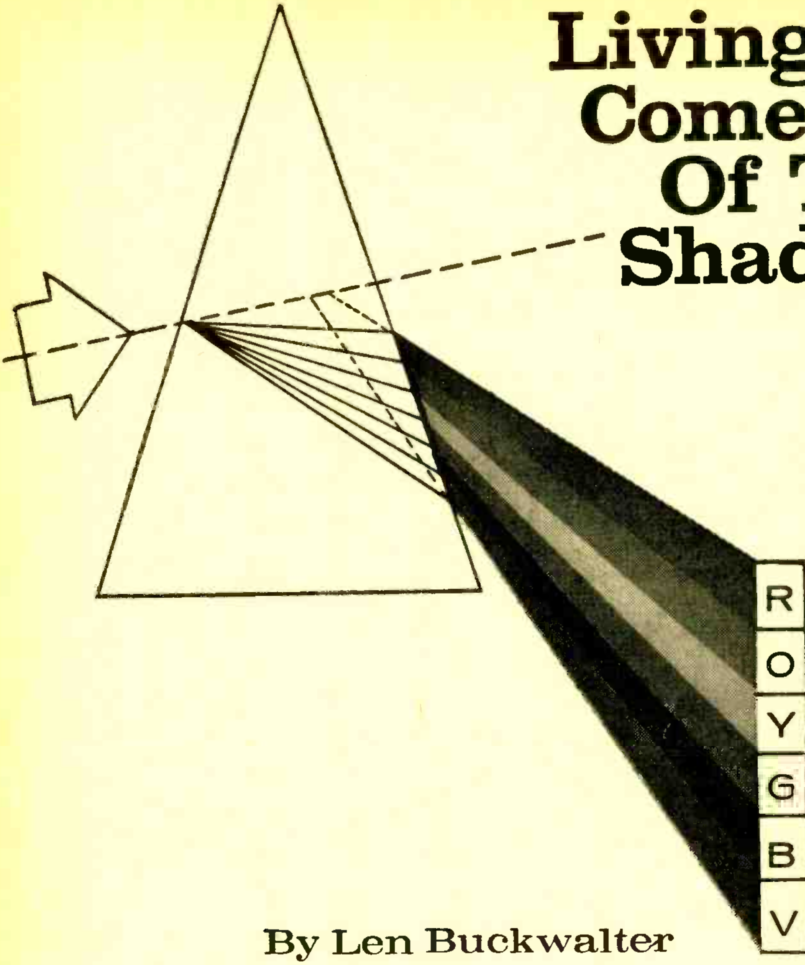
If your listening habits favor one end of the band over the other, or one station more than another, it is best to adjust the RF trimmer for the maximum output at the frequency of the favored station. If you listen to stations at all ends of the band, the compromise discussed above is most desirable.

Repeat the RF alignments at 1400 kc and 600 kc until the best compromise is achieved. Now remove leads from signal generator and remove RF coil you made.

**"Looking Backwards."** It is true that the last few sections of this article describe the complete alignment procedure. However, armed with the complete knowledge of the superheterodyne receiver reviewed here in the first sections, you can not only have a complete understanding of why you are performing certain adjustments, but can create procedures of your own for the unusual situation. ■

* Some receivers have a capacitor between the parallel combination of C1C-C1D and the oscillator coil. This is the padder condenser. A padder condenser may be placed in a similar position in the RF circuit.

# Living Color Comes Out Of The Shadows




**The new Lawrence Color tube, the Chromatron, has lifted the shadow mask from the conventional color tube revealing the true colors of the light spectrum**

By Len Buckwalter

**That** living-color picture—a peacock fanning a color-splashed tail—is in for a big change. After a decade of home color reception built around the "shadow mask" picture tube, a new breed of color tube is bowing in. It is the Lawrence tube, conceived by a university professor 14 years ago, cheered as an engineering marvel—and once rejected as impractical. Today it is a reality. Far from a laboratory curiosity (like most other stabs at a new-type color tube) the Lawrence version has followed a tortuous path of development until refined to the point of practicality. The first commercial TV sets containing Dr. Lawrence's radically different technique will soon be here. You'll be seeing the tube under a new name, too; it's now the "Chromatron."

According to its present developers, Paramount Pictures Corp., the Chromatron promises several advantages. First is increased color brightness. More vivid color gives the illusion of depth in the picture and permits viewing under more room light. It's simpler, too. The number of tubes required over a black and white set is reduced by four or five. Circuits, are fewer; adjustments, less. The Chromatron could also open up the big, untapped field of small-screen color TV. The tube lends itself exceptionally well to under 21-inch screen sizes.

**Seeing Is Believing.** By what technical wizardry does the Chromatron hope to capture a sizeable segment of the growing color TV market? To find the answer, I traveled to New York's big Paramount theater—to an office situated a few floors above the huge movie screen. The attraction in that office proved far more exciting than the current movie attraction floors below. There were three side-by-side TV receivers, each displaying the identical program in black and white.

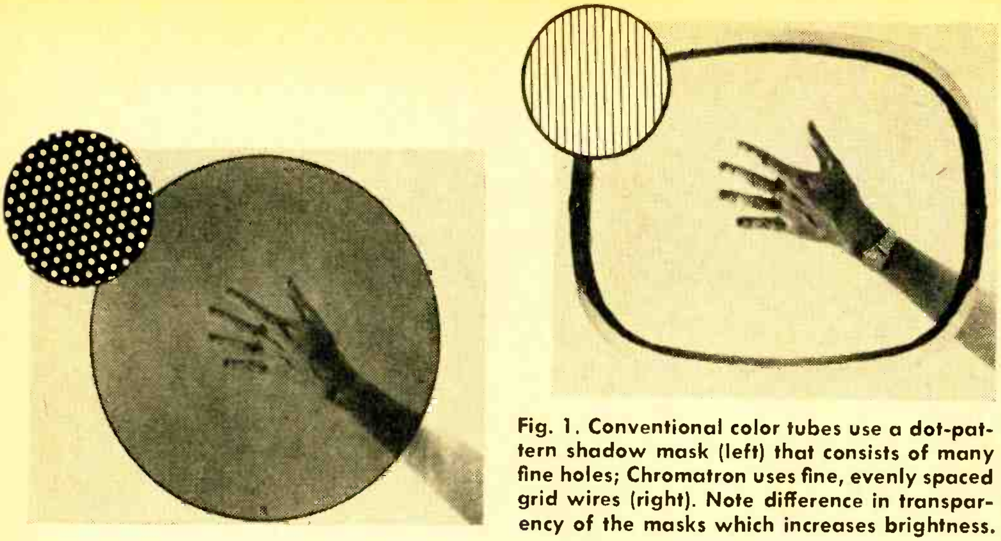


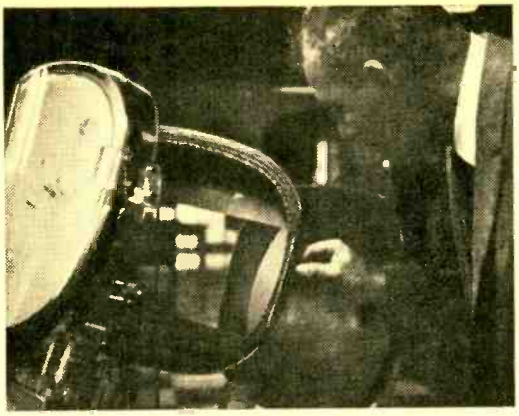
Fig. 1. Conventional color tubes use a dot-pattern shadow mask (left) that consists of many fine holes; Chromatron uses fine, evenly spaced grid wires (right). Note difference in transparency of the masks which increases brightness.

The time: 10:27 a.m. I was instructed to watch and carefully compare the screens. In three minutes the local TV station would start transmitting in color. As 10:30 came up, the peacock obligingly fanned its polychromatic tail. The eye could not resist being drawn to the center screen; the bird appeared in brilliant and vivid color, nearly eclipsing the images on the two sets alongside it. (One was black and white, the other a conventional color receiver.) After some minutes, an engineer flicked on two white fluorescent lamps, aiming their beams directly at the two color screens. Again the results were startling. The center screen continued to display strong, clear color, suffering little "wash out" from the bright lamplight. I moved in close to the center screen, placing my eye about two inches from it. Instead of the usual fine dots I'd been accustomed to seeing on the usual color screen, there were numerous thin lines similar to what you see on a black-and-white screen when viewed up close. On this TV picture tube, however, those lines ran up and down, and glowed in different colors.

That center screen was the business end of a Chromatron. Paul Raibourn, vice-president of Paramount, then conducted an interesting demonstration to illustrate how increasing color brightness sharpens and suggests a 3-dimensional quality in the image; a bowl of fruit appeared to pop out from its background. An identical picture, of less illumination, appeared flattened. This, of course, dramatized the big advantages in Chromatron's ability to deliver high-intensity color. But to probe the inner workings, operation and theory of the tube, I toured the lab where actual developments had occurred; Paramount Picture's Chromatic Division.

**Inside the Chromatron.** Easily the most significant feature of the Chromatron is a unique grid structure of fine stainless steel wires positioned just behind the viewing screen. Here lies the secret of the tube's "transparency"—the characteristic which determines how brightly the screen can light up. In a regular black-and-white tube, transparency presents little problem; an electron beam issuing from the neck of the tube strikes the viewing screen and causes it to glow with light. There is little to block its path.

But in color tubes, some additional element must be introduced between the tube neck and screen. Although its function varies, as shown later, this element generally serves to keep colors on their correct screen position. But in performing its job, this element also cuts down the number of electrons which may reach the screen. Brightness suffers. We can compare this effect in Fig. 1. In the conventional color tube, electrons must enter small holes in a "shadow mask"—only a certain number can get through to the screen. The grid wires of the Chromatron, however, present rather wide spaces to the beam so electrons in greater numbers may continue on to the screen. As explained



**Mockup of basic Chromatron structure (upper left) shows glass phosphor screen, left, wire grid, center, then bellshape section leading to neck of tube. Layout of small Chromatron (above) that will be seen late next year. Note dark frame held by hand. It permits one-piece assembly of fine grid-wire suspension; an important breakthrough for mass-producing the Chromatron. At lower left, Engineer John Petro looks at eight-inch Chromatron.**

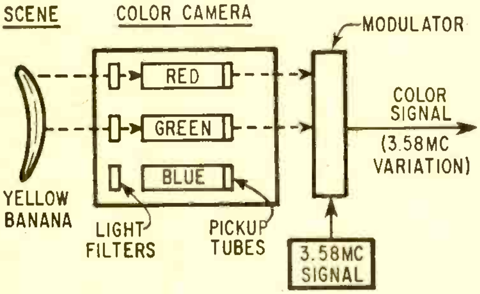



**Fig. 2. TV camera breaks scene into primary colors—converts them to electrical signals.**

by Emil Sanford, engineering manager of the division, the grid is 90 percent transparent vs. 16 percent for the conventional color tube. It results in approximately seven times more brightness.

The second key feature of the new tube is in its electron gun; the structure contained in the tube neck which supplies electrons, and aims them toward the screen where they generate visible light. The conventional tube utilizes a *3-gun* arrangement. The Chromatron, however, achieves color with a *single gun*.

To draw further comparisons, and venture more deeply into Chromatron operation, it's necessary to consider certain features of the transmitted color signal. They can be considered more simply at the studio end, where the televised scene is broken down into basic colors, then into corresponding electrical signals by the camera. As we will see, any color tube at the receiving end principally acts to reverse the order of what occurred in the camera.

**The Color TV Camera.** The drawing in Fig. 2 reveals a color-separating action of the studio camera. Based on a system of primary colors, the camera is seen in three distinct sections. Each responds to a different color; red, green or blue. There are, of course, many more than three hues in a

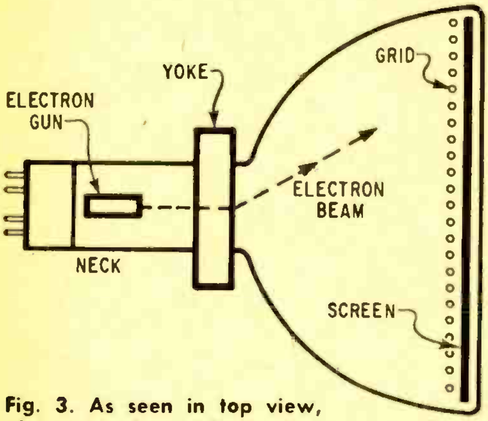



**Fig. 3. As seen in top view, Chromatron has grid wires just behind viewing screen. Grid is shown greatly magnified.**

scene. The human eye, in fact, can discern up to about 40,000 different ones. But just as the artist mixes primary colors to gain countless combinations so does color TV rely on a tri-color system to handle a huge number of hues. The color camera, however, achieves a neat trick that would befuddle the artist. It begins with a *complete* picture (the scene to be televised), then breaks it down into three primary colors. You demonstrate the principle everytime you look through a piece of colored glass or cellophane. If it's tinted red, for example, only the red content of the scene filters through. Thus, the camera in Fig. 2 has red, blue and green filters—equivalent to primary colors —for dividing many colors in the scene into their simplest form.

We've shown a yellow banana in front of the camera to illustrate the point. Yellow, it's been discovered, is actually a mixture of two primaries—red and green. This might sound disturbing to an artist who, upon mixing red and green, would get some muddy-looking combination. Color TV however, mixes *light,* not paint pigments. Light mixtures follow a different set of principles. Another example is that the artist cannot mix red, blue and green to get white. But in working with these colors as *light,* the following percentages will form white: 30 percent red, 59 percent green and 11 percent blue. So our yellow banana shows up in the color camera as red and green, after its light is split by filters. The pickup tubes, operating like photocells, convert the colored shafts of light into corresponding electrical signals. In this fashion, thousands of colors are decoded into three separate signals ready for transmission over the air.

There remains another important step—modulation. Since the color TV system must satisfy the needs of both monochrome and color receivers to be compatible, color signals must not interfere with black and white. This is done by side-pocketing color information on its own carrier. This is the 3.58 mc in Fig. 2. In the modulation process, color signals are encoded on 3.58 mc, which is subsequently rejected by black and white sets. The Chromatron, however, utilizes it in a unique image-producing system.

**The Color Picture.** Let's see how signals are converted back into light of the correct color at the receiving end. In Fig. 3 is an overall view of a Chromatron tube. Housed in the narrow neck of the tube is an electron gun. Its hot cathode boils off electrons which travel as a beam in the direction of the yoke. Purpose of the yoke is to deflect the beam over the entire surface of the screen. Based on magnetic push-pull action, the yoke moves the beam over a familiar path: the same one your eyes now traces over the printed page; from left to right and top to bottom. The screen, therefore, is completely scanned. Occurring 60 times per second, the eye sees the screen uniformly filled with light. (Identical scanning action is also occurring at the studio camera. Camera and receiver beams are locked together by synchronizing signals

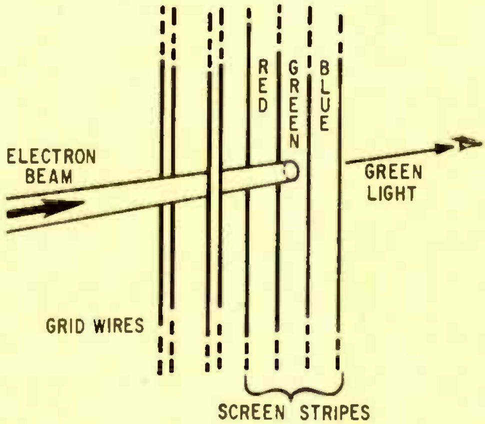



**Fig. 4. Electron beam passes between grid wires undeflected—shown striking green phosphor stripe between red and blue ones.**

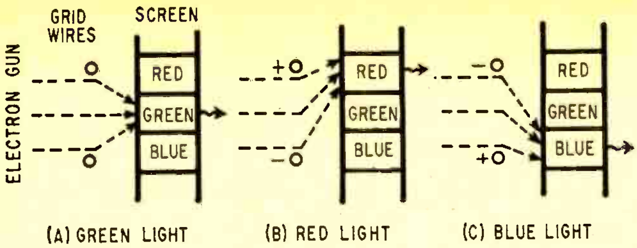


**Fig. 5. Applying voltages to pairs of grid wires focuses the electron beam on one of the three phosphor screen stripes.**

transmitted by the station.) As the beam travels away from the yoke, it passes through the grid of fine wires mentioned earlier, then strikes the screen. Chemical phosphors deposited over the screen surface glow with light under the impact of the electron beam. The Chromatron, up to this point, has provided two important effects: a scanning electron beam in step with that of the camera, and a screen illuminated with light. There remains now the task of applying color and positioning it in the correct place on the phosphor screen.

**Grid Wires.** Let's examine a small section of the screen and the grid which lies just behind it, as illustrated in Fig. 4. The screen consists of thin stripes of phosphor material which emit red, green or blue light when struck by electrons. (Only three are shown for clarity, but they are repeated over the whole screen width. Note the position of the two grid wires shown. Since the electron beam is passing between them, striking only the middle phosphor stripe, the color green would be produced at this instant.

To understand the action of the grid, try this simple demonstration. Hold your arm up and point your index finger toward the wall. Now start to wiggle your index finger from side to side while, *at the same time,* sweeping your whole arm across the wall. This is a good illustration of the grid's function: it "wiggles" the *tip* of the electron beam so it moves over red, green and blue phosphor stripes. (Your sweeping arm movement represented the overall scan of the beam caused by the yoke in the tube's neck.) Now to look more closely at how the grid achieves this effect—and the role it plays in selecting correct colors.

In Fig. 5 is a portion of the screen viewed from the top. Shown are three possible beam positions for producing primary colors. Consider, first, Fig. 5 (A). Green is being produced, as just described; the beam passes through the grid wires and strikes the green phosphor. Now let's apply an electrical charge to the pair of grid wires. If the upper wire, shown in Fig. 5 (B) is impressed with a *positive* charge, it will attract the electron beam (which is negative) in the direction shown. A *negative* charge placed on the lower wire aids this direction by repelling electrons. Thus, the overall effect is to deflect the beam toward the red phosphor. The final example, Fig. 5 (C), simply reverses the charge on the grid wires and the beam now strikes the blue phosphor stripe. It should be apparent that by placing the proper electrical charges on the grid, the beam can be angled to select any of the three primary colors.

This system can not only produce white, but all the mixtures needed for rendering a color program. To generate white light, it is necessary to wiggle the beam among the three stripes—red, blue and green. It's done by placing an alternating voltage on the grid wires, as illustrated in Fig. 6. Although movement is extremely rapid, the beam remains just the right amount of time on each primary color for producing the white mixture. The viewer's eye blends the primary colors, since the glowing stripes are narrow and close together, and the complete screen appears white. And a complete scale from black to gray to white can be produced by varying the strength of the electron beam. This function—beam strength—will be provided by control voltages applied to the electron gun.

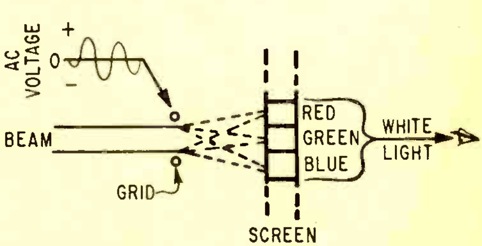


**Fig. 6. An alternating voltage on grid wires shifts the beam among screen stripes.**

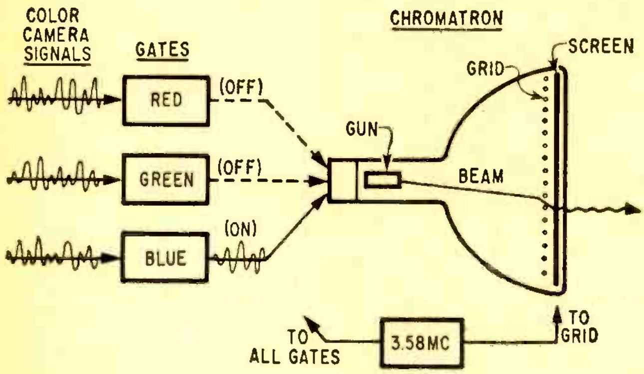



**Fig. 7. Action necessary for producing blue image on phosphor screen—the 3.58-mc signal simultaneously positions beam on blue screen stripe and opens blue gate. Blue signal (originally from TV camera) may now control gun's beam strength at this short instant.**

**3.58-mc Carrier.** Now to create a full-color image on the screen. Recall, for a moment, what happened back at the TV studio. Electrical signals corresponding to primary colors were modulated onto a 3.58-mc carrier. When these signals arrive at the receiver, a detector circuit reverses the modulation process to recover the original information. Signals are now restored to the same form as when they emerged from the camera. The 3.58-mc carrier, however, is not discarded; it serves to synchronize the Chromatron, as shown in the block diagram of Fig. 7. Note that 3.58 mc is applied directly to the switching grid of the tube. Here it fulfills the same function ascribed earlier to the "alternating voltage;" that is, to wobble the beam among the three phosphor stripes. But note the same 3.58-mc energy is also being fed to red, blue and green "gates" which feed the electron gun. As the name implies, the gate opens or closes to permit the color signal to reach the Chromatron's electron gun. Let's assume that we want the color red only to appear on the screen. *As the 3.58-mc grid switching voltage focuses the beam on a red stripe*, it also unlocks the *"red gate."* This permits the red color signal to pass through the gate. It turns on the electron gun and red appears. At the same time, green and blue color signals are unable to turn on the beam; their gates are locked. As 3.58-mc energy switches the beam to green, it simultaneously opens the green gate—and shuts red and blue gates. Thus the Chromatron's circuits continuously sort out the incoming color signals and place them on their correct stripes. This would be equivalent to the filtering, or color separating, action in the studio camera.

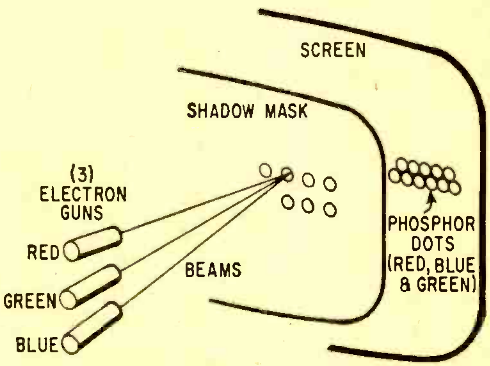


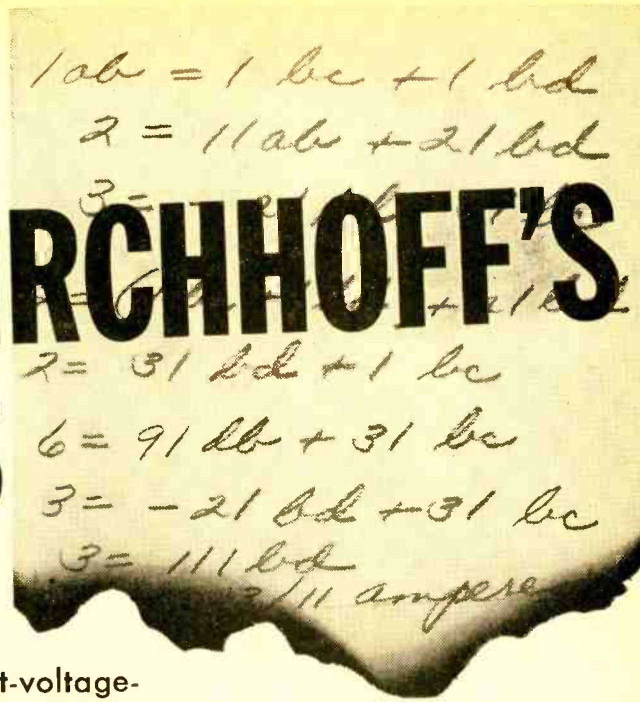

**Fig. 8. Conventional color tube uses three guns, shadow mask, and phosphor-dot screen.**

**A Yellow Banana.** Now that we can position colors properly, there remains the problem of their mixtures. Creating the pure yellow banana televised earlier is not too difficult to visualize; as the beam swings over the screen area of the banana, red and green stripes illuminate (the blue gate shuts). The viewer sees a yellow mixture. A whole range of other colors is possible by varying the strength of the electron beam for each primary hue. Incoming color signals provide this information. As the strength of a given color increases, the signal raises the strength of the electron beam. Countless juggling of proportions presents all necessary screen hues for reproducing the color signal.

This, in simplified form, is the Chromatron's operation. Bringing it to its present state of development was no mean feat. That color switching grid, for example, presented

*(Continued on page 128)*

# AFTER OHM'S LAW... KIRCHHOFF'S LAWS




**Determining the current-voltage-resistance relationship in complex circuits is beyond the province of Ohm's law**

By Jay Copeland

**Without** a doubt, Ohm's law is the first and most frequently quoted law learned by most beginners in electronics. And so, not to be different, here is Ohm's law—

> The amount of current, $I$, which will flow through a resistance, $R$, when a voltage, $E$, is impressed across its terminals is expressed mathematically as follows:

$$I = E/R$$

The equality sign in the above equation is possible when $I$ is given in amperes, $E$ is in volts, and $R$ is in ohms.

Ohm's law applies to a single element in a circuit or many elements that can be combined into one resistive element. However, there exist circuits where the resistive elements cannot be reduced to a single element for calculating purposes. Also, there may be more than one voltage source to further the difficulty in applying Ohm's law. These circuits cannot be dealt with without other basic circuit laws or mathematical methods.

**Kirchhoff's Current Law.** *At any junction in a circuit the total current entering that junction is equal to the total current leaving that junction*—this is Kirchhoff's current law. Fig. 1a shows a three-wire junction that is useful in demonstrating and explaining the current law. Since we do not know the currents flowing in the junction, we assign algebraic symbols to describe them—$Ia$, $Ib$, and $Ic$. And from the above stated law we can now state in equation form the currents entering and leaving the junction:

$$Ia = Ib + Ic$$

This does not come as a great surprise since we can logically expect current $Ia$ to split into two parts (not necessarily equal parts), currents $Ib$ and $Ic$. And since the junction cannot make or destroy current, whatever enters the junction must leave the junction. Currents entering the junction are equal to currents leaving the junction, hence, in Fig. 1b we can expect the following current relationship or equation:

$$Ia + Id = Ib + Ic$$

or simply

$$Ia = Ib + Ic - Id.$$

In the schematic diagram shown in Fig. 2, the currents entering and leaving junction B

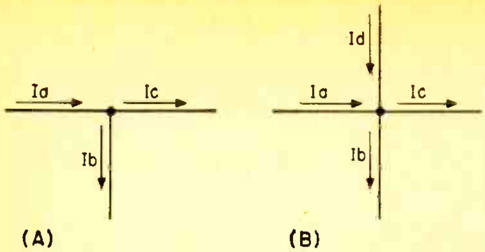



**Fig. 1. Three-wire (A) or the four-wire junction (B) illustrates Kirchhoff's current law.**

can be stated as

$$Iab = Ibc + Ibd.$$

Where *Iab* is the current flowing from A to B through the one-ohm resistor, *Ibc* flows from B to C through the 3-ohm resistor, and *Ibd* flows from B to D through the 2-ohm resistor.

**Kirchhoff's Voltage Law.** The sum of all the source voltages in a closed path of a complex circuit are equal to the sum of all the voltage drops in the path. Looking back at Fig. 2 we can see two closed paths—they are DABD and DBCD. Note that the paths start and stop at the same point in order for the paths to be closed. Now, let's write equations for the voltage sources and voltage drops for Fig. 2 starting with path DABD.

$$2 = 1Iab + 2Ibd.$$

The two (2) on the left side of the equation is for the 2-volt battery voltage source. The term *1Iab* is the voltage drop across the one-ohm resistor as determined by Ohm's law—$E = IR = (Iab)(1) = 1Iab$ or just *Iab*. Since current *Ibd* is passing through the 2-ohm resistor, its voltage drop is *2Ibd*.

The equation for path DBCD is

$$3 = -2Ibd + 3Ibc.$$

The method for setting up the immediately above equation for path DBCD is the same as for path DABD except for the minus sign. In traveling from point D to B, we are traveling against the current. The voltage drop across the 2-ohm resistor is positive at point B with respect to point D. (We are using the conventional current which flows from positive to negative terminals of a battery, however it doesn't matter which method is used.) Hence, instead of a voltage drop from point D to point B, there is a voltage rise. Since the resistor appears to be doing the opposite of its normal function, the negative voltage drop is expressed as a voltage rise.

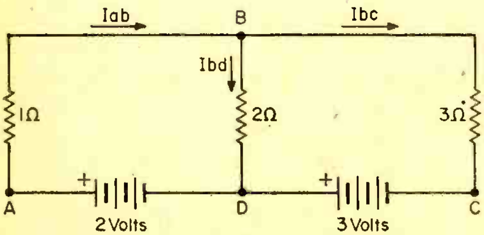



**Fig. 2. Kirchhoff's voltage law analyzes closed path circuits; two here are DABD and DBCD.**

**Solving a Problem.** Looking again at Fig. 2, you may want to find the voltage drop across each of the resistors. If you knew the current passing through each of them, you could apply Ohm's law and *voila*, the solution would be easy. But the real problem is finding the currents. Hence, let us list the three equations we developed earlier while talking about Kirchhoff's current and voltage laws.

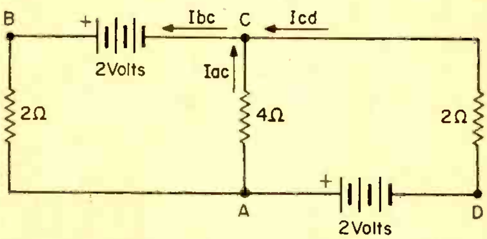



**Fig. 3. When solving Kirchhoff's voltage law for closed loop circuits, remember that if the resulting current value is negative, current's flowing opposite from direction you assumed.**

$$Iab = Ibc + Ibd \qquad (1)$$
$$2 = Iab + 2Ibd \qquad (2)$$
$$3 = -2Ibd + 3Ibc \qquad (3)$$

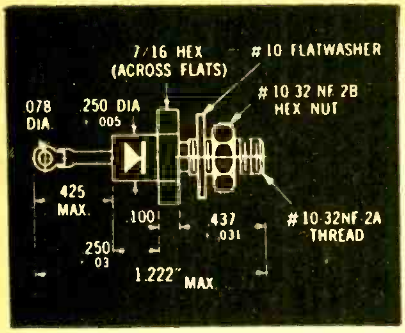
Note that the equations are numbered.

Since we now have three equations with three unknowns, we can reduce these to two equations in two unknowns by replacing Iab in equation (2) with (Ibc + Ibd). We can do this because equation (1) says these quantities are equal.

$$2 = (Ibc + Ibd) + 2Ibd$$
$$2 = 3Ibd + Ibc \qquad (4)$$

Now, let's multiply both sides of equation (4) by the numuber 3, and then subtract equation (3) from equation (4).

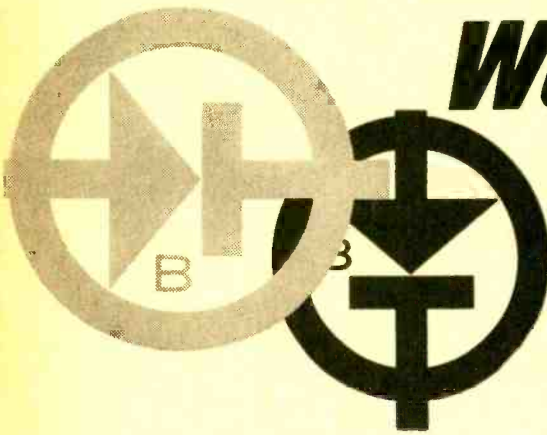
*(Continued on page 130)*




# simple experiments show...

# HOW ZENER DIODES WORK

By Louis E. Garner, Jr.



**Breakdown voltage of a diode was once a necessary evil—but in the Zener it's the operating principle**

**ALTHOUGH** widely used in laboratory, military and industrial electronic equipment, the Zener diode is virtually ignored by the majority of hobbyists and experimenters. This is surprising, for the Zener is an extremely versatile semiconductor device. It can be used as a voltage regulator or reference element, for overvoltage or surge protection, as a coupling or biasing device, as a limiter or clipper, as a temperature sensor, or as a control element. Its potential equipment applications are almost limitless . . . receivers, transmitters, computers, amplifiers, test instruments, controls, monitors, power supplies and medical equipment.

