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MAY-JUNE 75¢

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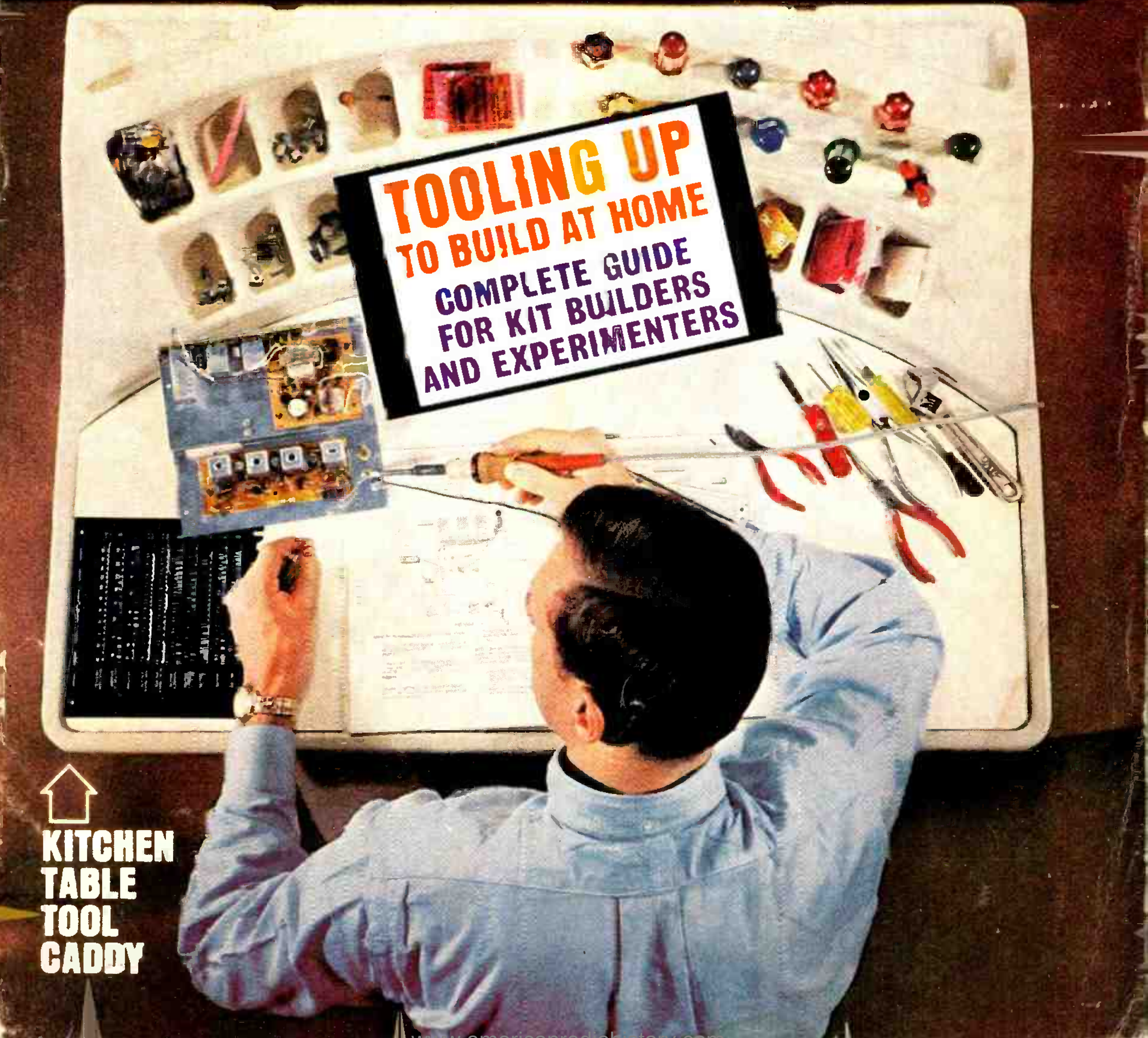

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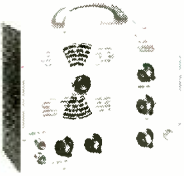

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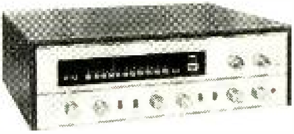

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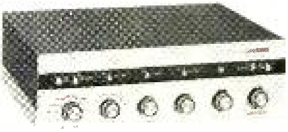

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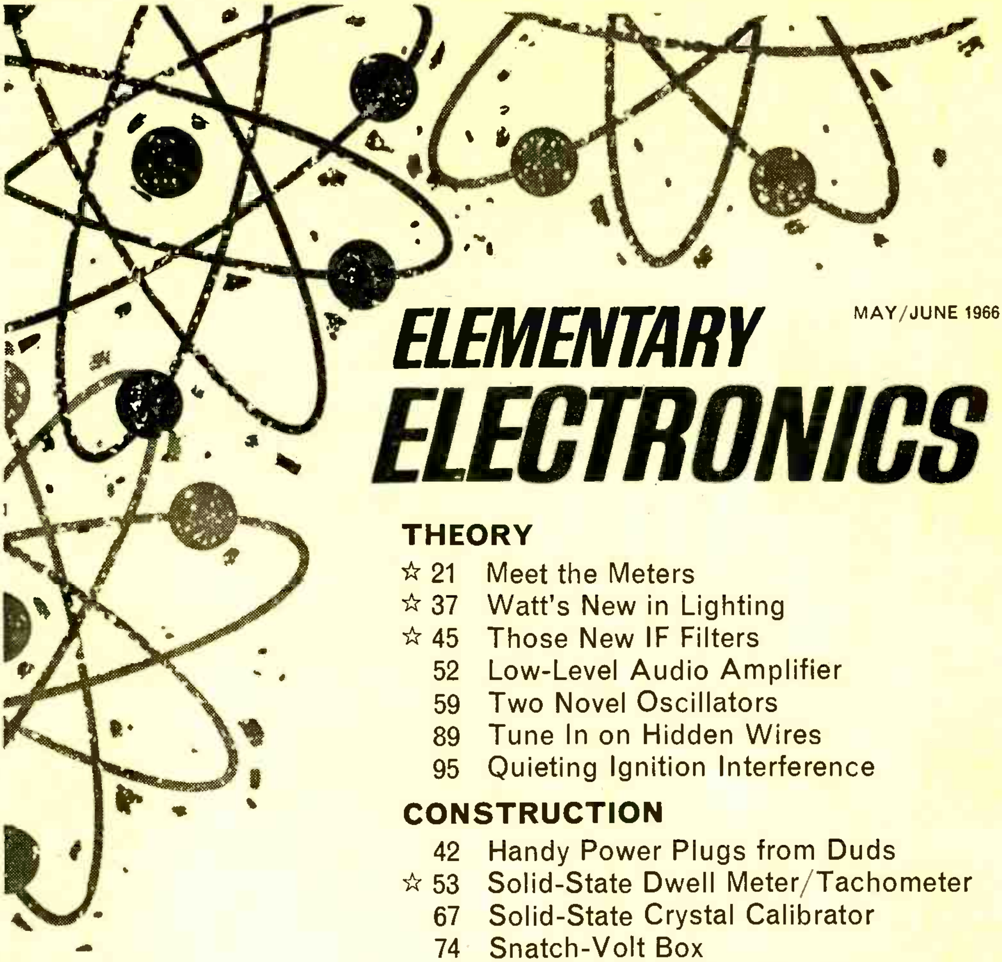

MAY/JUNE 1966

ELEMENTARY ELECTRONICS

☆ **Cover Highlights**

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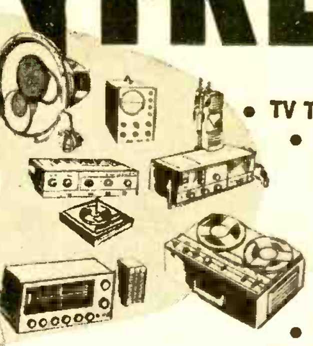

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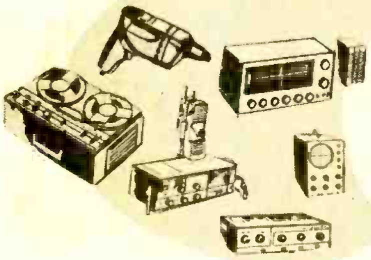

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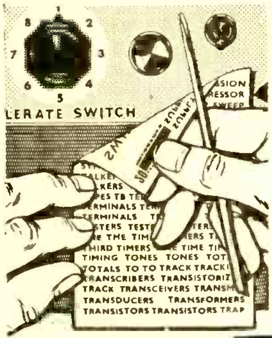

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MAY-JUNE 1966 Vol. 2 No. 2

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ELEMENTARY ELECTRONICS, Vol. 2, No. 2 (#785) is published bimonthly by SCIENCE& MECHANICS PUBLISHING CO., a subsidiary of Davis Publications, Inc. Editorial, business and subscription offices: 505 Park Ave., New York, N. Y. 10022. One-year subscription (six issues)—$4.00; two-year subscription (12 issues)—$7.00; and three-year subscription (18 issues)—$10.00. Add $1.00 per year for postage outside the U.S.A. and Canada. Advertising offices: New York, 505 Park Ave., PL-2-6200; Chicago: 520 N. Michigan Ave., 527-0330; Los Angeles: 6253 Hollywood Blvd., 213-463-5143; Atlanta: Pirnie & Brown, 3108 Piedmont Rd., N.E., 404-233-6729; Long Island: Len Osten, 9 Garden Street, Great Neck, N. Y., 516-487-3305; Southwestern advertising representative: Jim Wright, 4 N. Eight St., St. Louis, CH 1-1965.

EDITORIAL CONTRIBUTIONS must be accompanied by return postage and will be handled with reasonable care; however, publisher assumes no responsibility for return or safety of manuscripts, art work, or photographs. All contributions should be addressed to the Editor, ELEMENTARY ELECTRONICS, 505 Park Avenue, New York, N Y. 10022.

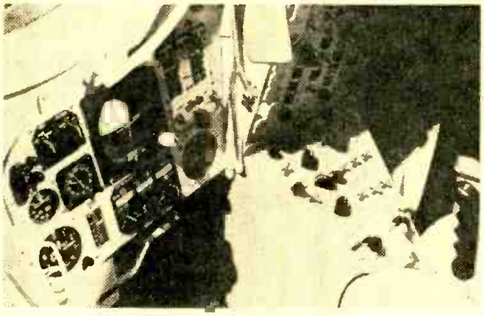
Second-class postage paid at New York, New York and at additional mailing office.

NEWSCAN

Transistor Space Time

An Accutron electronic clock was on the control panel of the Gemini 5 spacecraft during its record-breaking 8-day mission. The 24-hour-dial clock was specially designed and manufactured by Bulova Watch Company, Inc. but the transistorized timekeeping unit of the clock was identical with that used in the watch-size consumer models of Accutron timepieces. And like each consumer model, the clock was guaranteed to maintain an accuracy of plus-or-minus two seconds a day. A similar clock was on the control panel of the Gemini 4 spacecraft during its June 3-7 mission. The Gemini 6, which is now scheduled for its space mission next month,

(Continued on page 8)



An Accutron clock was incorporated in the control panel of the Gemini 5 spacecraft facing Astronaut L. Gordon Cooper, Jr., command pilot of the spacecraft during its record-breaking eight-day mission August 21-29. This photo shows the 24-hour-dial Accutron clock (left center) installed on the control panel of the actual size mockup of the Gemini 5 at the NBC News Space Center at Rockefeller Center, New York City. The transistorized electronic timekeeping unit inside the clock is identical with the timekeeping unit used in all 77 consumer models of the Accutron time-piece.

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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.

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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.

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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.

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It is understood and agreed that should the Progressive Radio "Edu-Kit" be returned to Progressive "Edu-Kits" Inc. for any reason whatever, the purchase price will be refunded in full, without quibble or question, and without delay.

The high recognition which Progressive "Edu-Kits" Inc. has earned through its many years of service to the public is due to its unconditional insistence upon the maintenance of perfect engineering, the highest instructional standards, and 100% adherence to its Unconditional Money-Back Guarantee. As a result, we do not have a single dissatisfied customer throughout the entire world.

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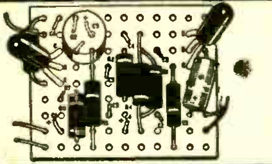
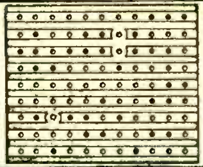




NEWSCAN

Continued from page 5

will also be equipped with an Accutron clock. As far as can be determined, the Accutron timekeeping unit was the only product originally developed for the consumer market that was part of the Gemini 5's instrumentation. The clock was incorporated in the control panel immediately in front of the command pilot, Lieut. Col. L. Gordon Cooper, Jr.

The Accutron timekeeping unit uses a one-inch tuning fork as its frequency standard. It hums gently (between E and F above Middle C) as it vibrates 360 times a second, or 31,104,000 times each 24 hours, or 144 times as fast as the oscillation rate of the balance wheel in a conventional watch movement. Like all consumer models, Gemini 5's Accutron clock operated on about .000008 watt (eight one-millionths of a watt). Power was transmitted through a transistorized electronic circuit from a tiny power cell contained within the clock case. The cell lasts at least a year, as is the case with consumer models.

The mission of the Gemini 5 spacecraft established five world space records for the United States, and set three world space records for individuals and two American space records. The five world records set for the U. S. are:

1. Longest manned space flight: 190 hours 56 minutes.

2. Longest multi-manned space flight: 190 hours 56 minutes.

3. Most revolutions for manned space flight: 120.

4. Brought total of U. S. man-hours in space to 639 hours 48 minutes.

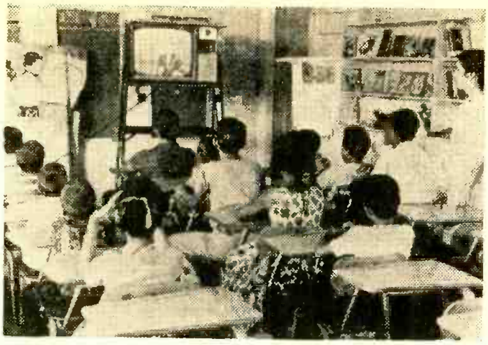
5. Brought total of U. S. manned space flights to 9.

ETV in Puerto Rico

Puerto Rico has placed an order with General Electric for nearly 1,800 educational TV sets in a move that is expected to have far-reaching effects in the ETV field.

Believed to be the largest single ETV receiver order ever placed with a manufacturer, the $537,000 five-year contract was won by International General Electric Puerto Rico which will supply, install and service the sets designed specifically for school use.

The order is especially significant in view of the heavy effort being made by Puerto Rico's Department of Education to improve the quality of education in the island commonwealth. Through expansion of the ETV program, it will be possible to offer a richer curriculum to the greatest number of students. At the same time, by watching the performance of an excellent teacher, instructors will have an additional resource for improving their teaching methods and knowledge of subject matter.



A specially designed educational TV receiver—one of the nearly 1,800 to be supplied by General Electric—is shown in operation in a rural Puerto Rican school. The sets were installed this past summer for the 1965-66 school year.

Puerto Rico's action is also expected to spur increased use of ETV in other sections of the world. When the ETV program was started in 1962, there were only five classroom subjects being taught to about 11,000 pupils. Under the full-scale program, dozens of subjects will reach hundreds of thousands of school children in 71 school districts.

As part of the contract, G.E. has guaranteed to have any set requiring service back in operation within 24 hours. Installation and service will be performed by the company's service shops and by franchised service dealers located throughout Puerto Rico.

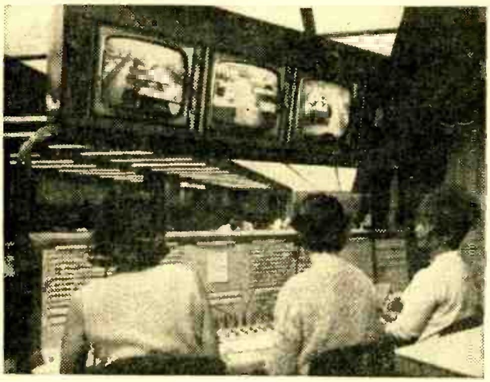
Eventually with more sets in operation in a network, educational television will reach almost every school on the island commonwealth. Large urban elementary and high school buildings as well as rural one-room school buildings will be included in the Government operated ETV network. It will even extend to such offshore islands as Culebra and Vieques.

In addition to the primary use as an audio-visual instruction tool, each set can be used with phonograph or a tape recorder amplifier and as part of a public address system. In these uses, the ETV picture and its allied circuitry are turned off to prolong set life.

Other special features are high-fidelity sound components with 6- x 9-inch speakers and 12 watts of audio power; a tamper-proof cabinet with a locking door; and a built-in "Glarejector" which is a tilted and tinted safety window that minimizes reflections.

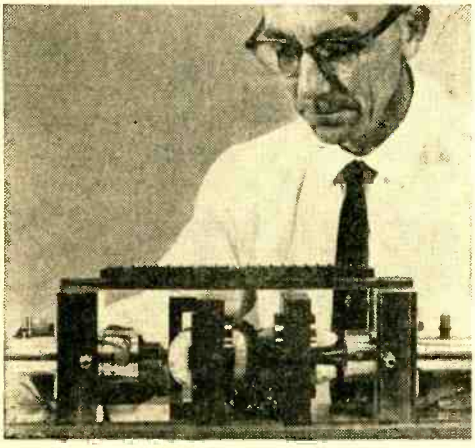
TV and 'Phone—Hand in Hand

Telephone operators at the Bethlehem Steel Corporation use a closed-circuit television office monitoring system to route calls to sales personnel. Three Sylvania television cameras are installed to allow telephone operators to view sales areas, not in the line of sight, from the telephone switchboard. By looking at the TV monitors (above), the operators can determine if a Bethlehem salesman is at his desk to receive incoming phone calls. If he is not available, the operator can refer the call to another desk or activate a red light on the telephone to indicate that there is a message at the switchboard. Other installations using Sylvania equipment serve Bethlehem's Chicago and Atlanta offices. Bethlehem Steel's Sales Department believes that the closed circuit television system enables them to provide their customers with faster and more efficient telephone service.



Not a New Dance But It Does Push, Pull and Twist

A unique three-dimensional electric motor that can simultaneously rotate and push and pull a shaft has come out of the ITT Federal Laboratories. Invented by Stanley A. Cory, a senior member of the ITTFL technical staff, the device evolved from a developmental contract from the U. S. Air Force for a miniature gas-bearing compressor.



According to Mr. Cory, the length of the motor's stroke can be adjusted within broad limits. Between one stroke and 32 strokes per revolution are possible. In addition, the motor can supply reciprocating thrust while rotating through 90, 180, or 360 degrees. Power is obtained from a pulsed DC source, but a standard 60- or 400-cycle electrical system can be used under certain conditions.

The new motor could be built to any size, depending on the particular application. However, a range of from 1/1000th horsepower to 5 horsepower appears most practicable at this time. In addition to fulfilling the specific compressor need, ITT engineers expect the device to refine considerably machines for such operations as cutting tools, mixing, precision winding, engraving, air circulation, and lock stitching.

2-Way Radio Way Up

Two-way radios enabling a Gemini astronaut walking in space to talk with orbiting spacecraft are being produced here by a division of International Telephone and Telegraph Corporation. The AM radio voice communication sets are expected to be used operationally for the first time on the Gemini 9 mission. The radio will be contained in the Gemini astronaut's back-mounted Modular Maneuvering Unit which Ling-Temco-Vought, Inc. is developing under U.S. Air Force contract. The Air Force maneuvering unit contains propulsion and other spacecraft type systems which will enable the astronaut to perform experimental maneuvers in the weightless environment of space.

Good to the Last Drop

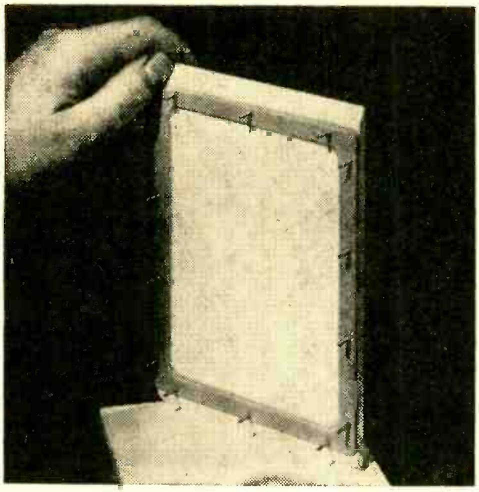
Water separator plates made of porous glass have played a key role in the fuel cells aboard the Gemini spacecraft. Fuel cells combine hydrogen and oxygen to generate electricity. A byproduct of the chemical reaction is water—about a pint per kilowatt-hour. Unless the water is removed, the cells will drown themselves and cease to operate.