Basically, a Zener diode is a semiconductor diode designed for operation in a reverse breakdown condition. When used below its breakdown (or Zener) voltage rating or forward-biased, it behaves much like a conventional detector (or rectifier) diode.

**About the Monikers.** The common, and perhaps most popular, name for the device honors Dr. Carl Zener, the scientist who pioneered the study of diode breakdown mechanisms. However, these devices also may be identified as *voltage regulator, voltage-reference, breakdown* and *avalanche* diodes. Of these alternate names, the first two terms are descriptive of their major applications, the latter two of their mode of operation.

Although the typical industrial Zener diode is a relatively expensive close-tolerance device, several manufacturers have introduced low-cost types for Ham, hobbyist and experimenter applications (Fig. 1). These Zeners are available both as individual units and in kit-type assortments.

Zener diodes are specified according to their *Zener voltage, tolerance* and *wattage* rating. The first specification indicates the unit's nominal breakdown voltage when re-

# Zener Diodes


Fig. 1. Low cost Zeners for experimenters.

verse biased. The tolerance is given as a percentage of rated voltage and indicates the unit's maximum and minimum breakdown limits. Finally, the wattage rating indicates the device's power-handling capacity and, therefore, its maximum current rating.

An example may prove helpful. The *GE* type X11, which may be used in the experiments we'll discuss later, is a 1-watt type with a nominal Zener voltage rating of 8.2 volts and a ±10% tolerance. This means that its actual breakdown voltage may range from 7.38 (8.2 −10%) to 9.02 (8.2 +10%) volts, and that it can handle a maximum current of approximately 120 ma. (when dissipating 1 watt).

As shown in Fig. 2, any of several schematic symbols may be used to identify a Zener diode, depending on individual manufacturer's preferences. For the most part, these are all standard semiconductor diode symbols modified slightly to show that the device is used in a reverse breakdown state. Typically, one popular symbol includes the letter "B" as an abbreviation for "breakdown."

**What You Need.** A few simple experiments will demonstrate how Zeners work and what they can do. As specified in the Parts List, relatively few components are needed . . . a variable voltage power supply (made up using standard 9-volt transistor batteries and a small potentiometer), a Zener diode, a small general purpose VOM or multitester (Fig. 3), a few resistors, and an experimental chassis or breadboard are the basic items needed. All the parts are readily available through both local and mail order distributors.

Although a metal chassis may be used for assembling the various test circuits, the majority of experimenters probably will prefer (as did the author) to use a perforated *Masonite* board. Exact size is not critical, but the board should be equipped with rubber feet to prevent scratching table, desk or workbench tops. Fahnestock clips, terminal strips, brackets and similar hardware items may be attached to the board using small machine screws and nuts. Electrical components and wiring are soldered in place, although clip-equipped test leads may be used for connecting the (battery) power supply and test meter.

**Some Tips.** Always follow the basic "rules" of laboratory practice, both to insure accurate results and to prevent accidental damage to your meter and components. When soldering the Zener diode in place, use a hot, well-timed iron (or gun) and complete the operation as quickly as possible. Semiconductor devices (and Zeners are not an exception) may be damaged by excessive heat.

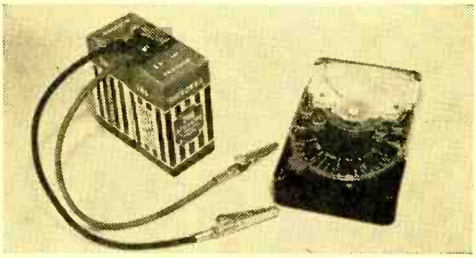


Fig. 3. The required multitester and battery.

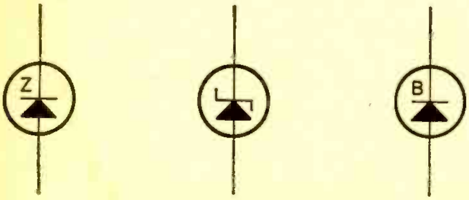



Fig. 2. Center symbol seen most in industry.

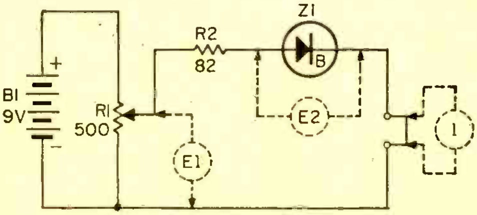



Fig. 4. Diagram for forward characteristics.

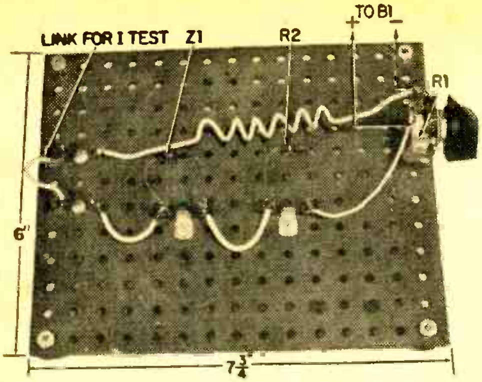



Fig. 5. Components are mounted on Masonite.

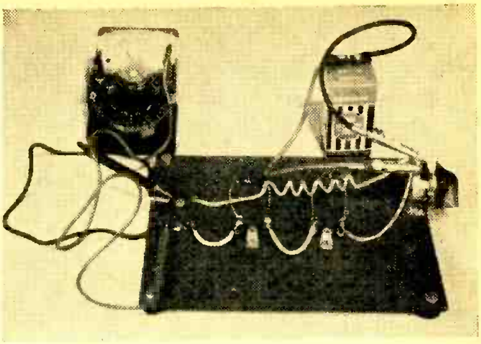


Fig. 6. Ammeter hooked to Fahnestock clips.

Disconnect circuit power *before* inserting your meter to measure currents and always check all wiring and D.C. polarities before reapplying power. Set your multitester to its highest range for the type of measurement needed, switching to lower ranges as necessary to obtain satisfactory readings. Remember, too, that voltage measurements are made by connecting the meter *across* the points to be checked, while current measurements are made by opening the appropriate circuit and connecting the meter in series.

Naturally, you needn't expect *your* test measurements to correspond exactly to the values obtained by the author and given in Tables A through F. These apply *only* to the specific diode used by the author and other diodes, even of the same type, may be expected to give slightly different results.

**EXPERIMENT 1: Determining a Zener diode's forward characteristics.**

A diode's "forward" characteristics are those obtained when the device is biased in its conducting direction. The basic circuit used in this Experiment is illustrated in Fig. 4, while a breadboarded version is shown in Figs. 5 and 6. Note that a small hook-up wire "link" (between the Fahnestock clips) is provided to facilitate opening the circuit for current measurements. The potentiometer (R1) serves as a voltage control while series resistor R2 is included simply for current-limiting purposes to protect the diode.

With the circuit wired as shown, change the applied voltage in small steps by adjusting R1, recording the input voltage (E1), diode voltage (E2) and circuit current (I) at each step as in Table A. Use steps of, say, 0.1 or 0.2 volts up to 1.0 volt and, afterwards, 0.5 or 1-volt steps.

Your results will show that little or no current flows until the applied (source) voltage is approximately a half-volt and that the current increases with increasing voltage rapidly once this voltage is exceeded. At the same time, the voltage drop across the diode (E2) will change very little with increasing current.

The voltage at which conduction starts when the diode is forward biased (anode positive) is its *barrier potential.* Virtually all standard diodes (including detector and rectifier types) exhibit this characteristic, and, in general, the barrier potential is the same for all diodes of a given type, seldom exceeding a fraction of a volt.

**EXPERIMENT 2: Determining a Zener diode's reverse charactristics.**

A diode's "reverse" characteristics are those obtained when the device is biased in its non-conducting direction (anode negative). The circuit used in this Experiment is illustrated in Fig. 7. Note that the basic arrangement is essentially similar to that shown in Fig. 4, except that the diode's polarity is reversed. In addition, an 18 (rather than 9) volt power supply is used.

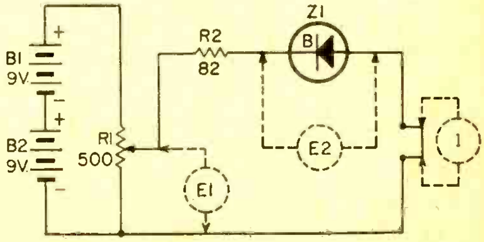



Fig. 7. Diagram for the reverse characteristics.

## EE Zener Diodes

As in the previous experiment, change the applied voltage in small steps by adjusting R1, recording the input (source) voltage (E1), diode voltage (E2) and circuit current (I) at each step as in Table B. Use steps of either 0.5 or 1.0 volts.

Once your measurements are tabulated, you'll find that little or no current flows until the applied voltage equals the device's rated Zener voltage and that current increases rapidly once this voltage is exceeded. You'll also find that the voltage drop across the diode (E2) remains more or less constant at the Zener voltage even with relatively large currents.

The small current which may flow before the Zener voltage is reached is known as the Zener's "leakage" current. As a general rule. the lower the leakage current, the better the diode.

Your measurements may be used to plot the diode's overall characteristics as in Fig. 8. Use the results obtained in both Experiments to establish points on graph paper, drawing a smooth curve through them. The general *shape* of the resulting curve is the same for all standard semiconductor diodes, even though the exact slopes may vary somewhat as well as the voltage values at which current changes take place. All diodes, then, exhibit a reverse breakdown characteristic when their Zener voltage is exceeded and permit relatively little current flow in their forward direction until their barrier potential is reached.

In a broad sense, *any* semiconductor diode may be used as a Zener diode . . . and any Zener diode may be used as a detector or rectifier type, *provided maximum ratings are observed.* In practice, however, it is best to use diodes in the applications for which they are designed . . . small signal types as detectors, power types as rectifiers, and Zener types where specified.

**TABLE A: Zener Forward Characteristics**

| E1 (Source) | E2 (across Z1) | I |
|---|---|---|
| 0 | 0 | 0 |
| .2 v. | .2 v. | 0 |
| .4 | .4 – | .03 ma |
| .6 | .5 | .4 |
| .8 | .55 | 2.15 |
| 1.0 | .56 | 4 05 |
| 1.5 | .60 | 9.50 |
| 2.0 | .62 | 14.50 |
| 2.5 | .63 | 19.00 |
| 3.0 | .65 | 24.50 |

**TABLE B: Zener Reverse Charactristics**

| E1 (Source) | E2 (across Z1) | I |
|---|---|---|
| 0 | 0 | 0 |
| .5 v. | .5 v. | 0 |
| 1.0 | 1.0 | 0 |
| 2.0 | 2.0 | 0 |
| 4.0 | 4.0– | .02– ma |
| 6.0 | 6.0– | .27 |
| 8.0 | 7.6 | 4.0 |
| 10.0 | 7.8 | 21.0 |
| 12.0 | 8.0 | 43.5 |
| 14.0 | 8.1 | 70.0 |
| 16.0 | 8.1 | 88.0 |
| 18.0 | 8.15 | 105.0 |

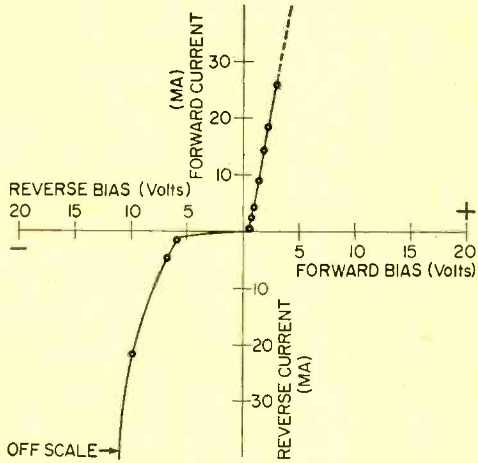



**Fig. 8. Forward and reverse characteristics.**

**EXPERIMENT 3: The Zener as a series voltage regulator with changing load current.**

Zener diodes are used extensively as voltage regulators. Two basic circuits are employed . . . *series* and *shunt.* In a series regulator circuit, the Zener is connected in series with the load, while in a shunt regulator circuit, the Zener is connected in parallel with the load. We'll examine the advantages . . . and disadvantages . . . of each arrangement in this and the next three experiments.

An experimental series regulator circuit is illustrated schematically in Fig. 9. A breadboard version of the circuit is shown in Fig.

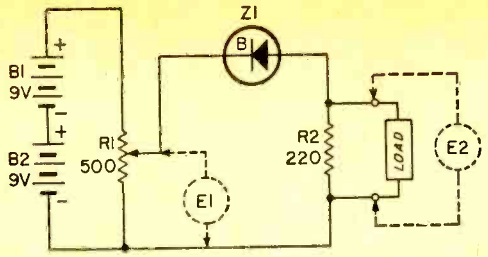



Fig. 9. Schematic diagram shows use of Zener diode in the series voltage regulator circuit.

**TABLE C: Series Voltage Regulator**

| Source E—18 volts | |
|---|---|
| **LOAD (R)** | **VOLTAGE (E2)** |
| 10,000 ohms | 10.0 v. |
| 4,700 | 10.0 v. |
| 2,200 | 10.0 v. |
| 1,000 | 10.0 v. |
| 470 | 10.0 v. |
| 220 | 10.0 – v. |
| 100 | 9.8 v. |

10. The *load* may represent a receiver, transmitter, or other piece of equipment. For our experiment, we'll use fixed resistors of different values to simulate a change in load currents.

Adjust R1 to supply full battery voltage (18 volts) and check the output voltage across R2 (E2). Next, connect various load resistors across the output, checking the output voltage each time. The exact resistor values are not critical but, typically, may range from 10,000 ohms to 100 ohms. The results should be tabulated as in Table C.

Your experiment will show that the load voltage (E2) remains essentially constant as the load increases and is approximately equal to the source voltage (E1) less Z1's Zener voltage. With an 18-volt source and an 8-volt Zener, the output voltage is 10 volts.

**EXPERIMENT 4: The Zener as a series regulator with variations in source voltage.**

Having observed the behavior of a series regulator circuit with changes in load current, let's see what happens when a fixed load resistor is used and the source voltage is changed.

Use a 1,000 ohm load resistor. Next, adjust R1 to reduce the source voltage (E1) in small steps, checking the load voltage (E2) each time. Record your measurements as in Table D.

Your tests should demonstrate that the load voltage (E2) drops as the source voltage is reduced, with the difference between the two measurements approximately equal to the diode's Zener voltage rating. In the author's experiment, a source voltage of 10 volts delivered a little over 2 volts to the load when a 8-volt Zener was used.

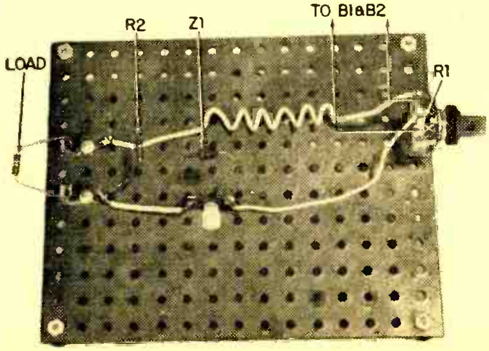



Fig. 10. Series voltage regulator breadboard.

**EXPERIMENT 5: The Zener as a shunt regulator under changing load conditions.**

A typical shunt regulator circuit is given in Fig. 11. Note the similarities . . . and differences . . . between this circuit and the one used in Experiments 3 and 4.

We can determine the effect of changing load conditions on such a circuit by using the same technique (and load resistors) as in Experiment 3. First, of course, adjust R1 to supply full battery voltage and check the output voltage across Z1. Now, connecting various load resistors across Z1, one at a time, check the output voltage (E2), recording the results as in Table E.

You should find that the output voltage remains constant even with large changes in loading and that it is equal to the diode's (Z1) Zener voltage rating.

**EXPERIMENT 6: The Zener as a shunt regulator as source voltage changes.**

Using the same circuit as in the preceding experiment, connect a 1,000 ohm resistor across the output terminals (across Z1). Next, adjust R1 to reduce the source voltage (E1) in small steps, checking the load voltage (E2) each time, and recording your measurements as in Table E.

Your results will show that the load voltage remains essentially constant with changes in source voltage until the source voltage starts to approach the diode's rated Zener voltage. If the source voltage is *less* than Z1's Zener voltage, the diode becomes ineffective as a regulating device.

The results of the last four experiments should permit you to compare the relative performances of series and shunt regulator circuits.

First, the series circuit is valuable where the desired load voltage is greater than the diode's Zener voltage rating. It is especially useful where there is a small difference between source and load voltage . . . as, for example, where 24 volts must be supplied by a 30 volt source; here, a 6-volt Zener could be used.

Second, the series circuit will tolerate wide changes in loading, but is not effective when the source voltage varies. The shunt regulator, on the other hand, will maintain a constant output voltage with changes in *either* the supply voltage *or* the load.

Third, the entire load current must be carried by the Zener diode when the series circuit is used, while, where the shunt arrangement is used, the Zener need carry only the *difference* between the load's minimum and maximum requirements. As a result, a larger Zener (higher wattage rating) may be required for series than for shunt regulator applications.

Finally, the shunt circuit requires that the Zener diode's voltage rating be equal to the desired output voltage. In practice, this may mean that a higher voltage Zener is required than would be needed by a similar series circuit or as an alternative, that several Zener diodes be connected in series.

**TABLE D: Series Voltage Regulator**

| Load—1,000 ohms | |
|---|---|
| SOURCE (E1) | LOAD (E2) |
| 18.0 volts | 10 volts |
| 15.0 | 7.5 |
| 12.0 | 3.9 |
| 10.0 | 2.1 |

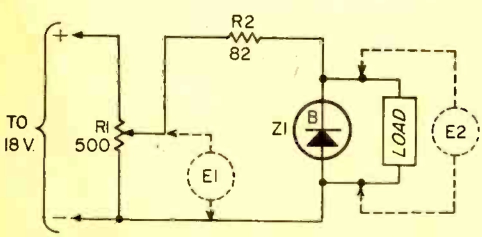



**Fig. 11. Schematic of shunt regulator circuit.**

**EXPERIMENT 7: The Zener diode as a limiter.**

Although we have confined our preceding experiments to D.C. circuits, Zener diodes are equally effective in A.C. applications. Here, Zeners may be used as clippers, limiters, surge suppressors, and square-wave generators. The basic circuit arrangements used are similar to those employed in D.C. applications.

**TABLE E: Shunt Voltage Regulator**

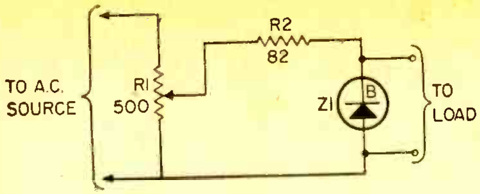
| Source E—18 volts | |
|---|---|
| LOAD (R) | VOLTAGE (E2) |
| 10,000 ohms | 8.3 v. |
| 4,700 | 8.3 v. |
| 2,200 | 8.3 v. |
| 1,000 | 8.3 v. |
| 470 | 8.3 v. |
| 220 | 8.3 v. |
| 100 | 8.2 v. |

A typical shunt-type limiter is illustrated in Fig. 12. If you have a suitable low-voltage A.C. source available, such as a 12 to 18 volt filament transformer, you can repeat the basic tests conducted in Experiments 5 and 6, using your multitester as an A.C. Voltmeter.

In operation, Z1 acts as a conventional rectifier on those half-cycles when its anode is positive and limits the peak voltage applied to the load at its Zener rating on alternate half-cycles. If *both* half-cycles of the applied A.C. voltage are to be limited, two Zeners may be connected in series "back-to-back." A practical application of such an arrangement is illustrated in Fig. 12B.

Referring to the schematic diagram, the source voltage is applied to the circuit through P1, while the limited output voltage is obtained through J1. Diodes Z1 and Z2 serve to limit alternate A.C. peaks at their rated voltages, dropping the excess voltage across series resistor R1.

Assembled in a small case or *Minibox*, such a circuit can serve as a useful *Headphone Limiter* to prevent "blasting" as, say, a radio



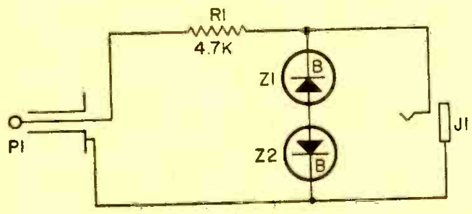




**Fig. 12. Limiting one or both of half-cycles.**

operator tunes his receiver to pick up exceptionally strong stations. In a practical instrument, PL1 could be a standard 'phone plug, R1 a half-watt resistor, J1 an open circuit jack, and Z1 and B2 3.9-volt, ½ or 1-watt Zener diodes. In use, P1 would be inserted in the '*phones* jack of the receiver with which the device is employed, while a standard headphone plug would be inserted in J1. Best results are obtained if high-impedance crystal or magnetic headphones are used.

**EXPERIMENT 8: Using the Zener diode in a transistor radio Auto Adapter.**

An inexpensive Zener diode may be used in an easily built adapter to reduce the 12-volts D.C. supplied by modern automobile electrical systems to the 9-volts required by the majority of portable transistorized radio receivers. Permitting "plug-in" operation (to the cigarette lighter receptacle), such an adapter can be a useful . . . and battery-saving . . . accessory when a portable receiver is used for extended periods on, say, beach parties, picnics, and camping trips. The schematic diagram of the adapter is given in Fig. 13 while an interior view of the author's model is shown in Fig. 14.

Circuit-wise, the device is a simple modification of the basic shunt regulator circuit studied in Experiments 5 and 6. The only change is the addition of a small resistor (R2) in series with Z1 to raise the effective output voltage from 8.2 to approximately 9 volts. Although this change reduces circuit efficiency, the voltage regulation is satisfactory for normal applications.

Referring to Fig. 13, P1 is a standard battery charger plug, R1 a 2-watt resistor, and R2 a half-watt unit. Z1 is a *GE* type X11 Zener diode. CN is a standard 9-volt battery connector . . . you can save money on this component by salvaging a suitable connector from an exhausted 9-volt battery.

Construction is straight-forward, with neither layout nor lead dress critical. The entire circuit can be assembled in a small aluminum case. The author's model, as shown in the photographs, was wired in a small aluminum chassis, with a second chassis used as a "cover." If you are handy with sheet metal tools, you may prefer to make up a case the same size as the battery which the adapter replaces. The charger plug (P1) is attached to the adapter proper by means of a 12 to 18 foot length of ordinary twin-lead "zip" cord.

Several circuit modifications are possible to meet special needs. First, the schematic, as shown, is for a *negative-ground* system; if your automobile has a positive-ground electrical system, interchange the connections to PL1. Second, the Zener *and* R2 may be replaced with a single 9-volt Zener diode (such as an *International Rectifier* type 1N3019A); this change will improve overall regulation. Finally, the battery connector (CN) may be connected at the end of flexible leads rather than permanently mounted on the adapter case.

In use, the receiver's battery connector is snapped off its battery and onto the adapter,

**TABLE F: Shunt Voltage Regulator**

| Load—1,000 ohms | |
|---|---|
| SOURCE (E1) | LOAD (E2) |
| 18 volts | 8.3 v. |
| 16 | 8.3 |
| 14 | 8.3 |
| 12 | 8.2 |
| 10 | 8.0 |

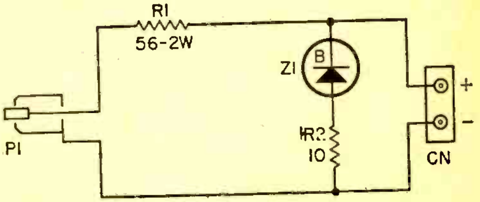



**Fig. 13. 12- to 9-volt Zener diode converter for powering transistor radio from automobile.**

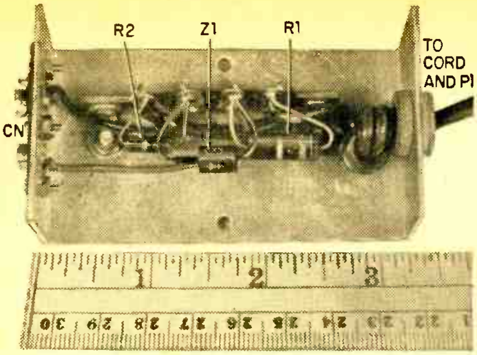



Fig. 14. Underside of auto adapter chassis.

with the adapter placed within the receiver's case if space permits. The charger plug (PL1) is then inserted in the automobile's cigarette lighter receptacle.

**Conclusion.** The experimental Zener diode circuits we've described were chosen to require a minimum of components and a single general purpose multitester. If additional test instruments are available, many more experiments might be performed and a more rigorous approach could be used. For example, an adjustable D.C. source, such as an *Electro Products Laboratories* Model PS-3A Power Supply, is preferable to the battery-potentiometer supply used. An Oscilloscope, if available, is useful for studying A.C. clipper and limiter action, for it permits actual signal waveforms to be observed. Finally, an assortment of Zener diodes would permit experiments with series, series-parallel and back-to-back circuit configurations.

Remember, too, that the basic circuits shown may not always be used in the exact form shown. The shunt regulator circuit, for example, may be modified for protection of a meter movement or other delicate component against overloads rather than in a power supply application. Similarly, the *Headphone Limiter* circuit, if driven by a relatively high voltage source, could serve as a simple square-wave generator.

Readers who wish to study Zener diodes in greater detail will find it worthwhile to refer to the following manufacturers' publications. . . .

**ZENER DIODE HANDBOOK** . . . available at $2.00/copy from *International Rectifier Corporation*, 233 Kansas Street, El Segundo, California.

**SILICON ZENER DIODE AND RECTIFIER HANDBOOK** . . . available at $2.00/copy from *Motorola, Inc.*, Semiconductor Products Division, 5005 E. McDowell, Phoenix, Arizona. ■

Adapter plug P1 fits cigarette lighter jack.

### PART LIST

**Experiments 1 through 6:**

Meter—General purpose Multitester (*Triplett* Model 310)
B1, B2—9-volt transistor batteries (*Burgess* 2N6)
Chassis—Perforated *Masonite*, approx. 6" x 7¾"
Potentiometer—500-ohm, 2-watt
Resistors—½ watt, at 82 ohms, 100, 220, 470, 1,000, 2,200, 4,700, and 10,000 (total of 8 resistors)
Z1—Zener diode—*GE* type XII or equivalent
Misc.—test leads; knob; (2) two-terminal strips; (2) Fahnestock clips; battery connectors; small L-bracket; (4) rubber feet; soldering lugs; hook-up wire; machine screws; nuts; solder; etc.

**Experiment 7:**

Above, plus 12 to 24-volt filament or bell transformer, or equivalent A.C. source

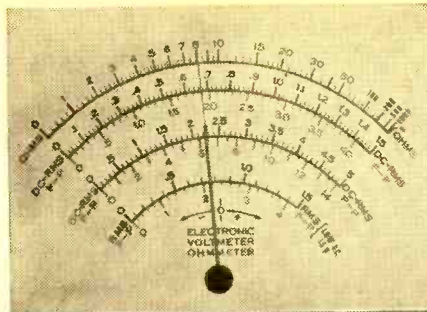
**Headphone limiter** (Fig. 12B)

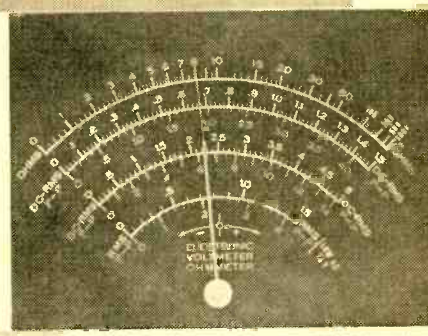
R1—4,700-ohm, ½-watt resistor
Z1, Z2—3.9 volt, ½ to 1-watt Zener diodes
P1—Standard 'phone plug
J1—Open-circut 'phone jack
Misc.—Small *Minibox*; wire; solder; machine screws & nuts; etc.

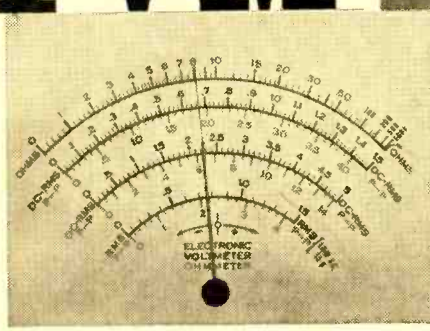
**Experiment 8:**

P1—Battery charger plug (*Schauer* Model A-8412)
R1—56-ohm, 2-watt resistor
R2—10 ohm, ½-watt resistor
Z1—8.2-volt Zener (*GE* type XII) (see text)
CN—Battery connector (salvage from old 9-volt battery)
Misc.—Small aluminum box, rubber grommet, 4-point terminal strip, line cord, hook-up wire, solder, machine screws and nuts, etc.

# Inside the VTVM







By Len Buckwalter

## Discover how a vacuum tube increases measurement accuracy

"No measurement is ever absolutely correct" says the Encyclopaedia Britannica. Whether you weigh an apple, check tire pressure, or just dip a thermometer in water—the act of measuring disturbs the something you're trying to measure. Error, however small, is introduced. In electronic circuits that error could be serious. Simple voltmeters, for example, can utterly upset some circuits. They might even make a defective circuit check out OK. One of today's most important test instruments—the vacuum-tube voltmeter—takes a giant step toward solving the problem. It's found in service shops and labs everywhere for good reason. The VTVM approaches the ideal instrument; one that measures, but little affects the circuit under test.

**Inside the Meter.** The inner workings of a standard voltmeter reveal why it's nearly worthless for certain measurements and fine for others. Simple voltmeters operate somewhat like an electric motor. Power drawn from the circuit drives the needle up the scale. The basic action is illustrated in Fig. 1. The 8-volt source is the voltage to be measured. The moving coil, pivoted so it may rotate, picks a portion of circuit power and converts it to a magnetic field. Note that the coil also lies between the poles of a per-

## Inside the VTVM

manent magnet. Through forces of magnetic attraction and repulsion, the coil rotates and varies the needle position.

Also in the voltmeter of Fig. 1 is a resistor. It protects the meter against absorbing too much circuit power and risking burnout of the delicate coil. In many meter movements, it takes 1 milliampere of current to make the needle read full scale—10 volts in our example. Now this tiny amount of current leaves certain circuits unaffected. For example, check voltage at an AC wall outlet, and such a meter is highly accurate. The outlet might be rated 15 amperes, which is 15 *thousand* times more current than the meter needs to push the needle all the way. The AC line won't know whether the meter is there or not.

But connect that same meter across the grid of an amplifier tube to find a missing voltage and amplifier performance nosedives. Grid signals are generally low in level. Consider an input socket on a hi-fi amplifier, the one that takes an FM tuner. The tuner signal may be about 1 volt, but available current can run *less* than the current required to drive the voltmeter fully up scale. Place the meter across this kind of circuit and the result is a near short circuit. The 1-volt signal lost, the meter reads near zero.

**Making 'em Better.** Increasing meter sensitivity is one answer. More delicate construction provides readings with far less current to the coil. (There are standard 50-microampere movements.) Not only are these instruments costly, but fragile construction increases the risk of burnout. Place the meter probes on too-high voltage and the fragile coil evaporates! There's a much better approach to sensitivity and ruggedness. It's the vacuum tube voltmeter—VTVM.

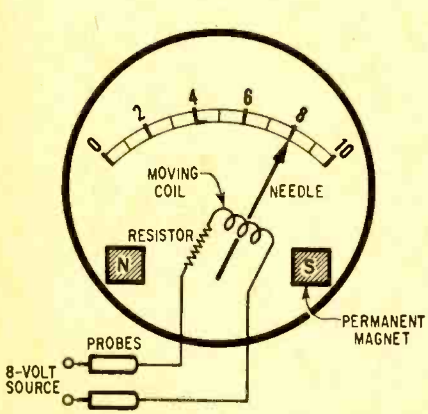



Fig. 1. Basic voltmeter circuit showing the resistor and the moving coil loading effect.

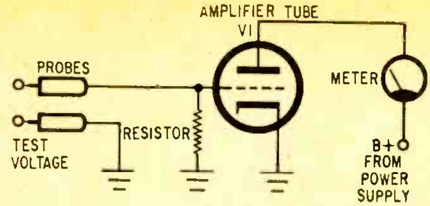



Fig. 2. A simple VTVM circuit that is much more useful for a discussion than application.

The VTVM's special features derive from vacuum-tube construction. Tubes provide amplification. With the ability to magnify, current, the instrument requires less sampling current from the circuit under test to produce readings. The VTVM is effectively isolated from the circuit to a greater degree than is possible with the usual voltmeter. The instrument won't cause *loading*, or short-circuiting, in most practical testing jobs.

**Simple VTVM.** We've shown one of the simplest VTVM types in Fig. 2. It is merely a 1-tube amplifier. Note that a probe is placed on a voltage source, the one to be measured. This is applied to the tube grid which commences to control electrons (originating in the power supply) which stream from cathode to plate. The meter, wired into the plate circuit, indicates the amplified flow. Most important is that a tube grid requires a negligible amount of power to control the large current flow through tube and meter. Now it is possible to measure circuits which characteristically operate at extremely low levels. Mere fractions of a microampere are drawn by the VTVM grid to vary several hundred microamperes in the tube. And the action is *linear*; that is, double the signal to the grid and the amplified plate signal also doubles.

Another big VTVM advantage is not readily apparent. It's built-in meter protection. Assume that the probes are accidentally placed on 100 volts when the meter's voltage selector switch is on a 10-volt range. In the usual voltmeter this could cause burnout or, in less severe cases, slam and bend the needle. The tube in the VTVM, however, automatically limits meter current. It's due to plate saturation—the tube can conduct current only up to a specific value. Excessive input voltage cannot generate currents high enough to burn out the meter coil. At worst, the tube itself can be damaged—a one dollar loss.

**Balanced Bridge VTVM.** The simple VTVM of Fig. 2 has disadvantages. It is difficult to make the tube current swing exactly in step (linearly) with applied voltage. Also, small changes in power supply voltages due to fluctuations of the AC line, produce errors which are not easy to cancel out. The practical solution is in Fig. 3; a simplified schematic of the circuit employed in most VTVM's today. It is a "balanced bridge," selected for accuracy and flexibility. Let's build it up step-by-step to observe some basic functions. Note that if a dividing line were drawn down the center of the schematic, both halves would be just about identical. This provides the "balance" mentioned above.

First consider the tube at left, V1. A steady flow of current (electron flow) travels from the cathode to the plate (see arrow). It is simply a result of applying power supply voltages. Since tube current also passes through a resistor placed in series with the cathode, a certain amount of voltage appears at the top of the resistor, shown as 3 volts. If we shift attention to the other tube, V2, the same conditions are seen. A meter connected across the two cathode resistors will read zero. Although each side of the meter is tied to three volts, the meter "sees" no voltage *difference;* it indicates zero. This is the resting, or balanced condition of the circuit.

Now place the meter probes on a voltage source and the bridge arrangement is thrown off balance. If the test voltage is positive, it drives the grid of V1 positive and causes current through tube V1 to increase. The increased current travels through the cathode resistor and a higher voltage appears at this point. Let's say the normal 3 volts on V1 cathode is now raised to 4. (The other tube, V2, has no such increase and continues to produce 3 volts on its cathode.) These new conditions now cause the meter to see a voltage difference between cathode resistors —a total of 1 volt—and the meter pin indicates the voltage on the scale. The meter scale is calibrated to indicate the actual value of the test voltage. Now to add refinements on this basic circuit to make it resemble more closely the practical VTVM.

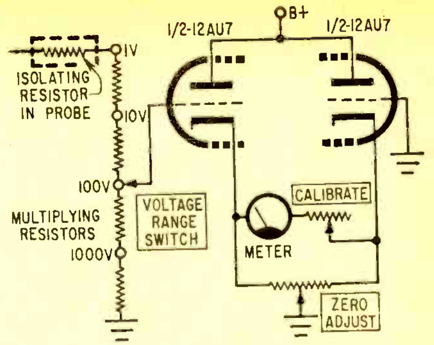



**Fig. 4. Basic VTVM circuit showing the zero adjust and calibrate potentiometers.**

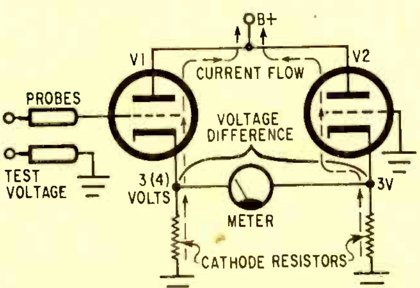



**Fig. 3. Simplified balanced bridge circuit that is usually used in modern VTVM devices.**

**The Practical VTVM.** In Fig. 4, two additional variable resistors are shown; *Zero Adjust* and *Calibrate.* The zero potentiometer allows the operator to perfectly balance the instrument before each use. Small differences in tubes, aging of components and power supply work against exactly equal currents through both sections. The operator can quickly bring the pin to zero with the control. It permits enough shifting of the two cathode voltages so the meter movement sees no potential difference.

The *Calibrate* control affects meter sensitivity, and thus the highest position the needle can reach. Only one potentiometer is shown here, but in a practical instrument there are usually three; two inside the case, one accessible from the front panel. These permit the meter to be separately calibrated for three major functions; *DC volts, AC volts* and *ohms.*

Let's consider the VTVM's ability to measure DC volts, as illustrated in Fig. 4. For the sake of accuracy and linearity, any voltage applied to the VTVM is generally held down to a maximum of about 3 volts—whether you're measuring 1 volt or 1,000. This is accomplished by using a string of resistors which cut down the input voltage. The operator selects the correct resistance with a range switch. It will be seen that the *Voltage Range* switch is set on the 100-volt position. We'll assume that a circuit of approximately 50 volts is touched by the meter probes. As voltage enters the string of voltage-dividing resistors, it is reduced to about 1½ volts. Since the needle rises to full scale for 3 volts, 1½ volts drive it just halfway up. The operator views the appropriate meter scale and reads 50 volts. The identical process occurs for a 1,000-volt range. The switch is flipped to insert more resistance and again the meter indicates half-scale for 500 volts. In this fashion, it is possible to employ a large number of voltage ranges in the meter without ever applying more than 3 volts to the tube grid. Everything is proportional. Observe that one resistor is housed inside the probe. This helps isolate the long test leads and further reduces interaction between the circuit and VTVM.

**Input Resistance.** The series of voltage-multiplying resistors determines an important VTVM rating; input resistance. If all the resistors were added, including the one inside the probe, they would total about 11 megohms in the typical instrument. This is the total load placed upon the circuit being tested. It scarcely affects the operation of most devices under test.

**Sensitivity.** It's instructive to return, for a moment, to the standard voltmeter and compare it with the VTVM's special ability. In Fig. 5 is a circuit being measured, first with a simple voltmeter, then with a VTVM. The true voltage at the plate of the amplifier

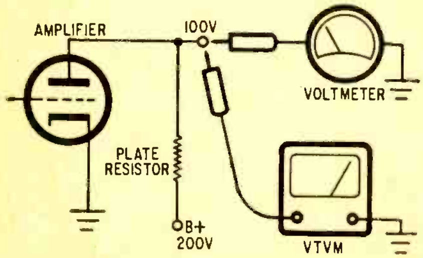



**Fig. 5. Voltmeter presents a greater load to the tube's plate circuit than the VTVM.**

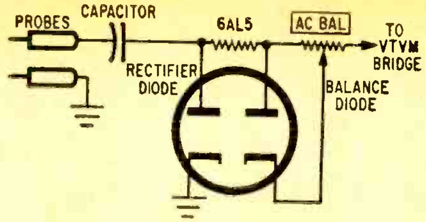



**Fig. 6. Typical rectifier circuit used in VTVM's to convert AC to DC for measuring.**

tube is assumed to be 100 volts. The simple voltmeter, however, can falsely indicate as low as 20 volts. This is due to the instrument's low sensitivity—rated at a certain number of ohms-per-volt. If the voltmeter contains a 1-milliampere movement, for example, sensitivity will be 1,000 ohms-per-volt. This enables us to calculate the meter resistance, or load on the circuit; simply multiply 1,000 ohms by the volts scale in use. In Fig. 5, this would be the 100-volt scale, so the meter presents a total of 100,000 ohms to the circuit. No longer does the tube plate resistor alone drop the 200 volts being fed from the power supply (B+). The meter itself forms part of a voltage divider and the plate receives considerably less voltage than before. This short-circuiting effect can be reduced by using a better voltmeter; a more sensitive 20,000 ohms-per-volt unit would present 2 megohms to the circuit. The VTVM, however, can indicate extremely close to the actual 100 volts due to an unvarying input resistance of 11 megohms. (Some lab VTVM's are rated at much higher input resistances.)

**Zero Centered Scale.** An interesting by-product of VTVM operation is an ability to act as a zero-center meter. Let's say you wished to view the voltage in a circuit which could be positive or negative. A good example is the detector circuit of an FM radio. During one alignment step, it's necessary to make an adjustment which exactly zeros the voltage output of the detector. Misadjustment may produce either positive or negative output. Here, it's convenient to adjust the VTVM's zero control so the pin rests exactly halfway up the scale. Although the bridge is now unbalanced, we can consider the mid-scale reading as zero volts. (And, in fact, the VTVM scale is calibrated with a zero mark at this point.) Now feed in a test voltage; if it's negative, the pin swings left of zero; for positive it swings to the right. The FM detector is easily zeroed. (Another application is balancing the output tubes of a hi-fi amplifier.) The VTVM's sensitivity, too, is especially valuable for measuring detector circuits of all types. AM or FM detectors are extremely susceptible to short-circuiting action of the simple voltmeter.

**Measuring AC Voltages.** Although the VTVM is primarily considered a voltmeter for indicating DC, it also contains other valuable functions for making AC and resistance measurements. Fig. 6 shows the addition of a rectifier tube for AC readings. The left half of the dual-diode converts an AC signal picked up by the probe to DC. A second diode is employed to act as a balancing section. Otherwise, an interfering DC voltage, termed *contact potential*, could introduce error. The balance control is set up initially to cancel out any undesirable voltage developed by the left diode. The AC test signal, now rectified to DC, is fed into the rest of the VTVM circuit and read as an AC value on the appropriate scale.

There is some variation in AC readings given by different VTVMs. The one just described indicates the *peak* value of AC. For example: common house current is 110 VAC —although the voltage is actually swinging plus to minus 60 times per second. The figure is used since it can be directly compared to DC of the same value. (A lamp on 110 AC or DC glows at the same brightness.) The 110 figure is an *RMS* rating (or *root mean square*, which describes the formula for determining the value). Our VTVM in Fig. 6, however, will read about 155 volts, the *peak*, or highest voltage, reached by the AC line. Since there is a definite relationship between RMS and peak voltages, the meter face may be calibrated for both values. In circuit checking, the RMS value is the more common. For some service work, a VTVM which can read *peak-to-peak* AC is valuable. This instrument indicates the total AC swing between plus and minus on complex waveforms encountered in TV receivers, for example.

Adding a rectifier to the VTVM, unfortunately, decreases its sensitivity and usefulness on some AC measurements. This is no problem when checking line voltage, tube fila-

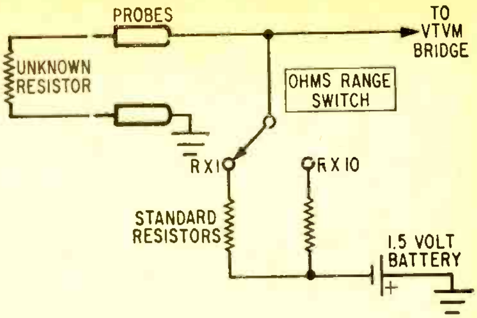
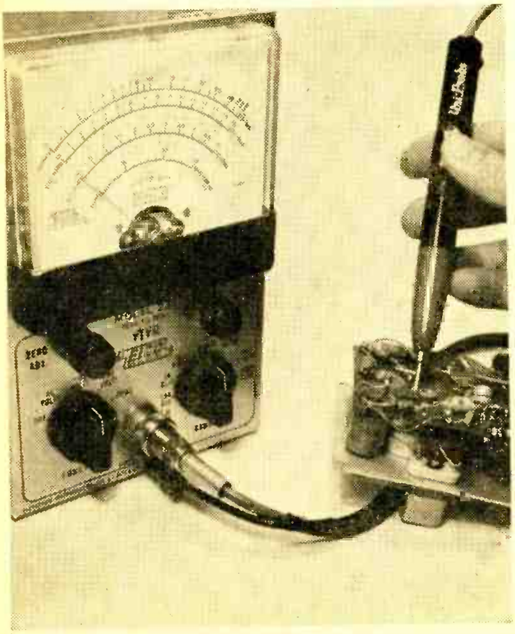
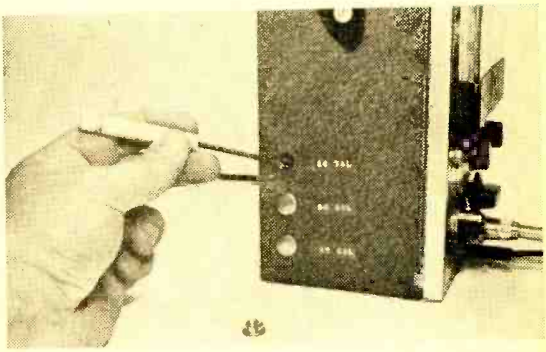



**Fig. 7. Simplified input circuit to VTVM bridge circuit for measuring resistance values.**



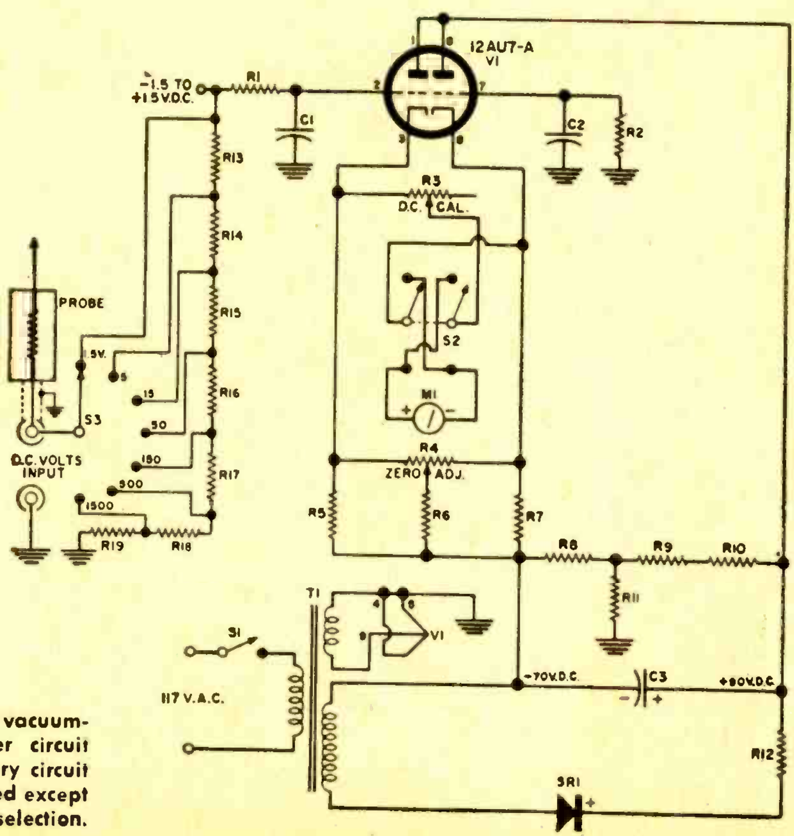



**Left: VTVM is used on home project. Unit shown is an EICO 232 assembled from a kit. Top right: balance controls can be reached without removing case. Bottom right: controls are Zero and Ohms Adj.; Function, Range.**

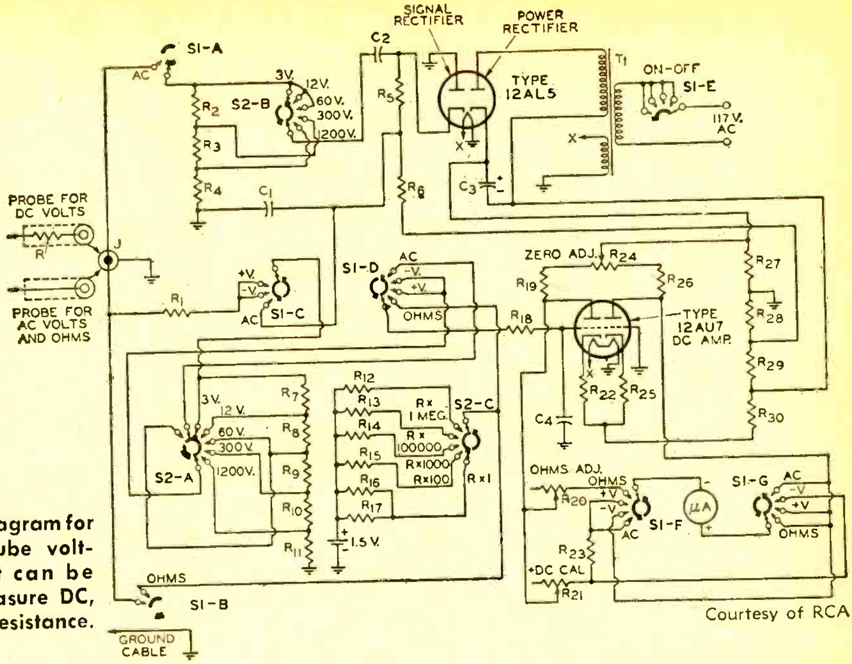
ments or power supplies, for example, since the meter won't load such circuits. There is however, a short-circuiting effect on delicate AC signal circuits (tube grids, for example). Such critical measuring jobs are usually relegated to the oscilloscope, which not only eliminates the loading problem but gives a picture of the AC signal, as well as its voltage. One highly specialized instrument, the AC VTVM, fills a gap left by the oscilloscope. It's the measurement of extremely low-level AC signals which may not show up well on the typical 'scope. The AC VTVM contains an additional amplifier tube(s) to keep the instrument from loading the AC circuit. Such units are usually used for audio troubleshooting and are best suited to checking output of such devices as microphones and phono pickups.

**Measuring Resistance.** The final major section of the standard VTVM is an ohmmeter for resistance measurements. Again, the basic circuit is modified with a simple addition, as shown in Fig. 7. Notice that a small battery appears. The operating principle is that an unknown resistor applied to the probe will divide a certain amount of battery voltage. This drop is indicated, as ohms, on the meter scale. The various standard resistors provide a number of different resistance ranges and serve as part of the voltage divider formed with the unknown resistor. When a VTVM is first placed on its ohms function, the needle automatically swings all the way up scale. This is because the bridge is now reading the full battery voltage. The operator then turns an ohms-adjust control to bring the pin precisely to the highest point, corresponding to infinite ohms. (The control is actually changing meter sensitivity, as described earlier.) Next, the probes are short-circuited together to bring the pin down to zero, and the zero control is used for perfect calibration on this end of the scale. Inserting an unknown resistor between the probes now will cause the pin to read at some intermediate scale point.

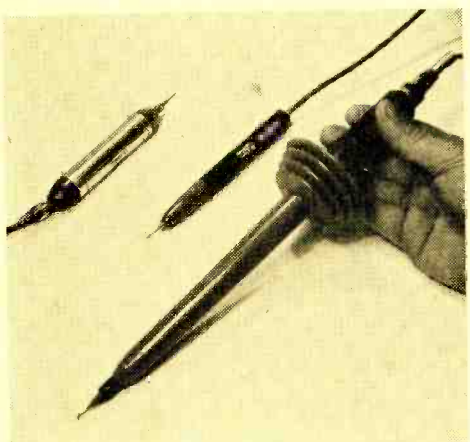
**Current.** These three measuring jobs—




**Here is a simple vacuum-tube DC voltmeter circuit with all unnecessary circuit switching eliminated except on/off and range selection.**




**Schematic diagram for a vacuum-tube voltmeter that can be used to measure DC, AC, and resistance.**

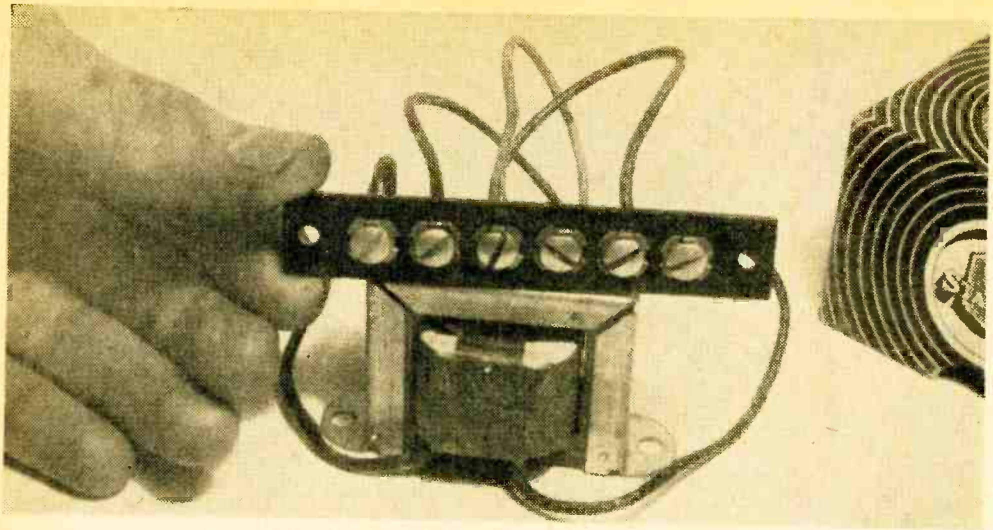


**H-V probes increase range of the DC scales.**

AC, DC and Ohms—are found on all popular VTVM's. It is rare to find an instrument of this type which can also measure current. The reason is that ampere measurements in radio-TV servicing are rarely required. The advent of the transistor may change this. Vacuum tubes are customarily voltage-operated devices and the VTVM can handle just about all required checks. Transistors, on the other hand, frequently function at extremely low, difficult-to-measure, voltages. Many checks are more properly of *operating currents*. Since a VTVM is easily modified for current measurements, manufacturers may introduce more models with this feature. The conversion is done by using the existing meter movement and suitable multiplying resistors for different current ranges. The tubes and bridge circuit are not required.

**The Cons.** Does the VTVM have any disadvantages? Perhaps the most limiting factor is the need for a source of AC power. The VTVM, therefore, is inconvenient for some field checks, as in car-radio servicing. Transistorized design may change this. Requiring just a small battery for power, such units would make the VTVM fully portable. (A kit-type model may be in the offing.) Another minor disadvantage of the conventional VTVM is susceptibility to error when used in the vicinity of a strong radio-frequency field, near an operating transmitter.

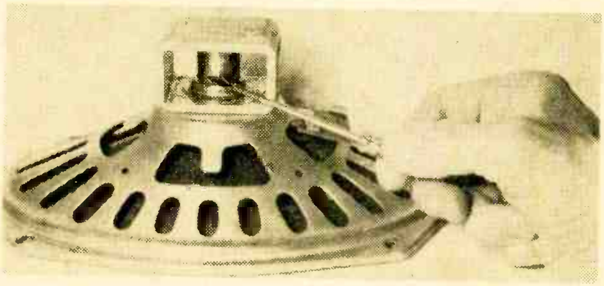
If you've never operated a VTVM before, be prepared for an occasional, mysterious indication. After calibrating the instrument, the needle may climb the scale of its own accord—even though the circuit has no other defect. The reason is build-up of static electricity on the transparent face plate, which affects the meter movement. To prove it, place a finger on the face plate and the pin should change position. The remedy can be applied in a moment; wet a cloth with some household detergent and water, then gently swipe it across the meter face. As the static charge is neutralized, the pin drops quickly back to zero. ■

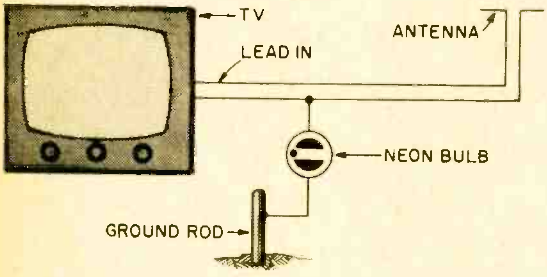


Handy for experimental hookups: Attach a terminal strip to a small transformer, soldering one lug to transformer housing; solder leads to the strip as shown. This prevents lead breakage due to twisting of the leads while they are being soldered and unsoldered from hookups.

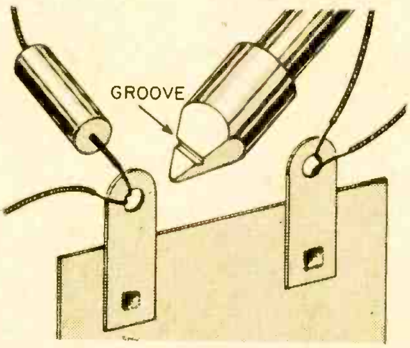
# circuitricks

A screwdriver can be magnetized by touching it to the voice-coil end of the magnet slug in a PM speaker as shown. Blade will be sufficiently magnetized to pick up and hold many small iron and steel objects, including screws, nails, bits of gear, etc.






Lightning can ruin a TV set, even one with a lightning arrestor. For added protection connect a glow lamp (NE-7) between the set's antenna terminals and ground rod as shown. Voltages over 55 volts will then pass through the bulb to ground, thus bypassing the set.




File a groove in one side of your soldering iron for "pouring" solder on connections of a crowded chassis.

# the db

## The Audiophile's Yardstick

By Mannie Horowitz

WHEN you read any scientific text, the physicist, chemist, or engineer seems like the most logical individual in the world. Every bit of logic follows from a previous bit of information or a carefully performed experiment. Every mathematical equation follows every other equation in logical sequence. These books describe physical occurrences "to the letter."

But is the scientist really so logical and precise? Frequently, he is. At times, the theories and equations have been derived from observing a physical occurrence. Mathematical equations have been derived or simply written to describe in precise terms just what the scientist observed in the laboratory. Later on, when all has been proven accurate, the observations and mathematics are written in the form of a textbook with a seeming natural flow of logic.

The decibel (abbreviated db hereafter), is no exception to the rule. It was determined by experimentation on

# The db

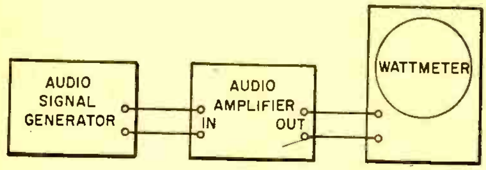



**Fig. 1. Setup to measure db gain of an amplifier—wattmeter has 16-ohm resistor.**

human guinea pigs. At least, that is the way the story goes. I would personally not bet on the veracity of the tale.

**The Beginnings of the Decibel.** The story related by word of mouth, starts a number of years ago. The exact date by now has faded from my memory. A number of scientists got a number of people into a room and let them listen to signals from an audio signal source. They varied the level. As soon as a majority of these people were able to determine that the sound level had changed, they indicated this to the scientists. Whether they did this by shouting "now," "stop," "hey-you," or just simply raising their hand (right or left) is no longer known. But what is known is that the minimum difference in sound intensity that they were able to hear, was called 1 db.

With this established, they next played a musical passage on their Victrola. They determined from this test that a variation of 3 db intensity was the least audible difference when using music material. Two facts were thus established never to be disputed by anyone (hardly anyone):

☐☐ **1.** On a single note, the minimum audible difference in intensity level is 1 db.

☐☐ **2.** On musical passages, the minimum audible difference in intensity level is 3 db.

Armed with this information, the scientists and engineers turned their attention to state everything concerning the db with mathematical precision. After all—the textbooks must follow logical sequences.

**The Mathematical Definition.** The equation defining the decibel turned out to look deceivingly simple. It is stated as

$$decibel = 10 \log (Po/Pi). \qquad (1)$$

Just what does this mean?

Suppose you have an audio amplifier. You feed a signal to it so that there is 10 watts at the output. This output power from the amplifier is *Po*. Then you check the power you must feed to the input to get this output. Suppose it is 2 watts—this input power is *Pi*. The ratio of these two powers appears in the equation as *Po/Pi*. In the example, the power ratio is 10 watts ÷ 2 watts, or simply 5.

It would be simple to state the gain of the amplifier as being 5. It is the actual gain. But it does not include the human factors discussed above.

To find this power gain in terms of the decibel, the logarithm of 5 (log 5) must be found from log tables. The figure is then to be multiplied by 10.

The decibel is basically the logarithm of a

**TABLE 1. Table of Common Logarithms**

| No. | Log | No. | Log | No. | Log | No. | Log | No. | Log | No. | Log |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | .000 | 2.5 | .398 | 4.0 | .602 | 5.5 | .740 | 7.0 | .845 | 8.5 | .929 |
| 1.1 | .041 | 2.6 | .415 | 4.1 | .613 | 5.6 | .748 | 7.1 | .851 | 8.6 | .935 |
| 1.2 | .079 | 2.7 | .431 | 4.2 | .623 | 5.7 | .756 | 7.2 | .857 | 8.7 | .940 |
| 1.3 | .114 | 2.8 | .447 | 4.3 | .634 | 5.8 | .763 | 7.3 | .863 | 8.8 | .945 |
| 1.4 | .146 | 2.9 | .462 | 4.4 | .644 | 5.9 | .771 | 7.4 | .869 | 8.9 | .949 |
| 1.5 | .176 | 3.0 | .477 | 4.5 | .653 | 6.0 | .778 | 7.5 | .875 | 9.0 | .954 |
| 1.6 | .204 | 3.1 | .491 | 4.6 | .663 | 6.1 | .785 | 7.6 | .881 | 9.1 | .959 |
| 1.7 | .230 | 3.2 | .505 | 4.7 | .672 | 6.2 | .792 | 7.7 | .887 | 9.2 | .964 |
| 1.8 | .255 | 3.3 | .519 | 4.8 | .681 | 6.3 | .799 | 7.8 | .892 | 9.3 | .969 |
| 1.9 | .279 | 3.4 | .532 | 4.9 | .690 | 6.4 | .806 | 7.9 | .898 | 9.4 | .973 |
| 2.0 | .301 | 3.5 | .544 | 5.0 | .699 | 6.5 | .813 | 8.0 | .903 | 9.5 | .978 |
| 2.1 | .322 | 3.6 | .556 | 5.1 | .708 | 6.6 | .820 | 8.1 | .909 | 9.6 | .982 |
| 2.2 | .342 | 3.7 | .568 | 5.2 | .716 | 6.7 | .825 | 8.2 | .914 | 9.7 | .987 |
| 2.3 | .362 | 3.8 | .580 | 5.3 | .724 | 6.8 | .833 | 8.3 | .919 | 9.8 | .991 |
| 2.4 | .380 | 3.9 | .591 | 5.4 | .732 | 6.9 | .839 | 8.4 | .924 | 9.9 | .996 |

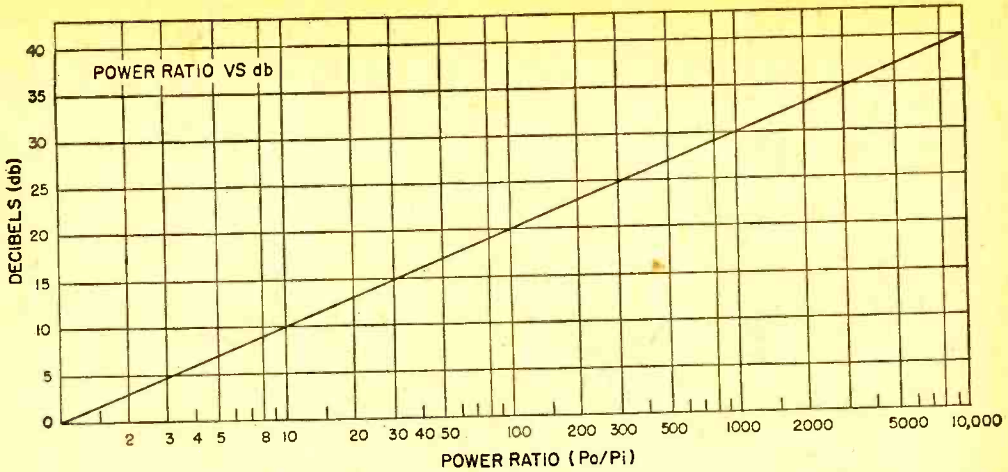



**Fig. 2. Graph of power ratio versus decibels eliminates computations.**

ratio of two power levels. In the example discussed above, it is the logarithmic ratio of the output of an amplifier to the input. It could also be the logarithmic ratio of the gain of an amplifier when the level control is set to maximum output to the gain when the level control is set at a mid-rotation point. It could also be the logarithmic ratio of the maximum power output to the power delived by the residual hum and noise in the amplifier. This is known as the *hum level* as expressed in db below rated power.