A unique porous glass, developed by Corning Glass Works, is used to separate gas and water in fuel cells made by the General Electric Company for the Gemini program.

Moisture-absorbing wicks collect the water formed on the oxygen side of the fuel cell and channel it to the inside surface of the glass water separator plates. The porous glass absorbs water rapidly from the wicks. The water passes through

Stanley A. Cory examines the unique three dimensional motor he developed at ITT Federal Laboratories division of International Telephone and Telegraph Corporation. Still in its test stage, new motor is being evaluated for potential application.

the glass plates and is stored outside the fuel cell. But the plates will not permit oxygen to enter the water system. A positive pressure differential inside the cell prevents water from being re-absorbed and re-entering the cell. Each cell uses three water separator plates approximately 5¼ x 7¼ inches. Plate thickness is about ¼-inch. Pore size is approximately 5½ microns.



Porous glass water separator plates help keep the fuel cells functioning aboard the Gemini spacecraft. Unless the by-product water is removed, the cells will drown themselves and cease to operate.

"Claims he has a Marine Operators License!"

ELEMENTARY ELECTRONICS ETYMOLOGY

By Webb Garrison

Jack

▲ A receptacle connected with one or more electrical circuits and arranged for convenient plugging in of other circuits has to have a name in order to be talked about. But on the surface there seems no good reason why the device should be regarded as masculine and called a *jack*.

Beneath the surface of modern speech, however, there are strong currents that made the emergence of this term all but inevitable. As a familiar form of John, the most common of English masculine names "Jack" was for several centuries encountered everywhere. It was Jack, you remember, who went up a hill with Gill (later Jill) to fetch a pail of water. This name figured in many nursery rhymes, children stories, and legends.

Any Cornishman was long known simply as Cousin Jack. Ordinary folk and even great writers like Dickens used "every man Jack" to mean "every individual person." A sailor was certain to be called Jack Tar, and any serving man or laborer could expect to be called Jack, no matter what his real name might be.

Small wonder, therefore, that any contrivance or machine or utensil that took the place of a lad or a man should be known as a "jack." There were dozens of special applications, ranging from the machine for turning a spit in order to roast meat to a special vessel used in soap making. Today's unabridged dictionaries list two or three dozen special and technical applications of the well-worn name.

Pioneer workers with electricity might have invented a new word for the much-used and versatile device they employed. But they didn't. Borrowing from common speech they took an already over-worked name and gave it still another special meaning with the result that you're often badly handicapped without at least one jack. ▲

Oscillator

▲ Scientists and inventors of the 17th century discovered several different ways to produce machines with vibrating parts. Because such an instrument had some resemblance to a pendulum, they borrowed from Latin *oscillare* (to swing) and named it the oscillator.

Use of the vivid descriptive label was not restricted to laboratories and machine shops, though. Reporters and novelists borrowed it to name a person who fluctuates back and forth between two opinions. So for a period, the most familiar of oscillators was an indecisive man or woman.

Nikola Tesla, now sometimes called the father of modern electrical science, created a great uproar when he first announced that he had invented a machine to produce regular electrical vibrations. He was widely ridiculed, especially in England.

In spite of ridicule the novel device was quickly improved and put to practical use. It has of course been modified many times in recent decades, but the old name has stuck. Today's spark, arc, and electron-tube radio-frequency generators have no parts that call up memories of swinging pendulums. In spite of the fact that such a device may involve no mechanical vibration at all, it still retains the title *oscillator*. ▲

Radio

▲ Scientists and inventors became increasingly interested in various types of radiant energy during the latter half of the 19th century. Rays were often emitted over roughly circular areas. So from the *radius* of a circle, physicists coined *radio*—as a combining form that was used in many varied terms.

By 1881, the radiograph was rather widely known as an instrument to measure intensity and duration of sunlight. A radiophone, on the other hand, produced sound by means of intermittent radiant energy such as light or heat. This device had no equivalent of a telephone but employed a block of vulcanite as receiver; vibratory contraction and expansion produced by heat of the beam resulted in an audible sound.

In the light of this wide usage, it was natural for the new beam-powered communication device of the era to be known both as the wireless and as the radiotelegraph. "Wireless" won out in England and parts of Europe, but the title was too cumbersome for U. S. enthusiasts.

At the 1906 International Radiotelegraph Convention in Berlin, Americans succeeded in substituting "radio" for "wireless telegraphy." Six years later the young word was officially adopted by Congress. First used to designate an individual wireless message, *radio* has since come into global supremacy as the name for organized broadcasting of news, music, and other programs—even when deliberately beamed in such fashion that the original comparison with "radius of a circle" no longer holds true. ▲

Volt

▲ Alessandro Volta, born in 1745, considered himself a philosopher rather than a scientist. He took great interest in the phenomena linked with the newly-discovered and mysterious forces of electricity and at age 24 wrote a treatise on "The Attractive Force of Electric Fire." A few years later, in 1776, he became professor of natural philosophy at the University of Pavia in his native Italy.

Volta invented several electrical devices before stumbling upon a way to produce a continuous current of electricity by contact of different substances. This "Voltaic pile" made him an international celebrity. Sir J. F. W. Herschel called it "the most wonderful of all human inventions." Learned societies competed with one another for the honor of bestowing medals upon him, and Napoleon brought him to Paris in order to demonstrate his discoveries before the members of the French Institute. Eventually he was given the title of count and made a senator of the kingdom of Italy.

Fellow pioneers in the study of electrical phenomena were faced with the problem of selecting names to indicate quantities and effects with which they dealt. For several decades there was no attempt at standardization. But delegates to the International Electrical Congress of 1893 realized that order had to be brought out of chaos. So they defined a number of basic electrical units and gave each of them a name. In honor of Alessandro Volta, *volt* was selected to stand for "that electromotive force which steadily applied to a conductor whose resistance is one ohm will produce a current of one ampere."

Practically equivalent to 10^8 C. G. S. electromagnetic units, the name of the volt is familiar to millions of persons who know little or nothing of Volta and his famous Voltaic piles. ▲

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DX CENTRAL REPORTING

■ It's very seldom that one comes across regular magazine coverage of one of the most fascinating aspects of electronics, that is DX'ing (or "SWL'ing, if you prefer that term) on the so-called "utility" bands. The utility bands are those portions of the radio spectrum wherein operate thousands of ships, aircraft, radio telephone stations, scientific, police, military, and press stations. These are the "cream of DX, almost all of the stations are of relative low power, many of them will QSL.

We at ELECTRONIC EXPERIMENTER have always felt that these utilities stations are sort of the private domain of the experimenter, and our own international monitoring station, DX CENTRAL, devotes a considerable amount of time to listening in on these transmissions.

We have convinced the operators at DX CENTRAL to part with some of their DX loggings and will present them here for our readers. In addition, we'll frequently take a look at some particular piece of monitoring equipment (even military surplus gear) which you can use to your advantage. Now and then, we will even have a little contest for our readers. We will also be looking for reports from our readers regarding their own loggings.

Go Aero. One of the best ways to get started and rack up new countries is on the aeronautical frequencies, which chatter away with DX both day and night. On these frequencies you'll be able to log countries which can't be heard on the short-wave broadcast bands. Some of the most interesting and active of these frequencies are 2945, 2966, 2987, 5611, 5619, 5641, 6537, 6567, 8837, 8845, 8871, 8879, 8888, 8905, 8930, and 8947 kc. Look for rare countries such as Eire (home of the wee folk), Italy, Senegal, Brazil, Scotland, Azores Islands, Curacao (N.W.I.) and dozens of others.

Best times to listen on these frequencies are after dark in your local area. Tune in one of the frequencies we have listed and "sit on it" for a few hours. Try to see how many different stations you can hear in a given time period. Soon you'll find that one or two of the frequencies will become your favorites, you'll probably even get to recognize the voices of the operators after a while.

The aero stations usually identify by the name of the city in which they are located, so you are liable to hear "Santa Maria" in the Azores, "San Juan" in Puerto Rico, or "Dakar" in Senegal. If you hear "Brooklyn" calling, you'll know it's that Flatbush CB'er tuning up his final.

You will be hearing ground stations communicating with each other, or working airline flights. While some of the ground stations are elaborate communications centers, many are little more than a single operator talking into a desk-top transmitter at an isolated airdrome. Pressing the mike button with one hand, swatting mosquitos with the other, these operators let you sit-in on the exciting world of international aviation.

Let Us Know. Say, what about one of those reader contests we mentioned? Suppose we tried this on the aero frequencies for a starter. See how many different countries you

"No kidding? It's a color TV set?"

DOES BUYING HI-FI COMPONENTS CONFUSE YOU?

It's no wonder with so many to choose from. Just which do you buy—which is really best for your home?

If this is your problem, or if you just enjoy keeping up-to-date on the newest components available, the new Mid-Year 1966 edition of HI-FI BUYERS' GUIDE will be a most valuable companion.

You'll find a thorough and detailed section devoted to test reports conducted by an independent laboratory. In this issue of HI-FI BUYERS' GUIDE, this objective testing organization has reviewed high fidelity integrated stereo amplifiers (preamps and power amps on one chassis—both stereo solid state and vacuum tube models), high fidelity stereo phono cartridges and high fidelity stereo headphones.

Each unit reviewed has been rated:

☐ **APPROVED**
☐ **NOT APPROVED**

There's a comprehensive feature on the best methods of selecting a microphone for your tape recorder. This is more than an expanded glossary of terms; this article explains the various microphone types and how their characteristics and prices should be considered in light of the buyer's recording needs.

There's a provocative article on Record Clubs; another on the latest trends in "housing" high fidelity components in furniture. There are 96 highly informative pages which will aid you in making your next high fidelity purchase an easy and fun-filled task.

On sale April 5th, $1.25

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can hear on aero channels and send us a listing of the "heard" stations and their frequencies and we'll publish the winners in a future issue. No prizes, no cash, just the glory of being the top of the heap. Address your loggings to: DX CENTRAL, ELECTRONIC EXPERIMENTER, *505 Park Avenue, New York, N.Y. 10022.*

There's More. Other good bets on the utility bands include station ZUO which sends out time signals from Johannesburg, South Africa, on 5 mc. Try for them around 2200 EST beneath WWV and WWVH. Oh, speaking of WWV, did you know that they send out a very nice QSL card if you address your reception report to: Station WWV, National Bureau of Standards, Beltsville, Md.

Listen for KLW61, operated by the Voice of America at Greenville, N.C. They have been heard on 18,500 kc. working the VOA relay station in Monrovia, Liberia. Liberia's call signs are 5L25 and 5L28. Look for these stations on SSB at about 0800 EST.

Pull in a Cop. Utility listening wouldn't be complete without a police station or two, and our nomination for a good starter would be KEA317 of the Monmouth County Police Department in Freehold, N.J. They can be heard on 2422 kc. most evenings with a powerful signal. If you send them a detailed reception report and enclose a stamped, self-addressed reply card, you will probably be proud to add their verification (QSL) to your collection.

Before we sign off for this visit to your monitoring station, we will pass along to you a few of the busiest utilities frequencies which you might wish to tackle. On 2182 kc. you will get a kick out of marine calling and distress operations. Between 2600 and 2800 kc. there are a number of U.S. Coast Guard and Navy channels offering tasty DX fare for the hobbiest. At the upper and lower edges of the standard broadcast band a number of slow-speed CW beacons can be heard during the evenings. These are located in Canada, and throughout most of Central and South America.

We will be looking forward to reading your reports. Don't forget to include time (in EST), frequency, call, location, etc. And if you have a picture of yourself at your gear, send it along. We're apt to print anything. ■

ASK ME ANOTHER

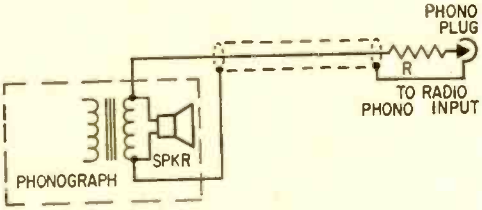
Elementary Electronics brings the know-how of an electronics expert to its readers. *Leo G. Sands,* columnist for *Radio-TV Experimenter,* will be happy to answer your question. Just type or print your unsolved problem on the back of a 4¢ postal card and send it to "Ask Me Another," *Elementary Electronics,* 505 Park Avenue, New York, New York 10022. Leo will try to answer all your questions in the available space in upcoming issues of *Elementary Electronics.* Sorry, Leo will be unable to answer your questions by mail.

Force Feed

What would happen if I fed the output from the speaker of my portable phonograph into the phono input of my radio?

—L. B., Oliver, B. C., Canada

You would feed too strong a signal into the radio's audio amplifier. You can reduce the level of the signal by connecting a resistor in series with the speaker-to-radio circuit, as shown in the diagram. The value of the resistor depends upon the resistance of the radio's volume control, with which it forms a voltage divider. Try various values from 100,000 ohms to several megohms.



Dry-cell Eliminator

My tape recorder employs two 1.5-volt cells, used in series when rewinding (to give 3 volts) and in parallel when recording or playing back, plus a 9-volt battery. Can you give me a circuit for a power supply for replacing the batteries?

—G. B., Sioux Falls, S. D.

(Continued on page 20)

Literature Library

Numbers in heavy type indicate advertisers in this issue. Consult their ads for additional information.

ELECTRONIC PARTS

1. This catalog is so widely used as a reference book, that it's regarded as a standard by people in the electronics industry. Don't *you* have the latest *Allied Radio* catalog? The surprising thing is that it's free!

2. The new 510-page 1966 edition of *Lafayette Radio's* multi-colored catalog is a perfect buyer's guide for hi-fi'ers, experimenters, kit builders, CB'ers and hams. Get your free copy, today!

3. *Progressive "Edu-Kits" Inc.* now has available their new 1966 catalog featuring hi-fi, CB, Amateur, test equipment in kit and wired form. Also lists books, parts, tools, etc.

4. We'll exert our influence to get you on the *Olson* mailing list. This catalog comes out regularly with lots of new and surplus items. If you find your name hidden in the pages, you win $5 in free merchandise!

5. Unusual scientific, optical and mathematical values. That's what *Edmund Scientific* has. War surplus equipment as well as many other hard-to-get items are included in this new 148-page catalog.

6. Bargains galore, that's what's in store! *Poly-Paks Co.* will send you their latest eight-page flyer listing the latest in merchandise available, including a giant $1 special sale.

7. Whether you buy surplus or new, you will be interested in *Fair Radio Sales Co.'s* latest catalog—chuck full of buys for every experimenter.

8. Want a colorful catalog of goodies? *John Meshna, Jr.* has one that covers everything from assemblies to zener diodes. Listed are government surplus radio, radar, parts, etc. All at unbelievable prices.

10. *Burstein-Applebee* offers a new giant catalog containing 100's of big pages crammed with savings including hundreds of bargains on hi-fi kits, power tools, tubes, and parts.

11. Now available from *EDI (Electronic Distributors, Inc.)* a catalog containing hundreds of electronic items. *EDI* will be happy to place you on their mailing list.

12. VHF listeners will want the latest catalog from *Kuhn Electronics*. All types and forms of complete receivers and converters.

23. No electronics bargain hunter should be caught without the latest copy of *Radio Shack's* catalog. Some equipment and kit offers are so low, they look like mis-prints. Buying is believing.

25. Unusual surplus and new equipment/parts are priced "way down" in a 32-page flyer from *Edlie Electronics*. Get one.

75. *Transistors Unlimited* has a brand new catalog listing hundreds of parts at exceptionally low prices. Don't miss these bargains!

HI-FI/AUDIO

15. A name well-known in audio circles is *Acoustic Research*. Here's its booklet on the famous AR speakers and the new AR turntable.

16. *Garrard* has prepared a 32-page booklet on its full line of automatic turntables including the Lab 80, the first automatic transcription turntable. Accessories are detailed too.

17. Build your own bass reflex enclosures from fool-proof plans offered by *Electro-Voice*. At the same time get the specs on *EV's* solid-state hi-fi line—a new pace setter for the audio industry.

19. *Empire Scientific's* new 8-page, full color catalog is now available to our readers. Don't miss the sparkling decorating-with-sound ideas. Just circle #19.

22. A wide variety of loudspeakers and enclosures from *Utah Electronics* lists sizes shapes and prices. All types are covered in this heavily illustrated brochure.

26. Always a leader, *H. H. Scott* introduces a new concept in stereo console catalogs. "At Home With Stereo" the 1966 guide, offers decorating ideas, a complete explanation of the more technical aspects of stereo consoles, and, of course, the complete new line of *Scott* consoles.

27. An assortment of high fidelity components and cabinets are described in the *Sherwood* brochure. The cabinets can almost be designed to your requirements, as they use modules.

95. Confused about stereo? Want to beat the high cost of hi-fi without compromising on the results? Then you need the new 24-page catalog by *Jensen Manufacturing*.

99. Interested in learning about amplifier specifications as well as what's available in kit and wired form from *Acoustech?* Then get your copy of *Acoustech's* 8-page colorful brochure.

TAPE RECORDERS AND TAPE

31. "All the Facts" about *Concord Electronics Corporation* tape recorders are yours for the asking in a free booklet. Portable battery operated to four-track, fully transistorized stereos cover every recording need.

32. "Everybody's Tape Recording Handbook" is the title of a booklet that *Sarkes-Tarzian* will send you. It's 24-pages jam-packed with info for the home recording enthusiast. Includes a valuable table of recording times for various tapes.

33. Become the first to learn about *Norelco's* complete Carry-Corder 150 portable tape recorder outfit. Four-color booklet describes this new cartridge-tape unit.

34. The 1966 line of *Sony* tape recorders, microphones and accessories is illustrated in a new 16-page full color booklet just released by *Superscope, Inc.*, exclusive U.S. distributor.

35. If you are a serious tape audiophile, you will be interested in the new *Viking of Minneapolis* line—they carry both reel and cartridge recorders you should know about.

91. Sound begins and ends with a *Uher* tape recorder. Write for this new 20 page catalog showing the entire line of *Uher* recorders and accessories. How to synchronize your slide projector, execute sound on sound, and many other exclusive features.

HI-FI ACCESSORIES

76. A new voice-activated tape recorder switch is now available from *Kinematix*. Send for information on this and other exciting products.

39. A 12-page catalog describing the audio accessories that make hi-fi living a bit easier is yours from *Switchcraft, Inc.* The cables, mike mixers, and junctions are essentials!

98. Swinging to hi-fi stereo headsets? Then get your copy of *Superex Electronics'* 16-page catalog featuring a large selection of quality headsets.

104. You can't hear FM stereo unless your FM antenna can pull 'em in. Learn more and discover what's available from *Finco's* 6-pager "Third Dimensional Sound."

KITS

41. Here's a firm that makes everything from TV kits to a complete line of test equipment. *Conar* would like to send you their latest catalog—just ask for it.

42. Here's a colorful 108-page catalog containing a wide assortment of electronic kits. You'll find something for any interest, any budget. And *Heath Co.* will happily send you a copy.

44. A new short-form catalog (pocket size) is yours for the asking from *EICO*. Includes hi-fi, test gear, CB rigs and amateur equipment—many kits are solid-state projects.

AMATEUR RADIO

46. A long-time builder of ham equipment, *Hallicrafters* will send you lots of info on the ham, CB and commercial radio-equipment.

CB—BUSINESS RADIO SHORT-WAVE RADIO

48. *Hy-Gain's* new CB antenna catalog is packed full of useful information and product data that every CB'er should know about. Get a copy.

49. Want to see the latest in communication receivers? *National Radio Co.* puts out a line of mighty fine ones and their catalog will tell you all about them.

50. Are you getting all you can from your Citizens Band radio equipment? *Amphenol Cadre Industries* has a booklet that answers lots of the questions you may have.

100. You can get increased CB range and clarity using the "Cobra" transceiver with speech compressor—receiver sensitivity is excellent. Catalog sheet will be mailed by *B&K Division* of *Dynascan Corporation.*

54. A catalog for CB'ers, hams and experimenters, with outstanding values. Terrific buys on *Grove Electronics'* antennas, mikes and accessories.

90. If two-way radio is your meat, send for *Pearce-Simpson's* new booklet! Its 18 pages cover equipment selection, license application, principles of two-way communications, reception, and installation.

93. *Heath Co.* has a new 23-channel all-transistor 5-watt CB rig at the lowest cost on the market, plus a full line of CB gear. See their new 10-band AM/FM/Shortwave portable and line of shortwave radios. #93 on the coupon.

96. If a rugged low-cost business/industrial two-way radio is what you've been looking for. Be sure to send for the brochure on *E. F. Johnson Co.'s* brand new Messenger "202."