**Use of Logarithms.** Working with exponents is one of the manipulations discussed early in math courses. It is learned early in the arithmetic experiences that $3^2$ (3 squared) means $3 \times 3$ or 9; $3^3$ (3 to the third power or cubed) is $3 \times 3 \times 3$ or 27, etc. The exponent (the small number above and to the right of the larger number) indicates how many times the larger number should be multiplied by itself.

So what has this to do with logarithms? *Wait!*

Suppose we don't use 3. Use 10 instead. Then $10^2$ is $10 \times 10$ or 100. $10^3$ is $10 \times 10 \times 10$ or 1000, etc. It should also be remembered that $10^1$ is 10 and $10^0$ is 1. Any number to the zero power is 1.

So what has this to do with logarithms? *Wait!*

In order to multiply two numbers with exponents, you simply add exponents. This can be readily shown as $10^2 \times 10^3 = 10^5$. Doing it the long way, $10^2 = 100$ and $10^3 = 1000$. $100 \times 1000 = 100{,}000$, which is $10^5$, for $10^5$ is $10 \times 10 \times 10 \times 10 \times 10$ or 100,000.

Division is similarly accomplished. You subtract the exponent of the number in the denominator from the exponent of the number in the numerator. Thus, if $10^3$ is divided by $10^2$, or $10^3/10^2$, you get $10^1$. Proof: $10^3 = 1000$; $10^2 = 100$; $1000/100 = 10$; which is $10^1$.

So what has this to do with logarithms? *Now!*

The numbers with exponents can be written in terms of a logarithm. It is simply another way of stating the same information.

$$log_{10}n = e. \qquad (2)$$

This equation states that 10 to an exponent e, is equal to a number n. Written in the previous exponential form, $10^e = n$. If e is 2, n is 100.

It can be seen that 10 (shown in equation 2) has been omitted in equation 1. The logarithm is so commonly used to the "base" 10, that the 10 is an understood quantity.

Values of e and n are given here as integral or whole numbers, such as 1, 2, 3, etc. But what happens if they are not whole integral numbers? How to handle numbers between these integral values can be found in textbooks. A good discussion of methods and tables will be found in books such as "Electronics Math Simplified" by Alan Andrews (Howard W. Sams, published 1961). Table 1 is provided in this article to give logarithms for two digit numbers.

Just as numbers with exponents can be multiplied and divided, logarithms of numbers can be multiplied and divided. The rules are simple and follow from the rules of exponential manipulation.

## EE The db

$$\log (a \times b) = \log a + \log b \qquad (3)$$
$$\log (a/b) = \log a - \log b \qquad (4)$$

Equation 4 is of the same form as equation 1, which is the mathematical definition of the decibel. Just multiply equation 4 by a factor of 10, and you have equation 1. This is so because

$$\text{decibel} = 10 \log (a/b) = 10 [\log a - \log b].$$

**Example 1.** Suppose you connect an audio amplifier into the setup shown in Fig. 1. Feed a 1000 cycle signal through the amplifier so that you read 10 watts on the wattmeter. A neighbor then walks into your house. You want to talk to him. You must make the output lower so that your conversation will not be drowned out. You turn the gain down on the amplifier until you read 1 watt on the wattmeter. How much less power, in terms of db, is your amplifier delivering now to the speaker or load?

You must use equation 1 to determine the value of this ratio in db. Substitute all numbers into equation 1. This gives

$$\text{db} = 10 \log (P_2/P_1)$$
$$= 10 \log 1/10 = 10\ [\log 1 - \log 10] = 10 [0 - 1]^*$$
$$\text{db} = -10$$

The minus (−) sign means that the gain has decreased 10 db or, more simply, less power is being used now than before.

Now, suppose the neighbor walks out and you increase the gain so that you once again get 10 watts out. The increase in gain in db is

$$\text{db} = 10 \log (P_2/P_1)$$
$$= 10 \log 10/1 = 10 [\log 10 - \log 1] = 10 [1 - 0]$$
$$\text{db} = 10$$

The lack of a minus sign indicates an increase in gain.

The fact that the numbers stating the increase in actual gain and the number in db are identical, is only coincidence. But it is a good number to remember. Stating this as a rule:— An increase in power by a factor of 10 is equivalent to an increase of 10 db. A decrease in power by a factor of 10 is equivalent to a decrease of 10 db.

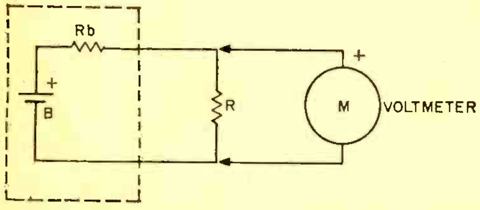



**Fig. 3. Circuit using a voltmeter to check the power dissipated by the load resistor.**

**Example 2.** Next, when all was quiet, you listened to your amplifier and decide it has too much hum. You use the setup in Figure 1 to check the hum level and convert the measurements so that the final figure is in terms of db.

The procedure to check the hum level is straight-forward. First, you turn up the signal generator and measure the maximum power your amplifier can deliver at 1000 cycles before it distorts. You can either connect an oscilloscope to check the waveshape, or listen until the signal sounds as if it is beginning to distort. You note this figure. Let us say it is 20 watts. If you are lazy, use the manufacturer's stated rating value provided it is not given in *music power*.

Now, you remove the generator and turn all level controls on the amplifier up to maximum. The output meter will then read the hum and noise power generated by the amplifier. Let us say it is 0.2 watts. The hum level, in db, is then

$$\text{db} = 10 \log (20/0.2) = 10 \log 100$$
$$= 10\ (2) = 20 \text{ db}.$$

[ NOTE: $20/.2 = 100$ and $\log 100 = 2$ ]

A power ratio of 100:1 is 20 db. And well you might complain about this much hum in your amplifier.

**Power ratios.** In the examples, you can see that power ratios represent specific numbers of db. Thus a ratio of 10:1 was 10 db and 100:1 was 20 db. If the ratio was 1:10, the result was −10 db.

The absolute numbers in terms of db remain unchanged if the ratios are the same. If the final output is less than the initial output, the resulting number is negative and thus has a minus sign in front of it. If the final output is greater than the initial output, the resulting number is positive.

In the first case, it is called a *db loss* and referred to as "db below a certain figure." Then the minus sign can be omitted, but it is still understood. When the figure is positive, it can be called a *db gain* or db above a certain figure. In either case, db represents a logarithmic power ratio.

Because db is a logarithmic power ratio, we can set up a graph of the power ratios

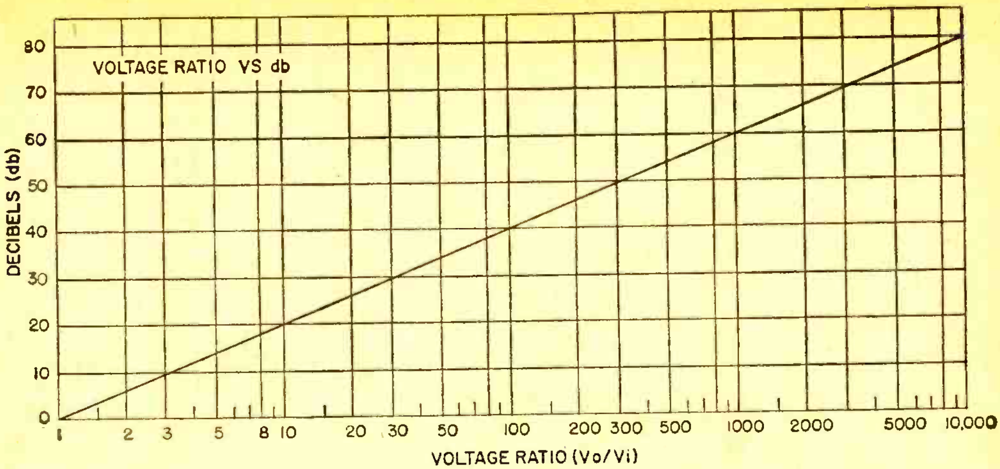



**Fig. 4. The above graph can be used to find db when voltage ratios are known.**

plotted along the horizontal axis and the equivalent value in db plotted along the vertical axis. The power ratios can be determined and the db figure representing this ratio can be read from the graph shown in Figure 2. Special log paper has been used so that the resultant curve on the graph will be a straight line.

On the graph, the numbers indicated on the horizontal axis are $P_0$ in equation 1. $P_1$ is understood to be 1. Thus the number 2 indicates a power ratio of 2:1; 50 indicates a power ratio of 50:1, etc.

It is worthwhile to remember a few of the numbers corresponding to power ratios. For convenience, let us take the four power ratios in Table 2, and remember them.

**TABLE 2. Power ratios and Their Equivalent in db**

| Decibel | Power ratio |
|---|---|
| 10 db | 10:1 |
| 9 db | 8:1 |
| 7 db | 5:1 |
| 3 db | 2:1 |

If you but recall that db is a logarithmic function, a factor you will not be permitted to forget throughout this discussion, it is easy to see how this table will let you determine just about every power ratio in terms of db. The log function leads to a rule based on equations 3 and 4.

> **Rule:** In table 2 (or table 3 to follow), if you multiply the numbers in the ratio column, you must add the numbers in the db column.

How to use this rule advantageously is quite simple.

Suppose, in example 2, that you found you had a power ratio of 100:1. You could, of course, look it up on the curve in Fig. 2 and find the db figure (20 db) immediately. But suppose you did not have Fig. 2 with you, but you did remember Table 2. First you break down 100:1 into a product of power ratios, so that the product of these ratios is 100:1. It may be 10:1 × 10:1.

Next, you remember from Table 2 that 10:1 is 10 db. But you have 10:1 two times. The rule tells you that you must add numbers in the db column. The power ratio products 10:1 × 10:1 = 10 db + 10 db or 20 db.

Take another case. This time assume the power ratio is 160,000:1—a pretty large but not unusual ratio. Using the rule, 160,000:1 can be composed of 10:1 × 10:1 × 10:1 × 10:1 × 8:1 × 2:1. The equivalent sum in db is 10 + 10 + 10 + 10 + 9 + 3 = 52 db.

In this second case, you not only saw an example of how to calculate a large power ratio in terms of db, but you also saw a good reason for using the db. A large power ratio is represented by a small number. Thus, the ratio 160,000:1 can be replaced by the number 52 db, with equal significance.

**Converting to Voltage Ratios.** No matter what you read from here on, it must always be remembered that db refers to a power ratio. This was stressed throughout the discussion above. No arithmetic or measurement will ever change this. The discussion to follow does not change this.

First, let us recall some of the basic theory

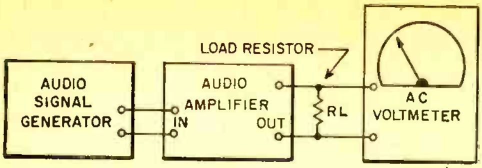



**Fig. 5. An AC voltmeter and a calibrated load resistor can be used to measure db's.**

we learned a long time ago. In Fig. 3, you see a voltage source (B), a resistor (R), and a voltmeter (M) to measure the voltage across this resistor.

The battery can be represented by a voltage source in series with a resistor, Rb. This is the internal resistance of the battery. It increases as the battery gets older or used for a long period of time. Because of this resistor, the voltage across resistor, R, is less than the battery voltage, a portion of the battery voltage appears across its own internal resistance, Rb. Therefore, a meter, M, is required to measure the voltage across resistor R. It is assumed that the resistance of meter M is so large that it does not affect the voltage drop through the circuit, but only reads the voltage across R.

Now that we know the voltage V across R (read on the meter), the power dissipated by the resistor R is

$$P = V^2/R. \quad (5)$$

Now comes a little algebra. If you can follow it, you should be commended for you can get an excellent insight into what is happening. If you cannot follow it, jump down to equation 8, which will be very useful to you in any event.

Suppose that at one power level, Po, the battery voltage in Fig. 3 is Vo; then the power dissipated by the resistor R, is

$$Po = Vo^2/R \quad (6)$$

Then, at a second power level, Pi, the battery voltage is Vi. Now the power dissipated by the same resistor is

$$Pi = Vi^2/R \quad (7)$$

Substituting equations 6 and 7 into equation (1) yields

$$\begin{aligned} \text{decibel} &= 10 \log Po/Pi \\ &= 10 \log (Vo^2/R)/(Vi^2/R) \\ &= 10 \log (Vo^2/Vi^2) = \\ &\quad 10 \log (Vo/Vi)^2 \end{aligned}$$

$$\textit{decibel} = 20 \log Vo/Vi \quad (8)$$

To put it in a nutshell, equation 8 states that if the voltage is measured across the same or equal resistors, the decibel change can be determined from the voltage ratio, using equation 8. It should be remembered that db still represents a power ratio, but under one condition—that of two voltage levels being measured across the same or equal resistors—can the ratio in terms of db be determined from the voltage ratio. It is not a change in definition of db, but just a change in the method of arriving at the figure.

As you might expect, a table can be derived for voltage ratios, which is very similar to that used for power ratios. The voltage ratio equivalent in db is stated in Table 3.

**TABLE 3. Voltage ratios and their equivalent in db**

| Decibel | Voltage ratio |
|---|---|
| 20 db | 10:1 |
| 18 db | 8:1 |
| 14 db | 5:1 |
| 6 db | 2:1 |

It is interesting to note that the db reading for voltage ratios is double that for identical power ratios. That this should be so can be determined from equations 1 and 8, where in one case the log of the ratio is multiplied by 10 and in the second case it is multiplied by 20. Because one factor multiplication is double the other, the final db figures in both tables must also be different by a factor of two.

The rule for multiplying the number in the ratio column and adding the number in the db column applies to Table 3 as well as it did to Table 2.

There should be no confusion in using these tables or the graph in Fig. 4 which is derived from equation 8. Table 2 assumes the power is known and the ratio of two powers is considered. Table 3 assumes the voltage is known and the ratio of two voltages is calculated. In our example, it was determined that the power ratio of 160,000:1 was 52 db. Because power is proportional to the square of the voltage (equation 5), the measured voltage ratio would be $\sqrt{160{,}000:1}$ or 400:1. Using our rule.

400:1 = 10:1 × 10:1 × 2:1 × 2:1

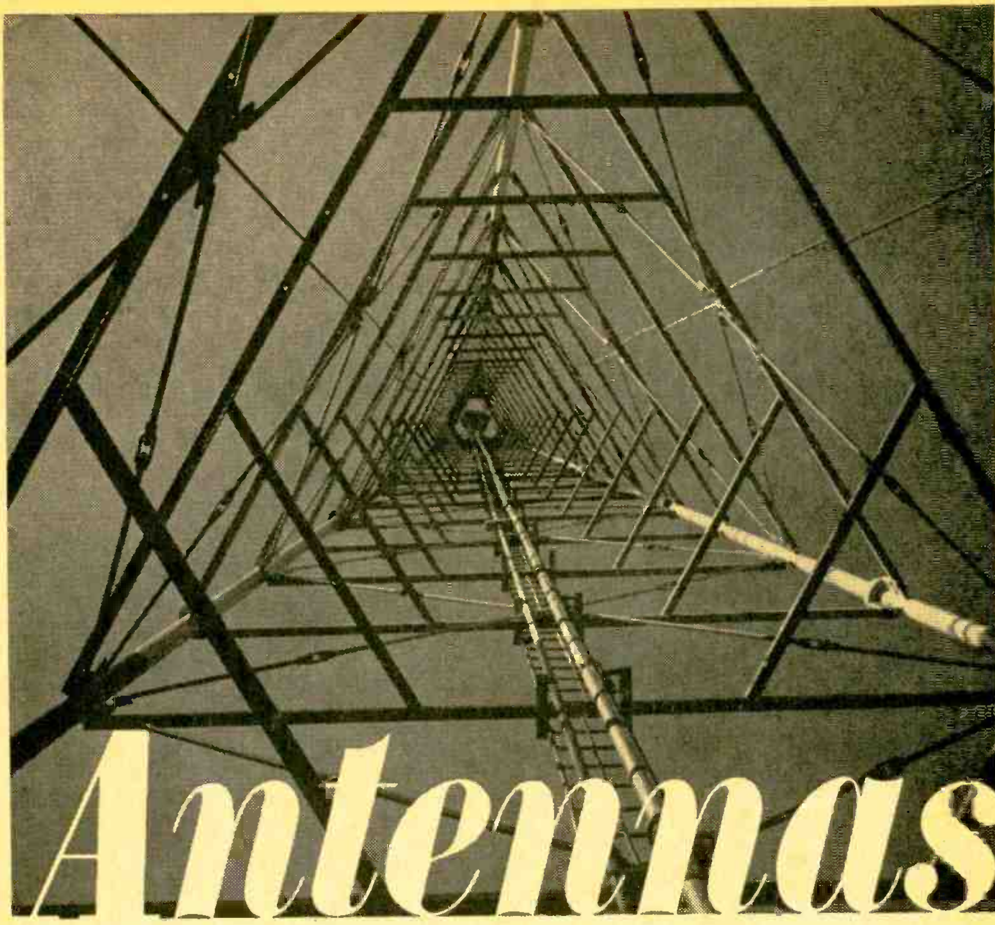
which is the same as writing (for voltage ratios)

20 db + 20 db + 6 db + 6 db = 52 db.

52 db is identical to the number determined above for the power ratio. The results are the same—only the equations used are different.

**An Example.** Fig. 5 is similar to that of

*(Continued on page 126)*



# Antennas

If you're a newcomer to amateur radio—whether a new novice or a general class—most likely your new shack is buried in a mountain of antenna literature all of which claims the most sophisticated design yet. And your mind is cluttered with all the variables involved in making the best selection for your particular circumstances. There are dipoles, trap antennas, beams, and Yagis, and colinears, and verticals, and so on, and so on. In fact, any radio catalog worthy of the name has at least several pages of "superb," "magnificent," or "extraordinary" sky hooks, and, of course, they all have extraordinary prices.

Getting the right antenna is more than just a question of plunking down your money and picking the antenna with the most esoteric specs or the most cleverly merchandised name—some of which are doozies. You have to know what you want the antenna to do, and a fledgling rarely knows what's needed until he has kicked around the band and gotten the hang of things.

Most often, the best antenna requires only a few dollars worth of wire and an hour or so of time, following, of course, all the adequate forethought. You want something simple that works right off the bat; and an antenna that doesn't require a hundred bucks worth of test gear and five years of experience to get going. Don't laugh! There are

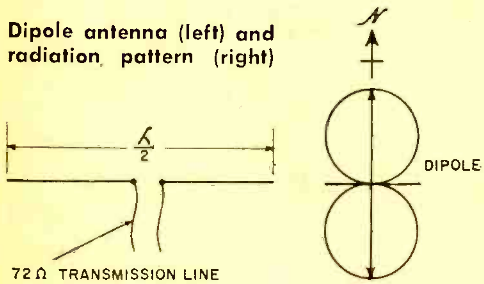
# for the new amateur

By Herbert Friedman, W2ZLF

many fine antennas that give outstanding performance when tuned to a gnat's eyelash, but when they're not tuned you'd be better off coupling the transmitter to the bedspring. Many antenna types fall into the "simple" or the "quick and dirty" category, and most of them do a fine job, not only for the novice but for the Ol' Timer as well.

**The Dipole.** The dipole is the basic antenna to which all other antennas are compared. It has an overall electrical length of half-a-wavelength from end to end. We say *electrical* half-wavelength since the antenna is physically shorter than a calculated half-

Dipole antenna (left) and radiation pattern (right)




wavelength. Something known as "end effect" electrically shortens the antenna, so it must be shortened physically to be electrically correct. For this reason, a dipole's length is calculated from the modified formula.

$$L(feet) = 468/f(mc)$$

The freespace formula is

$$L(feet) = 492/f(mc)$$

Keep in mind that the end effect only applies to antennas supported on the ends by insulators. If you erect a dipole that is supported by a mast in the center, there are no end effects and the standard formula

$$L(feet) = 492/f(mc)$$

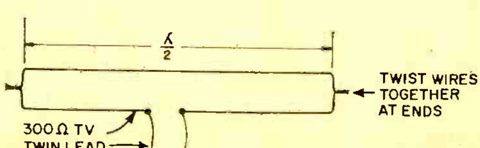
is used. The feedpoint impedance (radiation resistance) of the antenna at its resonant frequency is 72 ohms, a value easily matched by either 72-ohm coaxial or twinlead transmission line. Fifty-two ohm coax will also work well.

Note that the energy of a dipole is radiated at right angles to the wire axis. If the wire axis is running from east to west, the energy is radiated north and south. A perfect dipole would have no east-west radiation. This fact must be considered when erecting your antenna. If you live on the east coast and want to work Europe, the dipole must be positioned so it radiates essentially east and west. South America would require an east-west alignment of the antenna, naturally. It's almost impossible to cover several directions with a single dipole, and for reasonably full coverage it may be necessary to string two dipoles at right angles to each other.

**The Folded Dipole.** While similar in characteristics to the straight dipole, the folded dipole is often attractive to new amateurs because it's the cheapest and the easiest antenna to erect. The folded dipole is an electrical half-wavelength loop, open at the center. If the loop is made from ordinary 300-ohm TV twinlead, the feedpoint impedance is 300 ohms; another section of 300-ohm twinlead can be used for the transmission line. With the price of twinlead at one to two cents a foot, an entire folded dipole installation for 80 meters can be bought for less than four dollars. The energy distribution pattern (radiation pattern) of the folded dipole is the same as for the straight dipole.

**Loaded Dipoles.** One of the problems the modern urban amateur has to face is that his Old Homestead rarely includes a rear 20 acres. If he's got a plot 40 or 80 x 100 he's lucky. A few simple calculations shows that it's going to be difficult to stretch a 135-foot, 80-meter dipole on a modern lot; and not many neighbors appreciate antennas or "those wires" crossing their property. And 80 meters isn't the only headache; if you've got to string your antenna in the tight dimensions of 60 x 100 even a shoehorn won't squeeze in a 65-foot, 40-meter antenna. What to do?

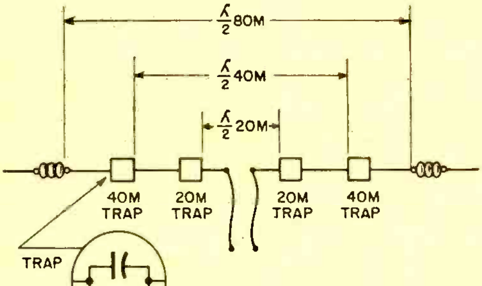
Antennas can be physically shortened with a device known as a loading coil. You remove a substantial section of that long length of wire, stick in the coil, and *voila!*, a short resonant dipole. You could build your own loading antenna but you're better off buying one. Several manufacturers offer loaded antennas, and if you're interested in working




Folded dipole antenna

the low bands but haven't the space, look into a loaded "short antenna."

**Trap Antennas.** One of the variables to consider in setting up your rig is the number of bands you'll be working. Assuming you'll want the provision for working 10, 15, 20, 40, and 80 meters as most amateurs do, you'll



**Multi-band antenna using parallel resonant traps.**

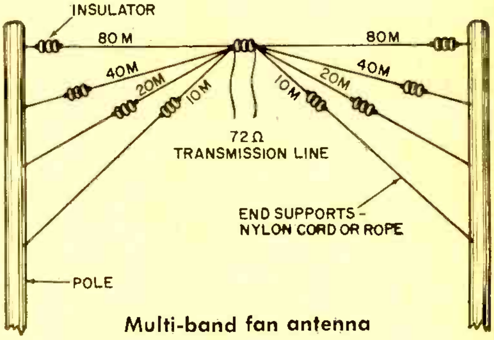
start studying your too-cozy back yard and wonder, how? Figuring that multi-band operation means an antenna for each band, you will visualize your lovely backyard cultivated to an antenna farm and forget the whole thing there and then. But this is where trap antennas pay off.

The trap antenna is a basic dipole at the lowest operating frequency you desire—80 meters, most likely. Parallel resonant tuned circuits (traps) are placed at the electrical half wave length points for the higher operating frequencies. The 40-meter traps "stop" the 40-meter energy and as far as the transmitter is concerned it is working into the length of a 40-meter antenna. The 40-meter traps become effective only when 40-meter energy is fed into the antenna system. Similarly, the 20-meter traps electrically shorten the antenna only when 20-meter energy is fed into the antenna. The action is similar to that of an automatic switch—the frequency of the RF energy determines which antenna section is utilized.

Again, you could build your own trap antenna, if you had the necessary test equipment to get one working, but you're better off buying a manufactured model.

**The Multi-Band Fan.** For the save-a-buck operators: a multi-band antenna known as a "fan" can be built for just a few dollars. Individual dipoles, spaced about a foot apart at the ends, are tied together at a common feed point. Nylon cord or rope is used to make up the difference in length for the higher frequency antennas. This system can be fed with 72- or 52-ohm cable, and, as with the trap antenna, the transmitter "sees" only the correct antenna for the band in use.

**Harmonic Hazards—and Tricks.** Whenever you use a multi-band antenna—whether trap or fan—keep in mind that it will radiate harmonic energy just as efficiently as the fundamental. This is unlike a single band antenna, such as a straight dipole which radiates efficiently only at its resonant frequency. If, for example, you're working 80 meters with a strong 40-meter harmonic, a multi-band antenna will put you on both bands! Similarly, if you're working 80 meters and the transmitter has a 10-meter parasitic, a multi-band antenna with a 10-meter section will do a great job of radiating the parasitic. Therefore, when using any multi-band antenna, make certain your transmitter is as clean

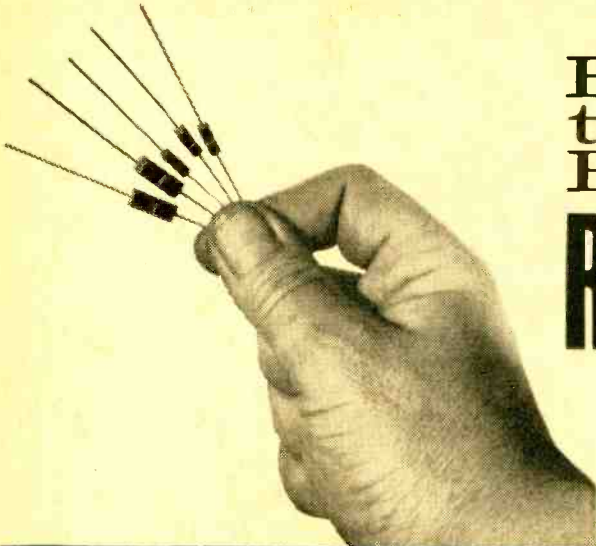


**Multi-band fan antenna**

as you can make it. If you suspect a high harmonic output, utilize an antenna tuner between the transmitter and the antenna system; the tuner will stop harmonic energy before it is radiated.

You may have noted that in the fan antenna drawing there is no provision for 15 meters. But you can still work this band! A dipole will operate with reasonable efficiency on the third harmonic, so the 40-meter antenna is used for 15 meters.

**Get on the Air Fast.** While there are many other antenna types, the basic configurations we've covered are recommended because they give the least trouble, work efficiently, and allow you to get on the air fast. Many of you will become "antenna men" coming up with a new design every week, but while you're digging into those antenna books you'll be on the air with these pure and simple work horses. There are still many Ol' Timers and DX Hounds using them year after year accumulating an enviable collection of QSL's. ■



# How to Buy FIXED RESISTORS

By Jay Copeland

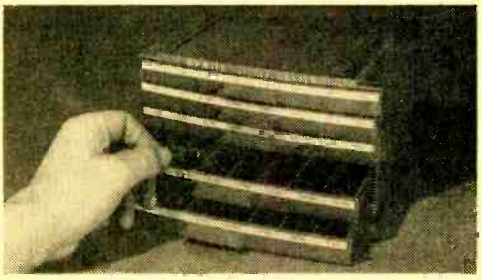
**How** many times have you solved an Ohm's law problem and come up with 156.86 ohms at .266 watts as a value for a cathode bias resistor. Now, the next trick is to find a stock resistor at that value. Impossible, as you probably know. There *ain't* no such animal. Quickly you study the characteristic curves for the vacuum tube used in the circuit and find that any resistor from about 130 ohms to 180 ohms will do the job.

**The Parts Catalog.** Next thing to do is look into an electronic parts catalog and see what's available. First, resistors of the common fixed composition variety are available in 1/10, ½, 1 and 2 watt ratings. Since the resistor's computed value was .266 watts, the next largest size should be used—½ watt (.500). On over rated wattage capacity increases the safety margin of the resistor in the circuit function it was selected.

Checking the catalog again you will see that the closest resistance value available is 160 ohms but only as a 5% tolerance type. This means that the true value of the 160 resistor is somewhere between 152 ohms to 168 ohms. This resistor can be used in place of the computed 156.86 ohms if you are willing to pay 24 cents. However, if you use a 150 ohm resistor with 10% tolerance—it ranges from 135 ohms to 165 ohms—its true value is still within the desired resistance range and it's priced at 12 cents.

**Money talks.** Price is very important in projects that use many resistors. For example, let's assume you are putting together an amplifier that uses 27 resistors rated at ½ watt. Using the *Allied Radio* catalog as a price guide, you can buy these resistors for \$5.13 if they are 5%'ers and for \$2.43 if they are 10%'ers. Fortunately, except for the rare critical circuit, 10% tolerance resistors are good enough for almost all the projects you will ever build.