101. If it's a CB product, chances are *International Crystal* has it listed in their colorful catalog. Whether kit or wired, accessory or test gear, this CB oriented company can be relied on to fill the bill.

102. *Sentry Mfg. Co.* has some interesting poop sheets on speech clippers, converters, talk power kits and the like for interested CB'ers, hams and SWL'ers, too.

103. *Squire-Sanders* would like you to know about their CB transceivers, the "23'er" and the new "S5S." Also, CB accessories that add versatility to their 5-watters.

SCHOOLS AND EDUCATIONAL

56. *Bailey Institute of Technology* offers courses in electronics, basic electricity and drafting as well as refrigeration. More information in their informative pamphlet.

57. *National Radio Institute,* a pioneer in home-study technical training, has a new book describing your opportunities in all branches of electronics. Unique training methods make learning as close to being fun as any school can make it.

59. For a complete rundown on curriculum, lesson outlines, and full details from a leading electronic school, ask for this brochure from the *Indiana Home Study Institute.*

61. *ICS (International Correspondence Schools)* offers 236 courses including many in the fields of radio, TV, and electronics. Send for free booklet "It's Your Future."

74. How to get an F.C.C. license, plus a description of the complete electronic courses offered by *Cleveland Institute of Electronics* are in their free catalog. Circle #74.

94. *Intercontinental Electronics School* offers three great courses: stereo radio & electronics; basic electricity; transistors. They are all described in *Inesco's* 1966, 16-page booklet.

ELECTRONIC PRODUCTS

62. Information on a new lab transistor kit is yours for the asking from *Arkay International.* Educational kit makes 20 projects.

66. Try instant lettering to mark control panels and component parts. *Datak's* booklets and sample show this easy dry transfer method.

64. If you can use 117-volts, 60-cycle power where no power is available, the *Terado Corp.* Trav-Electric 50-160 is for you. Specifications are for the asking.

67. "Get the most measurement value per dollar," says *Electronics Measurements Corp.* Send for their catalog and find out how!

92. How about installing a transistorized electronic ignition system in your current car? *AEC Laboratories* will mail their brochure giving you specifications, schematics.

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70. *Heath Co.* now has a 25" rectangular-tube color TV kit in addition to their highly successful 21" model. Both sets can be installed in a wall or cabinet: both are money-saving musts!

73. Attention, TV servicemen! *Barry Electronics* "Green Sheet" lists many TV tube, parts, and equipment buys worth while examining. Good values, sensible prices.

72. Get your 1966 catalog of *Cisin's* TV, radio, and hi-fi service books. Bonus—TV tube substitution guide and trouble-chaser chart is yours for the asking.

29. Install your own TV or FM antenna! *Jefferson-King's* exclusive free booklet reveals secrets of installation, orientation; how to get TV-FM transmission data.

97. Interesting, helpful brochures describing the TV antenna discovery of the decade—the log periodic antenna for UHF and UHF-TV, and FM stereo. From *JFD Electronics Corporation.*

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78. Scrulox square recess screws pose no problems for the serviceman who carries either of *Xcelite's* two new compact Scrulox screwdriver sets in his pocket or toolbox. Bulletin N1065 has the details.

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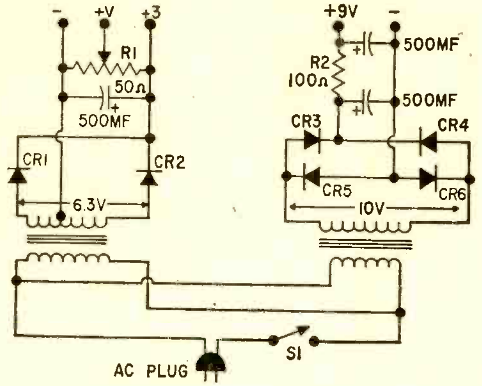
Ask Me Another

Continued from page 17

You ought to stick to the batteries to avoid new problems. If you want to try a power supply, you can use two filament transformers and half a dozen diode rectifiers in the circuit shown. Set potentiometer R1 for 1.5 volts with the machine operating.

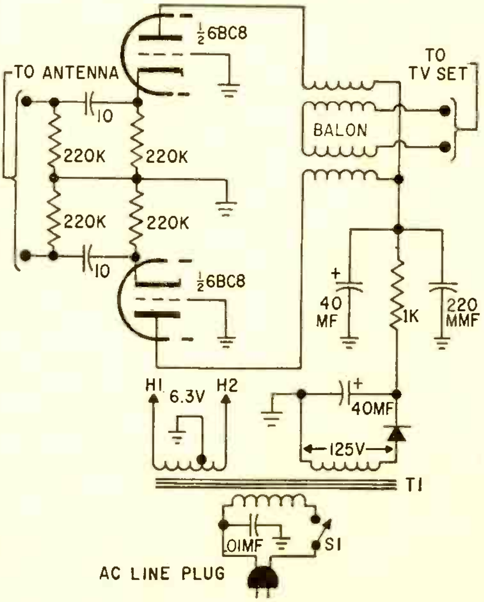


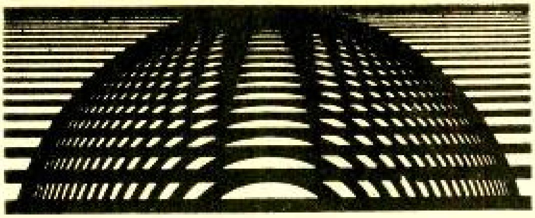
Simple TV Booster

Can you give me a circuit of a TV booster amplifier using tubes?

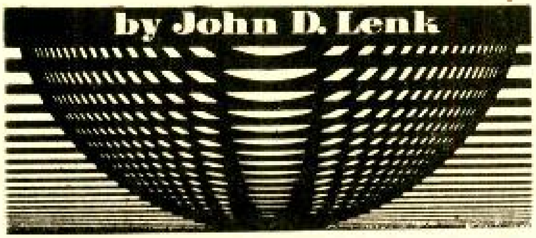
—*J. P., Kansas City, Kan.*

A 6BC8 dual triode is used in a balanced, grounded grid amplifier circuit shown in the diagram. The output coil is a balun normally used in a TV tuner. You may have to get one at a TV repair shop since they are not normally sold at parts stores.





Meet the Meters



by John D. Lenk

Volt, Ohm and Milliammeters, meggers and galvanometers too, are introduced!

■ Whether you're a hobbyist or plan to follow electronics as a profession, there'll be many times when you'll want to check up on some circuits to see what's going on; what voltage you have, how much current is flowing, and so on. You may want to repair a circuit that has gone bad, or you may even be building a new circuit. On such jobs, you can make very good use of instruments to measure *voltage, current*, and *resistance*. A single instrument that will measure all of these values is the *volt-ohm-milliammeter* or VOM. There are dozens if not hundreds of VOM's available at prices to fit most every pocketbook. As the price goes up, you get better accuracy, more scales or functions, and the scales will have greater range. But no matter what the price, it is almost impossible to get by in electronics without some form of *VOM, multitester or multimeter.*

In today's electronics field, practically everyone buys a ready-wired or kit VOM rather than designing and building their own, as many experimenters did in times long gone. This is primarily because of the reduced prices, and (from a practical standpoint) the difficulty of making up accurate meter scales. This trend is unfortunate because there is much to be learned from building a VOM. You must add resistance to make a basic meter movement into a working ammeter or voltmeter, or you add battery power and resistance to a basic movement and convert it to an ohmmeter. The dry-as-dust electronic theories such as Ohm's and Kirchoff's laws now become practical values that are more easily understood when you work with them.

It is not the purpose of this article to start a build-it-yourself movement in the meter field. But it will tell you how a VOM is made from a basic meter movement. If you know how an instrument works, you'll know why the instrument gives you the information you need. And you'll also know how to check on the instrument's operation. This alone will give you a headstart when you buy your first meter.

Besides a VOM, the basic meter movement can also be used in other electronic test instruments. Two of these are the *wheatstone bridge* and the *megger*. Both will be discussed later. To be really useful a VOM must measure both AC and DC. Here again, the same basic meter movement will do the job. For special purpose AC work, however, there are special meter movements and circuits, such as the dynamometer, hot-wire ammeter, moving-vane meter, and thermocouple meter. Although these are not found in garden-variety VOM's, you may run into them in other electronic instruments, so we will go over them, too, briefly.

But for now, let's talk about straight DC meters.

The D'Arsonval Movement. The simplest and most commonly used movement is the D'Arsonval meter movement. It was named after the inventor who worked on it in the early 1880's. The basic arrangement is shown

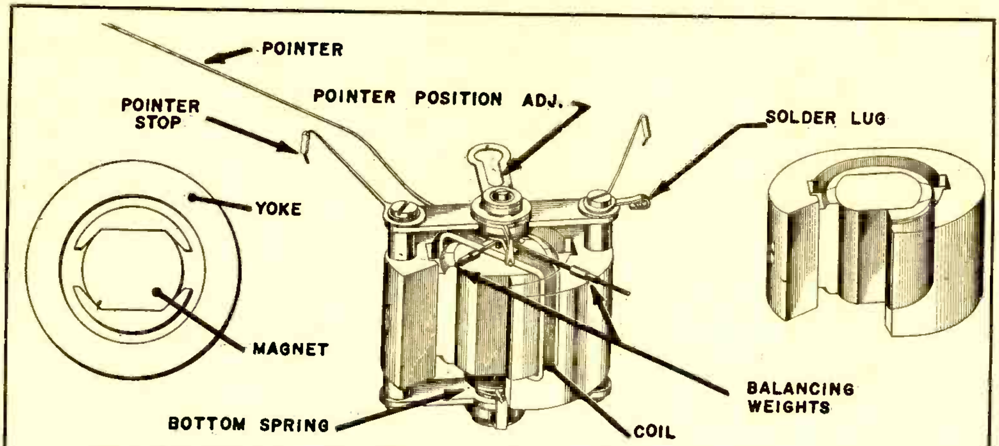


Fig. 1. A typical moving-coil core-magnet type D'Arsonval movement used in Weston meters.

in Fig. 1. Early D'Arsonval movements had a core made of soft iron. A coil of very fine wire was wound on an aluminum form around the core. Today, the iron core is usually omitted, but the coil and aluminum form remain.

The coil is essentially an armature somewhat like that found in a motor. It is mounted on a shaft which is seated in jewelled bearings (so as to be free of friction and to turn easily.) Rotation of the coil is controlled by springs on each end of the shaft. These springs help steady the coil movement, and act as current leads to the coil.

The coil is placed between the poles of a U-shaped permanent magnet. One end of a pointer is fastened to the armature shaft. As the shaft rotates, the other end of the pointer moves over a calibrated dial. Current through the armature coil sets up a magnetic field. The field, around the coil, reacts with the magnetic field of the permanent magnet to rotate the coil with respect to the magnet. *Like* magnetic poles repel, while *unlike* poles attract. When current passes through the coil, its magnetic field is such that the poles repel, or push away from the permanent magnet. Since the permanent magnet can not move, the coil rotates on its bearings. As the current increases, the coil's magnetic field gets stronger and rotates the coil that much further. You can measure the travel of the pointer attached to the coil to determine the amount of current flowing through the meter. The meter scale calibrations can then be related to some particular amount of current. For example, if 1 milliampere is required to rotate the coil and pointer from one end of the scale to the other a half-scale reading will be 0.5 milliampere, a quarter-scale reading will be 0.25 milliampere, and so on.

The usual arrangement is such that maximum rotation (full scale reading) of the coil (armature) is completed in less than a half-turn in a clockwise direction. The whole working assembly is enclosed in a glass-faced case that protects it from dust and air currents. This enclosed meter movement can be used all by itself as a very sensitive ammeter. However, it is more often part of an instrument, such as a VOM or in a panel connected to an electrical circuit. A resistance nework can be included in the case to extend the range of the basic movement (as an ammeter), or to convert the basic movement into a voltmeter.

No matter how the basic movement is used, you must make sure that the leads carrying the current are attached to the correct terminals when the movement is connected into the circuit. If not, the meter may be damaged, possibly beyond repair. Basic meter movement terminals are marked positive and negative—the symbols (+) or (−) are used. At least one terminal is marked. If this connection is reversed, the armature will start to rotate in the opposite direction. This, at the very least, will bend the pointer.

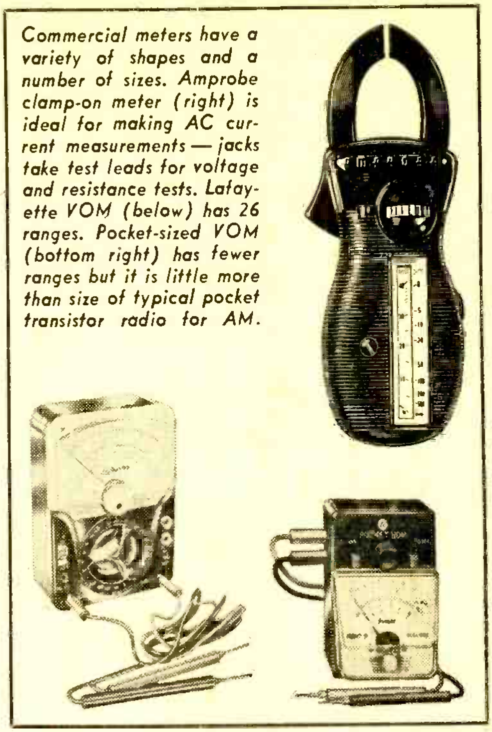
Now, let's see how meter movement can

be put to practical use.

Ammeters. An ammeter measures current. The name is made up from the first part of the word *am*pere combined with the word *meter*. A true ammeter measures currents in amperes. In electronics, current is more often measured in milliamperes (1/1000 of an ampere) or microamperes (1/1,000,000 of an ampere). The basic movement is designed to measure very small currents, usually no more than a few milliamperes. When you want to measure more *current* than the full-scale rating of a meter movement, you connect a *shunt* across the meter movement terminals.

A shunt can be a precision resistor, a bar of metal, or a simple piece of wire. If the meter movement is used in a panel, to measure heavy current, for industrial work, the shunt will most likely be a metal bar. On the other hand, VOM shunts are usually precision resistors that can be selected by a switch. Either way, the shunt is a precision resistance, and the operating principle is the same. Generally the shunt resistance is only a fraction of the movement (coil) resistance. The current divides when it reaches the shunt. Part of the current flows through the movement, and part through the shunt. Because current takes the path of least resistance, the greater portion of the current flows through the shunt.

Shunts must be carefully made and calibrated to match the movement. Unless you have a precise ratio of resistance between meter and shunt, you won't know accurately what the movement readings really mean. Suppose that 5 milliamperes (ma) of current are necessary to cause a full-scale deflection of the pointer and that the resistance of the movement coil is 99 ohms, and that you install a shunt which has a resistance value of 1 ohm. Because the resistance of the movement is 99 times that of the shunt, 99/100ths of the current will flow through the shunt. The remaining 1/100 will flow through the movement. Here's an example. Assume your 5 ma. movement reads 4 ma., indicating that 4 ma. must be flowing through the movement. The resistance of the movement is 99 times as great as the shunt resistance. Consequently, 99 times as much current must be flowing through the shunt itself. By simple multiplication of 99 x 4 you get a value of 396 ma. as the current flowing through the shunt. Add to this the 4 ma. flowing through the meter. A total of 400 ma. of current flows in the entire circuit.



Commercial meters have a variety of shapes and a number of sizes. Amprobe clamp-on meter (right) is ideal for making AC current measurements — jacks take test leads for voltage and resistance tests. Lafayette VOM (below) has 26 ranges. Pocket-sized VOM (bottom right) has fewer ranges but it is little more than size of typical pocket transistor radio for AM.

If you buy a VOM, the shunt-resistance values will already be calculated for you, and the precision shunts will be connected to the movement through a selector switch. Figs. 2 and 3 show the two typical milliammeter range selection circuits for VOM's. In Fig. 2, the individual shunts are selected by the range scale selector. In Fig. 3, the shunts are cut in or out of the circuit by the selector. If the selector is in position 1, all three shunts are across the meter movement. This gives the least shunting effect (more current through the movement), so the meter reads the lowest current rating. With the selector in position 2, resistor R1 is shorted out of the circuit, with resistors R2 and R3 shunted

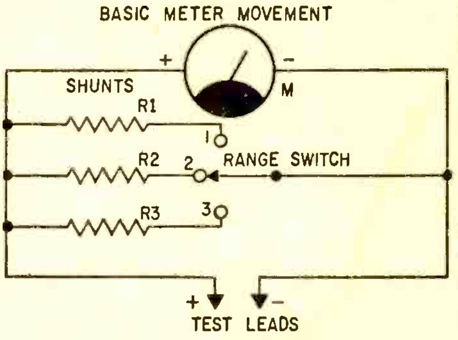


Fig. 2. Basic ammeter circuit shows the switch-selected shunts and the selector or range switch.

Meters by Triplett (left), Heathkit (center) and Simpson 100,000-ohms per volt instrument.

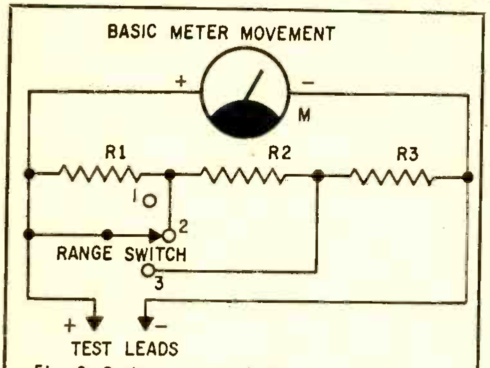


Fig. 3. Series connected shunts are shorted out of circuit to increase current measurement range.

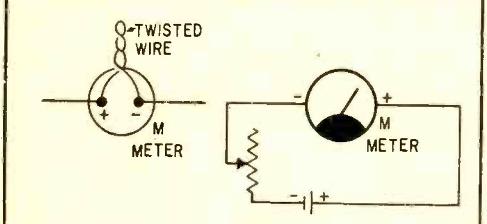


Fig. 4. (left) Make-shift shunt of bare wire is progressively shortened by twisting tightly. Fig. 5. (right) Circuit for calibrating shunt.

across the movement. Now, full-scale, meter reading will be a higher current range. With the selector in position 3, only R3 is shunted across the movement, and the meter will read maximum current.

Now suppose that you want to calculate and build your own shunts. There are two common formulas. Both require that you know the full scale meter reading, and the meter movement's *internal resistance*. Suppose that the meter movement (coil) resistance is 3 ohms, and the full-scale deflection represents 5 ma. and you want to find the shunt resistance necessary to extend the range of the meter to 100 ma.—it's not really as hard as it sounds.

A Simple Formula. First, using Ohm's law, find the voltage necessary to give a full-scale reading. Since the resistance of the movement coil is 3 ohms and the full-scale current is 5 ma. and $E = I \times R$, then:

$$I \times R = E$$
$$5\ ma \times 3\ ohms = Volts$$
$$.005\ ma \times 3\ ohms = .015\ volt$$

We know that if the wanted full-scale reading is 100 ma. and the meter movement is only 5 ma. full scale the additional 95 ma. must flow through the shunt. Again using ohm's law, we can find the answer. The shunt is in parallel to the meter coil. If .015 volt is required to make 5 ma. flow through the coil then 95 ma. must flow in the shunt when the .015 volt is present. Since

$$R = \frac{E}{I} \quad \text{then} \quad \frac{.015}{.095} = .158 \text{ ohm}$$

Another Formula. This is a little more complicated since additional factors become involved in the calculations. But the answer is exactly the same. To be perfectly sure you are correct it is best to do the calculations both ways—if you get the same answer both times then you must be doing something right.

The shunt resistance remains as *R*. The meter-movement resistance is represented by R_m. The N is a multiplication factor. The numerical value of N is found by dividing the proposed full-scale meter range (in this case 100 ma.) by the existing full-scale meter range (5 ma.)—100 divided by 5 just happens to be 20. So with the formula

$$R = \frac{R_m}{(N \quad -1)} = \frac{3}{(20 \ -1)} = \frac{3}{19} = .158 \text{ ohm}$$

Now, if you are on your toes, you'll be asking the 64-dollar question: where do you find a .158 ohm resistor? To make such a precision resistor would require elaborate test equipment. There is no simple answer to this question, but here is a method of extending the basic range of any meter movement using nothing but a piece of wire.

Twisted-Wire Shunts. The basic arrangement is shown in Fig. 4, while the calibration set-up is shown in Fig. 5. If you add a piece of wire across the terminals of a basic movement, part of the current will pass through the wire. If you twist the wire as shown, you can adjust the wire's resistance, and control the amount of current through the wire. You add some twists or you partly untwist the wire, depending on whether you need more or less resistance. You need not know the resistance of the shunt or the internal resistance of the meter movement, only the full-scale deflection of the meter movement, and the full-scale deflection you want. Using a 5 ma. movement, as before, here's how to extend the range.

Connect the meter movement to the calibration potentiometer and battery as shown in Fig. 5. Set the potentiometer to its full value before connecting the meter, then gradually reduce the potentiometer resistance until the meter reads full scale or 5 ma. Now connect the twisted-wire shunt. The meter movement should drop back toward zero. Twist or untwist the wire until the meter movement reads exactly half scale or 2.5 ma. With the shunt wire in this position, the full-scale reading of the meter will indicate 10 ma. If you want to extend the range still further, adjust the potentiometer until the meter reads full scale (now 10 milliamperes). Then twist the shunt wire some more until the movement again reads half scale. The full-scale meter reading is now 20 milliamperes.

A twisted-wire shunt has some obvious drawbacks. If the wire is exposed to any handling, the shunt resistance will change and throw the calibration off. But the method is quite accurate for temporary use.

The Voltmeter. As you may have suspected, a voltmeter measures voltage. Again, the basic movement we've been working with all along can be converted into a voltmeter by adding resistance in *series* with the movement. This resistance is known as a *multiplier* because it multiplies the range of the basic meter movement. The basic movement itself can be used as a voltmeter, but its range is extremely limited. For instance, assume that the 5 ma. movement we're using now has an internal resistance of 100 ohms. Using Ohm's law, we find that the voltage required for full-scale deflection is .5 volt, E = IR = .005 × 100 = .5 volt. If you wanted to measure less than a half volt you could use the meter movement directly. However the most recently made VOM meter movements require 1 milliampere or less for full-scale—their internal resistance is in the order of a few ohms. In any event, using multipliers provides a number of range scale for measuring voltage.

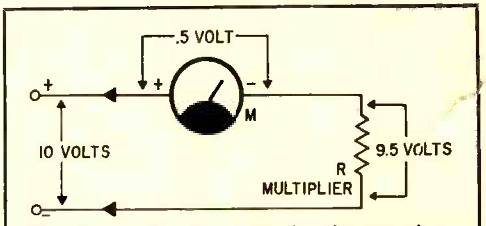


Fig. 6. Circuit of simplified voltmeter shows voltage drops across movement and multiplier.

The basic voltmeter circuit is shown in Fig. 6. As shown, the voltage is divided across the meter movement and the series (multiplier) resistance. Using the .5-volt full-scale deflection meter movement to measure a full scale of 10 volts, the series resistance would have to drop 9.5 volts. If you want 100-volts full-scale, the series resistance has to drop 99.5 volts, and so on. The value of the series resistance needed as a multiplier can be calculated by one of several formulas. We like the following formula:

$$Rx = \frac{Rm\ (V2 - V1)}{V1}$$ where

Rx is the series resistance
Rm is the meter movement resistance
V1 is the full scale voltage for the meter movement
V2 is the voltage you want for full-scale deflection of the meter

MEET THE METERS

For instance, assume that a meter has a 0- to 1- milliampere full-scale movement, with an internal resistance of 50 ohms, and you want a 0- to 5-volts full-scale voltmeter. The first step is to find the voltage drop for full-scale deflection of the meter. E = IR so

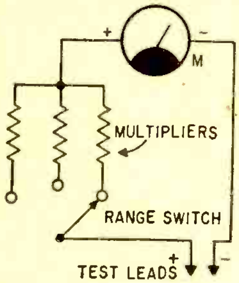


Fig. 7. Multipliers are selected individually by range switch. A separate multiplier is used for each range used.

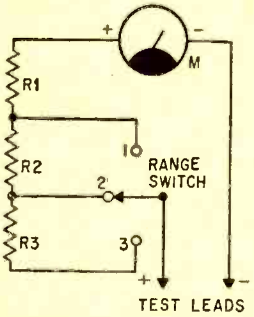


Fig. 8. Series-connected multipliers total resistance determine voltage range. Here switch position 3 has a total resistance of R1 + R2 + R3 for high-voltage range.

.001 × 50 = .05 volt. Then,

$$Rx = \frac{50\,(5\ -\ .05)}{.05} = \frac{50\,(4.95)}{.05} = \frac{247.50}{.05} = 4950 \text{ ohms.}$$

The multiplier resistors are built into a VOM. Figs. 7and 8 show some typical circuits. In Fig. 7, the individual multipliers are picked out by the *range selector*. In Fig. 8, if the selector is in position 1, only resistor R1 is in the circuit. This gives the least voltage drop, so the meter reads the lowest full-scale voltage. In position 2, both R1 and R2 are in the circuit. Now the meter will read a higher full-scale voltage. In position 3, all three resistors drop the voltage, so the meter will read maximum full-scale voltage.

You will often hear the term *ohms per volt* used to compare voltmeters. This is a measure of the meter's sensitivity, and represents the number of ohms required to extend the range by one volt. For example, if the meter movement requires 1 ma. for full-scale deflection, you will need a total of 1000 ohms (less the movement resistance) for each volt. If the movement required only .1 ma. (100 microamperes) you would need 10,000-ohms per volt. Therefore, the more sensitive the meter movement is the higher the *ohm-per-volt.*

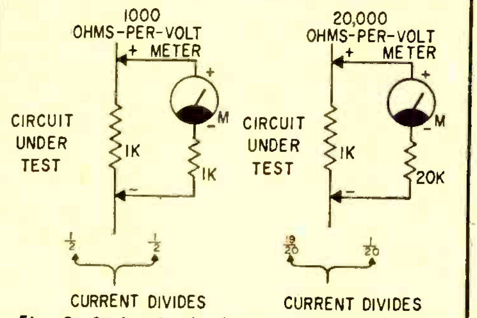


Fig. 9. Basic circuit demonstrates the loading effect meter of low sensitivity has on circuit.

The more sensitive voltmeters put less load on the circuit being measured. That is, they are less disturbing to the circuit's normal operation.

Assume that you have two meters, one at 1000 ohms per volt (with a 1-ma. movement) and the other at 20,000 ohms per volt (with a 50-microampere movement) as in Fig. 9. You are going to measure a one-volt drop across a 1000-ohm resistor. A one-volt drop across 1000-ohms will produce a 1-ma. current flow. If you connect the 1000-ohms per-volt meter across the circuit, the 1-ma. current flow will divide equally between the meter and the circuit since the resistances are equal. As a result, normal current through the resistor is cut in half and so is the voltage drop across it. If you connect the 20,000-ohms per-volt meter across the same resistor, only $^{1}/_{20}$ of the current will pass through the meter, and $^{19}/_{20}$ will continue through the resistor.

The Ohmmeter. An ohmmeter measures resistance. A basic meter movement can be converted into an ohmmeter by adding a series resistor (the same as you did for a voltmeter and a power source. The basic circuit is shown in Fig. 10. Here you have a 3-volt battery connected to a meter movement with a full-scale reading of 5 ma. The current-limiting series resistance R has a value that allows exactly 5 ma. to flow in the circuit. This resistance value is found by applying Ohm's law. Since E = 3 volts, and I = .005 amperes, the proper current-limiting resistance is:

$$R = \frac{E}{I} = \frac{3}{.005} = 600 \text{ ohms.}$$

In Fig. 11, the circuit has been equipped with two test leads. With no connection across the leads, the current will be zero. If you close the circuit by shorting the two leads, the meter will indicate its full 5 ma. reading. If you connect the leads across another 600-ohm resistor the total resistance is now 1200 ohms. The meter reading will drop to one-half its former full-scale indication—to 2.5 ma., since $I = \frac{E}{R} = \frac{3}{1200} = .0025$ amperes or 2.5 ma.

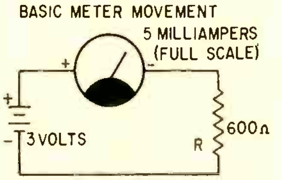


Fig. 10. Current for full-scale reading will be limited by R when probes are shorted for zero set.

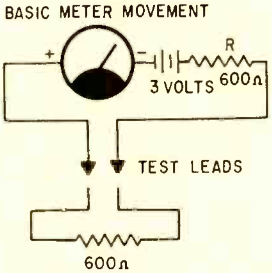


Fig. 11. With resistance doubled by measuring a 600-ohm resistance current reading will be half.

If the battery voltage and the limiting resistor R remain constant and the pointer will always move to indicate 2.5 ma. whenever the leads are put across 600 ohms. You can now mark this point on the scale of the meter as "600 ohms". The milliammeter has been converted into an ohmmeter, capable of reading one value of resistance—600 ohms.

Now put a 2400-ohm resistor across the leads. This, plus the internal 600-ohm resistance, equals 3000 ohms total. The pointer will now drop to indicate 1ma. on the scale, since $I = \frac{E}{R} = \frac{3}{3000} = .001$ ampere or 1 ma.

Again, *the battery voltage and the limiting resistance must remain constant,* for the meter will always read 1 ma. when you put a resistance of 2400 ohms across the leads. So, you can mark "2400 ohms" next to the 1 ma. point on the meter scale. The ohmmeter can now indicate 600 ohms and 2400 ohms. You could go on to plot any number of resistance values on the scale, provided you had the resistances of known value to put across the leads.

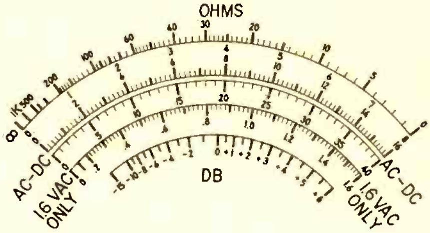


Fig. 12. Typical VOM scale shows OHMS, current, voltage (AC-DC), DB (audio AC) scales.

Of course, the scale of a commercial VOM will have its own markings or calibration. Fig. 12 shows a typical ohmmeter scale. The ohmmeter scale is printed on the meter face along with the voltage and current scales. However, the ohmmeter scale is quite different in two respects. The zero point is at the *right,* while maximum resistance (usually infinity or "open") is at the *left.* Also, the scale is not linear. That is, the divisions are not equal. The spaces between low-resistance calibration marks are wide, while the high-resistance marks are closely spaced.

There are other differences that make commercial VOM circuits more elaborate than the basic one just described. Usually, there is more than one ohmmeter range. Like voltmeter circuits the range of an ohmmeter can be extended or multiplied by connecting a resistor in series with the circuit.

A typical two-range circuit is shown in Fig. 13. Here the ohmmeter has two ranges that can be selected by a switch. In the *low* position, the shunt is connected into the circuit and reduces the current flow through the meter. While the meter range switch is marked R x 1, R x 10, etc., the actual basic range is the highest resistance

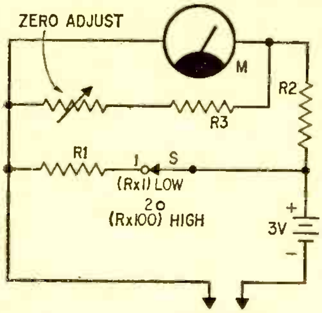


Fig. 13. Ohmmeter is a current measuring device. Shunt R1 is not used for high-resistance range.

range (R x 1000, usually). The lower ranges are subdivisions of the *high* range. R2 limits the current through M to a safe value. R1 reduces the current through M to 1/100 of that flowing in the unknown resistance.

You will also notice that no matter which scale is used, the meter and battery are in series with a variable resistance. This control is put in the circuit to make it easy to adjust the meter to *zero* ohms. As a battery gets older, its output drops and would not indicate zero resistance on the meter scale. The variable resistance is usually labelled *zero adjust* or *zero*. In use, the leads are shorted together, and the resistance is adjusted until the meter points to zero ohms (ohmmeter zero at the right hand side of the scale). When the leads are separated, the meter pointer then drops back to indicate *infinity* (∞) or *open* (left hand side), and the meter is ready to read resistance accurately.

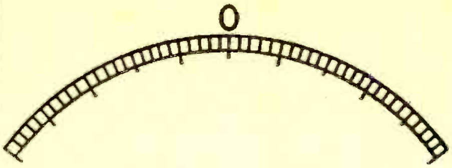


Fig. 14. Typical galvanometer scale may have no other markings but the zero (0) center marking.

The Galvanometer. Our same basic meter movement can be used as a galvanometer—a meter where the zero is at the center of the scale. With negative current the reading is to the left and with positive to the right. A galvanometer is often used to read *proportional* positive or negative changes in a circuit, rather than actual unit values. The scale of a typical zero-center galvanometer is shown in Fig. 14. A common use for such a meter is in bridge circuits, such as the Wheatstone bridge. And this happens to be the subject we are going to cover next.

Wheatstone Bridge. A Wheatstone bridge is an instrument used for making accurate resistance measurements. (Wheatstone bridges are also used in AC circuits to measure capacitance and inductance.) There are many variations of the basic bridge circuit shown in Fig. 15. All operate in a similar manner. The basic circuit consists essentially of three resistance arms, a sensitive zero-center meter or galvanometer, and a DC supply. Two resistors (R1 and R2) are fixed resistors of known values, the third (R3) is a variable resistor with a calibrated dial to read the resistance value for any setting. You connect the unknown resistance (Rx) across the terminals Y and Z, and a battery or other

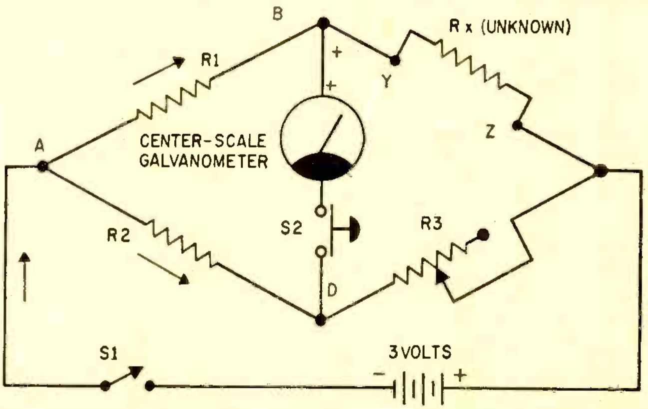


Fig. 15. Galvanometer in Wheatstone Bridge, used for resistance measurements, is a very sensitive movement. Calibrated scale is on R3 which is adjusted for zero current through galvanometer. At zero current R3 is equal in resistance to resistance RX.

DC power source across points A and C.

When you close switch S1, current flows in the direction of the arrows. A voltage drop appears across all four resistances in the circuit. Ordinarily, R1 is equal to R2. Next, you adjust variable resistance R3 so that the galvanometer indicates zero when pushbutton switch S2 is depressed. Zero for the galvanometer is in the center of the scale. At this adjustment, R3 is equal, in resistance, to Rx. By reading the resistance calibrations on the scale of R3, you know the resistance of Rx.

Here's why and how. Point B, in Fig. 15, will be at the same voltage as point D if the variable resistance R3 is equal to Rx and no current flows through the galvanometer when the switch S2 is pressed. If Rx is not equal in resistance to R3 then points B and D are not at the same potential, and current will flow through the galvanometer when the switch is closed.

The Megger. When you run into more than about 50-megohms resistance, the VOM is usually not satisfactory for accurate measurement. Many VOM units in the popular-price range do not provide accurate indications above 10 megohms. This is because the voltage used in the ohmmeter is very low. Many laboratory test setups have a built-in ohmmeter with a high-voltage power supply. The high voltage permits higher-value resistance measurements, but such an arrangement is not portable. A megger overcomes both disadvantages.

The megger is the first cousin to the ohmmeter.The megger scale reads measured values of resistance directly. The megger has two main elements, a magneto-type DC generator to supply current for making the measurements, and an ohmmeter which measures the value of the resistance you are testing. The armature of the generator is rotated by a hand-crank, the speed of armature rotation is stepped-up by gears. The normal output voltage of the generator is about 500 volts. A diagram of a typical megger is shown in Fig. 16.

The ohmmeter portion has two coils, which are mounted on the same armature shaft, but are set at right angles to each other. You will see that the circuit of coil A is of the same type used in most DC voltmeters. Coil B is smaller and is mounted so that at some positions it encircles a part of the core. Current is fed to both coils through flexible leads that do not hinder their rotation.

Coil A is the *current coil.* One terminal of this coil is connected to the negative brush of the generator, and in series with resistance R1 to the external terminal or test lead P2. The other external terminal or test lead P1 is connected to the generator positive brush. When an unknown resistance (Rx) is connected between the external terminals, current flows from the generator through coil A, resistance R1 and the unknown external resistance (Rx). Resistance R1 will limit the current to a low value so that even if the line terminals are short circuited, the current coil will not be damaged.

Coil B, the voltage coil, is connected across the armature through resistance R. If the test leads or terminals are left open circuited (or if the external resistance Rx is of large value) no current will flow in coil A, and coil B alone will move the pointer. Coil B will take a position opposite the gap in the core, and the pointer will indicate infinity or open. However, if you put a resistance Rx between the line terminals, current will flow in coil A. The additional magnetic field

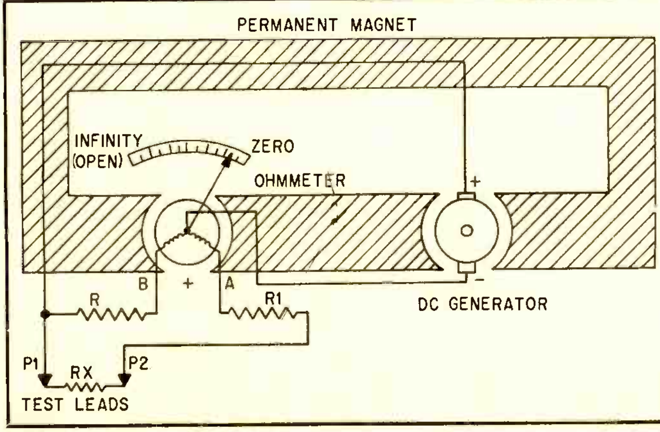


Fig. 16. Basic Megger shown here uses common magnetic field for meter and generator. Current is measured by coil A in series with R1. Voltage output of generator is measured by Coil B and series multiplier R. Voltage through Rx and current through it are indicated on megger scale as a value of resistance.

developed will move the meter pointer away from the infinity position into a field of gradually increasing strength until the fields between coils A and B are equal. Since changes of generator voltage affect both coils in the same proportion, variations in speed of the hand-cranked generator will not affect the readings of the megger.

Alternating Current Meters. AC meters are similar in many respects to DC meters. They both are current-measuring devices. However, since AC reverses direction during each cycle, the moving-coil, permanent-magnet D'Arsonval movement cannot be used in the same circuits as for DC. Therefore, you will have to use some method by which force in only one direction is obtained, in spite of the reversal in current. There are several ways of doing this, the most common of which is the *rectifier-type meter.*

As shown in Fig. 17, the current through a meter movement will be rectified if a diode is placed in series. That is, the alternating current can pass in one direction only, so it is converted into a pulsating direct current. However, this will rectify only half of the current, since no current will flow during the other half cycle. A more efficient system is the bridge rectifier shown in Fig. 18. Here, a direct current will flow through the meter movement on both half cycles. The remainder of the meter circuit can be identical to that of a DC meter.

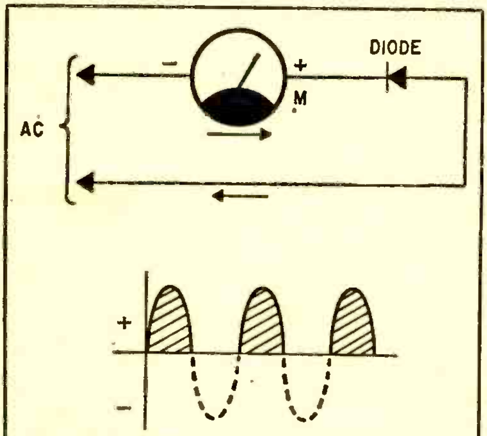


Fig. 17. Half-wave diode rectifier makes use of half the AC-cycle current flow for meter circuit.

RF Probe. A bridge rectifier will work well with alternating currents of low frequency. However, as the frequency increases you run into certain problems. One of these is that the capacitance and resistance of the meter movement and multipliers may load the circuit being tested. To get around this, a *radio-frequency (RF) probe* is connected ahead of the meter circuits. A schematic of such a probe is shown in Fig. 19.