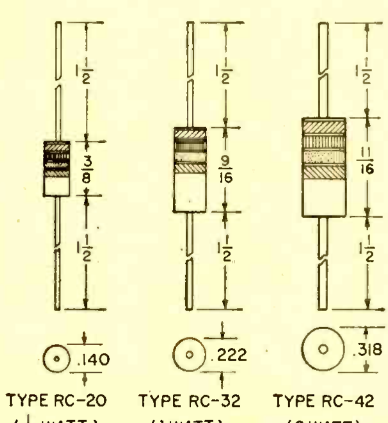
**Identification.** Almost everyone knows the RMA color code used to mark resistance values on resistors. But just in case you don't know what a *gray, red, green* and *gold* banded resistor is rated at, refer to figure 1. The illustration shows us that gray is 8, red is 2 and green the number of zeros follow-



**Buy 150 ½-watt assorted resistors and Ohmite will toss in a storage cabinet; \$18.00.**

## Standard MIL & EIA Resistor Values for Fixed Composition Resistors

| 20% | 10% | 5% | 20% | 10% | 5% | 20% | 10% | 5% | 20% | 10% | 5% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 10 | 10 | | 390 | 390 | 15000 | 15000 | 15000 | | 560000 | 560000 |
| | | 11 | | | 430 | | | 16000 | | | 620000 |
| | 12 | 12 | 470 | 470 | 470 | | 18000 | 18000 | 680000 | 680000 | 680000 |
| | | 13 | | | 510 | | | 20000 | | | 750000 |
| 15 | 15 | 15 | | 560 | 560 | 22000 | 22000 | 22000 | | 820000 | 820000 |
| | | 16 | | | 620 | | | 24000 | | | 910000 |
| | 18 | 18 | 680 | 680 | 680 | | 27000 | 27000 | 1.0 Meg. | 1.0 Meg. | 1.0 Meg. |
| | | 20 | | | 750 | | | 30000 | | | 1.1 Meg. |
| 22 | 22 | 22 | | 820 | 820 | 33000 | 33000 | 33000 | | 1.2 Meg. | 1.2 Meg. |
| | | 24 | | | 910 | | | 36000 | | | 1.3 Meg. |
| | 27 | 27 | 1000 | 1000 | 1000 | | 39000 | 39000 | 1.5 Meg. | 1.5 Meg. | 1.5 Meg. |
| | | 30 | | | 1100 | | | 43000 | | | 1.6 Meg. |
| 33 | 33 | 33 | | 1200 | 1200 | 47000 | 47000 | 47000 | | 1.8 Meg. | 1.8 Meg. |
| | | 36 | | | 1300 | | | 51000 | | | 2.0 Meg. |
| | 39 | 39 | 1500 | 1500 | 1500 | | 56000 | 56000 | 2.2 Meg. | 2.2 Meg. | 2.2 Meg. |
| | | 43 | | | 1600 | | | 62000 | | | 2.4 Meg. |
| 47 | 47 | 47 | | 1800 | 1800 | 68000 | 68000 | 68000 | | 2.7 Meg. | 2.7 Meg. |
| | | 51 | | | 2000 | | | 75000 | | | 3.0 Meg. |
| | 56 | 56 | 2200 | 2200 | 2200 | | 82000 | 82000 | 3.3 Meg, | 3.3 Meg. | 3.3 Meg. |
| | | 62 | | | 2400 | | | 91000 | | | 3.6 Meg. |
| 68 | 68 | 68 | | 2700 | 2700 | 100000 | 100000 | 100000 | | 3.9 Meg. | 3.9 Meg. |
| | | 75 | | | 3000 | | | 110000 | | | 4.3 Meg. |
| | 82 | 82 | 3300 | 3300 | 3300 | | 120000 | 120000 | 4.7 Meg. | 4.7 Meg. | 4.7 Meg. |
| | | 91 | | | | | | 130000 | | | 5.1 Meg. |
| 100 | 100 | 100 | | 3900 | 3900 | 150000 | 150000 | 150000 | | 5.5 Meg. | 5.5 Meg. |
| | | 110 | | | 4300 | | | 160000 | | | 6.2 Meg. |
| | 120 | 120 | 4700 | 4700 | 4700 | | 180000 | 180000 | 6.8 Meg. | 6.8 Meg. | 6.8 Meg. |
| | | 130 | | | 5100 | | | 200000 | | | 7.5 Meg. |
| 150 | 150 | 150 | | 5600 | 5600 | 220000 | 220000 | 220000 | | 8.2 Meg. | 8.2 Meg. |
| | | 160 | | | 6200 | | | 240000 | | | 9.1 Meg. |
| | 180 | 180 | 6800 | 6800 | 6800 | | 270000 | 270000 | 10.0 Meg. | 10.0 Meg. | 10.0 Meg. |
| | | 200 | | | 7500 | | | 300000 | | | 11.0 Meg. |
| 220 | 220 | 220 | | 820 | 820 | 330000 | 330000 | 330000 | | 12.0 Meg. | 12.0 Meg. |
| | | 240 | | | 9100 | | | 360000 | | | 13.0 Meg. |
| | 270 | 270 | 10000 | 10000 | 10000 | | 390000 | 390000 | 15.0 Meg. | 15.0 Meg. | 15.0 Meg. |
| | | 300 | | | 11000 | | | 430000 | | | 16.0 Meg. |
| 330 | 330 | 330 | | 12000 | 12000 | 470000 | 470000 | 470000 | | 18.0 Meg. | 18.0 Meg. |
| | | 360 | | | 13000 | | | 510000 | | | 20.0 Meg. |
| | | | | | | | | | 22.0 Meg. | 22.0 Meg. | 22.0 Meg. |



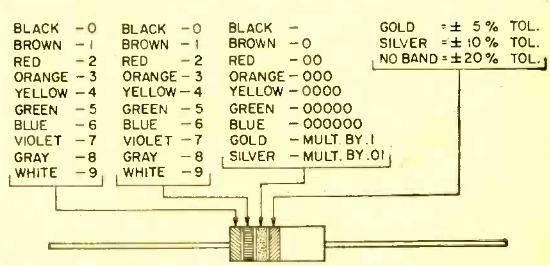




**Fig. 1. The standard RETMA color code is used to identify nominal resistance values.**

**Fig. 2. Dimensions of three common fixed composition resistors used in most projects.**

ing is 00000. Hence, the resistor is a 8,200,-000-ohm unit (8.2 Meg) and the last band—gold—tells us it is a 5% unit.

The physical size of the resistor indicates its wattage rating—refer to the drawings in figure 2. As the wattage rating increases, so does the physical size of the resistor. Obtain a ½-, 1-, and 2-watt resistors—look at them and roll them in your fingers—you will never forget what your senses of sight and touch teach you. Thereafter, you will be able to *sort on sight* resistors, by their wattage.

**What's available?** The table of standard resistance values given in this article has been accepted by government and industry. Values that do not appear on this table will be difficult to obtain, and then only by special order. There are some standard values for resistances below 10 ohms. However, as an experimenter you will seldom have call for these values except in some odd transistor circuits and even odder vacuum tube circuits. You may have trouble purchasing 20% tolerance resistors. Most dealers and distributors do not stock these resistors since the call for them has diminished considerably.

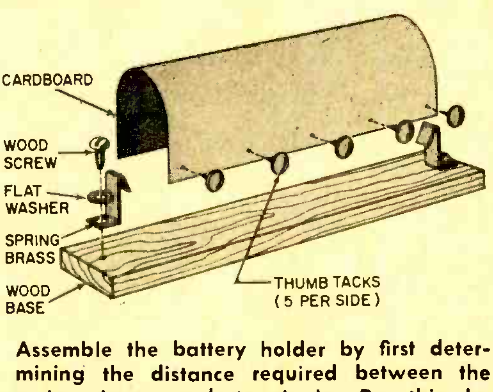
**How to buy.** If your stocks of resistors are very low, make a large purchase of 150 ½-watt assorted resistors for $18 and you will get an attractive resistor filing cabinet that is useful in keeping your stock orderly and easily accessible. You can have either a metal cabinet made by *IRC* or a plastic unit made by *Ohmite*. *Lafayette Radio* offers 100 ½-watt assorted plus a plastic hinged box for only $4.50. Although the box is not as good as the *IRC* and *Ohmite* models, the resistor assortment buy is hard to beat and is excellent for restocking purposes.

Let's see how you can save money on small purchases. Assume you have to buy four ½-watt resistors because your stock has been depleted in these resistance values. Using the *Allied* catalog as a price standard, these resistors will cost 48¢. Now let's double the order. Not only do you get extra resistors to beef up your depleted stock, you also enjoy a price lowering for quantity reasons. The price for the eight resistors is 72¢—the second four resistors cost only 24¢ to stock. In another instance, let's assume you need 31 ½-watt resistors for a home-built amplifier. The cost is $2.79. Now, if you were to order 19 more resistors to add to your shop's stock (a total of 50 resistors), the price would be only $2.75—you save 4¢ and get 19 resistors *free*. Now that's quantity buying that's hard to beat!

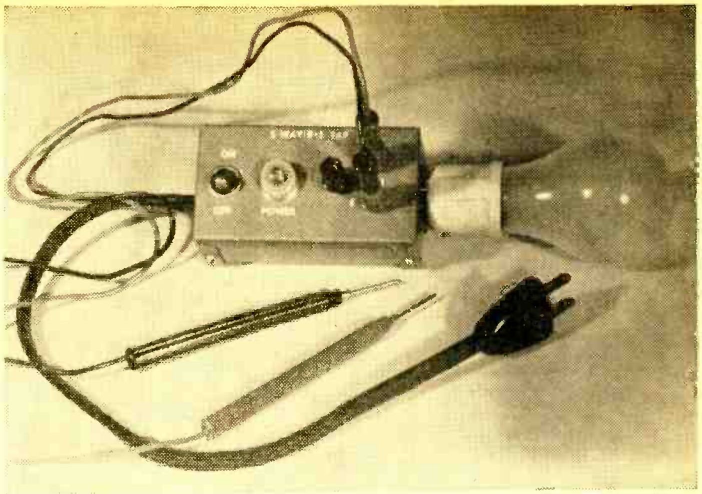
**Round up of facts.** If you are learning something new about resistors for the first time, point an accusing finger at yourself for not reading the fine print in your radio parts catalog. All the information in this article was obtained from one electronics parts supply house and checked against several others which were equally informative. The next time you buy component parts in quantity, read the catalog pages carefully and don't forget the small print. That's where you can multiply your penny savings into dollars. ■

# Workbench Battery Holder

**A simple** but practical workbench dry cell holder can be made by the experimenter from a scrap of wood, some stiff cardboard, thumb or carpet tacks, two small wood screws, and two pieces of spring brass or steel from an old clock. The holder can be made for one to five or more dry cells in series provided the tension of the two springs insures sufficient contact pressure between all the dry cells and the springs. Connect a red and black insulated wire, if desired, under each flat washer—black to minus, red to positive—and connect alligator clips to the ends to provide quick connect or disconnect. ■




**Assemble the battery holder by first determining the distance required between the spring brass end terminals. Do this by laying out the number of dry cells the holder will mount and scribe lines at ends.**

# Five-Way Power Tap

By James A. Fred

## Eliminating temporary setups saves time, fumbling, and shocks

The 5-way power tap inserted between an electrical appliance and an ac outlet enables you to make five checks on small electrical appliances, electric lamps, electric motors, and other electrical devices. This low cost test gadget may be dispensible in the radio repair shop, but it has proven itself invaluable in the repair of home appliances and motors. The five most common applications of the tester are:

1. Measuring current drawn by electrical devices
2. Detecting shorts, grounds, or continuity in appliances
3. Testing appliances suspected to be faulty
4. Testing line voltage or voltage drop across an appliance
5. Tapping off line voltage safely.

**Current Measurement.** To measure the amount of current drawn by an appliance an ammeter can be plugged into the two red binding posts placing it in series with the appliance. The appliance is then plugged into the receptacle.

**Continuity Test Lamp.** To use this device as a test lamp for checking shorts, continuity, and grounds, plug the lamp and adapter into the receptacle and plug a set of test leads into the two red binding posts. To check for low resistance leakage use a 100 watt bulb, to check for medium leakage use a 7.5 watt bulb, and to check high resistance circuits use a neon bulb. The usual procedure when checking for shorts or grounds is to touch one test prod to the case or frame of the appliance or motor and the other test prod to one pin at a time of the line cord (not plugged in of course). To check for continuity touch each test prod to one pin of the line cord.

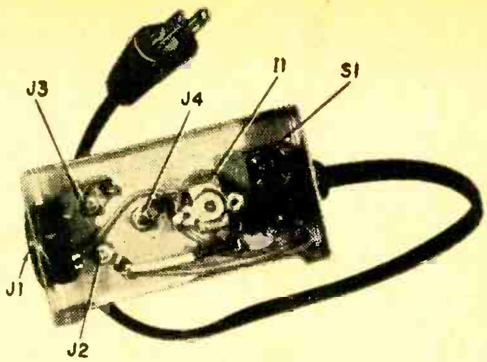
**Fused Outlet.** To use the device as a fuse box, a fuse block is constructed that will plug into the two red binding posts. Fuses of various amperages can then be used. The rating of fuse will depend on the current being drawn by the appliance being tested. Checking every repaired appliance this way will relieve the embarrassment of blowing out the line fuses and plugging your household into darkness.

**Appliance Voltage Drop.** Often it is desirable to be able to measure the line voltage drop of an electrical appliance. An appliance is plugged into the receptacle and a voltage reading is taken at the red binding post on the line side and at the black post. A fuse of the proper rating is inserted into the two red posts and another reading is taken. The difference between the two readings is the voltage drop.

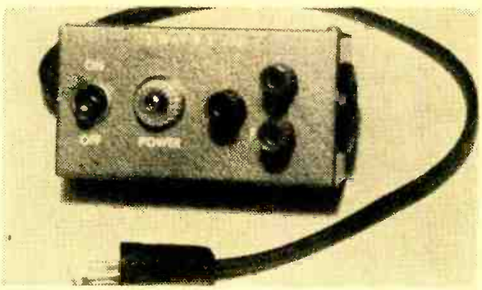
**Line Voltage Tap.** When making experimental hookups it is often necessary to tap into the line voltage. By connecting clip leads to the black post and the red post on the line side, you can tap off the line. By using a fuse in the two red posts, and moving one clip lead to place the fuse in the circuit, you have a fused voltage available. The neon pilot light reminds you when the EI tap is plugged in—so be careful with those hot test probes!

**Construction Tips.** The tester is built into a very compact aluminum box. As shown in the photograph, the d.p.s.t. toggle switch, neon pilot light, and three binding posts are mounted on top of the box. On one end is a single female receptacle and on the other a short power cord. These components can be laid out in any arrangement that is convenient. If you intend to use the tester in a garage or basement, it would be wise to use a three wire line cord and a grounding receptacle.

In construction, be sure to use at least number 16 wire line cord and a d.p.s.t. toggle switch. Number 16 wire is necessary for working on the higher current appliances; and the d.p.s.t. switch breaks both sides of the line which will save you the trouble of removing the line cord from the wall. The pilot serves to remind you to throw the switch off before changing accessories. Of, course, use number 16 wire to wire the receptacle, switch, and binding posts.




**Underside of chassis, above, shows number 16 wire used throughout for working on higher current appliances. Below is front panel.**



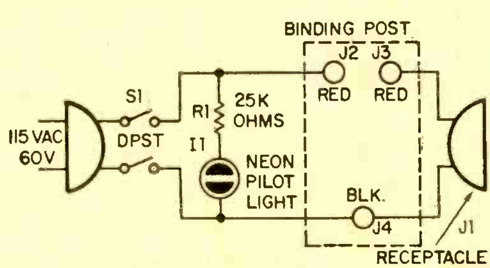
Most of the parts used in the tester can be obtained from any well-stocked radio parts supply house. The lamp adapter used for the test lamp can be purchased at the housewares rack of your local supermarket.

**A Capital Investment.** The little time and energy invested in building the 5-way tester is returned in time and aggravation-saving dividends everytime you would otherwise try to accomplish its function by fumbling with wires and temporary setups. ■

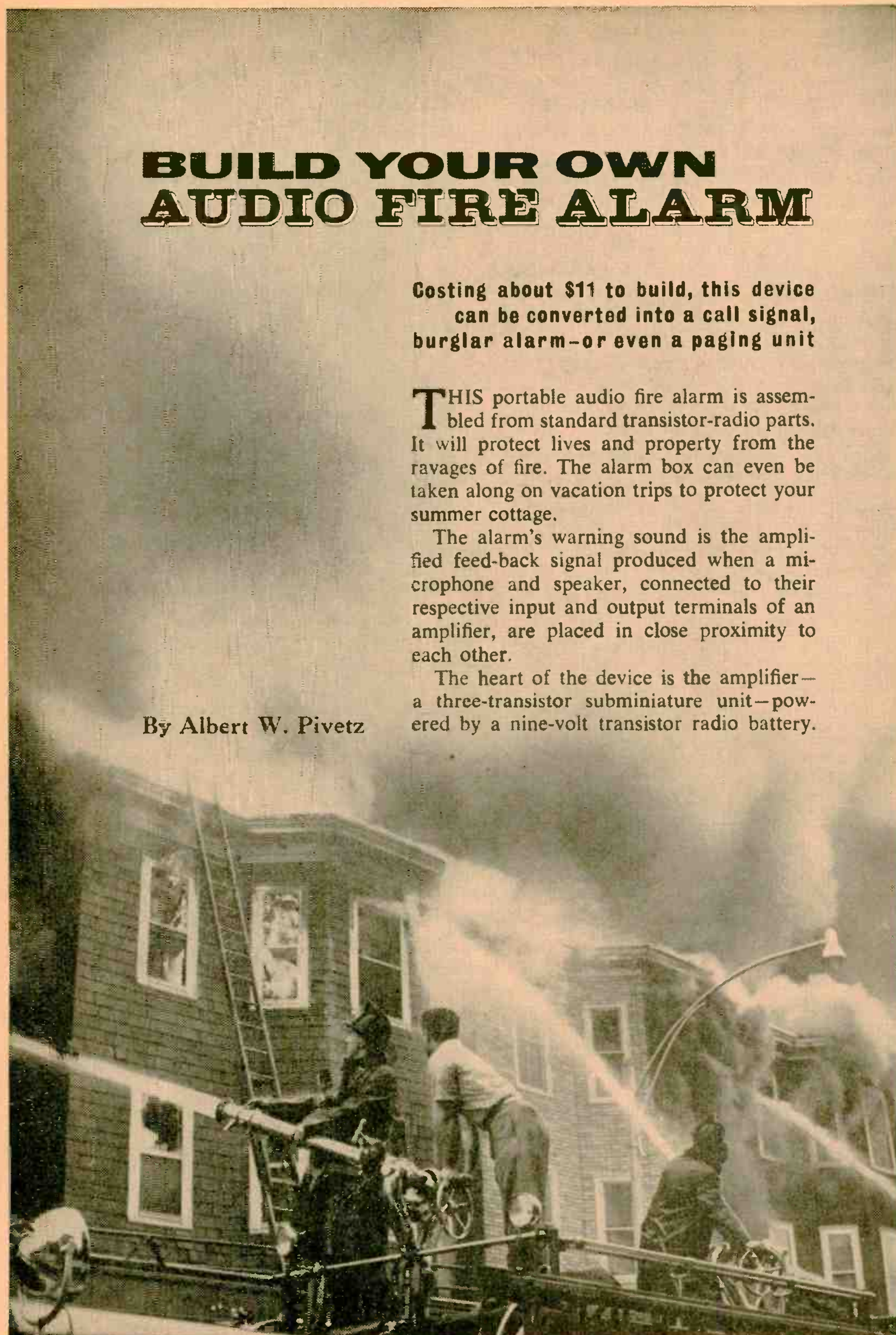
**PARTS LIST**

- I1—Neon pilot light, NE-51H
- J1—Female receptacle, Amphenol 61-F (Allied Radio 40H677)
- J2, J3, J4—Binding posts; 2 red and 1 black (Allied Radio 41H368 and 41H367, respectively)
- R1—25,000-ohm, ½-watt resistor
- S1—D.p.s.t. toggle switch
- 1—Aluminum chassis box 4"x2⅛"x1⅝" (Bud CU-2102A)
- Misc.—line cord, screws, nuts, decals, etc.

Estimated cost: $5.00
Estimated construction time: 1½ hours




**The neon pilot light connected across the line voltage reminds you the tap is "hot."**



# BUILD YOUR OWN AUDIO FIRE ALARM

**Costing about $11 to build, this device can be converted into a call signal, burglar alarm—or even a paging unit**

By Albert W. Pivetz

THIS portable audio fire alarm is assembled from standard transistor-radio parts. It will protect lives and property from the ravages of fire. The alarm box can even be taken along on vacation trips to protect your summer cottage.

The alarm's warning sound is the amplified feed-back signal produced when a microphone and speaker, connected to their respective input and output terminals of an amplifier, are placed in close proximity to each other.

The heart of the device is the amplifier—a three-transistor subminiature unit—powered by a nine-volt transistor radio battery.

# Audio Fire Alarm

A new battery will operate the alarm continuously for more than an hour.

To develop the signal, a speaker used as an input microphone and an output speaker are connected to the amplifier. Two miniature PM speakers will do the job nicely.

The unit's alarm sounds when its thermostatic switch closes. A preset detector switch closes the circuit when the surrounding air temperature reaches 135°F.

**Construction.** The fire alarm is housed in a plastic case measuring 2 x 3¾ x 6¼ inches. The case's predrilled cover serves as the back wall of the case.

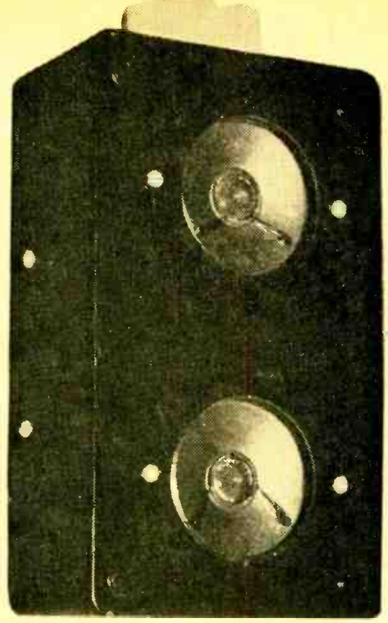
Drill a hole at a central point in the panel to permit hanging it from a nail on the wall. Then drill a ¼-inch hole midway between the two sides of the panel and about one inch from one end of the panel. The two speakers will face out from the case. The back of the case serves as the front face of the alarm box, so drill two holes in it for the speakers.

To fasten the speakers to the inside bottom of the case, drill a ⅓₂-inch hole through each side of the afore-mentioned speaker holes and about ³⁄₁₆ inch from the edge. Place the speakers in the case face down; fasten them to the case with at least one 4-40 x ½-inch machine screw, or with plastic cement applied around the rim of the speakers.

Fasten the amplifier flat against a side wall of the case. This will necessitate removing the amplifier's 30-mfd capacitor by unsoldering the capacitor from the bottom of the amplifier's mounting board—being sure to first note its position and polarity in the circuit. Then resolder it to the top side of the mounting board.

Enlarge one of the holes at each end of the perforated mounting board with a ⅓₂-inch drill to get the mounting holes for the amplifier. Using both holes as a template, locate the position of the fastening holes on the case wall and drill two corresponding ⅓₂-inch holes through the wall. Place the amplifier in the case and fasten it to the wall with two 4-40 x ½-inch machine screws.

**Thermostatic Switch.** The switch turns the alarm on and off; on by means of a bimetallic strip of heat-sensitive metal which touches a contact point when the surrounding air temperature reaches 135°; off when, upon cooling, the strip and point separate.



Alarm's shrill signal is started and maintained by feedback from the output to input speaker.

This detector switch is housed in a plastic case which fastens to the bottom of the amplifier case with two 4-40 x ½-inch machine screws. Drill two ⅙-inch holes through the bottom of the upper case, using the holes in the detector-switch case as a template.

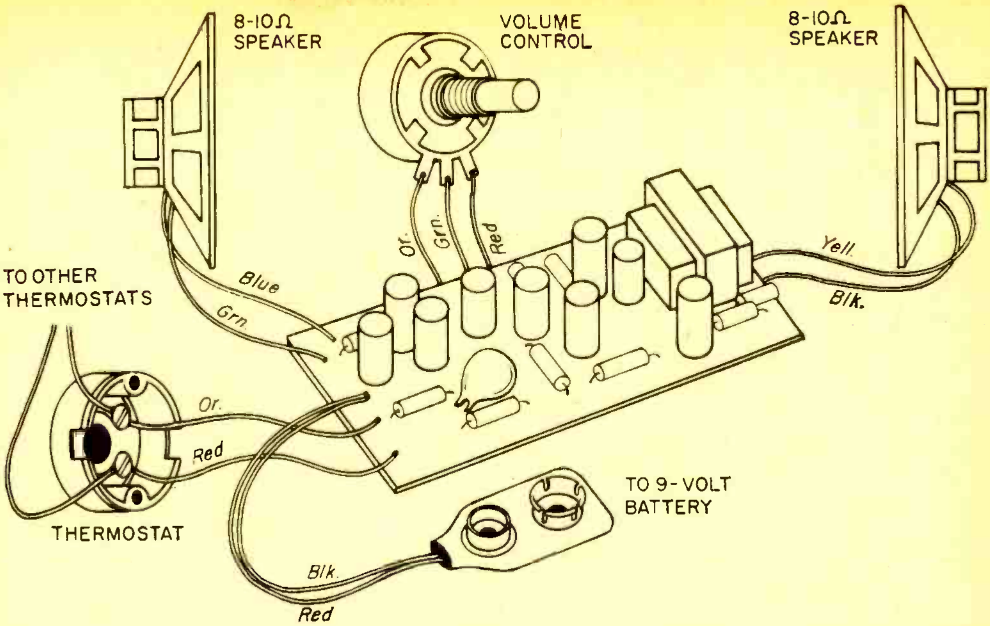
To provide for the two terminal wires which lead from the alarm switch, drill a ⅙-inch hole through the center of the amplifier case and detector-switch case where they join. The detector switch now must be wired before its case is tightened in place.

**Added Versatility.** Providing outside terminal connections makes it possible to connect alarm buttons in other rooms to the same alarm, and also permits the signal to be sounded by other types of contact switches connected to the terminals, so the device can be used for other purposes besides a fire alarm (burglar alarm, P.A. system, etc.).

The outside terminals (two Fahnestock clips) connect the two wires from any outside switch to the alarm circuit. They can be located at any point outside the case. We located them on the top center.

Drill two ⅙-inch holes about one inch apart. Then use two 4-40 x ½-inch machine screws—with two nuts for each screw—to hold the clips to the case.

**Now for the Wiring.** All hook-ups are made with No. 20 acetate-covered wire. Since




**Thermostat is connected as on-off switch, and control is adjusted for desired alarm signal.**

the amplifier comes with its own leads, you'll need only two additional short wires to connect the outside terminals in parallel with the thermostat.

The amplifier comes from the supplier with an instruction sheet and diagrams showing the color of the lead provided at each of the amplifier terminals. We'll refer to these lead colors in describing the point at which each part hooks into the amplifier.

First solder the amplifier's green and blue leads to either of the speakers' terminals to connect the input microphone. Solder the amplifier's yellow and black leads to the other terminals to connect the output speaker.

The thermostatic switch is cut into the circuit at the point where an on-off switch would normally be located. Fasten the red and orange leads found at this point to the two thermostatic switch terminals.

The outside terminals are wired in parallel to the thermostatic switch with two six-inch lengths of hook-up wire. Connect each wire to an outside terminal, fastening their other ends to the corresponding thermo-switch terminals. (The connection at the outside terminals consists of the inner end of the machine screws holding the Fahnestock clips in place, and the extra nuts are used to tighten the wires down.) Finally, snap the nine-volt battery into the amplifier's battery clip.

**Testing The Unit.** Hold a lighted match under the case about an inch from the thermostatic switch button. When the temperature of the button reaches 135°, the switch will close to complete the circuit and the signal—a shrill whistle—will sound.

When the match is removed, the switch button will cool and automatically open the circuit to determine the signal.

**More Than One Use.** As mentioned before, this device can be used for a number of applications besides that of a fire alarm.

A push button converts it to a call signal. A contact switch or mat turns it into a burglar alarm. Connect the outside terminals to a telegraph key and the device becomes loudspeaker signal for code practice. ■

**PARTS LIST—AUDIO FIRE ALARM**

- 1—Subminiature 3-transistor audio amplifier (Lafayette 99G9034 or equiv.)
- 1—2½"-dia. PM miniature speaker, 10-ohms (Lafayette 99G6097 or equiv.)
- 1—5,000-ohm miniature potentiometer Lafayette 99G6019 or equiv.)
- 1—9-volt transistor battery (Burgess 2U6 or equiv.)
- 1—Thermostatic switch (Lafayette EL-103)
- 1—Plastic case and panel (Lafayette 19G2001 and 19G3701 or equiv.)

Misc.—Hardware, washers, hook-up wire, solder, glue, etc.
Estimated construction time: 2 hours
Estimated cost: $10.75

**COVER STORY**

# ELECTRONIC FILTER

***A simple one-evening project that will reduce the AC hum from battery eliminator outputs to less than ten millivolts for currents up to five amps***

By John Potter Shields


**Here's** a little piece of electronics that should appeal to both the experimenter and service technician who works with transistor circuitry. Connected to the output of a relatively unfiltered low voltage DC power supply, the Electronic Filter will provide a continuously variable, low-ripple direct current—so essential for the testing and operation of transistorized equipment. Depending upon the current capabilities of the power supply to which it is connected, the Electronic Filter will furnish a current output of up to 0.5 amps, at 12 volts DC. Connected to the output terminals of a typical "battery eliminator," this gadget will reduce the output voltage ripple to less than 10 millivolts at a current of 0.5 amps.

Other features of the Electronic Filter include short circuit protection by means of a fast-acting thermal circuit breaker in its output circuit, small size when compared with "equal performance" filter elements, simplicity, and last, but not least, low cost.

**Circuit Details.** Operation of the Electronic Filter is based on the principle of *capacitance multiplication*. The basic idea is shown in the simplified schematic of Fig. 1 which shows a transistor, Q1, connected in series with one of the output leads from the power supply to be filtered. A capacitor, C1, is placed from Q1's base to the other power supply lead. Resistor, R1, supplies operating base bias for Q1. With this arrangement, the effective filter capacitance appearing across the load is equal to approximately the value of C1 times the current gain of Q1. Thus, if C1 has a value of 100 mf. and the current gain of Q1 is 50, the effective filter capacitance value appearing across the output terminals is 100 $x$ 50 or 5000 mf.—a pretty fair amount of filter capacitance!

Fig. 2. is the schematic of the Electronic Filter which, while basically similar to the circuit of Fig. 1, has a number of improvements. Note that Q2 in Fig. 2 serves the same function as Q1 in Fig. 1. In Fig. 2 transistor Q1 is used as a current amplifier—this combination offering a higher current gain than if Q2 (the transistor that does the filtering) were used alone. The practical result of this is that a smaller value of C1 may be used.

The circuit breaker, CB1, connected in series with the unit's negative output lead is one of the new Sylvania "mini-breakers" which provides overload protection to Q1 and Q2 in the event of a short circuit at its output terminals.

Capacitor C2 is connected across the fil-

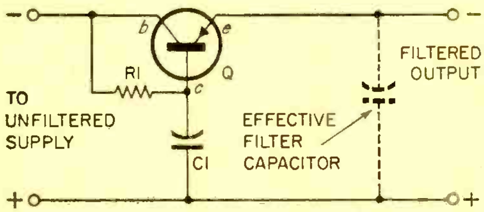
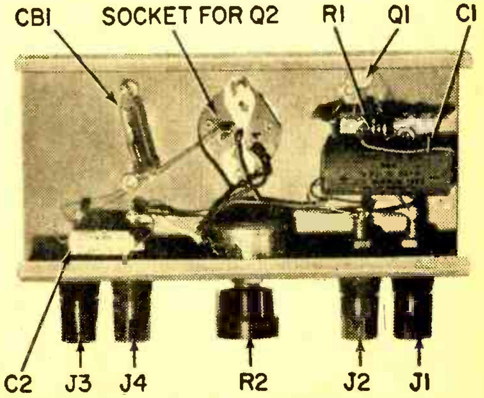
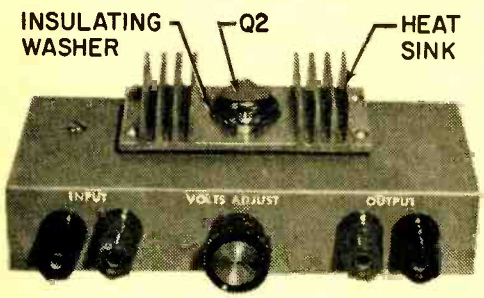



**Fig. 1, the schematic diagram above, shows the principle of the electronic filter. The combined effect of transistor Q and capacitor C1 in the circuit is an effective capacitance that is equal to the current gain of Q times the capacitance of C1. At the right is a bottom view of chassis showing component location.**



**PARTS LIST—ELECTRONIC FILTER**

C1—100-mf., 25-volt tubular electrolytic capacitor (Lafayette 99G5068 or equiv.)
C2—.01-mf., 200-volt paper capacitor
CB1—1-amp. circuit breaker (Sylvania Mite-T-Breaker MB-315, Allied Radio 34B075)
J1, J2, J3, J4—5-way binding post, 2 red and a black (Lafayette 99G6121 and 99G6120, or equiv.)
Q1—2N270 (RCA)
Q2—2N176 (Motorola)
R1—27,000-ohm, ½-watt resistor
R2—1,000-ohm, 2-watt carbon potentiometer, linear taper (Ohmite CU1021 or equiv.)
1—Transistor socket and anodized aluminum wafer for mounting Q2 (Allied Radio 40H713 and 40H339 or equiv.)
1—Heat sink. Any inexpensive type that will mount a 2N176 transistor. Optional.
1—Chassis: 6⅛" x 3" x 1¼" aluminum open end (Lafayette 12G8323 or equiv.)
Estimated cost: $7.50
Estimated construction time: 3 hours




**Top mount and heat sink dissipate Q2's heat.**

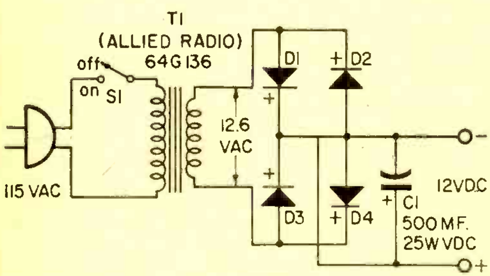



**Fig. 4. This power supply is easy to build.**

ter's output terminals to provide an effective RF bypass across the output terminals.

**Let's Build One.** As pictured in the accompanying photos, the unit is packaged in a small open end chassis. The 2N176 power transistor, Q2, is placed in a finned heat sink, which in turn, is mounted on the chassis. Actually, this extra heat sink is necessary only when the filter is packaged in a box where ventilation is nil. If you use an open chassis, the heat sink can be eliminated.