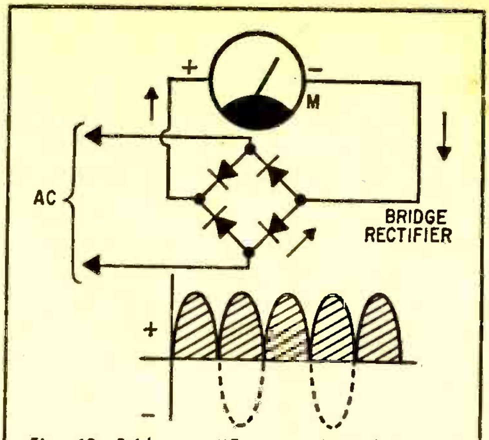


Fig. 18. Bridge rectifier uses both halves of cycle for DC movement in AC measurements.

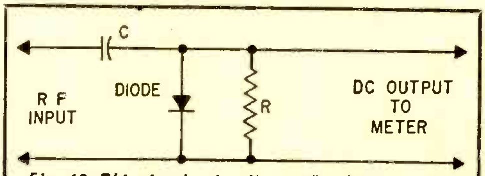


Fig. 19. This simple circuit rectifies RF for a DC-meter measurement. Capacitor doesn't pass DC.

The RF probe is nothing more than a slender metallic prod on the end of an insulated rod or handle connected to the instrument terminal through a flexible insulated lead. In operation, capacitor C is used to protect the diode from damage by DC in the circuit under test. The capacitor blocks DC, but passes AC and RF. The diode rectifies the RF voltage and develops a DC output voltage across the load resistor R. This voltage is then measured in the normal manner.

One of the problems with any type of AC meter is the scale indications. Actually, there are four measurements of an AC voltage: average, RMS peak and peak-to-peak. The peak voltage as shown in Fig. 20, is measured from the very peak of the half cycle. However, the *direct* current to the meter will be less than the peak *alternating* current, because the voltage and current drop to zero on each half cycle. In actual practice with a full-wave bridge rectifier the current or volt-

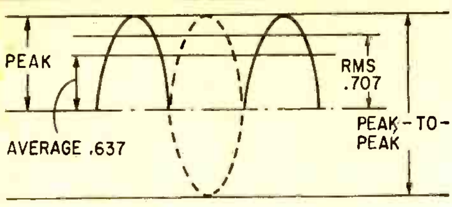


Fig. 20. Sine wave can be measured in many ways. All have constant numerical relationship.

age will be .636 times the peak value. This is known as average value, and many meter scales are so calculated. However, most meters use RMS, or root mean square, scales. In an RMS meter, the scale indicates .707 times the peak value. This value is closer to the *effective* value of an alternating current. A direct current flowing through a resistor produces heat. So does an alternating current. The *effective value* of an *alternating* current or voltage is that amount which will produce the same amount of heat in a resistor as a *direct* current or voltage of a given numerical vaue. The term RMS (root means square) is used since it represents the square root of the average value of all instantaneous or peak values in a *perfect* sine wave. Since you rarely measure perfect sine waves, this mathematical representation is not of particular importance. But it is important to know that the effective value of a sine wave (its heat producing equivalent of DC) is .707 of the peak value. Peak-to-peak voltages are important only when measuring AC waveforms—particularly nonsinusoidal ones.

One particular meter that is unique to AC measurements is the clip-on meter. (Fig. 21). Alternating currents set up alternating fields around a conductor as they pass through. You can pick up these currents if you place a coil of wire around the conductor. The picked-up currents then go through a transformer, and the basic meter measures the voltage at the transformer output. With proper calibration you can determine the current that is passing through the conductor. The clip-on meter is particularly useful where conductors are carrying heavy current, and you do not want to (or cannot) open the circuit to insert an ammeter.

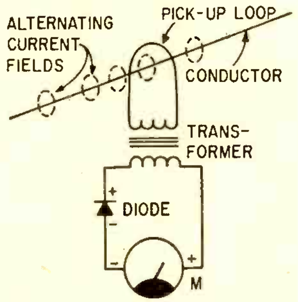


Fig. 21. Pickup-loop voltage is stepped up by a transformer for greater deflection of pointer.

Special Meters. So far, we have covered the meters which are in common use. There are a number of other meter types that you may run into, especially in more precise laboratory or industrial work.

The *thermocouple* meter will measure DC, AC and even RF. Here's how it works. When two dissimilar metals are connected at one end, and heat is applied to the junction (the connected ends), a DC voltage is developed across the open ends of the two dissimilar metals (Fig. 22). This voltage is directly proportional to the temperature of the junction of the heated wires. The generation of DC voltage by heating the junction of these two dissimilar metals is called *thermoelectric* action. The device is called a *thermocouple.* Any two dissimilar metals will produce a voltage across the open ends, when you heat their junction. But two wires, one an alloy of bismuth and the other an alloy of antimony, will produce the greatest possible voltage for each degree of temperature difference. An electric current passing through a wire or conductor will produce heat in that wire in proportion to the square of the current. Therefore, if you pass a current through the junction of a thermocouple, heat will be generated in the wires, and a voltage will be produced at the open ends. If you connect a calibrated meter movement to the free ends of the thermocouple wires, you can measure

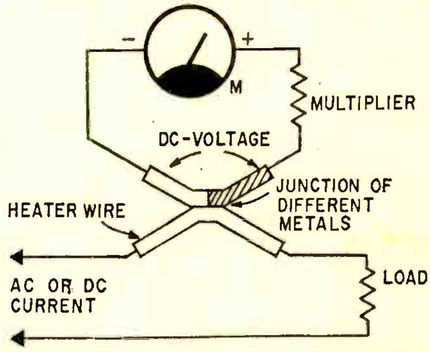


Fig. 22. Heater wire warms thermocouple junction generating proportional current at output.

this generated voltage. The direction of current in the thermocouple has no effect on the heating of the wire. So you can use the thermocouple to measure either AC or DC. When measuring very low currents, the thermocouple junction is usually sealed in a vacuum like the filament in a vacuum tube. This gives the greatest amount of heat for the minimum amount of current.

The *hot-wire* ammeter is one of the older methods used to measure small AC or RF currents. As shown in Fig. 23, the alternating current (or RF) travels through a fine wire stretched horizontally between points A and B. Another wire is attached to point C on the horizontal wire, and is fastened at point D. A fine thread attached to point E of this second wire is also attached to the indicator at point F and tied to a small spring at point G. As the current passes through the wire AB, the resistance causes the current to heat and expand the wire. This slight expansion lengthens the wire. The spring (G) then pulls the pointer to a corresponding value on the scale. The heating effect is proportional to the square of the current through the wire. So the calibrated spaces on the scale of a hot-wire ammeter are not equally spaced, but increase as the square increases.

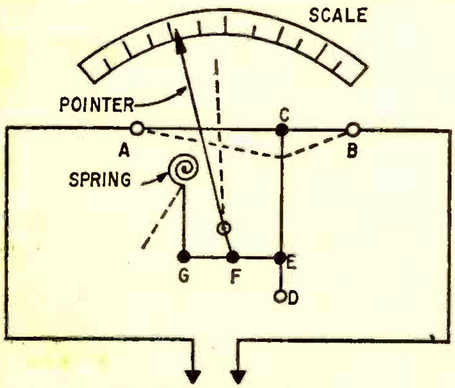


Fig. 23. Hot-wire ammeter depends on expansion of link A-B, from heat generated by current flow.

The *iron vane* meter will also measure AC, but is not too effective for RF. This meter (Fig. 24) has two soft-iron vanes mounted inside a coil. One vane is fixed, while the other is free to move. A shaft and pointer are attached to the moving vane. As the current flows through the coil of wire, the two vanes become magnetized. Since they are magnetized. in the same way, with like poles at the same ends, these vanes repel each other. The free vane moves away from the fixed vane. This turns the shaft and moves the indicator across the calibrated dial. Even though the direction of the current changes on each half cycle, the two vanes are always magnetized alike, and so continue to repel each other. Reversals in current have no effect on the indication of the pointer. Since the amount of magnetism developed in the two vanes is directly dependent on the amount of current passing through the coil, the value of the current is indicated by the pointer moving across the scale.

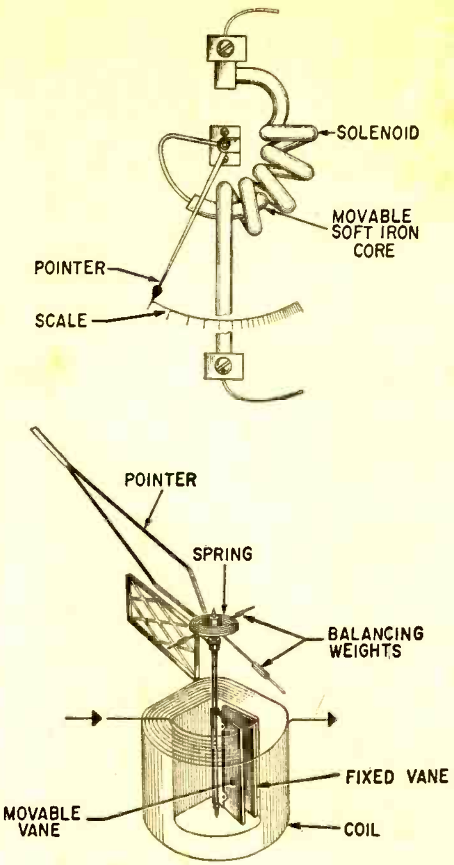
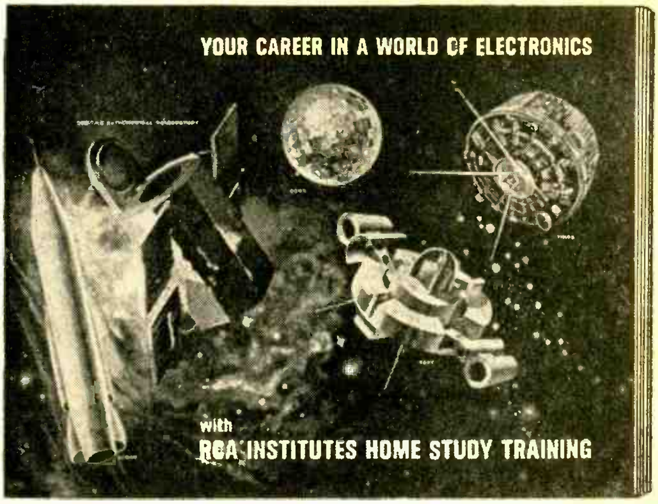


Fig. 24. Curved core, top, is drawn into coil by magnetic field produced by current flow through coil. Movable vane, above, is repelled by field of fixed vane. Both vanes have like fields. Both vanes are the core of the coil—an electromagnet.

The *dynamometer* is another meter move-

(Continued on page 36)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Meet the Meters

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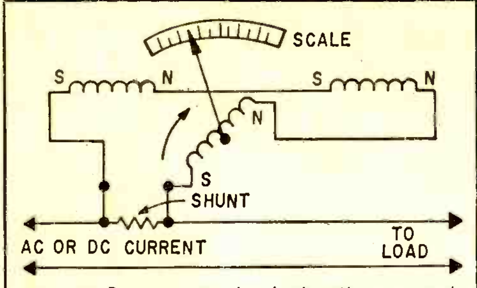


Fig. 25. Dynamometer has both coils connected in series, across shunt, to measure current flow.

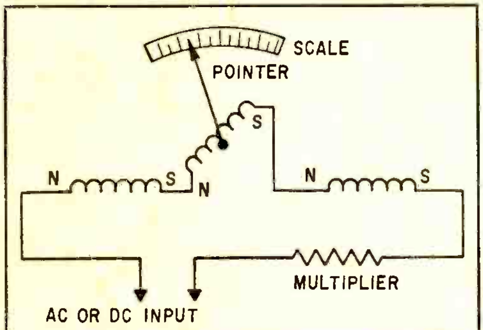


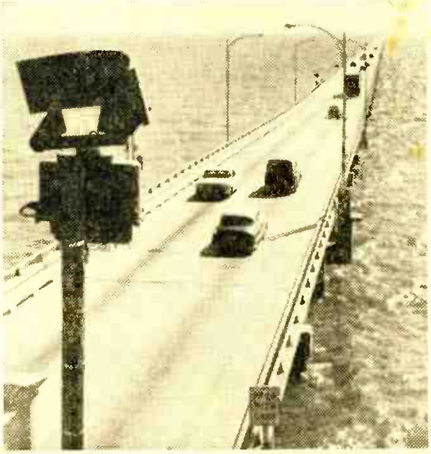
Fig. 26. Series connected coils and multiplier used for both AC and DC voltage measurements.

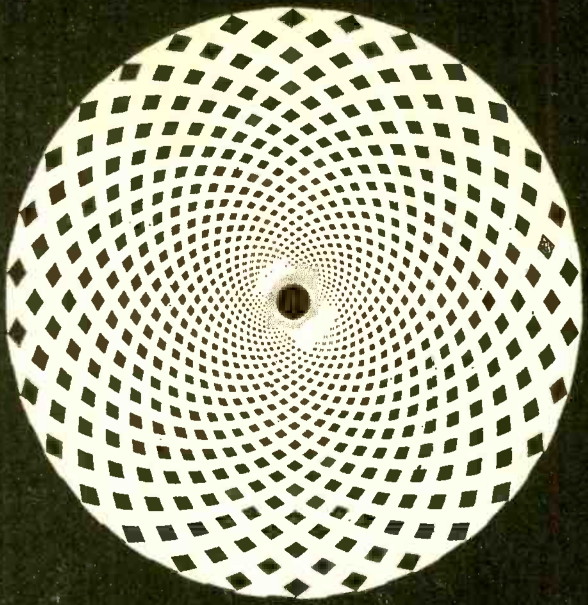
ment that will measure either AC or DC, and can be used either as a voltmeter or an ammeter. Fig. 25 shows how the dynamometer works as an ammeter, while Fig. 26 shows the voltmeter connections. By studying the action of movement on the first half cycle (Fig. 25) you will see that the fixed and movable coils are wound so that the magnetic fields turn the coil and pointer to the right. The distance moved is determined by the coil spring attached to the pointer shaft. When the tension on the spring becomes equal to the pull of the magnetic fields, the pointer will come to rest. On the opposite used quite effectively as a voltmeter when polarity of *all coils* will reverse. When this occurs, the same amount of force is still exerted to turn the movable coil, and the direction of rotation is the same as before, to the right or clockwise. The meter always reads in the positive direction. The same will occur when direct current is applied to the coils. With either AC or DC the readings are approximately equal to the square of the current. The dynamometer is somewhat limited as to current capacity, but can be used quite effectively as a voltmeter when a series resistor is added to the circuit as shown in Fig. 26.

If you have been paying attention, you now have an understanding of basic meter movements—what they do, and how they work. Learning to use them effectively is another subject. Despite the fancy dials, lights and chrome plating that dress up the many multipurpose instruments which now save the time of the technician, it is the meter that receives constant use. This is especially true with the old timers who spent years of servicing or experimenting without an oscilloscope or any other modern refinements in test equipment. Veteran technicians will tell you that, when full use is made of it, a good meter will handle most servicing jobs without any help from its more sophisticated contemporaries. So learn to use your meter!■

Radar Hits the Road

Radar antenna, on mast at left, looks out over world's longest causeway spanning 24-mile-wide Lake Pontchartrain near New Orleans, Louisiana. Raytheon radars and marine radiotelephones have been installed at the two bascule bridges, eight miles out from each shore, where ships cross the roadway. To safeguard motorists who "go to sea" in their cars in foggy weather, causeway personnel keep an electronic lookout for loose barges or disabled vessels that might stray from regular ship channels and drift towards the bridge. Using their marine radios the bridge tenders can call the Coast Guard or other agencies to recover drifting barges or warn the skipper of a wayward vessel.





Some illuminating facts about the new brilliance available in lighting fixtures

Watt's New In Lighting

by Len Buckwalter

■ Not long after Edison demonstrated the first practical lamp, he made a prediction. He believed it unlikely that the incandescent lamp would ever be improved. That was sixty-five years ago. Not only has the lamp undergone much improvement, but lampmakers now do things that would make an Edison stare in disbelief. Today they make bulbs that resemble waffles, some lamps called "people heaters" and, most shocking of all, they sell light you can't even see. The lamp industry is over 80 years old, but it's still trying to find new and better ways to eclipse its biggest competitor which, according to one General Electric official, is the sun.

The big change in lighting happened just before 1940. By scrapping a glowing filament, the fluorescent lamp proved it could deliver four times more light and last ten times longer than the traditional incandescent. You may use regular bulbs (still a big bargain) but more than two-thirds of all light produced today comes from an assortment of long, flattened or squiggly fluorescents. How do they work?

Fluorescent Operation. The light seen coming from a fluorescent lamp is the glow of a powdery phosphor that coats the inside of the tube. (A common white phosphor is calcium halophosphate.) But it is not the direct action of electricity that causes the phosphor to give off light. Light-giving action occurs when the phosphor is bombarded with ultraviolet rays, a type of light energy itself, but one that is not visible to the eye. The source of ultraviolet is mercury vapor which fills the fluorescent tube. What's more, it only takes normal line voltage to excite (ionize) the mercury vapor into giving off ultraviolet. Switching on a fluorescent lamp, therefore, triggers a chain of events: voltage causes the mercury vapor to ionize, making it radiate ultraviolet, which in turn activates the phosphor. The sequence is shown in Fig. 1. As line voltage is applied to the tube electrons flow through the ionized mercury vapor. (A small amount of argon gas is usually added to aid the starting action.) As mercury atoms become ionized they emit ultraviolet whose wavelength measures about 250 millimicrons. Although this energy alone is nearly invisible to the eye the phosphor responds with high efficiency. The phosphor glows with light waves which fall in the 350-750 millimicron wavelength range —or white light.

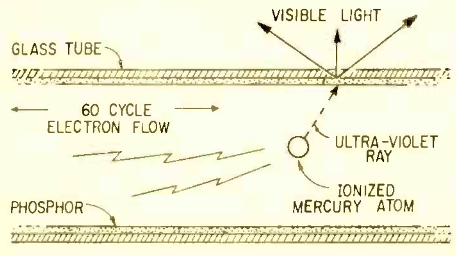


Fig. 1. Electron flow ionizes mercury atoms in vapor. Ultraviolet produced excites phosphor.

The various wavelengths of light emitted from the phosphor are charted in Fig. 2. Each frequency contributes a different color and the resulting combination is seen as white. Note that there are vertical bars shown above the curve. They represent some light output directly from the mercury vapor, which delivers energy on frequencies other than pure ultraviolet. Direct light from mercury vapor, however, is less than 10% of the lamp's light output.

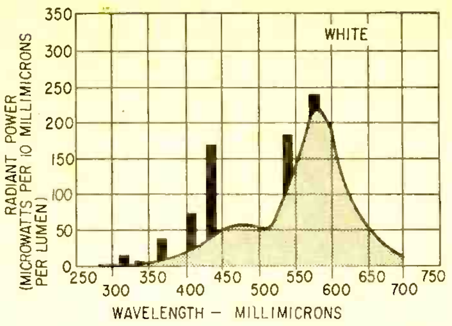


Fig. 2. Light produced by ultraviolet excited phosphor is combined from the many frequencies.

To make the fluorescent lamp operate in a practical system several devices are added to the basic set-up just described. These refinements are shown in Fig. 3. Note that a starter and ballast are used. The function of the starter is to momentarily turn on small filaments, or cathodes, located at the ends of the bulb. Purpose of the filaments is to supply electrons, quickly, which flow through the mercury vapor. The action occurs this way: When the on-off switch is turned *on,* line voltage reaches the starter whose contacts are initially open. Neon gas within the starter bulb, however, is fired by the voltage. The electron flow through the ionized neon gas warms the starter contacts—which behave like a thermostat—and they close. Current then flows through the cathode heaters (filaments) inside the fluorescent bulb. Next the starter contacts open again since voltage is needed to keep the neon gas inside the starter glowing.

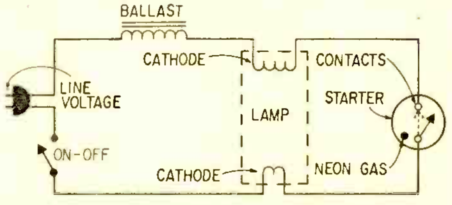


Fig. 3. Circuit of fluorescent fixture is typical of all single-lamp installations in use.

The opening of the starter contacts serves two purposes. For one, it removes the heating source—or filaments—which are no longer needed for bulb operation. Secondly, the opening of the starter causes a sudden collapse of a magnetic field stored in the ballast, which is an iron core with wire windings. The collapsing magnetic field creates and sends high voltage from the ballast to the lamp. This inductive kick helps the arc to form. Once the arc is established, the ballast settles back and performs a second function: it limits the amount of line current through the lamp, which would otherwise reach excessive levels; and the voltage drop across the ballast keeps the voltage across the lamp and starter below the ionizing potential of the neon starter.