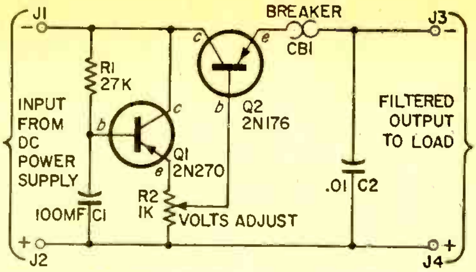



**Fig. 2. Schematic diagram of actual filter shows improvements over the basic principle.**

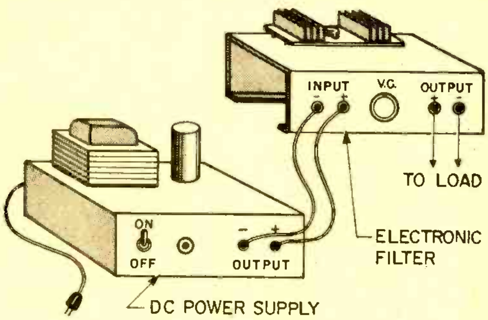



**Fig. 3. Filter is placed between power supply and load which, on the cover, is a tuner.**

When mounting the 2N176, be sure to use the mica insulating washer or better yet an anodized aluminum wafer between the transistor and heat sink, or chassis, as the metal case of the 2N176 must be electrically insulated from the chassis.

All other components are mounted on the underside of the chassis. Tie-point strips are used as mounting points for the various components, with point to point wiring being used between components. Input and output connections to the Filter are made to "5-way" binding posts, with decals being used to indicate input and output terminals.

**Using The Electronic Filter.** Fig. 3. shows how the Electronic Filter is connected to the unfiltered power supply and load. This sketch is pretty much self-explanatory. By the way, just in case you don't happen to have a suitable 12 volt power supply on hand, Fig. 4. shows a simple 12-volt DC power supply which should fill the bill. If you wish, you can build the power supply and Electronic Filter on the same chassis.

Well, there you have the Electronic Filter. Why not build one over the weekend? You'll find it both an interesting project to build and a handy piece of equipment to have on hand. ■

# BUILD A MIDGET MOTOR

By Harold P. Strand

**Designed for Science Fairs this can-do, home-brew motor packs plenty of spare torque to power Erector-set models**

This little motor has good torque for its size and will drive toys such as model cars and boats and most of the power-driven Erector-set and Tinker-Toy projects. The motor's speed can be varied to a wide range of lower speeds by inserting a rheostat in series with one of the armature leads. When connected in series it becomes a universal motor.

The motor has a three-pole armature with a winding, and also a wound field. It is self-starting and operates on 3 to 4 volts DC when connected with the armature and field in shunt. Connected in series it operates on 4½ to 6 volts DC. Two dry cells will produce 3 volts. If connected in series, it will operate on about 12 volts AC via a step-down transformer. Construction requires a metal-turning lathe, a drill press and metal-working hand tools.

The height of the motor is only 2⅜ inches. The four terminal posts are 6-32 screws and nuts. They are marked *F* for field and *A* for armature (see drawing, lower left corner). Countersunk flathead machine screws are used at the binding posts and at the points where the motor is attached to the base.

**Making the armature.** Since the armature is the most difficult part to build, we'll start with it. A piece of ½-inch hexagonal soft steel is used as the center core of the armature; cut it to a ¾-inch length; use the lathe to bore a 7/16-inch No. 30 hole through the center. Now drill a hole in each of the three sides of the armature stock where the poles of the armature will be fixed. A No. 21 drill is used and the holes tapped for 10-32 screws.

The shaft is a piece of .128x2¼-inch drill rod. It is press-fitted in the hole in the center core so that the end projects 9/32 inch beyond the core.

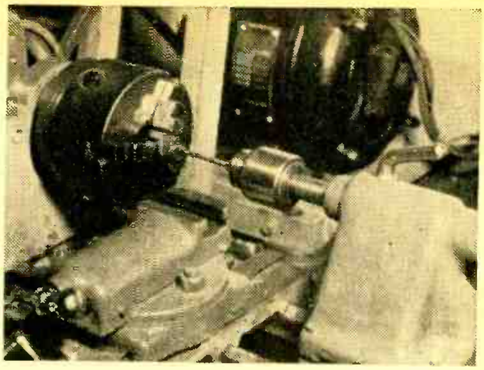
Three pieces of 1/16-inch-thick soft steel are next shaped for the pole pieces. Cut to size and dress the edges with a file. Give them a slight curvature by placing them on a V-block, laying a ¾-inch pipe coupling on top, and striking the coupling with a hammer.

Drill a hole in the center of each pole piece for a 10-32 flathead machine screw, one of which is turned into each tapped hole drilled in each of the three sides of the center core. Countersink the holes in the curved pieces so the screws will fit flush.

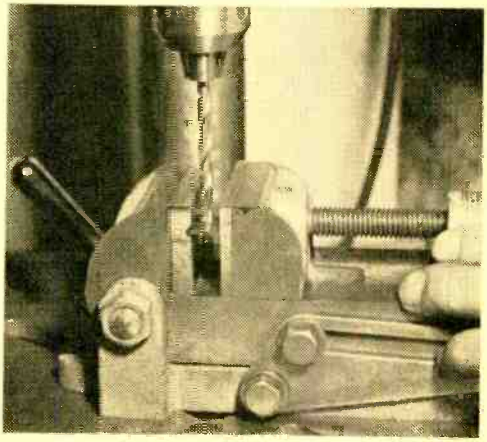
Assembly of the armature core parts uses a pipe spacer between the curved pole pieces and the core (see drawing). Prior to the installation of commutator and winding, place pieces of thin fiber or armature paper at each end of the pole areas; press-fit Bakelite washers on the ends of the spacer; and wrap insulating tape around the spacer.

**The commutator.** A piece of Bakelite rod on which a sleeve of thin brass tubing is pressed and secured with six 2-56 machine screws serves as the commutator. Hacksaw three cuts through the tubing to create a three-section commutator. Now drill a No. 30 hole through the Bakelite commutator which is then pressed on the long end of the shaft. Leave a space of about 1/32 inch between the steel core and the commutator. Adjust the commutator so the slots line up between the poles.

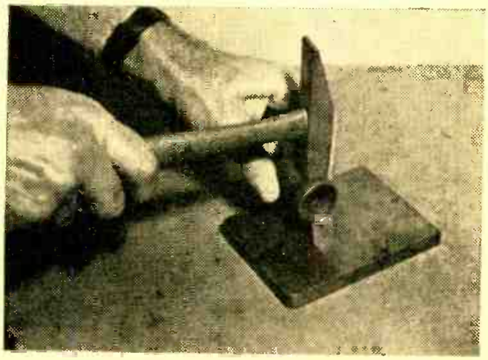
The winding around each pole is done by



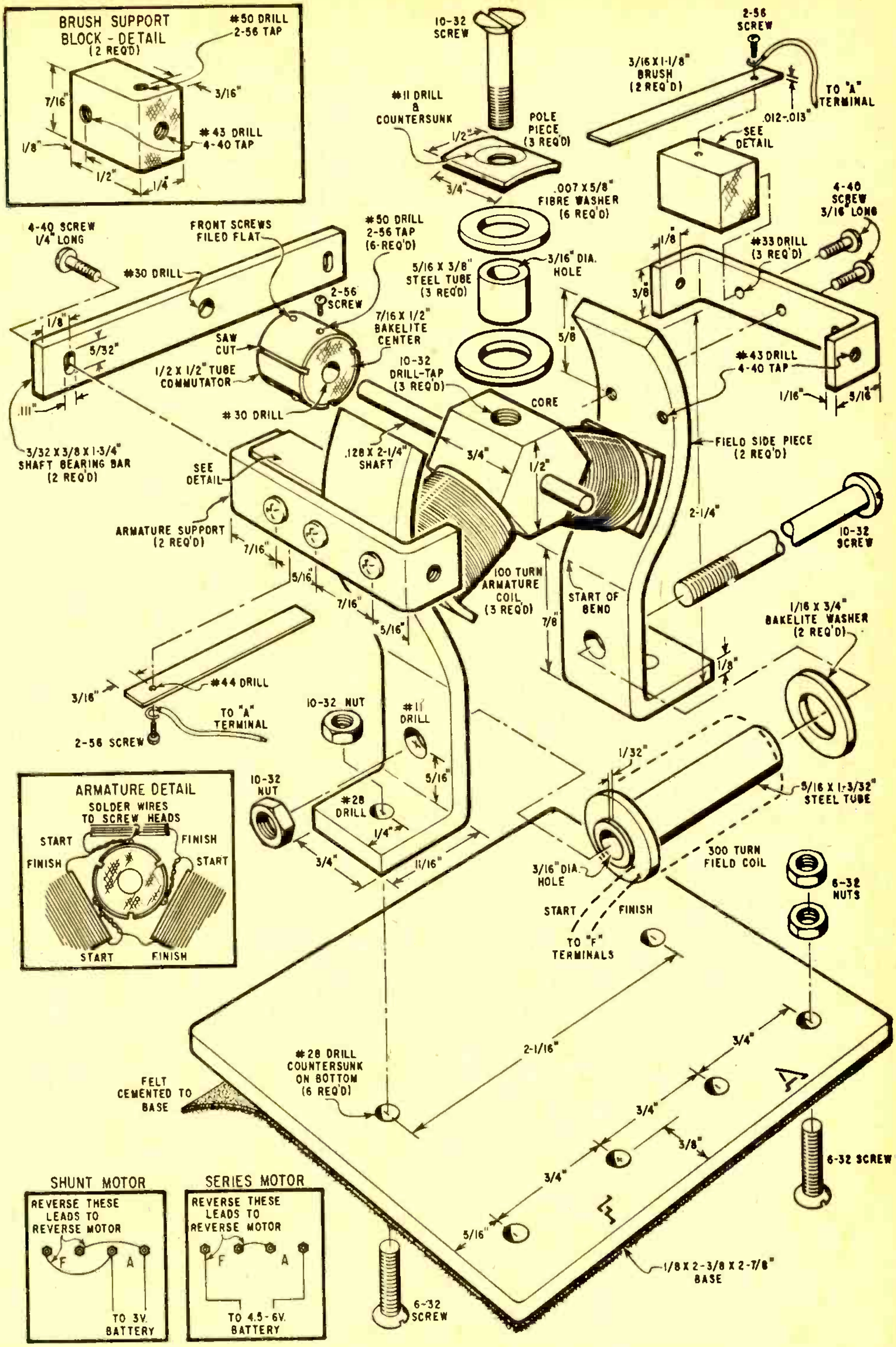
Lathe setup is used to drill .128-in. hole through center of hexagonal center core of mild steel which serves as motor armature. A drill press can do this job if a lathe is not available—be sure to hit center.



Drill, tap and countersink holes in three alternate sides of the armature to accept flush-fitting 10-32 flathead machine screws.



Slight curvature is given to the pole end pieces by striking a pipe coupling on a V-block with end piece in between as shown.




**The exact construction details for the author's unit are shown in the above detail drawing. Minor variations can be made to suit available materials.**

hand, placing 100 turns of No. 24 Formex or enameled magnet wire around each pole. Put the turns on evenly and tightly and bring the start and finish ends out close to the commutator. Connections are made by taking the start end of one coil and twisting it up with the finish end of the next one, removing the insulation, of course, before twisting the ends. These connections are carried out around the armature to prevent the three twisted leads coming between the three wound poles. Wind the coils in the same direction.

Now connect the leads to the commutator segments, carrying each to the nearest segment to the right where it is soldered to the appropriate screw heads (see drawing of armature detail).

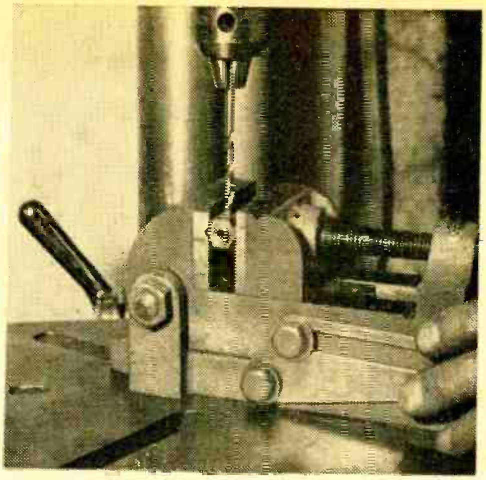
Apply lacquer to the windings to keep the turns tight, but keep it off the commutator and shaft; polish these parts with crocus cloth.

**Field Section Assembly.** A piece of 1/8 x 3/4-inch soft steel is bent around a pipe coupling to begin forming the two side pieces. Drill and tap the holes in these pieces as shown, then join them in position by means of the 5/16-1 3/32-inch pipe sleeve bolted between their bases. The field winding consists of 300 turns of No. 24 Formex or enamel magnet wire wound on the insulated pipe spacer before placing it in position between the two side members.

The start and finish ends of the wire are carried through small holes drilled in one of the spacer's ends. Wind the wire in neat layers with the turns tight and close together.

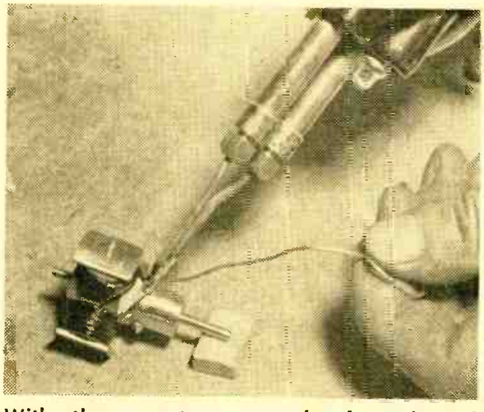
**Final Assembly.** The armature supports are two brass pieces attached to the field side members with screws at the center of the curved point on the side members. The actual shaft bearings are drilled holes in two end brass pieces which are secured to the armature supports with screws. Careful lining up of all parts is required in order to get the amature to turn freely. The holes in the end pieces or shaft supports are slotted to allow some adjustment as required. The air gap between the armature and the field poles should be about 1/16 inch and approximately uniform all around.

The two brush-support blocks must now be cut, drilled and tapped as shown in the

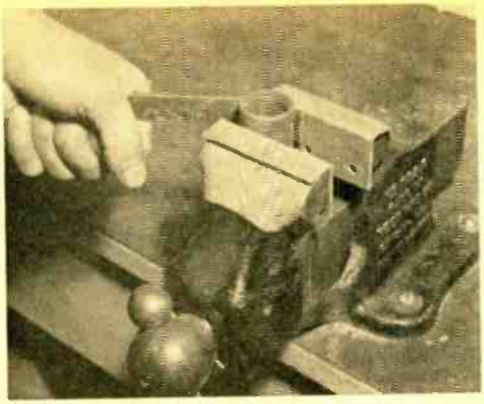


Each of three pole end pieces is drilled with a countersunk hole and tapped to take 10-32 flathead machine screws filed flush.

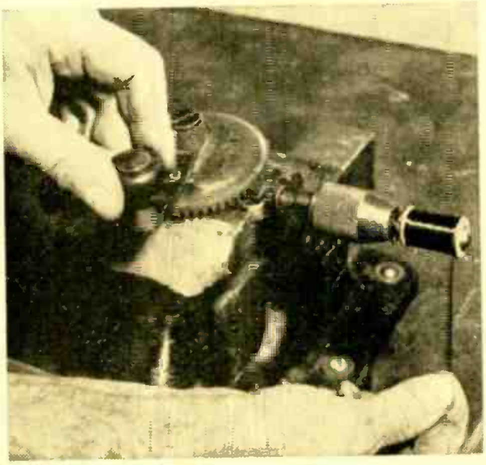
Completed armature less the commutator and winding. Note thin fiber washers on each of the poles for end insulation of the coil.



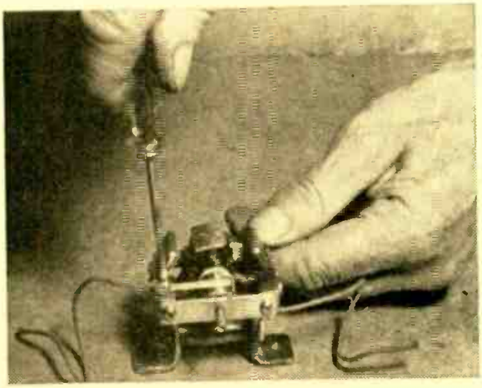
With the armature wound, cleaned and twisted leads from start of one pole to finish of next are soldered to commutator segment.



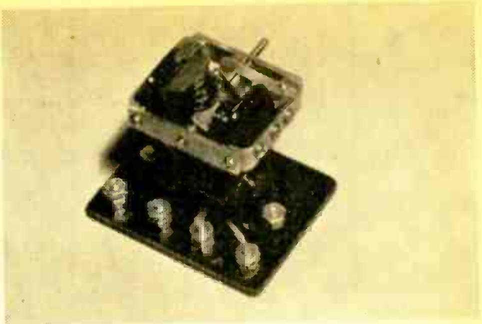
Field side pieces are made of soft, flat steel stock. Their curved portions are bent around the pipe coupling held in a vise as shown.



Hand drill used as shown helps speed the winding of 300 turns of wire on the field coil—a spool that measures 5/16x1-3/32 in.



An insulated wire is connected under each brush screw; the other ends are connected to the terminals marked A on base of the motor.



Close-up view of motor reveals simplicity of construction. Of an extremely compact design, the motor stands only 2 3/8 in. high.

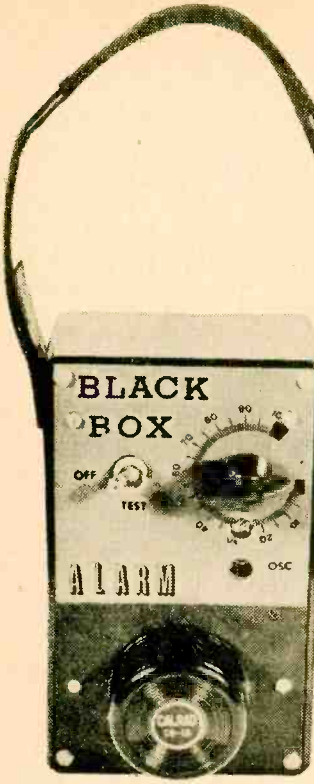
**MATERIALS LIST—MIDGET MOTOR**

| Amt. Req'd | Size & Description | Use |
|---|---|---|
| 1 pc. | 1/8x2 3/8x2 7/8" Bakelite | base |
| 2 pcs. | 1/8x3/4x3" mild steel | field side pcs. |
| 3 pcs. | 1/16x1/2x3/4" mild steel | armature pole ends |
| 1 pc. | 1/2x3/4" hexagonal mild steel | armature core pc. |
| 3 pcs. | 5/16" O.D., 3/16" I.D. & 3/8"-long pipe or steel tubing | armature pole spacers |
| 1 pc. | 5/16" O.D., 3/16" I.D. & 1 3/32"-long pipe or steel tubing | field coil spacer tube |
| 1 pc. | .128" dia. x 2 1/4"-long drill rod | shaft |
| 2 pcs. | 3/32x3/8x1 3/4" brass | shaft bearing bars |
| 2 pcs. | 1/16x3/8x2" brass | armature supports |
| 1 pc. | 1/2" O.D., 7/16" I.D. & 1/2"-long brass tubing | commutator |
| 2 pcs. | .012" or .013"x3/16x1 1/8" phosphor bronze | brushes |
| 2 pcs. | 1/4x7/16x1/2" Bakelite | brush support blocks |
| 1 pc. | 7/16" O.D. x 1/2"-long Bakelite rod | commutator |
| 2 pcs. | 1x1" Bakelite or fiber | cut to make washers on field coil |
| 1 pc. | .007x2 1/2x3" hard fiber | cut to make 6 washers for armature poles |
| 4 ozs. approx. | No. 24 Formex or enameled magnet wire | windings |
| 4 | 6-32 1/2"-long flathead brass machine screws | binding posts |
| 2 | 6-32 3/8" long flathead brass machine screws | motor-to-base |
| 10 | 6-32 hexagonal brass nuts | |
| 8 | 4-40 3/16"-long roundhead brass machine screws | armature support pieces |
| 2 | 4-40 1/4"-long roundhead brass machine screws | bearing bar at commutator end |
| 2 | 2-56 3/16"-long roundhead brass machine screws | brushes |
| 6 | 2-56 1/8" to 5/32"-long roundhead machine screws | commutator |
| 1 pc. | thin felt (2 3/8x2 7/8") | pad for base |
| 3 | 10-32 5/8"-long flathead iron machine screws | armature poles |

top left detail of the drawing. These are then attached to the side supports and serve as bases for the brushes.

**Brushes.** Two phosphor bronze strips about .012 to .013 inch thick are cut 3/16 inch wide and 1 1/8 inch long. An insulated lead wire is attached under each screw turned into the No. 43 holes tapped into the brush-support blocks, these serve as leads to the terminal posts on the base.

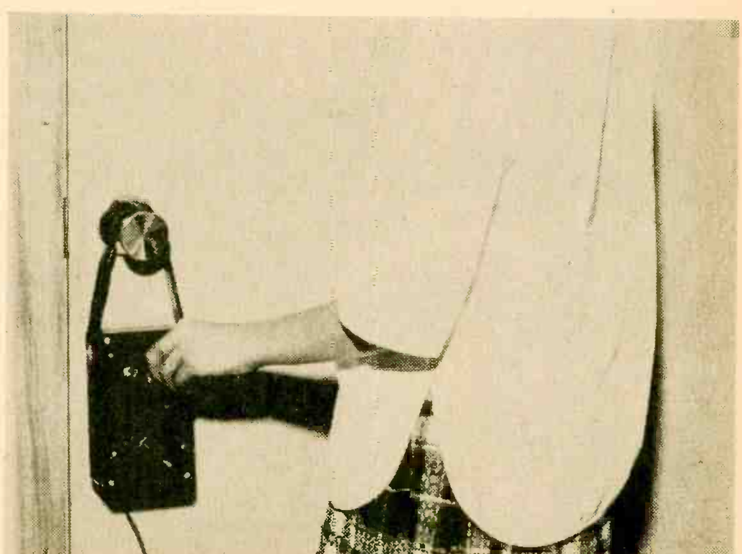
The balance of the project consists of making up a suitable base from either Bakelite or hardwood. Finally, cement a piece of felt to the underside of the base. ■




# BLACK BOX ALARM

By Homer L. Davidson

BENCH TESTED



**Most traps and alarms are detected by the expert burglar, but he will be thwarted by the lack of wires or electric eyes in this capacity actuated alarm. A babysitter can hang it on a door knob and easily adjust it.**

Ever been bothered with a peeping Tom, a shy burglar, or an unwanted intruder? Then build the Black Box Alarm and be protected! Hang the Black Box on any metal door knob—in a hotel, motel, or your own home—and the alarm will sound the minute someone grabs the knob from the other side.

Place the Black Box in an open window, and anyone approaching the window screen triggers the unit. Lay the capacity metal plate near your valuable possessions, and the alarm sounds off whenever an intruder draws near. The unit will cost you less than $15 to put together—a small price indeed for the positive protection it offers.

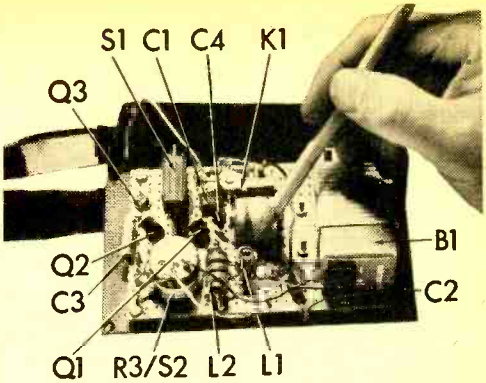
**The Circuit.** Basically, the alarm consists of three transistors: Q1 is an oscillator, while Q2 and Q3 act as amplifiers to drive the relay. Capacitor C1 is connected to jack J1 and couples the capacity plate to the base circuit of Q1. Jack J2 couples a common ground to the Black Box ground system. A trimmer capacitor (C3) and a choke (L2) in the emitter leg of Q1 control the point of oscillation.

Q2 and Q3 are conventional amplifiers with a sensitivity control (R3) in the collector circuit of Q2. The collector of Q2 and the base of Q3 are tied directly together, while an 8000-ohm relay appears in the output leg of Q3. Capacitor C5 is an electrolytic capacitor which eliminates relay chatter and provides smoother relay operation.

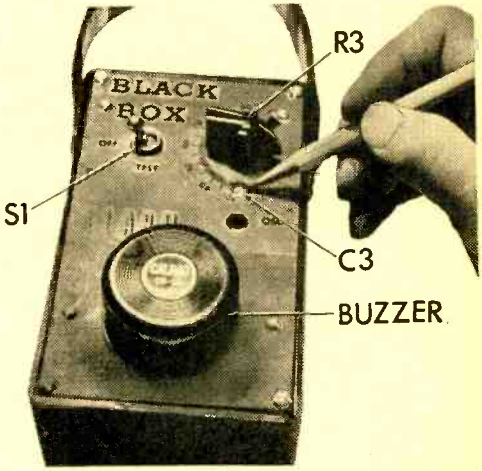
The whole unit is powered by one small 9-volt battery (B1). Whenever a person or a large animal comes near the capacity plate, Q1 is triggered into oscillation. Q1's output, meanwhile, is amplified by Q2 and Q3. The output of Q3 is fed into the relay, which will close and cause the buzzer to sound whenever the signal from Q3 is strong enough.

**Construction.** Start by mounting all of the larger parts as shown in the photos; parts placement isn't at all critical. Wire the smaller parts into the circuit as the unit is being put together. To avoid errors, it's always best to mark off on the diagram as the various components are wired in.

If you begin with the oscillator coil (L1), you can solder the small components to each terminal. Be sure that the bottom end of the coil (terminal 4) goes to a common ground point, and that the tap on L1 (terminal 3) is connected to L2 and C3. Take an ohmmeter, if handy, and measure the resistance between terminals 3 and 4 on the oscillator coil. This resistance will be extremely low in value, while the top half of the coil (between terminals 1 and 3) will measure around 4 ohms. Note that there are two terminals on the coil that aren't used; these are the ones from the primary winding.




**Transistor oscillator coil L1 is the fixed coil in the oscillator circuit. L2 is adjustable to provide increased sensitivity. The trimmer screw of oscillator circuit capacitor C3 is conveniently located on the front panel to provide easy adjustment to bring on oscillation.**




Once you have the coil and the other oscillator components properly wired, you can install transistors Q2 and Q3 and their associated parts. These include the test switch (S1) and resistor R1 in the base circuit of Q2, as well as resistor R2 and potentiometer R3 in the base circuit of Q3.

It's always best to adjust the contact points on the relay coil before it's wired up. Unscrew the mounting bolts and remove the relay from the perforated board. Take a piece of typing paper, rip it in half, and

# EE BLACK BOX ALARM

insert one piece between the armature leaf and the coil magnet assembly. This done, insert the other piece of paper between the bottom adjustment control screw and the leaf contact point.

Now adjust both contact screws so the paper will just slide in and out easily. Next, remount the relay coil on the perforated board. Finish construction by soldering in the small electrolytic capacitor and the buzzer itself.

**Testing the Black Box.** After the alarm has been completely wired, go over your work again just to make sure there are no errors. Solder the battery plug to switch S2 and ground; note that the negative lead goes to S2. If a milliameter is handy, insert it in series with the negative battery lead and S2. The unit shouldn't pull over 1.5 ma. when it's operating unless there's a short or a wiring error.

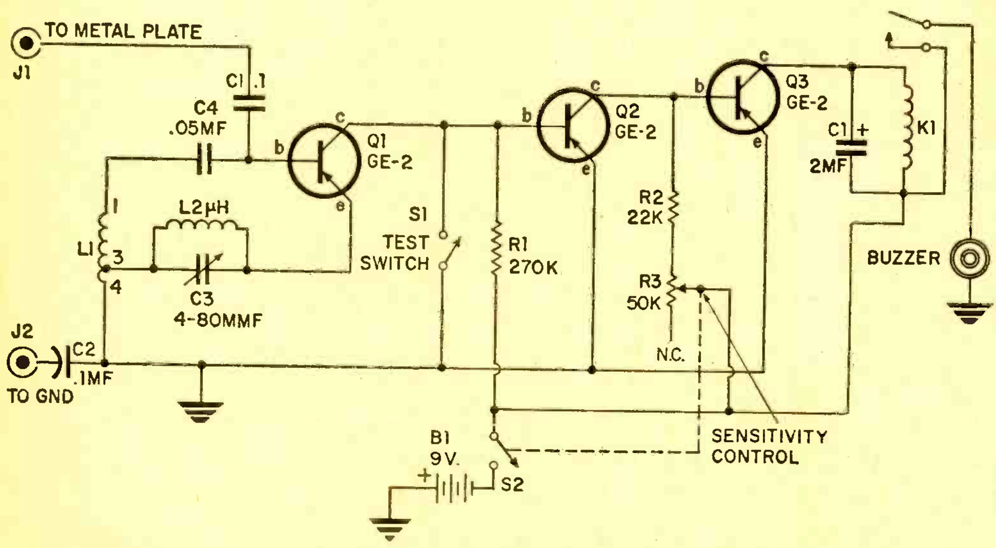
Turn S2 on and rotate R3 until the relay closes and the buzzer sounds. Now turn R3 back until the buzzer quits, then throw S1 on. The buzzer will also buzz at the point. Now tighten C3 until its plates are as close together as possible. Run a lead from the free end of C2 to a water pipe or other suitable ground. In addition, attach a lead from a 1-ft. square metal plate (an old chassis bottom plate is ideal) to the free end of C1.

The buzzer should now sound whenever you put your hand near the metal plate. If necessary, back off C3 or adjust the slug on L2 to control the point at which Q1 goes into oscillation. You can also vary the setting of R3 to control the triggering of the relay coil.

**Setting Up.** After the unit has been tested to satisfaction, mount the perforated board on the front panel of the meter case. The top half of the front panel was sprayed red with a small can of spray paint to finish off the unit and cause the decals and the lettering to stand out.

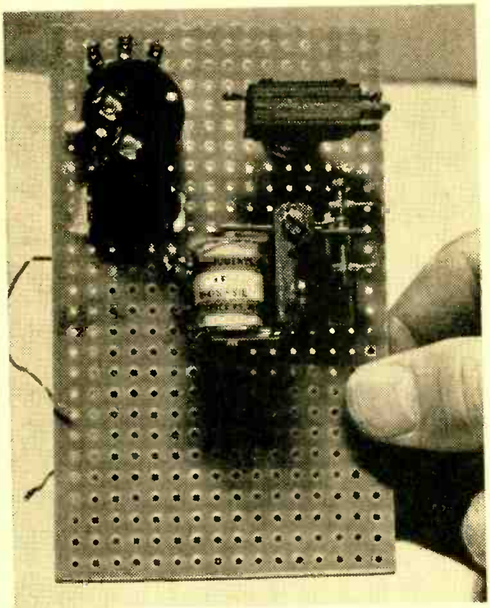
Two small phone jacks are mounted in the back of the case. The top jack goes to one end of capacitor C1, while the bottom jack connects to the free end of capacitor C2. It's best to use long flexible wire leads when making these connections.

Next, cut a plastic or cloth belt to 12 inches in length and tape thin brass or copper stock to the inside of the belt material. Solder




**Capacitance between an intruder and the metal plate or strap is coupled to oscillator transistor Q1 through jack J1 to trigger the circuit.**

**Although its circuit is deceptively simple, this capacity operated relay is a real watch dog; hang it on a door knob or sit it in a window—it'll tell you the minute someone approaches nearby**



Construction is started by mounting the larger components on the perforated board.

**Parts List**

B1—9-volt battery (Burgess 2N6 or equiv.)
C1, C2—.1-mf, 75 volt ceramic capacitor
C3—4-80 mmf trimmer capacitor
C4—.05-mf, 75 volt ceramic capacitor
C5—2-mf, 15 wvdc electrolytic capacitor
J1, J2—Miniature tip jacks
L1—455-kc transistor oscillator coil (Miller 2020 or Stancor RTC-9079)
L2—1.5-millihenry iron-core r.f. choke (Miller 70F153AI or Stancor RTC-8524)
Q1, Q2, Q3—GE 2 or equivalent (see text)
R1—270,000-ohm, ½-watt resistor
R2—22,000-ohm, ½-watt resistor
R3—50,000-ohm potentiometer with s.p.s.t. switch S2
K1—S.p.d.t. relay, 8000-ohm coil (Sigma 4F-8000-S/SIL)
S1—S.p.s.t. toggle switch
S2—S.p.s.t. switch (on R3)
1—Buzzer (Calrad CB-1.5 or Burstein-Applebee 22B51)
1—6¼" x 3¾" x 2" bakelite case (Lafayette MS-216 with MS-217 cover, or equiv.)
Misc.—Pointer knob, battery plug, phenolic board, cloth belt, spare chassis bottom plate, wire, cable, connectors, hardware, solder, etc.

Estimated cost: $21.00
Estimated construction time: 4 hours

a length of flexible wire to one end of the slim stock metal and connect it to jack J1. Now when you wish to hang the alarm on a metal door knob, you can use this metal belt instead of the metal plate to set off the alarm.

**Other Notes.** The three transistors used in the alarm circuit are the type GE2. If you have a transistor tester, use the best of the three transistors in the oscillator circuit. Assuming you can't obtain the GE2's or don't have them in your junk box, you can use 2N215 for Q1 and Q2 and a 2N217 in the relay circuit (Q3).

L2 was a standard 1.5 millihenry choke in the author's model, although a homemade unit can be used. One can be made by taking 15 feet of No. 36 enameled wire, or smaller, and scramble-winding it over a 10-megohm, ½-watt resistor.

Sensitivity control R3 should always be turned up until the relay energizes and then backed off a little until the relay armature drops out. The buzzer will come on when the relay is energized and will quit at the point of drop out.

J2 is a ground jack which couples the alarm to a common ground. A metal radiator, a furnace duct, or a water pipe can all serve for this purpose. Naturally, the alarm works best with this lead connected to a good ground.

When the capacity plate is used, L2 may have to be adjusted for more sensitivity. It is easier to adjust the oscillator coil than C3. C3 will give a greater change, while the oscillator coil adjustment is finer and slower.

To find out whether the oscillator is working, turn on a small table radio near the unit. With capacitor C3 turned all the way in, an oscillator hum should be heard around 700 kc/s on the dial.

If you still have trouble, throwing test switch S1 on grounds the output of the oscillator and thus enables you to check out the remainder of the circuit. If trouble does exist, you might check the resistances of the relay and oscillator coils for possible open windings. You might also try resetting the contact adjustment on the relay points to get a clean buzzer sound. ■

# *Legalize your taped telephone calls with...*

# *The "BOINGER"*


**By Fred Blechman K6UGT**

**Due** to the availability of inexpensive tape recorders and pickup devices, recording telephone calls has become very common in the last few years. Many people record long-distance phone calls for playback to the family, for example. Technical discussions recorded from the phone, and later played back, invariably disclose some facts that just didn't "register" during the brainstorming session. Telephone recordings can speed the transfer of information (dates, times, places, schedules, inventory, etc.), thus shortening the toll on long-distance calls, since it is not necessary to take the time to write out everything during the call.

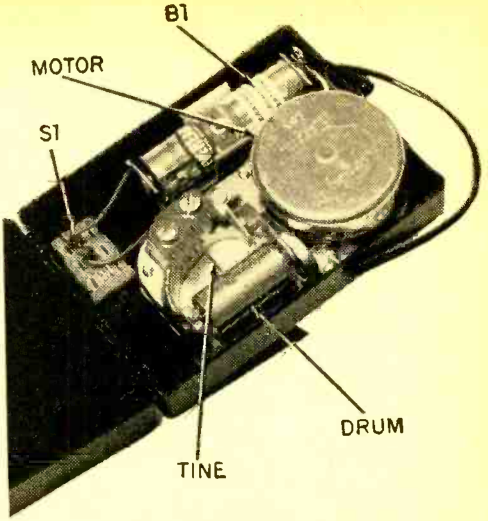
**The Law.** However, the Federal Communications Commission (FCC) realized a few years ago that recordings from the phone could also present the problem of invasion of privacy if the person called was not aware that the conversation was being recorded. Therefore, it is now Federal law that a characteristic tone be transmitted approximately every 15 seconds during any telephone call between two States if the conversation is being recorded. Many States have similar legal requirements on all recorded calls *within* the State that would include all local calls.

**The Boing.** We have all become familiar with the standard "beep" tone; people recognize this regular background interuption as an indication that the conversation is being recorded. Although the Boinger does not duplicate this sound precisely, its musical "boing" seems to fulfill the intention of the law, and with a great deal less cost and complexity than other means. Local and federal requirements for a recording identifier are difficult to define, and subject to interpretation. Therefore, anyone who does much telephone recording and would like to keep it legal, the Boinger proves satisfactory and certainly shows intent to comply with the law.

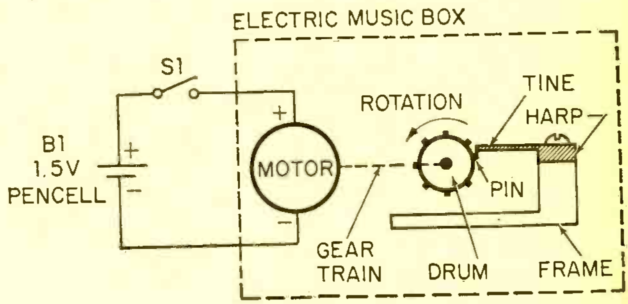
**The Boinger.** This gadget costs less than $3.50 to build from all new parts, is an extremely simple device that injects a musical "boing" into the telephone conversation every 15 seconds. The coupling to the telephone is acoustic, directly into the mouthpiece. The person at the other end of the line hears a sharp clear tone and the same tone is documented on the tape at the recording end. There is no tendency for recorder blocking during the tone which is an unfortunate characteristic of some telephone recording "beepers."

**Description.** The self-powered Boinger will run for hours on its built-in 15-cent battery. Connection to the telephone headset is quick and easy using the simple wire retainer that snaps into the mouthpiece groove. A small piece of foam rubber acts both as a spring and a cradle for the telephone. The regular telephone recording pickup attaches to the earpiece or under the telephone base in the usual manner.

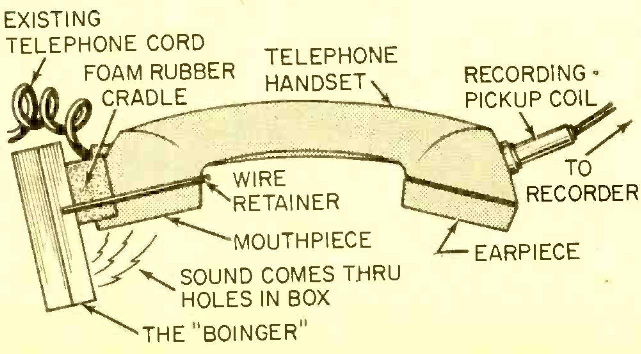
The heart of the Boinger is any inexpensive and small music box movement such as those available from Lafayette Radio for $1.98. When the movement is slightly modified, as described later, all that remains is to add a battery and a switch to make the Boinger. The music box, as purchased, is completely assembled, and contains the 1.5-volt motor, gears, drum, and a harp with about 20 tines. With switch S1 closed the battery powers the motor. Through a reduction gear arrangement, the drum turns at 4 revolutions per minute, which, by a happy coincidence, is one revolution and boing every 15 seconds. On the drum are small




**Small size of the music box movement makes Boinger feasible for use on telephone handset. Note the removal of all tines but one.**




**Combined schematic-pictorial diagram shows the switch and battery connected to the motor of the music box movement. Note the position of the tine with respect to the drum. The drum must turn in the direction shown (by using correct battery polarity) or may jam and burn out the motor, or the tine will shortly fatigue and snap.**




**The Boinger attaches directly to the mouthpiece of your telephone, and puts out an audible "boing" every 15 seconds. It is used when recording a telephone conversation to remind both parties that the conversation is being recorded. This is a Federal law on interstate calls and is also a law on local telephone calls in a large number of our 50 states.**

Foam rubber and wire cradle is so functional it could have been designed by Telephone Co.


projecting pins, so placed that they trigger various tines of the steel harp as they rotate past. The vibration of the tines makes the characteristic music box sounds. By removing all the tines but one, a single tone can be produced every 15 seconds!

**Construction.** The unit shown was built in a plastic box but a metal box is preferable. The reason is that noise has been noted in testing, caused by electromagnetic radiations from the motor being coupled inductively to the recording pickup at the other end of the headset. By using a metal box to house the Boinger, you can shield these radiations and eliminate this background static on the recording. The internal wiring is not at all critical, but the components should be arranged so that the most direct path is available from the tine to the mouthpiece. The switch should be located in a convenient spot, and several holes should be drilled in the box near the mouthpiece so the tone is directly coupled. (In the plastic box version, a small piece of metal, with holes, was mounted under the music box frame to act as a sounding board.) A piece of foam rubber, cut to shape with a sharp knife, is cemented to the box to form a cradle for the phone mouthpiece. A piece of music wire or coat hanger wire is formed around the mouthpiece groove and the ends bent to fit into two small holes in the side of the Boinger box. This wire swivels down for storage, swings up for attachment to the phone. A snug fit to the phone is provided by the springy foam rubber cradle.

Don't forget to modify the music box steel harp. This is easily done. Remove the two screws holding the harp to the frame, and snip or bend off all the tines except one near the center. Temporarily reinstall the harp and note which projections on the drum trigger the lone remaining tine, and then remove all these projecting pins but one with pliers or a file. Now, the one tine will be triggered only once each time the drum makes one revolution—which is once every 15 seconds—just what we want!

**Backward Boing.** Although at first thought it would seem that the polarity of the battery would not be important, it turns out to be quite important. The DC motor will operate with either polarity, but the direction of rotation is determined by the polarity. The tine must be triggered from below, or it will break off in a short time. If the drum is turning in the wrong direction, that is, triggering the tine from above, then turn the battery over in its holder. When the proper direction has been found, put a dab of red nail polish on the positive battery holder terminal so that you will know which end of the battery goes where when you replace the battery at some future date.

Install the tine firmly and check the positioning to insure that the remaining drum pin makes firm contact with the tine. There is enough slop in the harp screws to allow adjustment for a nice strong "boing." Now you are ready to put the Boinger to use.

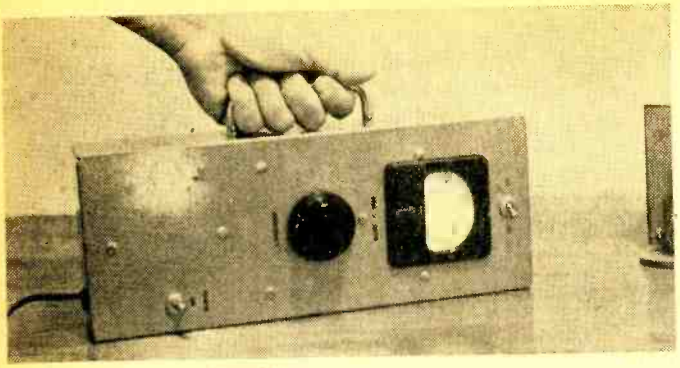
**Boinging.** When you intend to record a phone call, attach your regular recording pickup (either a suction-cup type, or a flat under-base type) and then clip the Boinger to the mouthpiece. Turn on the Boinger switch, place your call, and record. After you have completed your call, the Boinger will remind you to turn it off—it will boing every 15 seconds until you do! ■

**PARTS LIST**

B1—1.5-volt battery (Eveready 915 or equiv.)
S1—S.p.s.t. slide switch
1—Pencell holder
1—Electric music box movement (Lafayette 99-G-9013, 99-G-9018 or equiv.)
1—Aluminum Minibox 4¼x2¼x1½ (Premier PMC-1016)
Misc.—Foam rubber, coat hanger wire, cement, nuts, bolts, etc.

Estimated cost: $4.00
Estimated construction time: 2 hours

By Ron Michaels



BENCH TESTED

# Build a Stroboscope

## A specialized laboratory test instrument that freezes motion

**The** stroboscope has made possible the speed measurement of rotating, reciprocating, and oscillating machines and moving parts. For example, if you wanted to show someone how the loudspeaker in your hi-fi set is driven in and out, the strobe will do the job. First, connect a signal generator to the amplifiers AUX jack and supply a 400 cycle signal at a volume level that is bearable. Next, adjust the strobe frequency to 400 cycles and illuminate the speaker cone with the xenon flashtube light. Now, fine tune the strobe until the speaker cone just barely moves in and out. If you set the strobe at 399.9 cycles, the speaker cone will move in and out 6 times a minute—slow enough to visually observe.

Most professional stroboscopes cost upwards of several hundreds of dollars. Here's a built-it-yourself strobe that combines the accuracy of the professional jobs with a price tag the home builder can afford. Total cost of parts is about $40. However, a well stocked parts box and some astute purchasing can reduce the price to about $30.00.

**How It Works.** The stroboscope circuit is a kissing cousin to the photographer's electronic flash. In fact, it's basically an electronic flash hooked to an oscillator that makes it flash at an adjustable rate of between about 4 and 120 flashes per second.

The circuit can be split into four sections: flashtube and energy storage capacitor (C2); trigger circuit; variable frequency oscillator; and power supply.

In operation, the power supply charges the energy storage capacitor to about 185 volts DC, storing a large quantity of electrical energy. General Electric's flashtube FT-30 is a thin glass tube filled with xenon gas. It is connected directly across the charged capacitor C2. Initially, no current flows through the flashtube since xenon is a good insulator.

Silicon controlled rectifier (D5), capacitor C3 and trigger transformer T2 make up the trigger circuit. Whenever an input pulse (from the oscillator) fires the SCR, the SCR discharges C3 through the primary of T2, generating a high voltage spike in the secondary of T2. This high voltage spike is carried to the flashtube via a trigger wire—a few turns of bare tinned copper wire wrapped around the flashtube. The spike ionizes the xenon gas suddenly turning it into a conductor. C2 discharges rapidly through the flashtube, producing a short, intense, burst of blue-white light. Immediately after discharge, the xenon gas becomes an insulator again, permitting C2 to recharge, and the cycle to begin again.

The number of times-per-second the SCR is fired—and hence, the number of times per second the flash tube is triggered—is

# Stroboscope

controlled by a variable frequency oscillator built around unijunction transistor Q1. Potentiometer R8 is the frequency control; switch S2 selects high or low frequency ranges. Meter M1, inserted in the "emitter" lead of Q1 reads the oscillator frequency directly. Q1 is either a 2N2160 (preferred) or 2N1671 type.

The power supply has two output voltages: 185 volts DC for the flashtube circuit and trigger circuit, and 18 volts DC to power the unijunction oscillator.

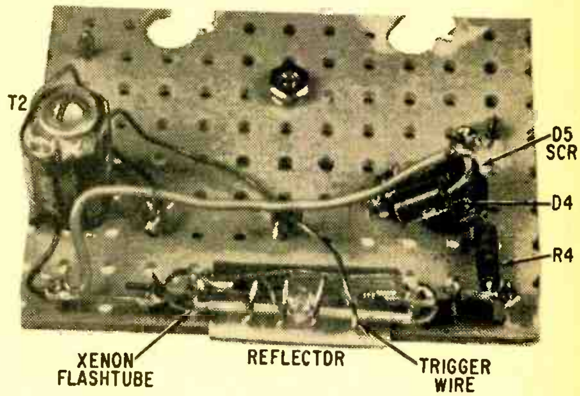
**Building It.** The stroboscope is built into a 13" x 5⅛" x 2⅝" aluminum case. Start by drilling and punching required holes. Use the accompanying photographs as parts placement guides. Follow placement of parts carefully—do not try to redesign.

The power supply circuitry is mounted directly on the top half of the aluminum case, using terminal strips as wiring points. Make sure that you don't accidentally reverse the polarity of the silicon rectifiers D1, D2 and D3, or the electrolytic capacitors and try not to overheat the rectifiers when soldering them in place.

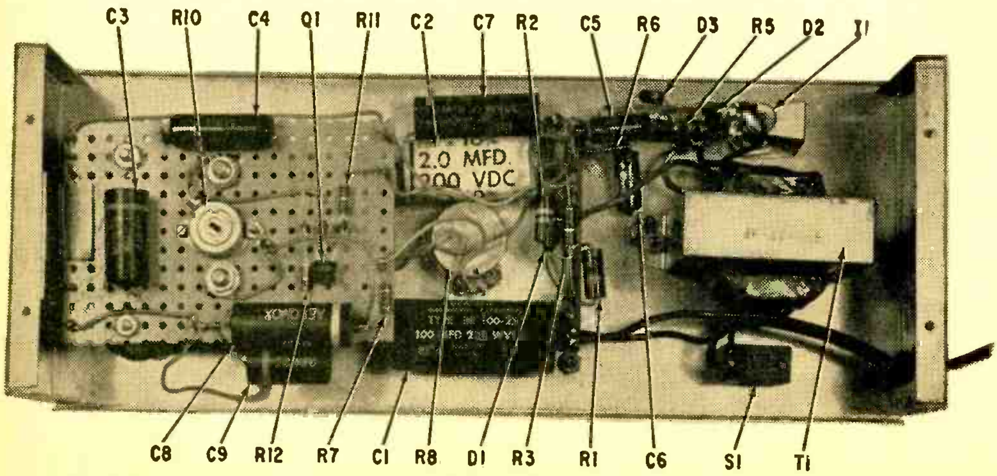
The flashtube, the oscillator circuit and the trigger circuit (with the exception of the meter M1, potentiometer R8, resistor R7 and switch S2) are mounted on a small piece of perforated phenolic chassis board (Vectorboard). Vectorboard push-in terminals make excellent soldering points and should be used. Be very careful when soldering unijunction transistor Q1 into place—grip its leads with needle nose pliers during soldering. The pliers act as a heat sink and protect the heat-sensitive transistor from overheating.

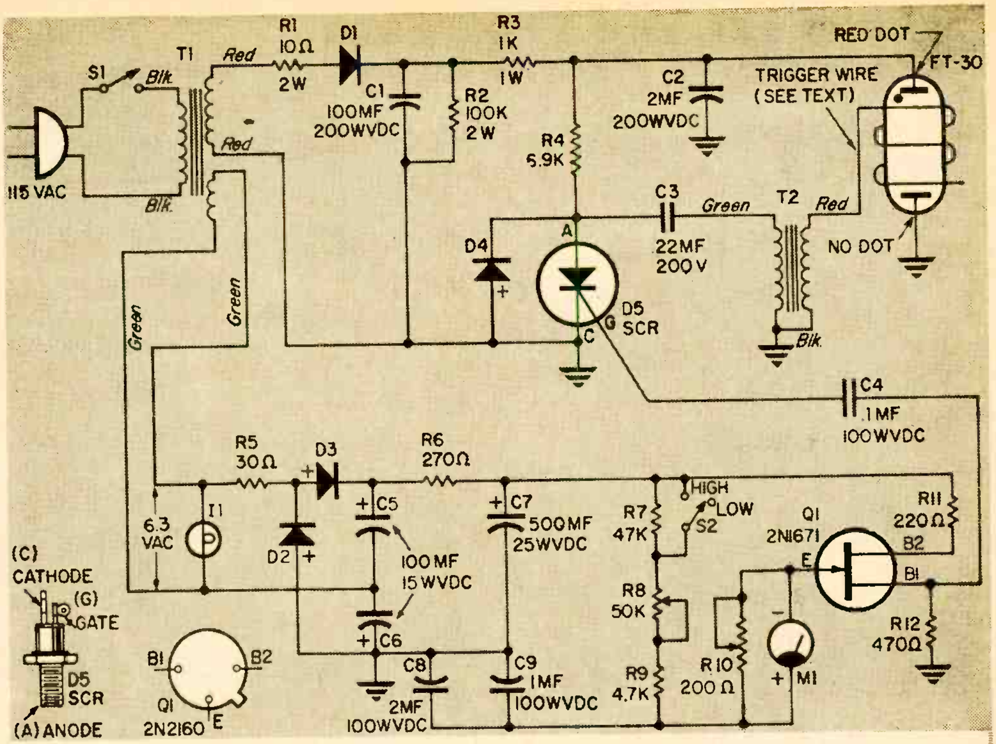
Fasten trigger transformer T2 to the circuit board with a 6-32 machine bolt passed through its center. Mount the flashtube FT-30 by pressing its electrodes *gently* into push-in terminals. Note that the end of the flashtube marked with a small red dot goes to the positive side (hot side) of capacitor C2. Connect the flashtube backwards and you will be buying a replacement in short order.

Capacitors C8 and C9 are wired in parallel




**The stroboscope is wired into a flat, long, aluminum chassis box permitting uncrowding of parts. Perforated circuit board (above) mounts on meter screw posts (see below). Except for resistor R9 (hidden under capacitor C2) all parts are shown in photos.**






## PARTS LIST

C1—100-mf., 200-volt electrolytic capacitor
C2—2-mf., 200-volt paper capacitor
C3—.22-mf., 200-volt paper capacitor
C4—.1-mf., 200-volt paper capacitor
C5, C6—100-mf., 15-volt electrolytic capacitor
C7—500-mf., 25-volt electrolytic capacitor
C8—2-mf., 100-volt paper capacitor
C9—1-mf., 100-volt paper capacitor
D1, D2, D3, D4—5A40 (International Rectifier) or 1 N 2069 (Sylvania, Texas Instrument)
D5—Silicon controlled rectifier, 200-volt reverse rating (Sarkes Tarzian 3TCRE)
I1—Pilot lamp assembly, 6.3-volt bulb, red jewel
M1—O-1 ma. DC milliammeter (Lafayette TM-60)
Q1—2N2160 or 2N1671 transistor (GE)
R1—10-ohm, 2-watt resistor
R2—100,000-ohm, 2-watt resistor
R3—1,000-ohm, ½-watt resistor
R4—6,900-ohm, ½-watt resistor
R5—30-ohm, ½-watt resistor, ±5%
R6—270-ohm, ½-watt resistor
R7—47,000-ohm, ½-watt resistor
R8—50,000-ohm potentiometer with linear taper (Clarostat Series A47)
R9—4,700, ½-watt resistor
R10—200-ohm "Humdinger" hum-adjust potentiometer (Clarostat Series 39)
R11—220-ohm, ½-watt resistor
R12—470-ohm, ½-watt resistor
(All fixed resistors are +10% unless otherwise specified)
S1, S2,—S.p.d.t. toggle switch (Lafayette SW-21 or equiv.)
T1—Power transformer; primary 115-v; secondary 125-volt, 55 ma. and 6.3-volt, 2 amp. (Knight 61 G 411 or equiv.)
T2—Trigger coil for flashtube (Stancor P-6426 or General Electric 86G41)
1—Flashtube (General Electric Company FT-30) (Available from Edmund Scientific Company, Barrington, New Jersey 08007 for $5.20 postpaid)
1—Aluminum chassis 13"x5⅛"x2⅝" (Bud MS-2150 or equiv.)
1—Misc. Perforated phenolic board (Vectorboard), push-in terminals, wire, solder, hardware, line cord, etc.

Estimated cost: $40.00
Estimated Construction time: 8 hours

to make a 3 microfarad, 100 volt DC capacitor. If you wish, substitute a single 3 microfarad capacitor for the pair provided you can find one available.

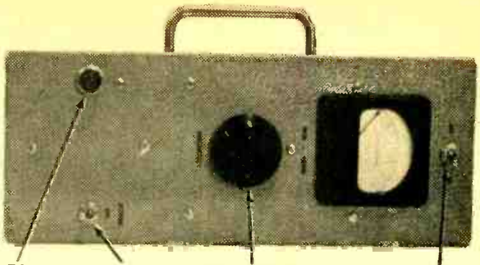
Before mounting the flashtube, wrap about 4 turns of bare #22 tinned copper wire around it, to form the trigger wire. Fashion a simple reflector from a tiny piece of tin-can stock. The reflector may touch the trigger wire, but it *must not touch* the tube's electrodes.

Mount the completed circuit board by securing it directly to the meter M1's terminal connection. Now's the time to probe and peak for shorts and bad soldering joints. Parts are too expensive to proceed blindly ahead by plugging in the power cord and throwing the power switch on.

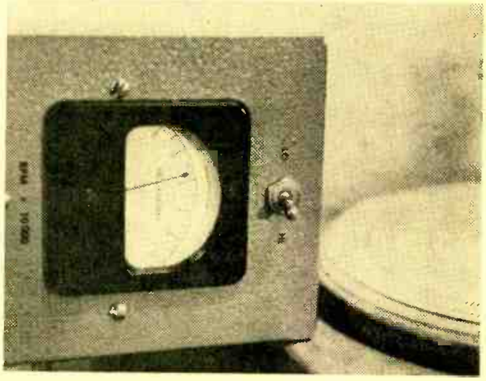
**Calibration.** The RPM reading on the meter face is linear, so only a single calibration is necessary. Operation of the high-low switch, S2, doesn't affect the calibration—the meter always reads the exact flashing rate. Full scale on the meter corresponds to 166.66 flashes per second, or 10,000 rpm. This was done even though the circuit won't operate above 120 flashes per second, to avoid drawing a new dial on the meter face.

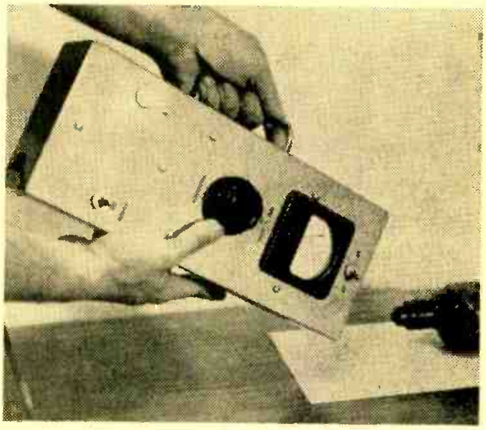
Use a phonograph and paper "stroboscope disc" as a frequency standard to make the single required calibration. Switch the phonograph to 33⅓ rpm, point the stroboscope at the 33⅓ band on the disc, and adjust frequency control R8 until the motion of the band is frozen. Now, adjust potentiometer R10 until the meter reads .36 ma-corresponding to 3600 rpm, or 60 flashes per second. If you wish, you can connect up a test setup with a loudspeaker and signal generator as mentioned at the beginning of this article. This way you can check the accuracy of the metering circuit throughout its entire range. Remember, multiply cycles per second by a factor of 60 to obtain readings in revolutions per minute.

There are several ways you can improve on the construction of the xenon flashtube strobe. If accurate frequency indication is required (better than the meter indication), you can add a vernier dial such as Lafayette's 2⅞" F-346, and calibrate the dial settings against an accurate audio signal generator and loudspeaker hookup. You may want to improve on the xenon flashtube reflector and add a collimator/lens assembly to efficiently beam the light to confined areas. Whatever changes you make, avoid repackaging the unit until you have bread-boarded the circuit. The trigger transformer, T2, should always be close to the flashtube so that the trigger wire is as short as possible. ■

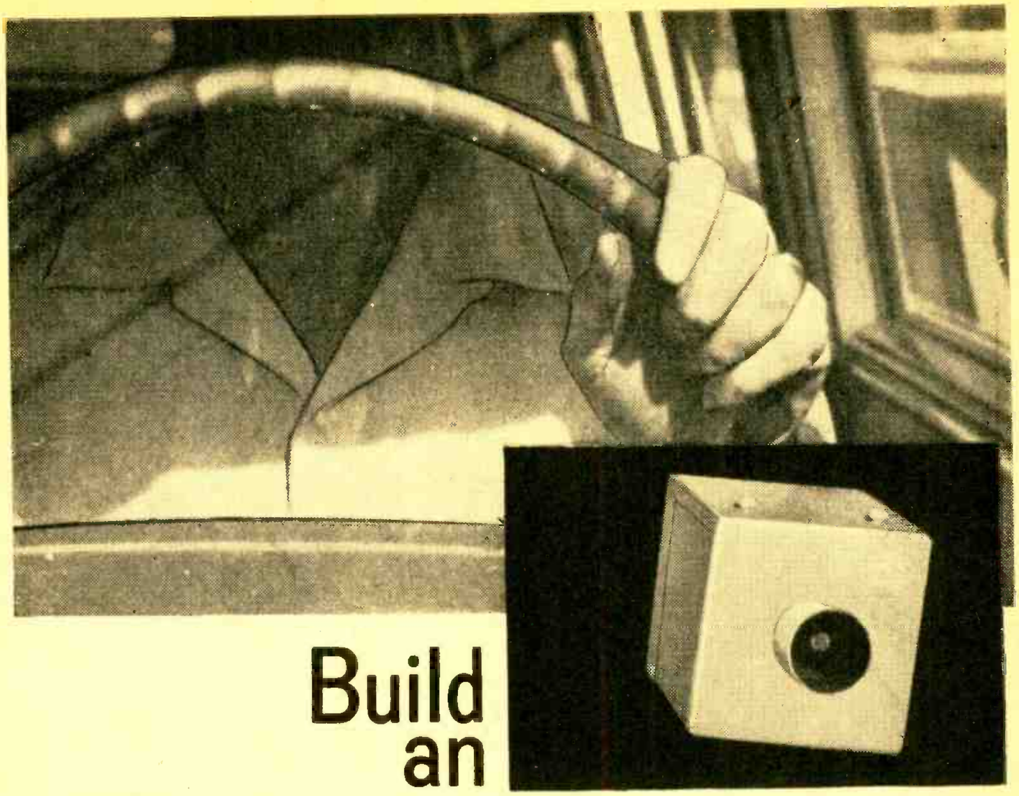



**Uncluttered front panel controls give the stroboscope a professional-like appearance.**





**A phono turntable and strobe disc (above) calibrate the stroboscope. Below, strobe measures unloaded speed of a power tool.**



# Build an AUTO-DIMMER for your car

BENCH TESTED

**By Carl Henry**

**Anyone** who does much night driving ends up telling himself the same thing again and again. "I need an automatic headlamp dimmer," he chides. And no bones about it, this is truly one of the handiest gadgets a driver can have on his auto. But it's also expensive—or is it?

Thanks to a new semiconductor, it's now possible to build a good automatic headlamp dimmer for only ten dollars. The headlamp control relay will cost about seven dollars more. So, for seventeen dollars and a little work, you can equip your car with an automatic dimmer, as good as any on the market, that will work well and be maintenance free.

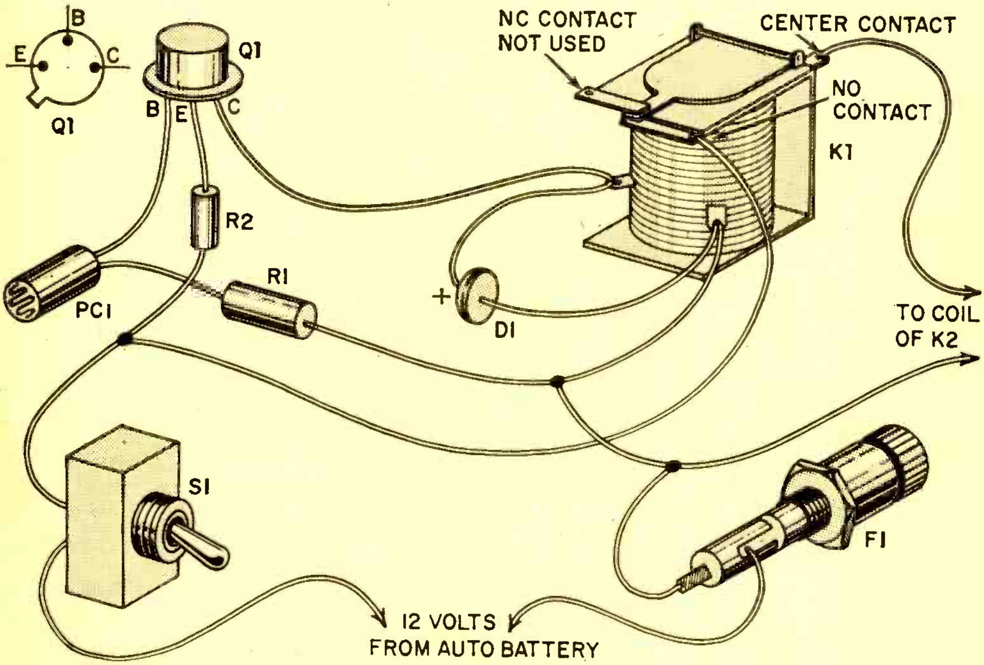
Construction is simple and straightforward. There are no tricky circuits to cause trouble, and installation in your auto is a matter of only an hour's work. Optional controls can be added to vary both sensitivity and time delay.

**The Circuit.** Before starting construction, let's take a minute to study the schematic diagram for the Auto-Dimmer. The key to the operation of the circuit is the photocell, PC1. This is a variable-resistance cell which automatically varies its resistance depending on the amount of light striking it. In total darkness, the resistance of the cell is about 2 megohms. But as the light on the cell increases, the resistance of the cell decreases; at 100 footcandles, the cell has a resistance on the order of 1000 ohms.