Developments in fluorescent lighting have eliminated the time delay caused by the preheating cycle of the starter-type lamp. They are the instant and rapid-start lamps. The *rapid-start,* introduced in the early 1950's, not only fires off the fluorescent in a much faster period, but it does not use a glow-switch starter. The operating principle is simple—an additional transformer winding is built into the ballast. This winding serves to continuously heat the lamp cathodes, even when the lamp is not *on.* The amount of energy consumed, however, is quite small. When the circuit is energized, cathodes quickly reach operating temperature and the lamp fires. To further aid the rapid-start lamp in firing, a metal ground strip must run the length of the lamp (it is usually made a part of the reflector).

The fastest lighting fluorescent is the *instant start.* Here a high voltage is applied to the cathodes which is great enough to fire the lamp with no preheating. These lamps generally have special fixtures to protect against shock hazard from high voltage. There are also small filaments that become heated during operation to insure a rich source of electrons to support the current flow through the ionized gas.

Although fluorescent lamps are undergoing continuous upgrading one significant improvement occurs when the lamp is operated at power-line frequencies above the usual 60 cps supplied by the power companies. Any fluorescent can function at higher power-line frequencies if a proper ballast is installed. A 40-watt lamp, in fact, will increase its efficiency by nearly 15% when operated on a power source which alternates at 20,000 cps. To this can be added a considerable saving in cost of the ballast since smaller iron cores and fewer turns of wire are needed to produce the same effect. The obstacle to high-frequency operation is the cost of equipment needed to convert 60 cps to higher rates. But due to great strides and price drops in such devices as transistors and silicon-controlled rectifiers, the day may not be too distant when 60 cps operation could disappear.

Mercury Lamps. This type is used mostly for street and industrial lighting in the 100- to 3000-watt category. It is not practical for indoor residential use since the light tends to be blue and thus does not provide the naturalness of other light sources. The sun lamp, however, is of the mercury variety. It has strong output at the ultraviolet frequencies which cause sun tanning.

The mercury lamp operates like a fluorescent but without a phosphor coating the inside of the tube. By employing mercury vapor at a higher pressure than is used in fluorescent lamps, the ionized gas will produce light output directly. In some mercury lamps, a phosphor coating is added to help correct the strong blue quality of the light emitted by these lamps.

Fig. 4 reveals the internal construction of a typical mercury lamp. Instead of the long glass tube of the fluorescent, there is a short arc tube which contains mercury and a trace of argon gas to aid in starting. The outer bulb serves to keep arc-tube temperature at a high, efficient level by minimizing the effects of outside air circulation. Other special features are a starting electrode, which strikes an arc close the main electrode when power is first applied. This arc ionizes argon, which helps start the main arc through the mercury. A starting resistor limits current through the starting electrode to a safe value and is designed to withstand the high temperatures in the glass bulb. The external

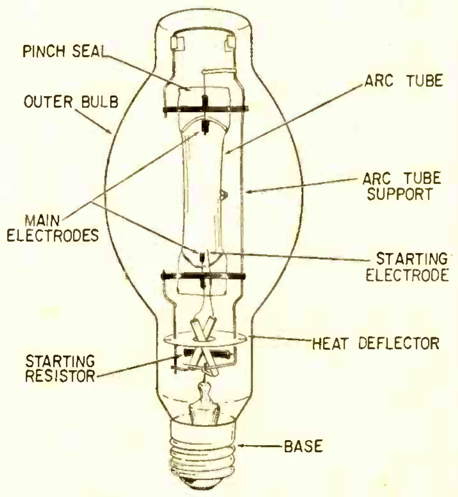


Fig. 4. Double glass of bulb and arc tube act like vacuum bottle to maintain the temperature.

circuit of the mercury lamp is similar to that of a fluorescent in that it requires a ballast to limit current and assure proper starting voltage. One of the key features of the mercury lamp, important in commercial applications, is long life: these lamps average about 16,000 hours, or more than 20 times that of an ordinary home-type incandescent.

Black Light. Here is a region of light energy just outside the limits of human vision—the same ultraviolet energy which drives the phosphors of a fluorescent lamp. If an ultraviolet source is directed at certain materials, the effect is dramatic and useful. These materials behave like the phosphor inside the fluorescent lamp. They absorb invisible ultraviolet energy and reradiate it in the visible spectrum. The effect is that such objects appear to glow in the darkness since the ultraviolet, or black, light is not seen.

Many substances in their natural state will fluoresce under black light. Oil is one and thus ultraviolet is used in the textile industry to reveal oil stains on materials that might otherwise go undetected. Certain fluorescing dyes are added to paints or varnishes. Painted surfaces can then be inspected under ultraviolet to check for uniform coverage. And, of course, there have been many applications in the entertainment field where people or objects can be made to give off an eerie glow in a darkened area.

There is no great difference between the production of ultraviolet energy and visible light. It is mainly a job of shifting the light spectrum so it concentrates frequencies in the desired region. A fluorescent lamp designed for ultraviolet service is similar to its white-light cousin except in the choice of phosphor. Instead of a chemical which radiates visible colors, the phosphor is selected to radiate most of its energy in the ultraviolet region of about 350 millimicrons.

A filament-type incandescent lamp will also radiate ultraviolet. But since it also emits some visible light, it must be fitted with a special glass envelope (bulb) or filter. Ultraviolet rays are permitted to pass out of the bulb, while the visible-light part of the spectrum is absorbed. Most commercial applications, however, rely on the cooler-running and more efficient fluorescent source. An exception is a mercury-vapor type lamp which can direct a strong concentration of black light in small areas and occupy little room itself.

Germ Killers. Another important application of ultraviolet light is to kill bacteria and other micro-organisms. The exposure must be intense and for a sufficient length of time. A typical application is the irradiation of air for killing bacteria which float through heating and air-conditioning ducts. It is also used in bakeries to prevent mold from contaminating baked goods, in cold-storage areas where it enables cooling equipment to run at somewhat-warmer temperatures with less danger of contamination, such as during automatic wrapping operations and numerous other uses where sanitary considerations are important.

The germicidal lamp is a fluorescent lamp with minor modifications. To make use of ultraviolet energy produced by mercury vapor, the phosphor coating is omitted in this application. Also, the germicidal lamp is made with special glass that transmits most of the ultraviolet energy generated by the mercury. Output energy from such a lamp would reveal the following percentages: 50% as ultraviolet; 48% as heat; and 2% as visible light.

Heating People and Products. In the Connecticut State Reformatory license plates are painted, then baked at 300 degrees F. In West Virginia, railroad cars get the same treatment. Commuters in Cleveland get a milder kind of warming when they stand in a chilly railroad station. These situations illustrate how light is used for heating. Ultraviolet, however, is not the source. Just beyond the opposite limit of human vision (see Fig. 5) lies infrared—light waves that produce heat. Unlike other heat sources, infrared needs no air currents to carry heat energy to people and objects. The radiation is like infrared rays from the sun, which can travel through 92-million miles of space. It

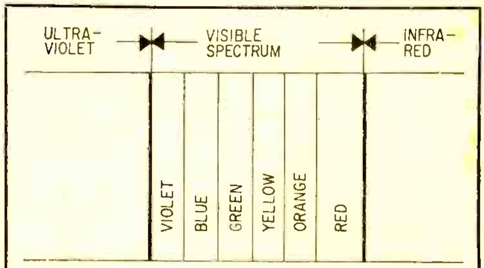


Fig. 5. The visible light spectrum begins at the low-frequency red and goes on up to violet.

is a form of electromagnetic energy that converts to heat as it strikes an object and is absorbed. The wavelength of infrared light —which ranges to about 1000 microns—is too long to be visible to the human eye.

An important source of infrared light is an incandescent lamp, similar to an ordinary light bulb, but with several modifications. Whereas a normal incandescent lamp (for lighting) operates at a filament temperature of about 4700 degrees F, an infrared type may operate at 4000 degrees F. At lowered temperature, less visible light is produced and more radiation occurs in the infrared region. (In a tungsten-filament lamp, some 86% of the electrical energy is in the infrared spectrum.) In some instances a red-colored bulb is used to filter out the small amount of visible light. In commercial applications of infrared, a quartz bulb is used. Quartz withstands heat better than glass, especially during the thermal shock that occurs when the lamp is turned *on* or *off*.

Other Developments. In their search for greater efficiency, or more light-per-watt, lampmakers have introduced a raft of new techniques and materials. In the GE Quartzline lamps, for example, there is a marked improvement over the basic incandescent. Regular tungsten filaments tend to evaporate and cast off material which collects on the inside surface of the bulb. This soon blackens the glass and reduces light output. But with the introduction of iodine into the lamp, deterioration is halted in this fashion: As the tungsten evaporates from the filament it combines with iodine vapor to form the gas *tungsten iodide*. As this gas circulates in the lamp it contacts the hot filament. The high heat decomposes the gas back into the original components—tungsten and iodine. The process repeats itself throughout the life of the lamp and enables light output to remain constant and long-lived. In Fig. 6 is shown a quartz-iodine lamp intended for modest outdoor floodlighting jobs (parking lots, patios, etc.).

Fig. 6. New Quartzline single-ended lamps made by General Electric are 250 watters. Available in miniature screw base and double-contact bayonet they will be housed in fixtures designed for their use in commercial, residential and sports floodlighting systems.

One of the most recent developments from GE is the Lucalox lamp. The company states that with this type it achieves an efficiency of more than 100 lumens-per-watt for the first time in the industry. With this new efficiency, street, highway, stadium and other lighting can be increased about 50 percent over mercury installations at the same operating cost.

The principle underlying the new Lucalox lamp is similar to that of the mercury lamp described earlier. An arc is struck through vapor, which produces light. And, as apparent from Fig. 7, the basic outline is the same. Increased efficiency, however, is obtained by operating at extremely-high pressure and temperature—where light output increases in relation to heat output. Another difference is that sodium, not mercury, is vaporized in the Lucalox lamp. If you've ever seen a conventional sodium lamp, used for highway lighting, you know that light output is a sickly yellow. Because of poor color rendition the standard sodium lamp is fading from the lighting field.

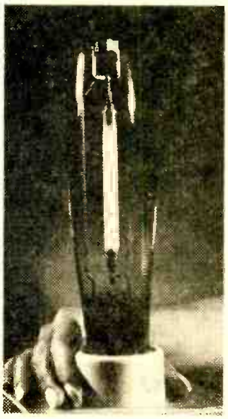


Fig. 7. The new Lucalox lamp, by General Electric is the most efficient general lighting source made by man. This 400-watt lamp produces 4200 lumens—105 units of light per watt consumed. Cigarette-sized ceramic tube contains the sodium vapor arc allowing high-temperature operation that had not been possible with other designs.

But the Lucalox lamp has managed to overcome this deficiency and still use sodium vapor by utilizing a new substance for its arc tube; the container which holds the glowing sodium. The material is a synthetic ceramic that can operate at extremely high temperatures and still transmit light to the outside. It replaces earlier arc tube materials of glass or quartz which quickly blacken under the required vapor temperatures. The Lucalox lamp operates at a high-enough heat level to convert the poor yellow illumination of sodium into a pleasant golden-white light of good color rendition.

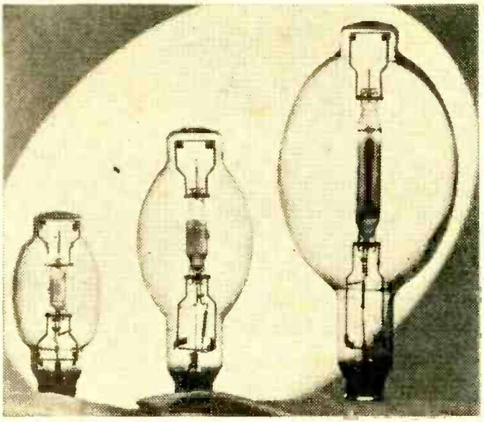


Fig. 8. Sylvania's newest Metalarc lamp (left) produces 10,500 lumens while consuming 175 watts. 400-watt model (center) produces 32,000 lumens and the 100-watt unit at right has 90,000 lumens output. The color temperature is 5000° Kelvin and all the lamps have an average life of 7500 hrs. of the whitest pinpoint source known.

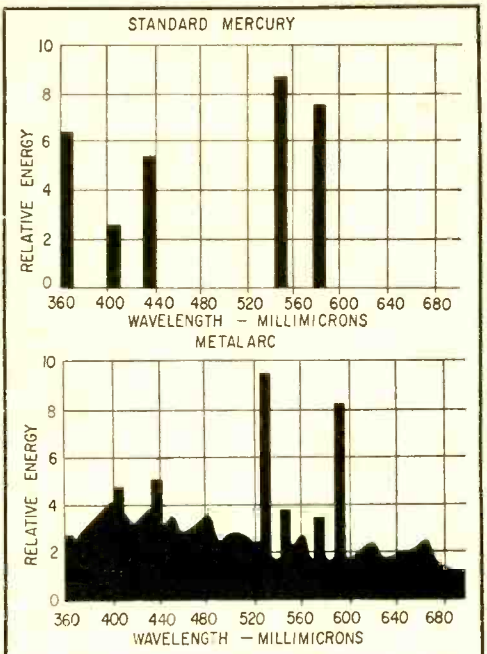


Fig. 9. Light-frequency output of mercury vapor (top) and Sylvania Metalarc lamps compared.

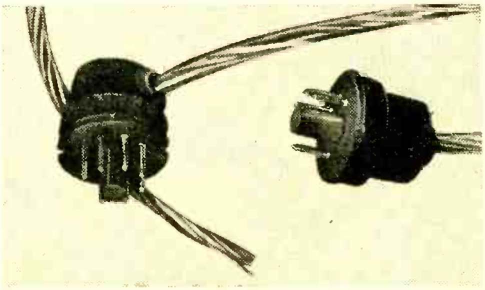
The ceramic material is a high-density polycrystalline alumina, similar to synthetic sapphire.

Sylvania's recent entry is the Metalarc lamp. As shown in Fig. 8, it is also a close relative of the mercury lamp. The Metalarc is intended for commercial and industrial applications. The lamp, however, avoids the undesirable bluegreen light of the mercury type. Introduced into the Metalarc is a combination of metals whose vapors radiate colors toward the red end of the spectrum—hues which balance the blueness of the mercury. The comparison chart (Fig. 9) of the standard mercury-lamp shows light output is rich in ultraviolet (left band) and spotty at other colors in the visible spectrum. The Metalarc chart, on the other hand, reveals a more continuous spread of colors which add up to a combination that more closely approximates white light.

There is strong reason to believe that even further improvement will be forthcoming from the field of lighting. Now lampmakers talk of "space conditioning"; a concept that would coordinate lighting, heating and cooling systems to create an ideal environment within a building. It would use such techniques as snaring the heat of the lighting system to help warm the building in winter—or get rid of it in the summer. You can bet a burned-out bulb that the lamp industry—now headed toward the $1 billion level—will create even more lumens per dollar. ■

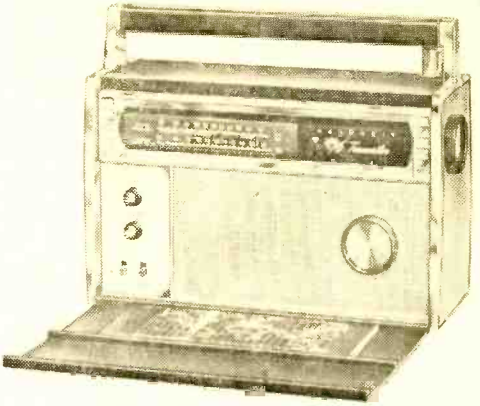
Handy Power Plugs from Duds

Stuck with some old 6H6's or metal tubes? Don't toss them away—they make excellent no-cost plugs for your next power cable assembly. Punch or drill a small hole in the metal shell to break the tube's vacuum seal. Then pry up four metal tabs that hold the shell to the base. Clean out the tube guts and odd glass and unsolder leads connected to the pins. Connect cable leads to base pins and pass cable through hole in metal cap, use grommet. Then replace metal shell and bend tabs. —*James A. Fred*



e/e COMMUNICATIONS

HEATHKIT MODEL GR-43
AM/FM/SW Transistor
Portable Receiver

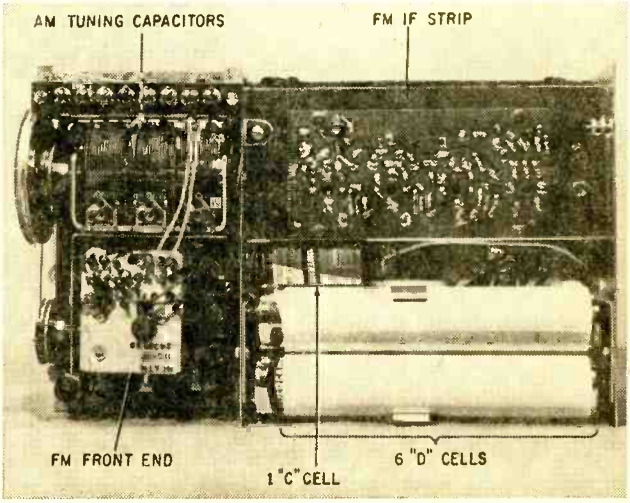


■ Weather reports, short wave broadcasts, FM, police, ship-to-shore, standard BC broadcasts, marine operators, beacon signals, the FAA; wrap them all in a handful of transistors, add a few batteries, and you've got the Heath GR-43—the hottest thing going since the birth of the transistor radio.

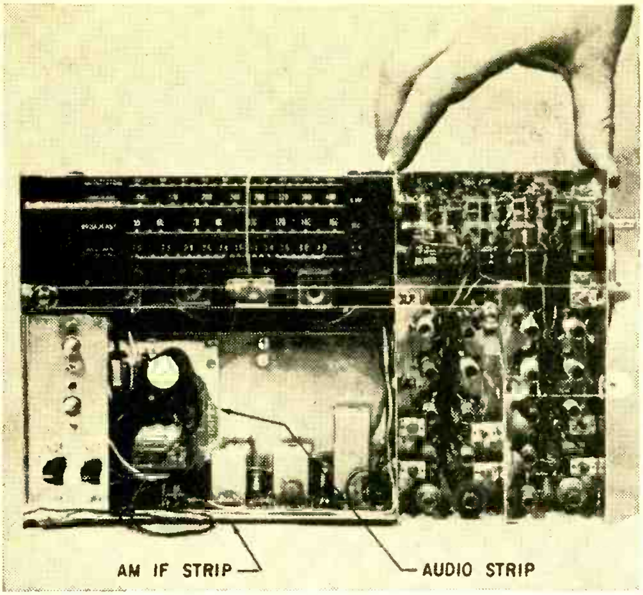
The Heath GR-43 is basically an *extended range* short-wave receiver; essentially, the only difference between it and a good quality AC powered receiver is that the GR-43 is a transistor portable. In 9 bands, it covers the frequency range from 150 kc. to 22.4 mc., plus the FM broadcast band. Tone and volume controls are provided as is switch-selected AFC (automatic frequency control) for FM reception. Built-in antennas are provided for all bands; the handle contains the loop antennas for longwave and BC broadcasts while a telescopic whip handles short-wave and FM. The bandswitch automatically selects the correct antenna. Special terminals are provided for external antennas for the DX specialist.

What's In It? One must not think of the GR-43 in terms of the usual tinny sounding transistor portable, for the GR-43 harks back to the big multi-band receivers of the 1930s. For example, the short-wave coverage is not just *added on* to standard BC reception with the usual *added-on poop-out above-4-mc circuitry*. Average sensitivity for the high frequency bands is 3 microvolts, with a 2 microvolt rating for 30 db of quieting on FM. As far as sound quality is concerned, the relatively large 4x6-inch speaker approximates the sound of a good quality table radio—reasonably good low frequency response with no high pitched shrillness common to transistor portables.

While the GR-43 is normally powered by six D cells plus a C cell for the dial light, the receiver can be powered by an optional AC power supply. The AC power jack au-



Rear view of Heath-kit GR-43 receiver showing unit's compact construction. To see exactly how chassis was built up turn to front cover four-color photograph. Complete chassis is inserted into cabinet where alignment can be performed with only the rear door opened. D cells (6 required) power the transistor circuit and C cell powers front panel illumination lamp.