The photocell is used to supply bias to the transistor, Q1. When the light "seen" by the transistor is sufficient to lower the resistance, the forward bias on the transistor increases and the relay, K1, closes. The transistor thus acts to amplify the action of the photocell. The transistor relay in turn operates the control relay which dims the auto headlamps. See schematic diagram of control chassis. This second relay is necessary to allow the manual footswitch dimmer to override the automatic dimmer under any conditions.

The balance of the circuit consists of two resistors, R1 and R2, which serve as current-limiting resistances for the transistor. Diode D1 is necessary to protect the transistor from surges caused by the operation of relay K1.

**Construction.** The author built his automatic dimmer on an old piece of printed-circuit board that happened to be handy. You can do the same if you have such an item in your junk box. Otherwise, you can wire the circuit on perforated phenolic board and use solder lugs for the connection points. Drill the board as shown in the detail drawing, then mount the relay on the board with 4-40 machine screws. Follow




**Pictorial diagram of the Auto-Dimmer showing how wires interconnect the various parts. Exact parts placement and lead lengths are not critical. However, it is suggested that the builder follow construction details in this article carefully.**

## once you have installed this light-sensitive semiconductor device

the mounting and wiring as shown in the pictorial diagram and photos. Punch the box for the automatic dimmer. Mount the fuse holder, switch and the grommet to hold the photocell.

A piece of plastic tubing is attached to the front of the box with epoxy resin to act as a light shield for the photocell. This prevents extraneous light from affecting the dimmer circuit. Mount the plastic tubing, then mount the circuit board using two 6-32 machine screws. Stand the board from the top of the box as shown.

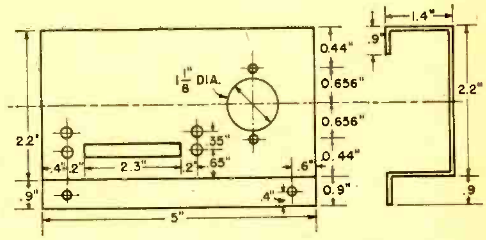
Now finish the wiring, and connect a 5-ft. piece of four-conductor cable to the proper connections on the box.

**Check-Out.** You can now make a preliminary test on the dimmer by hooking it to a 12-volt source. When you are sure that the wiring is correct, connect a 12-VDC source to the dimmer, and turn switch S1 to *Automatic*. Relay K1 should operate if there is enough light to see by. Putting your hand tightly over the photocell should cause the relay to drop out. If you have trouble, double-check your wiring again.

After the dimmer passes this check, you are ready to proceed with construction of the control chassis. Refer to the detail drawing on punching the control chassis and the schematic diagram for the control relay circuit. The author used a piece of scrap aluminum for the chassis, which he painted white after punching it.

You may wonder about the need for a second relay in this circuit. The answer is simple. The larger relay on the control chassis can switch the heavy current of the headlamp circuit better, and it also allows the driver to have complete control of the lights.

As you can see from the schematic diagrams, if the automatic dimmer holds the headlamps on bright, you can dim them sim-

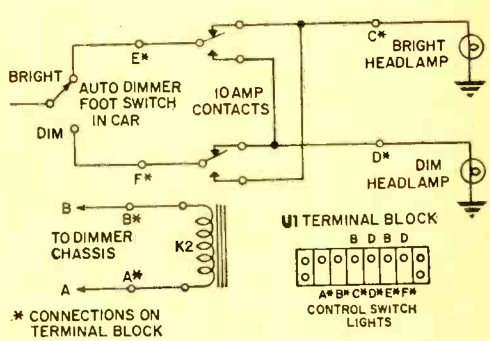



**The dimensions for the overall size of the control chassis is not critical except for mounting holes for relay K2 and 6-terminal barrier strip J1 where cables connect.**

### PARTS LIST

- D1—Silicon rectifier (International Rectifier 2E4 or equiv.)
- F1—½-amp fuse, 3AG
- 1—Fuse holder for 3AG fuse
- J1—6-terminal barrier strip (Cinch-Jones 6-140 or equiv.)
- K1—S.p.d.t. relay (Potter & Brumfield RS5D with 6-VDC coil)
- K2—Multi-contact relay (Potter & Brumfield KRP11D-G with 12-VDC coil)
- PC1—Photocell (Clairex CL-604L)
- Q1—Pnp transistor; use either 2N654 (Motorola) or 2N241A (GE)
- R1—470-ohm, 1-watt resistor
- R2—47-ohm, ½-watt resistor
- S1—S.p.d.t. toggle switch
- 1—Octal Socket
- 1—Aluminum chassis box, 4" x 2¼" x 2¼" (Bud CU2103A)
- 1—Scrap aluminum for control chassis, 5" x 7"
- Misc.—Shield for photo cell, phenolic board, rubber grommet, wire, cable, solder, etc.

Estimated Cost: $17.00
Estimated construction time: 6 hours with installation




**Schematic diagram for the control chassis mounted under the automobile's hood. The hot leads to the bright and dim headlamps are cut. Then, ends that trace back to the dimmer switch connect to terminals E* and F*. The ends that trace back to the headlamps connect to terminals C* and D*.**

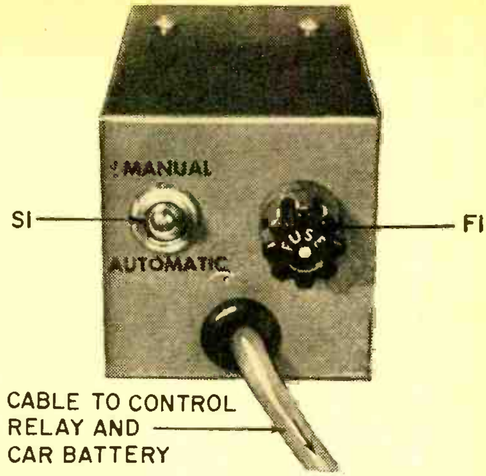
ply by pushing the footswitch. The reverse is also true—if the lights dim when they should remain bright, the footswitch will override the automatic dimmer and restore the lamps to high beam.

After completing construction and wiring of the control chassis, install it in your car, and break the wires from your footswitch to the headlamps through the terminal strip on the control chassis. After doing this, check your lights to see that they operate normally. There should be no change in the operation of the headlamps. Most important, if the lights were on bright when you started the wiring, they should still be on bright.

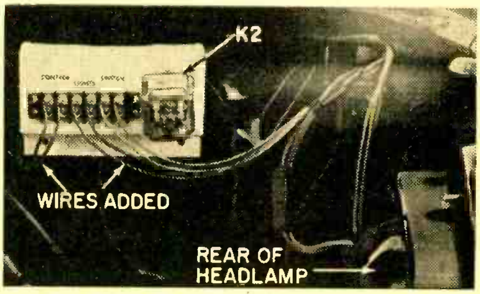
Install the automatic dimmer in your car, either to your left or on the center of the top of the dashboard. Be sure that windshield wipers, windshield stickers, or other items do not prevent the photocell from "seeing" the road. Point the dimmer straight ahead and level it.

Pick up 12 volts from the headlamp fuse for power to the automatic dimmer. Connect the other two output wires from the automatic dimmer to the terminals on the control chassis.

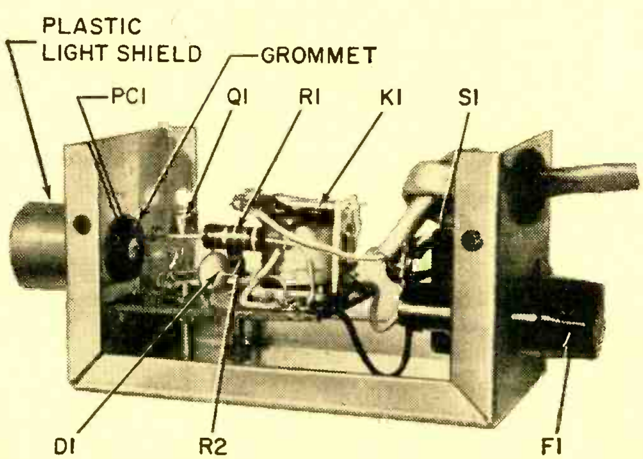
**Final Test.** Before giving the Auto-Dimmer a test road run, set switch S1 to *Manual.* The lights should then work normally, and so should the footswitch. Now switch to low beam, and turn S1 from *Manual* to *Automatic.* Assuming you are parked with no street lights close by, the headlamps should switch from low to high beam at once. Note that you can always override the automatic dimmer with the footswitch, and that



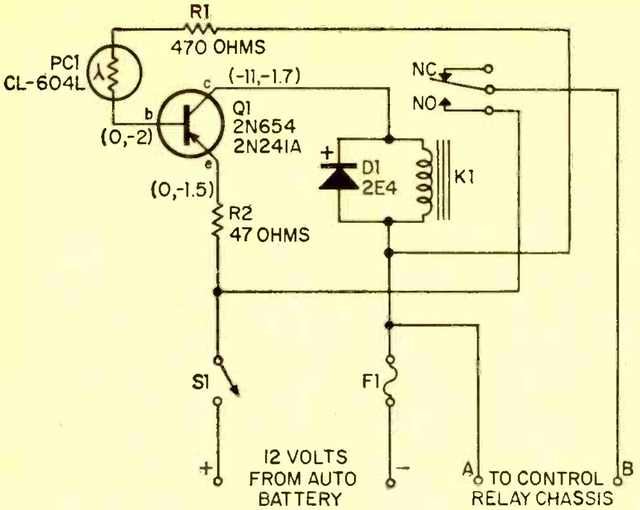

**Driver's view of the Auto-Dimmer mounted to the left of the driver next to the windshield. Final adjustment has to be made during road test to aim "eye" correctly.**




**View of the control chassis installed under the hood of the author's car. Mount where the unit will be accessible for inspection.**




**Inside view of the Auto-Dimmer showing location of parts. Relay K1 is isolated from metal case by phenolic board.**

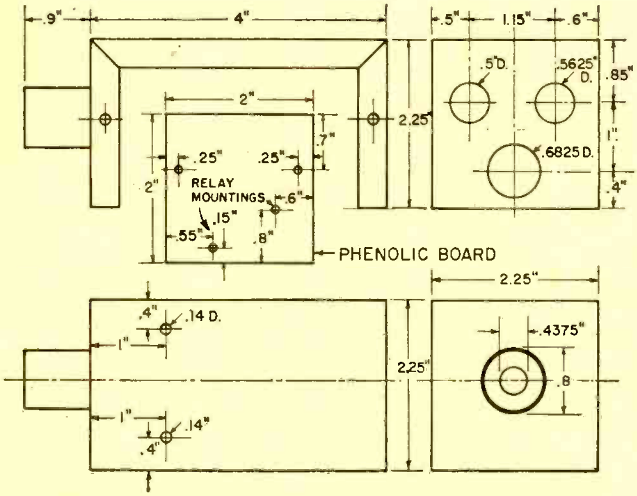



**The heart of the Auto-Dimmer circuit is photocell PC1 which serves as a light-sensitive, variable resistor that controls the conduction of transistor Q1. Light from a distant headlamp drops the internal resistance of PC1 down from 2 megohms to about 1000 ohms. Thus, a strong negative bias is applied to Q1 and the transistor conducts heavily drawing a large current through K1's coil. Result—relay is energized providing a closed circuit for the control chassis. Numbers in parenthesis are voltages with and without Q1 conducting respectively.**

the incident light in town is enough to hold the lights on low beam.

No provision is made for variable sensitivity. You can add this feature if you wish, although in general it is not necessary. To add this control, replace resistor R1 with a 100,000-ohm, 1-watt potentiometer connected as a 2-terminal resistor. This will give you a wide control over the light switching point of the circuit. At minimum resistance on the potentiometer, sensitivity will be at maximum.

The switching delay of the circuit can also be adjusted to a different value. If you wish to change the switching time, add a capacitor between the base of transistor Q1 and the positive side of the 12-volt source. You can use from 0.05 to 1.0 uf. in this position—the bigger the capacitor, the longer the delay in switching. ■




**Detail drawing of the Auto-Dimmer dashboard box. Follow plans exactly in order to fit parts in the box. Be sure that no wires press against relay K1's clapper closing it continuously. Mount relay on phenolic board and then mount board in box. Use an ohmmeter to check that no part of the relay is electrically connected to the chassis box. Phenolic board is raised about ¼-inch above the box bottom by means of spacers to prevent accidental shorts. Plastic light shield is painted black to reduce reflection.**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24. Here's a complete catalog of high-styled speaker enclosures and loudspeaker components. *University* is one of the pioneers in the field that keeps things up to date.

26. When a manufacturer of high-quality high fidelity equipment produces a line of kits, you can just bet that they're going to be of the same high quality! *H. H. Scott, Inc.*, has a catalog showing you the full-color, behind-the-panel story.

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32. You can learn lots about tape recorders. Big tape recorders for studios, little tape recorders for business men, all kinds of tape recorders from *American Concertone*.

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## The Decibel

*Continued from page 88*

Fig. 1. Here, the exception is that the load resistor, Rl, on the amplifier is shown, and a separate voltmeter is used. Assume Rl is 10 ohms.

Set a tone control on the amplifier to get a maximum treble cut. Now, feed a 400 cycle signal through the amplifier. Assume the voltmeter reads 100 volts. Next feed a 20,000 cycle signal through the amplifier and assume the voltmeter reads 10 volts.

The voltage ratio is 100:10. From Table 3, 100:10 = 10:1 or 20 db.

If you worked this in terms of power across the resistor, Rl, the same ratio in db will be found.

From equation 5, the power across the 10 ohm resistor when 100 volts is measured is

$$Po^2 = Vo^2/Rl = (100)^2/10 = 10{,}000/10 = 1000 \text{ watts.}$$

The power when 10 volts is measured is

$$Pi = Vi^2/Rl = (10)^2/10 = 100/10 = 10 \text{ watts.}$$

The power ratio is 1000:10 = 100:1. From table 1, 100:1 = 10:1 × 10:1 = 10 db + 10 db = 20 db.

Using the power ratio or the voltage ratio, the same results can be achieved. It must be remembered that voltage ratios can be used only if the measurements are made across the same or identical value resistors. With this factor in mind, the choice of which ratio to use depends solely on convenience.

**DB, DBK, DBM, DBV, DBW, DBRAR,** etc.! All these forms of the decibel seems to have been invented special to confuse. Actually, it should do no such thing.

In many amplifier specifications, the term db or dbm is stated without stating any specific reference power (Pi in equation 1). However, standards were established. Each one of the initials indicates what the reference power level is. In hi-fi, primarily db and dbm are used.

If db is used without an obvious reference, the Pi referred to is 6 milliwatts or 6/1000 of a watt.

If dbm is used, the Pi referred to is 1 milliwatt. The dbm is the more important of the two figures to remember.

For an example, assume that hum is rated at −9 dbm. From Table 2, 9 db or dbm represents a power ratio of 8:1. Therefore the hum power is ⅛ milliwatt.

If you wish to express any power in db with respect to 1 milliwatt, simply calculate the ratio of the known power to the 1 milliwatt level, and use either equation 1, Table 2, or Fig. 3.

**Reading db on a Voltmeter.** It is common practice not to measure or calculate db. Many voltmeters are calibrated in terms of db. These db scales can be used in measurements that are taken across the same or equal valued resistors.

Note the scales on a VTVM such as the EICO 255 AC voltmeter. Consider the top 0 to 1 volt scale and note the equivalent reading on the db scale at the bottom.

When the needle points to 0.8 volts, it also points to 0 db. When it points to 0.4 volts, it points to −6 db. This agrees with Table 3. The voltage ratio is .8 to .4 or .2. The db difference is 6.

Try it again. 0.7 volts is just above −1 db. 0.35 volts is just above −7 db. A .7:.35 or 2:1 ratio in this case also gives a 6 db difference (−7 db−(−1 db)). Do this with any voltage ratio and you will find that the same voltage ratio gives you the same db difference all across the scale. It also works on the 0 to 3 scale. Check it on both scales using any of the ratios in Fig. 4 or Table 2.

If you look carefully at the 0 to 3 and the 0 to 1 scales, you will note that they are set at a ratio of approximately 3:1 (or exactly 3.162:1) to each other. Checking the significance of this in Fig. 4, you will find it to be a factor of exactly 10 db.

When switching ranges, you can read the difference in two meter readings direct in db. Then you compensate by this 10 db difference for each range you switched to make the two readings. You can thus read wide differences in db directly on the AC meter.

As an example, suppose you fed a signal to the circuit in Fig. 5, and read −3 db on the 10 volt range. You then removed the signal and switched to the .3 volt range of the meter. On this range, you read −7 db. The difference between the two readings is 4 db. The range switch had to be moved three positions, indicating a change of 3 × 10 db or 30 db. The total level difference is then 30 + 4 or 34 db between the outputs with and without signal.

**The db in Retrospect.** When you consider the decibel, much can be done with very few factors. Equation 1 should be used to give the feel of db. The table of ratios and the discussion of the db scales on meters are of paramount practical importance. ■

## Storage Batteries

(Continued from page 36)

can lead to puncture of the separators and attendant short circuits.

**b.** Freezing of the electrolyte during cold weather and inability of the battery to deliver full power.

**Distilled Water.** Since water is one of the active ingredients essential for proper battery operation, it's obvious that it must be present in the proper quantity for satisfactory battery operation. As mentioned earlier, water is lost from normal evaporation and the electro-chemical reaction within the battery. Loss of water can result in an excessive concentration of acid in the electrolyte with the damaging results mentioned earlier. Also, if the water is not at correct level (completely over the plates) all of the plate area does not take part in the electro-chemical reaction, and battery performance suffers. Normally, acid need not be added to a battery; the only exception is when the acid has been accidentally spilled from the battery. Ideally distilled water should be used in a battery, but the addition of ordinary tap water is acceptable if it is not overly impure. Remember—slightly impure water is better for the battery than no water at all.

Another cause of battery deterioration is continual heavy overload or a direct short circuit. For example, battery damage can result if the car's starter motor is used to actually move the vehicle. Such an extreme continued overload can cause both battery and starter motor damage.

As mentioned earlier, a battery's electrolyte is in danger of freezing at low temperatures when the battery is discharged. Freezing of the electrolyte can cause cracking of the battery container as well as damage to the plates. Fig. 19 is a table indicating the electrolyte freezing temperature versus electrolyte specific gravity. The freezing temperature range from a charged to discharged condition is over 100 degrees! A full charge is "anti-freeze" to a battery.

The battery must be firmly secured in its mounting. Bouncing around of the battery can loosen the battery plates and separators and even damage the container causing electrolyte leakage.

**Charging Storage Batteries.** Before you charge a battery, it's important that the electrolyte is up to the correct level. Also, if the battery is cold, let it come up to room temperature before beginning the charge. Leave the cell vent plugs in place, but be sure that their holes are clear of any foreign particles which may prevent the escape of gas.

Connect the positive (+) terminal of the charger to the corresponding positive terminal of the battery. This may be marked by either a P, +, or Pos., and its diameter is slightly larger than the battery's negative terminal. Connect the charger's negative terminal to the battery's negative terminal which is identified by either a (−), N, or no marking at all.

Next, apply power to the charger and continue the charging process until a hydrometer reading of the battery's individual cells indicates full charge. Generally, a hydrometer reading of 1.260 indicates a fully charged battery.

When the battery is charged, remove power from the charger and disconnect the charger leads. It's not advisable to leave the charger connected to the battery as there may be a slight current drain from the battery back through the charger. Some chargers, however, have provision to prevent this flow of reverse current.

"Fast charge" chargers are available and capable of supplying up to 100 amperes for a 6-volt battery and up to 50 amperes for a 12-volt battery. The use of this type of charger will permit a battery to receive an acceptable charge in about an hour. When using this type of charger, however, care should be taken not to allow the battery's electrolyte to exceed a temperature of 120 degrees F.

"Utility" chargers, such as the one pictured in Fig. 20, can supply up to about 40 amperes and are capable of giving a battery a good overnight charge.

Trickle charges, providing about 4 amperes, are generally used to maintain a charge on a battery during its storage.

It's well to remember that both hydrogen and oxygen gases are released during the later stages of battery charging. Since these gases are extremely explosive when they combine, care must be taken to keep any flames or sparks away from a charging battery—particularly one on a "fast" charge.

Well, there's the story on storage battery operation, care, and maintenance. Now's the time to walk out to the garage, lift up your car's hood and take a good look *into* your car's battery. ■

## Living Color

*Continued from page 64*

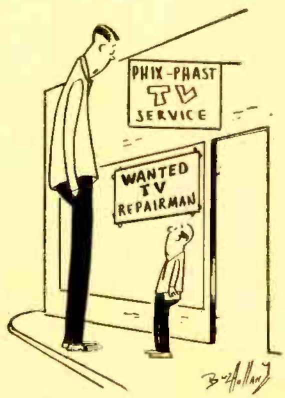
engineering problems in early models. The fast switching voltages applied to the thin stainless steel wires set up a type of oscillation, or ringing, not unlike a microphonic tube in an audio amplifier. As the wires vibrated mechanically, they affected color reproduction. Today the problem is cured by stringing a very fine glass fiber thread through the wires to damp out movement. Perfect alignment of the grid wire with phosphor stripes on the screen was also difficult. Now, an electron printing system is used; during manufacture, electron beams are swept across the raw screen to "print" the positions where the phosphor stripes are to be deposited. The resulting match is perfect.

**Unmasked.** Other features of the Chromatron are apparent when the tube is compared to the conventional "shadow" mask color tube, shown in Fig. 8. The standard tube utilizes three electron guns aimed at a screen covered with tiny phosphor dots. Each gun is driven by color signals from the station—red, blue and green—and the corresponding dots glow in color. The purpose of the shadow mask, is to prevent the triple beam from sweeping over the wrong dots. This is how color separation is achieved. The elimination of the shadow mask in the Chromatron is the basis that tube's claim to much higher color brightness. But another major factor occurs; convergence. The three beams of the conventional tube must focus precisely as they pass through holes in the shadow mask. Only in this fashion will they strike correct color dots. To provide the focusing action, there are special adjustable coils and magnets on the neck of the tube which compress, or converge, the beams together. Since the Chromatron has only one electron gun, the convergence problem is eliminated; the switching grid focuses the beam onto the proper stripe. The effects of the earth's magnetic field, too, are less in the Chromatron. This would ease the problem of moving a color portable from one room to another, or from a picnic area to seashore, for example. Variations in the earth's field are less disturbing to color purity.

**Want to Buy One.** When will you see Chromatron-equipped sets on dealer's shelves? It is expected that production models will make their initial entry into this country via Japan. Under license from Paramount, Japan's big Sony Corporation is concentrating on an 18-inch color portable. Among American companies, Raytheon appears to be closest to producing the tube for U. S. manufacturers. Size might be anywhere from 8 to 16 inches. The only problem now confronting U. S. producers is setting up the tube on a production line, have it spew out in large quantities, and retain close tolerances. When this kind of momentum is achieved, the uncomplicated, low-cost color receiver should come on strong. In any case, Sony considers the Chromatron just about ready for production and possibly could bring sets into the U. S. in the very near future. Price at this time has not been announced, but Peter Ramella, Chromatic's general manager, believes that ultimately the Chromatron approach could lop a sizeable chunk off the price of small-screen color. His estimate is an approximate $250 price tag.

Research has not ceased on the Chromatron. Even now there is an effort to further simplify the circuits outside the tube. Also under development are techniques which would enable the picture tube to accomplish functions now handled by small chassis tubes. New techniques, which promise even greater brightness, are in the offing.

With engineering now in a highly refined state, there remains only the mass-production details to work out. There is no question about the high interest being demonstrated by Sony and other Japanese firms. Combine this with interest already expressed by American producers and you can say that the Chromatron has come to color TV. ■




"Don't know much about fixing TV's, but I sure can install antennas!"

## Superheterodyne Receivers

*Continued from page 50*

dyne circuits for converting from the 150-174 mc band to a 20 mc IF and then to a 290 kc IF, for example.

A dual-conversion superheterodyne is formed when a marine, citizens or mobile radio band converter is used with a broadcast band auto radio, as shown in Fig. 8. The converter usually employs a fixed-tuned local oscillator, and a broad-banded converter input circuit. Tuning is accomplished by tuning the auto radio. Hence, the auto radio acts as a variable-frequency IF amplifier.

If the converter is for the citizens band and its local oscillator is fixed-tuned to 25.965 mc, Channel 1 (26.965 mc) will be heard when the auto radio is tuned to 1290 kc. Hence, all 23 citizens channels can be tuned in by tuning the auto radio from 1000 kc to 1290 kc. Within the auto radio, the signal will be again converted to a lower frequency before detection.

Television sets and FM broadcast receivers employ superheterodyne circuits. In a TV set tuner, the channel switch selects the appropriate RF amplifier, converter and local oscillator tuning circuits. The fine tune control varies only the local oscillator frequency and allows the user to vary the resulting IF signal frequency.

In FM broadcast receivers, the RF amplifier, converter and local oscillator stages are usually tunable through the entire band. FM receivers differ from AM receivers in that the IF amplifier stages are followed by one or more limiter stages and an FM discriminator. The limiter stages are IF amplifiers which keep the amplitude of the IF signal constant and the discriminator (or ratio detector) converts frequency deviations into audio.

The same principles, as discussed here, are applicable to transistor-type receivers as well as those that employ tubes. There are differences, of course, in components and voltages, but frequency conversions are made in the same basic manner.

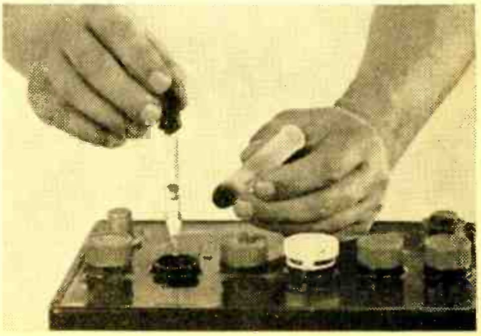
**The Switch to Superhets.** The Superheterodyne receiver revolutionized radio. It took a long time after Major Edwin H. Armstrong invented the Superheterodyne for these techniques to become widely adopted. The earliest mass-produced superheterodyne receivers, such as the Radiola 60, were superior in selectivity and sensitivity but were not as popular as later model Victor TRF receivers.

Superheterodyne receivers really caught on when Philco introduced its models 70 and 90 in the early 30's and reached a high state of perfection in its 16 series. The Majestic 52 and several Atwater Kent models were also early top performers. Among shortwave communications receivers, the superheterodyne reached a new performance plateau in the Hammarlund Super-Pro the National "HRO" receiver during World War II.

Most FM communications receivers are capable of handling signals at levels less than one microvolt. The sensitivity of a superheterodyne receiver can be truly amazing. The limiting factor is noise which, when stronger than the desired signal, puts a ceiling on practical sensitivity. ■

## *Instant Battery Tester*

Do you know for sure that your battery will start your car—even on the coldest day? Well, there is one way to eliminate the guess work and that is to check the state of charge of each cell in the battery with a hydrometer. To help the car owner along with this test, a compact cigar-sized Thexton Hydro-Mite battery tester tells you instantly whether your battery has a full, fair, or poor charge or is completely discharged. Easy to use, just insert tester into battery electrolyte, draw up the liquid, and count the number of floating balls. Unit has a leak-proof storage tube. Price: only $1.50 from Rutward, Inc., 1636 Bryant Road, Columbia Station, Ohio.



## TRF Receivers

*Continued from page 44*

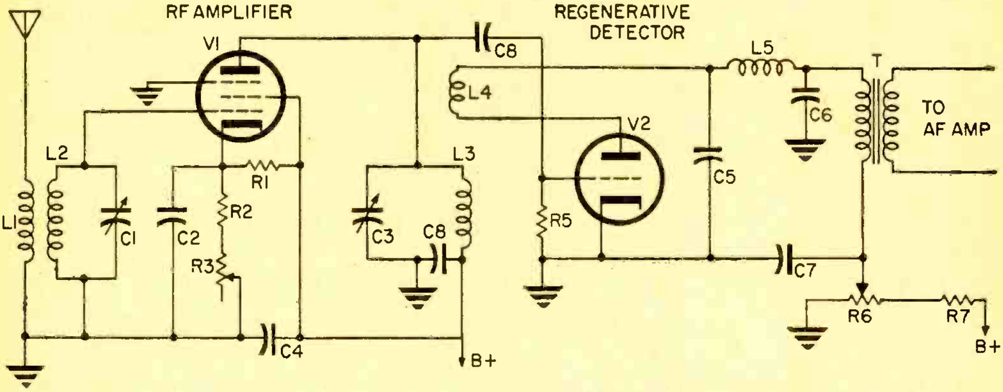



**Fig. 20. Receiver circuit with tuned RF stage and regenerative detector is very sensitive and quite selective for VLF to VHF.**

stant of resistor R5 and capacitor C8.

When operated as a superregenerative detector, sensitivity is almost as high as in a multi-tube superhet. But selectivity is reduced. Inherent AVC is obtained because of the amplitude limiting action of the detector, and the receiver can be used for FM as well as AM reception.

**All But Gone.** The TRF receiver has almost disappeared except for low-cost shortwave receivers. This is because of the greater sensitivity and selectivity of superheterodyne receivers.

But, don't sell the TRF receiver short. For good reproduction of AM broadcasts directly or through a hi-fi amplifier, it is usually better than a superhet on local signals. It is simpler to design and use than a superhet. And, when a regenerative or superregenerative detector is used, it can compete in overall performance with more complex and costly receivers.

## Kirchhoff's Laws

*Continued from page 66*

$$6 = 9Ibd + 3Ibc \qquad (4)$$

subtract $$3 = -2Ibd + 3Ibc \qquad (3)$$

and the difference is

$$3 = 11Ibd$$

or simply

$$Ibd = 3/11 \text{ amperes.}$$

Now substitute $3/11$ for Ibd in equation (3) and solve for Ibc.

$$3 = -2Ibd + 3Ibc \qquad (3)$$
$$3 = -2(3/11) + 3Ibc$$
$$3Ibc = 3 + 6/11$$
$$Ibc = 1\,2/11 \text{ amperes}$$

With Ibd and Ibc known, these values can be inserted into equation (1) to determine Iab.

$$Iab = Ibc + Ibd \qquad (1)$$
$$Iab = 1\,2/11 + 3/11$$
$$Iab = 1\,5/11 \text{ amperes.}$$

**You Solve It!** Now that we have gone through the step-by-step procedure for solving a simple network problem using Kirchhoff's laws, it's time you did one on your own. Refer to Fig. 3. Determine the current flow through each resistor and the voltage drop across them. There are several different ways this problem can be solved, so take the path that the author used. Write the current equation at point C in Fig. 3 using the currents so marked in the schematic diagram. Then write two voltage equations using the paths CBAC and DACD. If you use this method of writing the equations, then your solution will duplicate the author's solution which will be given in the next issue of ELEMENTARY ELECTRONICS. However, the values for the currents and voltage drops will not vary no matter what approach is used. Let us give you one hint: the currents through the two-ohm resistors will be equal in magnitude but of opposite sign. Do not use this hint in solving the problem, but only to check on your answers. *Good luck!* ■

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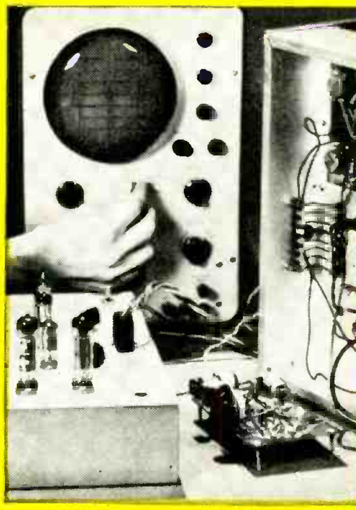

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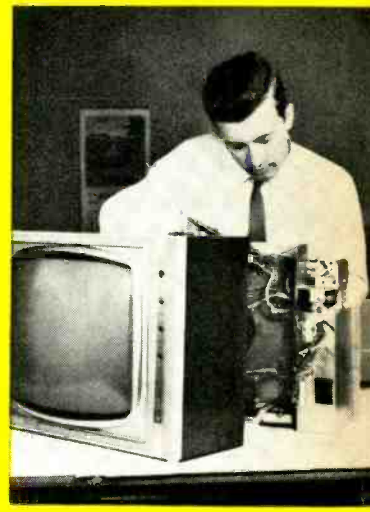

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