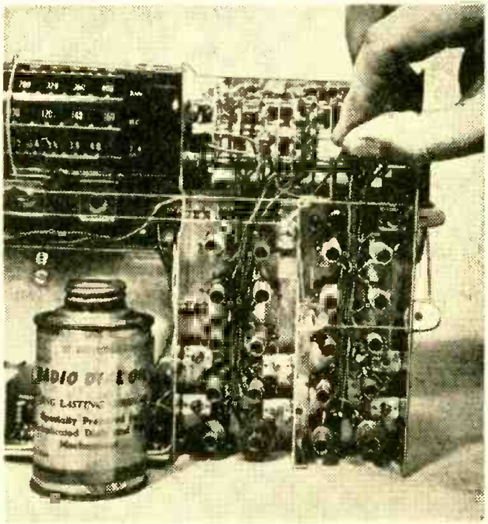
Fingers (left) span the AM/FM assemblies that are supplied pre-assembled and factory aligned. The difficult-to-wire bandswitch comes complete, tested and installed. Nothing the kit builder can goof-up here. Below, it was found best to lubricate the pulleys at their shaft points to improve dial cord drive action. Be neat, wipe away excess and keep oil off dial cord.

tomatically charges the internal batteries when the AC supply is plugged in. An earphone jack is also provided which automatically disconnects the collector voltage to the output transistors to reduce power consumption; the earphones connect to the audio driver stage.

Assembly and Alignment. Obviously, all the features cannot be crammed into a pocket size cabinet with 6 or 7 transistors. The GR-43 *is* big, 13½x5⅛x10⅜ inches, and it checks in at 17 pounds including its 16 transistors and batteries. But while you might think a kit this size would be complex, such is not the case.

The really critical circuit, and the most difficult to build, the front ends, is supplied completely pre-wired and aligned, and this includes the bandswitch. All that's left to the builder is the AM and FM IF strips, the audio amplifier and the mechanical assembly. The IF strips are assembled on separate printed circuit boards so each individual assembly is simply pushing the right parts into a small board and soldering. Similarly with the audio circuits. Since each section is handled separately there are no tight corners to snag even the beginner at kit construction.

Alignment is similarly a breeze as it is done without the need for any instruments. Since both the AM, FM and SW front ends are pre-aligned only the AM and FM IF strips are adjusted—and alignment consists of simply peaking for maximum interstation noise. Even the ratio detector is aligned without instruments. An instrument alignment procedure is provided which should be done only by a competent technician, and it should be done only if a breakdown affects a frequency determining circuit. Keep in mind, and this is important, an instrument alignment by the builder will make *no significant improvement* compared to the non-instrument alignment. An instrument alignment can cause trouble if you're not an expert at FM alignment.



Our Comments. Our only complaint with the kit is the dial cord drive. Several aluminum pulleys are used and we found some of them, while appearing to be loose, were actually slightly tight; causing the dial cord

(Continued on page 113)

Never needs alignment! Smaller size—better selectivity and gain!

Those New IF Filters

by John Potter Shields

■ If you are like most experimenters who keep a keen eye on all the new electronics components literature, you've probably been aware that a number of manufacturers are now offering receivers using either piezoelectric or mechanical IF (intermediate frequency) filters. Several firms are marketing filter assemblies for incorporation in existing equipment. Just what are these new IF filters? What are their advantages? How do they work?

Why Use a Filter? The selectivity of any superheterodyne receiver, whether it be a communications receiver, home BC set, or TV is almost entirely determined by the selectivity of the LC (inductance-capacitance) tuned circuit in the IF amplifier. The IF amplifier's selectivity is obtained by these LC circuits passing a single frequency while rejecting all others. The greater the selectivity of the IF amplifier the greater the receiver's ability to tune to a signal while rejecting all others. When the selectivity of the receiver is not as high as it might be it is difficult to separate the desired signal from other signals operating on adjacent frequencies. For better receiver selectivity manufacturers add additional IF stages which increases the number of tuned circuits.

To get a graphical idea of how the selectivity improves as the number of tuned circuits are increased, let's take a look at Fig. 1—the overall response curve of two typical IF amplifiers. Curve A is that of a single-stage IF amplifier which employs four tuned circuits. Curve B of a two-stage IF amplifier using six tuned circuits. Curve B is noticeably sharper, indicating that selectivity can be improved by increasing the number of tuned circuits.

This is all well and good, except that IF stages, with their tuned circuits, cost money. This is one reason why a receiver with high selectivity is considerably more expensive. Also, as the number of tuned LC circuits are increased, the problem of optimum align-

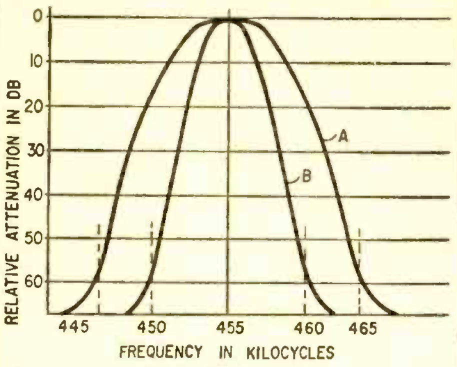


Fig. 1. Single-stage IF amplifier response curve (A) is sharpened (B) by adding tuned circuits.

ment becomes more critical because more tuned circuits must be aligned.

Not too long ago, several radically new types of tuned circuits, which contain no inductive or capacitive components were introduced. These new units, known as filters, have a number of advantages over conventional LC tuned circuits, including: high selectivity, permanent alignment, small size, ruggedness and stability.

These new high-selectivity filters fall into two general classes . . . *piezoelectric* and *magnetostrictive* (mechanical). Both types are currently being used in a number of communications receivers and CB gear. Certain types are available to the experimenter. Let's see how these new filters operate.

The Piezoelectric Filters. Two types of ceramic (piezoelectric) IF filters (Fig. 2) manufactured by the Clevite Corporation, Piezoelectric Division, Bedford, Ohio. Dubbed TRANSFILTERS, they are replacements for the conventional LC tuned circuits in an IF amplifier. The larger of the two units is equivalent to a standard double-tuned IF transformer. The smaller (two-terminal) unit is used, in conjunction with the larger filter, like a bypass capacitor.

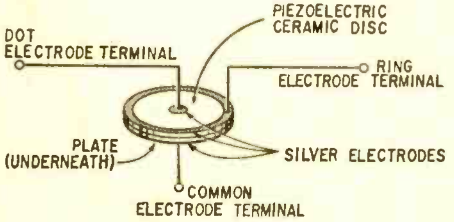


Fig. 3. Signal, applied to DOT and COMMON, is transmitted to RING as IF-signal voltage.

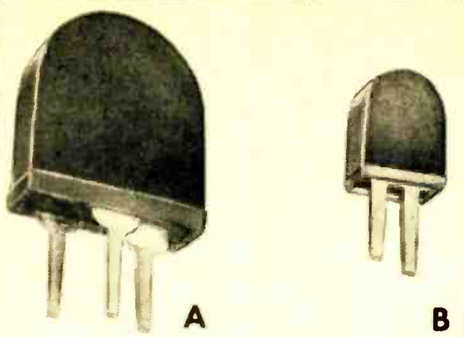


Fig. 2. Clevite ceramic filter (A) is like an IF transformer. Unit B—a tuned bypass capacitor.

Before getting into typical circuits for these filters, let's take a moment to examine their construction and basic operation. Fig. 3 is a sketch of the filter element—a piezoelectric-ceramic disc about the size of a large aspirin tablet. One side of the disc is completely covered by a conductive silver coating which serves as the *common* electrode. The other side of the disc has two separate electrodes . . . a ring electrode around its edge and a center or dot electrode. (The dot electrode is normally used as the input connection to the disc, and the ring the output electrode, although these connections may be interchanged.) This ceramic disc, with leads attached to flat pin connections, is encased in plastic as shown in Fig. 2.

In operation, a signal (whose frequency is the same as the disc's resonant frequency) is applied to the disc dot electrode, the disc is set into mechanical vibration due to piezoelectric action. (A piezoelectric material has the ability to convert an applied electrical signal into corresponding mechanical vibrations and vica-versa.) The mechanical vibrations of the ceramic disc, at resonance, produces a voltage at its ring electrode. At applied frequencies other than disc resonance, little or no voltage is developed at its ring electrode. Due to the characteristics of the ceramic disc, the selectivity of the filter is very sharp, negligible output voltage appearing at the disc's ring electrode when the applied RF signal is only a few kilocycles away from the nominal resonant frequency of the filter.

The two-terminal filter, Fig. 2 is basically the same as the three-terminal filter just described, except that its piezoelectric ceramic disc is smaller and has a plate electrode on both sides.

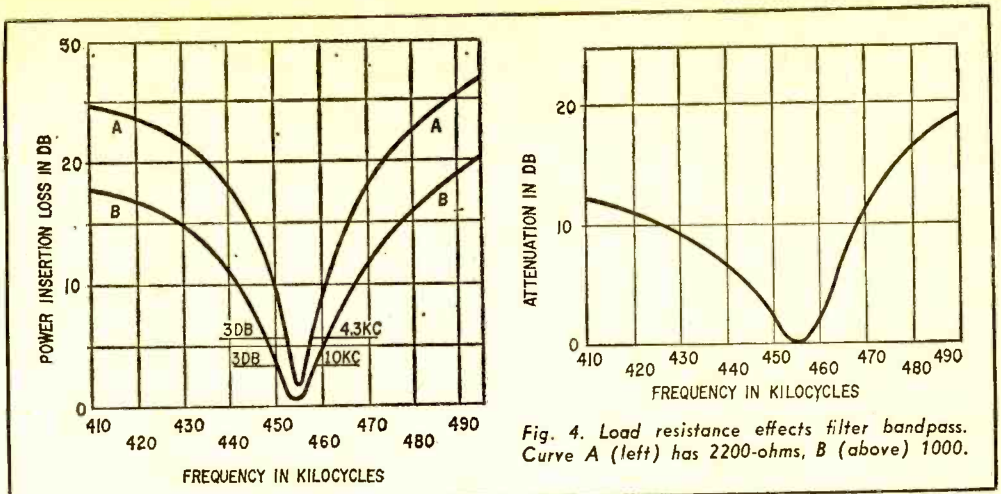


Fig. 4. Load resistance effects filter bandpass. Curve A (left) has 2200-ohms, B (above) 1000.

Electrically the two-terminal filter operation is similar to a conventional series-resonant LC tuned circuit. By this, we mean that it will offer, essentially, a short circuit to its resonant frequency signals and act almost as an open circuit to all other frequencies.

To give you an idea of the selectivity characteristics of these two piezoelectric filters, Fig. 4 shows the passband characteristics of the three-terminal filter with two different values of load resistance, and the characteristics of the two-terminal filter.

Fig. 5 is a simplified schematic of a two-transistor IF amplifier using the two TRANSFILTERS. The IF signal is applied to the base of Q1. R1 (in the emitter lead of Q1) provides a certain amount of degeneration, which, of course, will decrease the gain of Q1. Let's assume that the amplifier is designed to operate at 455 KC, and that for the sake of demonstration, we have connected a variable-frequency RF generator to the input of the IF amplifier. With the RF generator set, at say 400 kc, we slowly increase the output frequency toward 455 kc. At 400 kc, Q1's gain is low due to the presence of R1 in the emitter circuit. At this frequency, filter F1 is electrically out of the circuit since it is effectively an open circuit. As the input-signal frequency approaches 455 kc, the impedance of F1 will begin to decrease and it will begin to shunt the signal voltage, from Q1's emitter to ground, around R1. This decreases the degeneration and the gain of the stage increases. When the RF generator's output frequency reaches F1's resonant frequency, F1 will have minimum impedance and will be an essentially short circuit (across R1) for the signal frequency appearing at Q1's emitter. As a result, there will be negligible degeneration and the stage will have maximum gain. As the input frequency to the IF amplifier is increased still further; above F1's resonant frequency F1's impedance will again rise and the stage gain will again be reduced due to increasing degeneration. The resulting frequency *vs* gain characteristics of the stage are shown in Fig. 6.

The amplified IF signal (at Q1's collector) is fed to the dot electrode of the three-terminal filter, F2. As we mentioned earlier, this filter passes maximum signal (has mini-

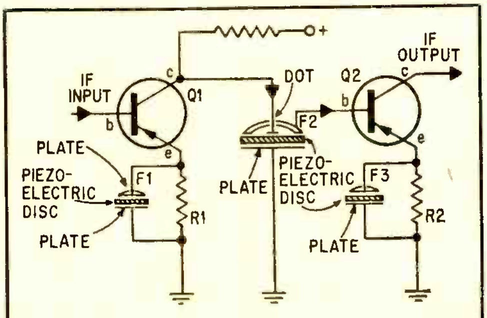


Fig. 5. Cut-in-half filters show how schematic symbol, used in Fig. 11, evolved from component.

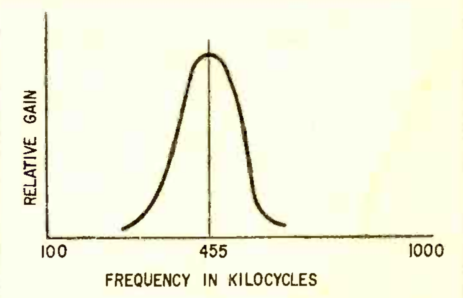


Fig. 6. Frequency vs gain graph shows bandpass characteristics of a typical filter IF stage.

mum insertion loss) from its input (dot electrode) to its output (ring) electrode when the signal frequency is the same as the filter's resonant frequency. Thus F2 as a coupling element, adds additional selectivity to the two-stage amplifier. In effect, F2 is a double-tuned IF transformer placed between Q1 and Q2.

The signal output from F2 is applied to Q2's base for further amplification. Emitter resistor R2 is also bypassed with a two-terminal filter, F3, which further improves selectivity.

So, by using piezoelectric ceramic filters the IF amplifier has selectivity characteristics equal to, or better than, a conventional AM receiver's IF amplifier using regular IF "cans." Aside from good selectivity, the IF amplifier with the piezoelectric-ceramic filter doesn't require any alignment and it is stable; it will retain its selectivity characteristics over a long period of time. And . . . the ceramic filters are a lot smaller than those miniature IF transformers.

Fig. 7. Clevite's ladder filter resembles tubular capacitor—mounted by leads in any position.

Fig. 7 shows a ladder-type piezoelectric ceramic filter. Its extremely-sharp selectivity is shown by the curve, Fig. 8. Notice that the filter's "skirt" (the sides of the curve) rise almost vertically, departing very little from the ideal curve indicated by the dotted lines.

The ladder filter gets its excellent selectivity by stacking a number of individual piezoelectric ceramic discs face to face as shown in Fig. 9. When a signal at the ladder filter's resonant frequency is applied to the input of the filter the discs are set into vibration and the signal passes down the line from the input disc to the output disc. Due to the nature of the discs, coupled with their number and mounting, the ladder filter achieves extremely-high selectivity.

Although considerably more expensive than the single-disc filters, piezoelectric ladder filters find extensive use in such applications as very-high-selectivity communications receivers and as single-sideband filters in transmitters. Fig. 10 shows how the piezoelectric ladder filter used in a two-transistor, high-selectivity amplifier basic circuit.

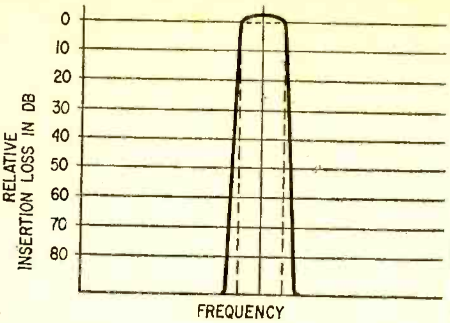


Fig. 8. Actual response of ladder filter (heavy line) is close to the ideal curve (dotted line).

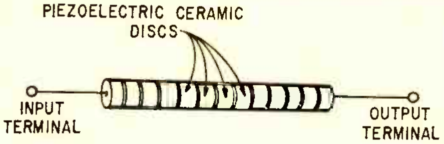


Fig. 9. Piezoelectric ceramic discs stacked in a roll like candy drops for increased selectivity.

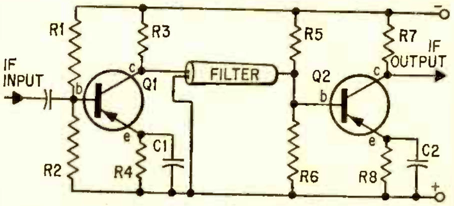


Fig. 10. Circuit for ladder filter is similar to that of a resistance-capacitance amplifier.

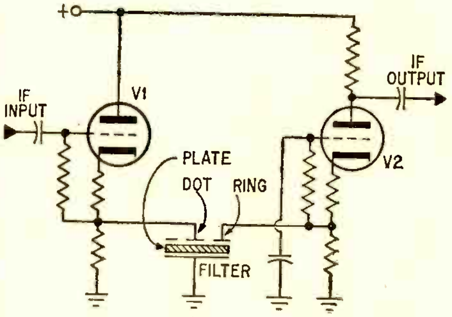


Fig. 11. Cathode-follower output from V1 and a grounded-grid input to V2 match impedances.

The piezoelectric filters just described are well suited for use with transistor circuits because of the filter's low-input and output impedances. However, it is possible to use these

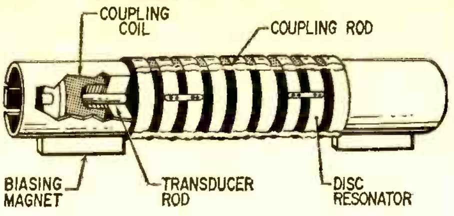


Fig. 12. Mechanical filter operation depends on physical vibrations—like resonant-reed relay.

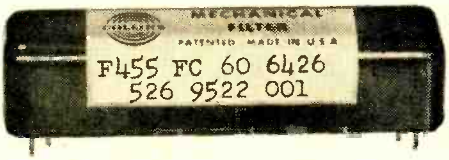


Fig. 13. Collins filter resembles a stretched miniature IF can without adjustment openings.

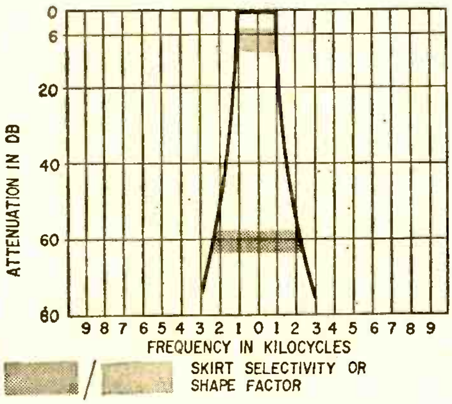


Fig. 14. Narrow bandwidth (1 kc at 6-db point) makes filters unsuitable for broadcast receivers.

filters with vacuum tubes as shown, basically, in Fig. 11. Cathode follower V1 has the three-terminal ceramic filter's input connected to V's cathode. The output of the filter is connected to the cathode (input) of V2, a grounded-grid amplifier. Since the vacuum-tube cathode follower has a low-output impedance and the grounded-grid amplifier has a low input impedance, the filter will be properly matched.

Mechanical Filters. With the information on piezoelectric ceramic filters under our belt, let's turn to mechanical filters.

While the piezoelectric filters depends upon the piezoelectric action of ceramic discs in its operation, the mechanical filter uses a series of metal-disc resonators driven by a magnetostrictive transducer for its operation. Figs. 12 and 13 show cutaway and assembled views of a mechanical filter made by Collins Radio Co., Component Sales Department, 19700 Jamboree Road, Newport Beach, Calif.

In operation, an input signal (whose frequency is the same as the filter's resonant frequency) is applied to the input transducer (coupling coil) of the filter. This transducer is a magnetostrictive device, consisting of a coil, a magnet and a metal rod. The input signal voltage applied to the coupling coil causes the rod to stretch or shrink in step with the applied frequency, thus transforming the input frequency to corresponding mechanical vibrations.

The *biasing magnet* performs a rather unique function. The magnetostriction rod *must* be biased magnetically to prevent it from stretching and shrinking at twice the resonant frequency. Maximum stretching and shrinking occur at the maximum and minimum magnetic fields. Without a small magnet to bias the magnetostriction rod maximum magnetic field occurs twice during

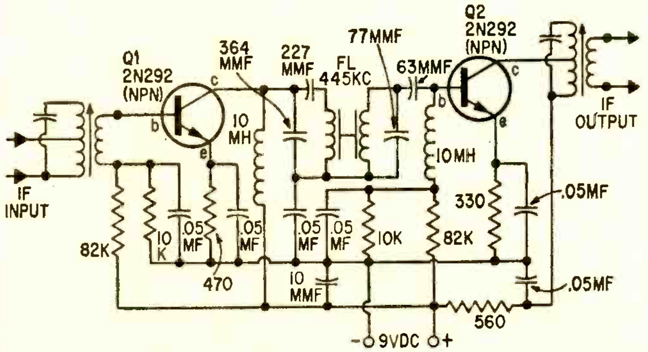


Fig. 15. Schematic diagram for IF amplifier using a mechanical filter has impedance coupling (inductor and capacitor) in both output of Q1 and input of Q2 to keep DC out of coupling coils. Electromagnet effect would upset magnetic field of bias magnets. Hence only 455 kc signal is let through input and output coupling coils of IF filter.

Fig. 16. Circuit for mechanical filter shows impedance coupling from V1 to keep plate current out of the coupling coil. Since negatively-biased grid of V2 does not draw current there is no electromagnetic field generated in the output coupling of the filter to upset the biasing-magnet field.

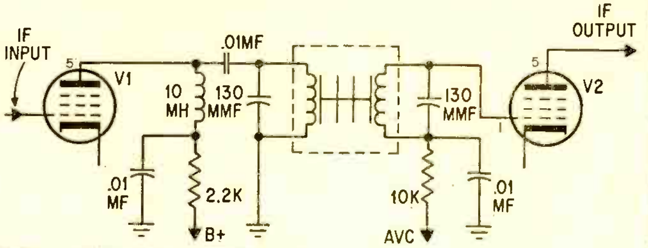


Fig. 17. Lafayette's mechanical-filter internal construction (right) and the complete assembly (below) can be installed in an existing tube-type receiver in place of the present IF transformer.

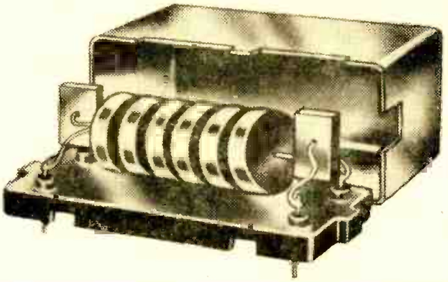
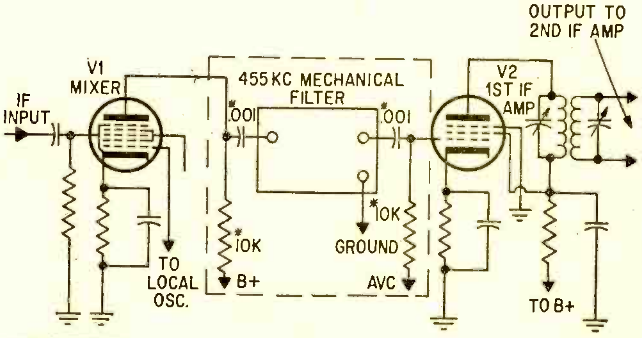


Fig. 18. Schematic diagram for modifying conventional IF amplifier to use mechanical filter in place of 1st-IF transformer. Parts indicated (*) are added to provide DC paths for plate current; AVC voltage to tubes.



each cycle—once for the positive peak and once for the negative peak. The signal-current flow through the *coupling coil* opposes or aids the magnetic field of the biasing magnet—making it stronger or weaker depending on the direction of signal-current flow.

The mechanical vibrations generated by the transducer are coupled to the disc resonators through coupling rods. The last disc is coupled to a second magnetostrictive transducer which converts the mechanical vibrations of the last disc back into an electrical signal. Due to the mechanical properties of the discs and their method of coupling, the mechanical filter produces the high selectivity shown by the response curve, Fig. 14. Increasing the number of discs increases the skirt selectivity of the filter, and varying the amount of coupling to the discs by making the coupling rods larger or smaller.

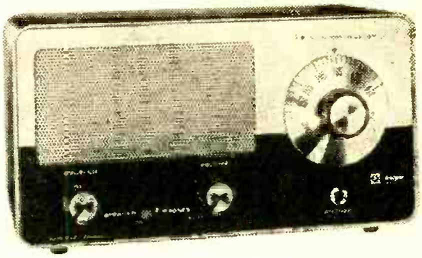
Fig. 15 shows how the Collins mechanical filter can be used in a typical two-transistor IF amplifier, while Fig. 16 shows a vacuum tube IF amplifier using the mechanical filter.

The Collins mechanical filter can also be used as a sideband filter in a transmitter.

Lafayette Radio Electronics, 111 Jericho Turnpike, Syosset, L.I., N.Y., has recently introduced an inexpensive mechanical filter assembly, Fig. 17. This unit (which comes complete with input and output matching transformers) can be easily incorporated into your present receiver. A recommended circuit for this filter appears in Fig. 18. ■

e/e COMMUNICATIONS

KNIGHT-KIT MODEL KG-221
152-174 Mc. FM
VHF Receiver Kit



■ Want to ride with police to a "shoot out"? Fight four alarmers from the top of an aerial ladder? Sweat it out with a ship captain as he gropes through a fog? Or how about getting really accurate weather reports from one who knows rather than some gorgeous doll whose total knowledge of the weather represents a walk from the taxi to the TV studio? From emergencies to chit-chat between husband and wife on the mobile phone, adventure is yours—in the comfort of your armchair—on the VHF public service bands; all it takes is a VHF FM receiver.

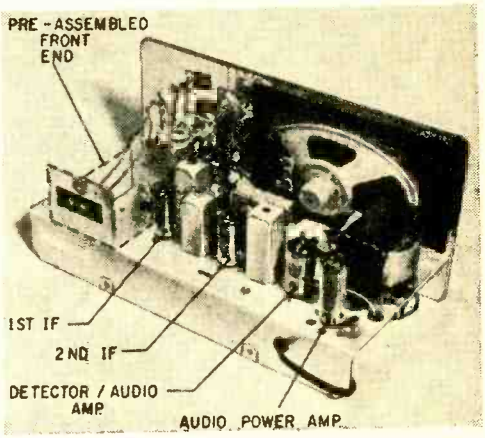
Perhaps the best buy we've seen yet in a VHF FM receiver is Knight-Kit's model KG-221—covering the 152 to 174 megacycle band. A companion receiver—the KG-220-covers 30 to 50 megacycles; since it utilizes a different front end and since we didn't test it our comments apply only to the KG-221.

The KG-221 is notably unsophisticated in design; only five tubes and a single transistor are used, providing an RF amplifier-mixer oscillator, two stages of IF amplification, three stages of audio amplification and an adjustable squelch (the transistor). That's all there is to the line-up; a sort of "All American Five" for VHF.

Putting It Together. Building the kit is about a one evening project—even for beginners. In fact, you may consider it a beginners kit as there's not much to assemble; the really critical circuits in the front end are supplied pre-wired, and, typical of Knight-Kits, the color coded leads are precut to size while the resistors are mounted on a keyed card. Teach the wife or girl friend to swing a soldering iron like a spatula and even she could build the KG-221.

Putting It on Freq. Both the front end and the IF transformers are supplied pre-aligned. Naturally, since individual wiring techniques differ, the lead placement of the IF transformer connecting leads will also vary, and the factory alignment will *not* generally be *on-the-button*. However, the Knight IF transformer alignment is very good, and our completed unit had a sensitivity of 14 microvolts against the specified 10. Aligning the IF transformers with a standard experimenter grade signal generator (special equipment is not needed) produced an input sensitivity of 9 microvolts, slightly better than specs. Very good for a unit priced at $39.95.

The front end factory alignment was perfect, a signal generator alignment made no improvement. We concur with Knight's recommendation that you do not attempt alignment of the front end unless a repair involves a tuned circuit; the front end alignment is tiresome and can be tricky if you're not experienced in tuner alignment. However,

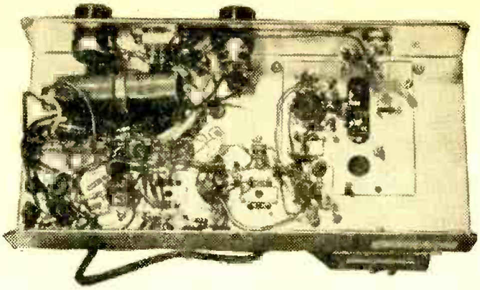


Except for its pre-assembled front end, the Knight-Kit KG-221 looks like a standard AM radio with power transformer. There are differences: IF's are tuned to 10.7 mc. and one-transistor squelch circuit kills noise.

while the Knight alignment procedure suggests special equipment rest assured you can do the job with any decent experimenter or service grade signal generator (someone at the Knight plant just got carried away and over-engineered the procedure).

It's Sound. The squelch is very good; fully adjustable, when set to the point where the background noise just cuts out it will release on the minimum usable signal (you couldn't ask for better).

There's plenty of clean speaker volume; however, at high volume levels the speaker vibrations are picked up by the front end and the receiver is subject to microphonic howling. But to their credit, Knight makes mention of this effect (common to low cost VHF receivers) and suggests a remote speaker be used; the speaker can be plugged into the panel mounted headphone jack.



A little care in parts layout on Knight's part made a clean layout—a must for novice kit builders. Wired unit duplicated pictorial diagrams supplied in manual.

At $39.95 the KG-221 rates as the top buy in VHF receivers. You'd have to spend a lot more before you'd get a significant improvement in performance. For additional information write to Allied Radio Corp., Dept. 20, 100 N. Western Ave., Chicago, Ill. 60680. Tell them Charlie sent you (they'll never figure out who Charlie is). ■

DESIGN CIRCUIT

Low-Level Audio Amplifier

■ Here is a classically simple low-level audio amplifier. Extremely stable over a wide temperature range, current gains over 40 are possible with less than 1.0% total harmonic distortion.

Optimum performance is obtained at an operating current of 1.0 ma DC where current amplification for the circuit is maximum.

Typical specifications are:

Input levels:
0.1 ma AC minimum,
20 ma AC maximum,
1.0 ma AC optimum.

Frequency response:
10-40,000 cps at 3 db down (current gain vs. frequency),
55-10,000 at 3 db down (voltage gain vs. frequency).

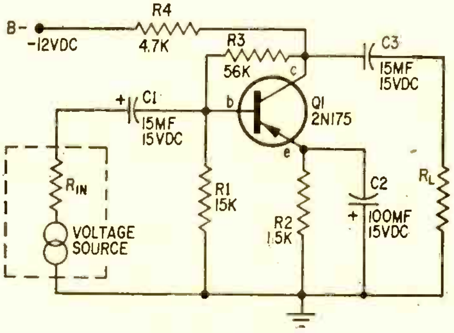
Distortion (THD):
for input signal current of 1.0 ma AC—
0.7% for Rin—5000-ohms,
1.0% for Rin—1000 ohms.

Gain at room temperature:

	Current	Voltage
R1 at 2000 ohms	13	36
R1 at 500 ohms	41	16

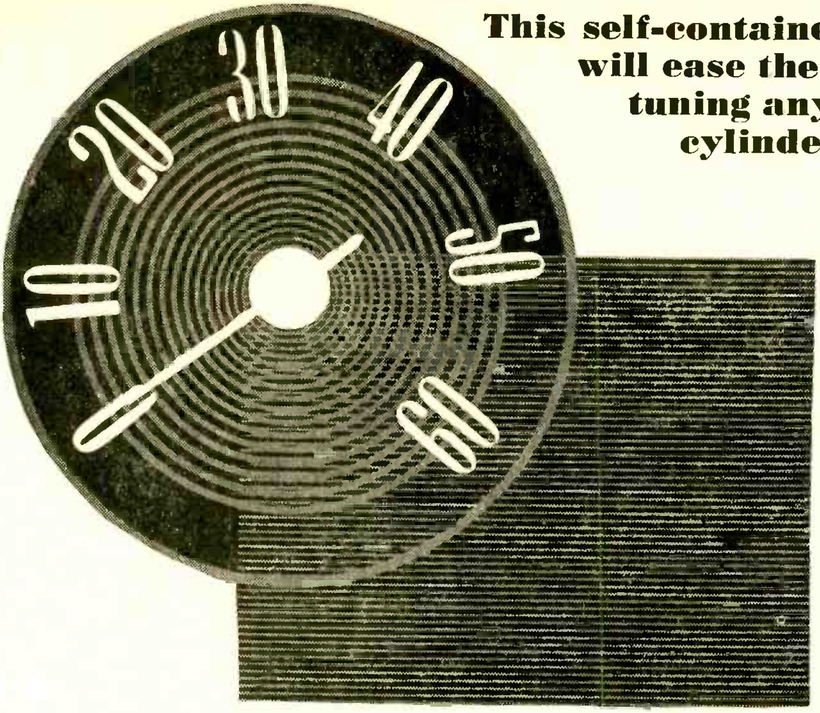
In operation the amplifier's emitter DC current is held constant against temperature variations by both degeneration (negative feedback) action of resistors R3 and R2. Capacitor C2 bypasses R2 to avoid loss of signal gain. However, R3 is not bypassed and reduces signal gain, reduces input and output impedances, and *extends* frequency response. Feedback effect of R3 is increased as load resistance, R1, or source impedance, Rin, are increased. Power supply requirements for the amplifier should be rated at 12-volts DC ± 10% at 1 ma DC.

—*Jay Copeland* ■



Electrolytic capacitor C3 couples the low-level audio amplifier's output to resistive load R_L. The positive terminal of C3 should be connected to R_L and negative, to the collector of Q1. When circuit is fed to next stage, play safe, use non-polarized electrolytic for C3.

This self-contained meter will ease the chore of tuning any 4, 6 or 8 cylinder engine



Solid-state Dwell-Meter and Tachometer

By Fredrick Foreman

■ Have you ever wanted to give your car a super tuneup but did not have a *dwell meter* and *tachometer* with which to do the job? If so, here is a completely self-contained solid-state unit. The internal mercury battery has its own test circuit to assure accurate and reliable operation when tuning any 4, 6, or 8-cylinder engine.

Two low-cost germanium transistors and a switching circuit are the heart of the multipurpose instrument. Both dwell meter and tachometer circuits take advantage of the transistor's stable saturation *current* and low saturation *voltage*.

The Dwell Meter. In the circuit diagram, transistor Q1 operates as a switch and is either an open circuit (from emitter to collector) or a closed circuit—depending upon whether the ignition breaker points are open or closed. When the breaker points are open Q1 is cutoff and no current will flow through it or meter M1. The transistor (Q1) will saturate (maximum current will flow) when the breaker points are closed. The collector current of Q1 is then limited only by the collector voltage, the voltage drop across the transistor when it is saturated and any series resistance in the emitter, collector and battery circuits.

Stability of the collector current, and therefore the dwell angle indication, will be constant if you use a mercury cell as the internal battery. Any cell with at least a 3600 mah (milliampere hours) rating will give a useful life in excess of 1000 hours of use. To compensate for aging of the cell a control R17 is included to adjust the supply voltage (B1) periodically.

The meter (M1), in the collector circuit of Q1, indicates the average current through the transistor. Since transistor Q1 is controlled by the breaker points the average current through Q1 is proportional to the amount of time the points are closed and the meter (M1) in the collector circuit can then be calibrated, in degrees, to indicate the dwell angle of the ignition breaker points.

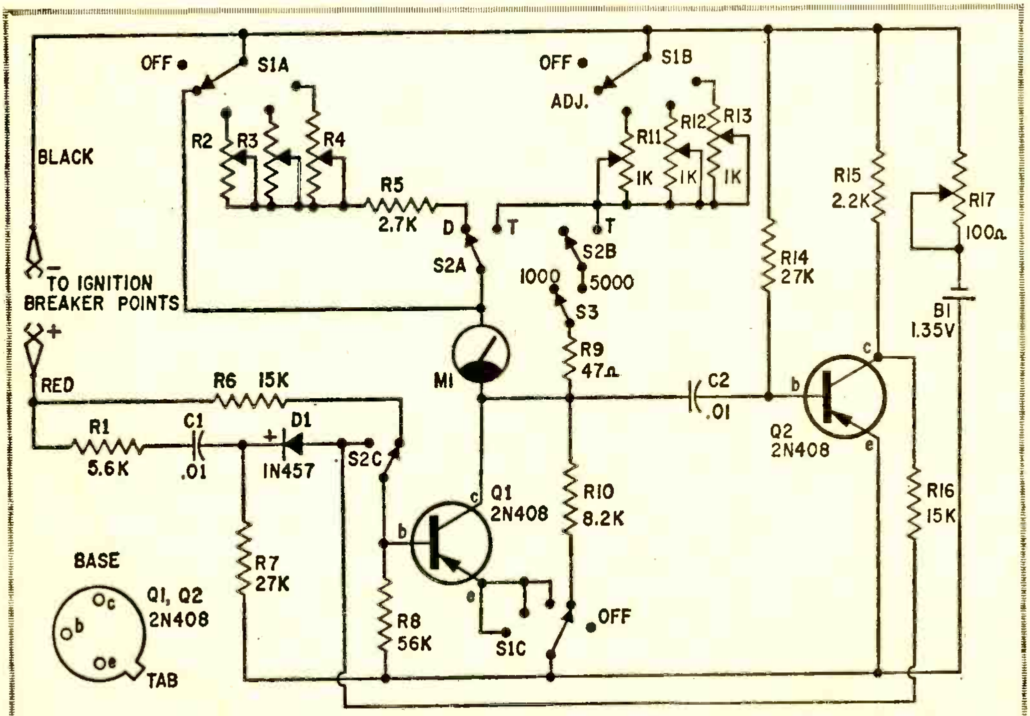
Tachometer Operation. Here we use the ratio of saturation current (*on* time) to cutoff current (*off* time) to give an indication of engine speed in revolutions per minute. The *on* time is of constant duration and is determined by C2 and R11, R12 or R13—depending on whether the unit has been set to the 4, 6 or 8 cylinder position. With switch S1 in the tachometer position, Q1 and Q2 become a monostable multivibrator. Transistor Q1 ics normally cutoff and Q2 is saturated—in its normally *on* condition. With Q1 cutoff there is no collector current to flow through M1.

When the breaker points open the positive-going pulse or spike (across the distributor breaker points and capacitor) turns Q1 *on*. Switching diode (D1) in the base circuit of Q1 maintains the input pulses at a constant polarity to eliminate the effects of any variations (pulses) in the generator and battery voltages. Reverse polarity pulses could affect the accuracy by upsetting the multivibrators operation.

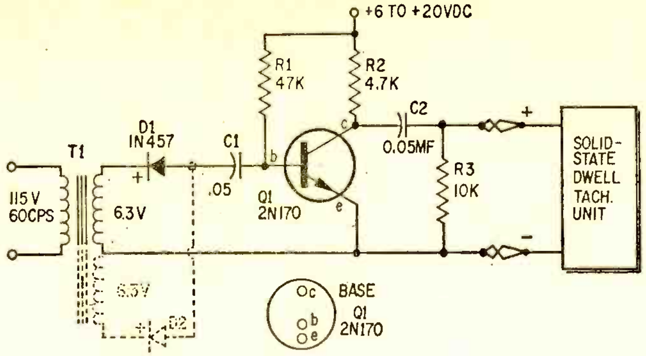
Transistor Q1 remains saturated for about 0.7 RC (70% of the time constant which is determined by C2 and R11, R12 or R13), after which time the multivibrator will return to its previous state—before the triggering pulse.

By keeping the *on* time of Q1 small, compared to the highest engine speeds encountered, the circuit will precisely indicate the engine speed—the circuit is sensitive only to the ratio of the multivibrator pulse to the total period. This ratio is measured by metering the current flow through Q1. The current flow is averaged by meter M1 and the position of the pointer can be calibrated in engine rpm.

Construction. First layout the metal cabinet and drill and cut the proper-size holes for the meter (M1), switches S1, S2, and S3 and attach the handle and rubber feet. (Although they aren't necessary for the



Schematic of Dwell-Meter/Tachometer shows that major portion of circuit is switching and calibration.



Calibrator circuit is just a wave shaper using 60-cycle AC-line as a signal source. A full-wave rectifier circuit will give twice the line frequency for additional check points for calibrating tachometer portion of scale of the combination unit when the construction is completed.

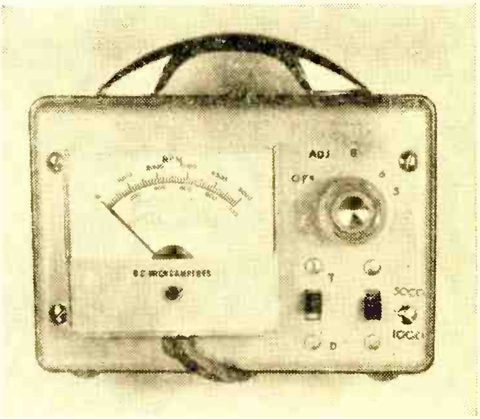
C1, C2—.05 mf., 600-volt, ceramic disc capacitor
D1, D2—1N457 switching diode.
Q1—n-p-n transistor (2N170, 2N216, 2N254, 2N517 or equiv.)
R1—47,000-ohm, ½-watt, resistor
R2—4,700-ohm, ½-watt, resistor
R3—10,000-ohm, ½-watt, resistor
T1—6.3-volt filament transformer or 12.6-volt centertapped filament transformer.

operation they do dress up the unit, and make it easier to handle—the rubber feet prevent the unit slipping off a fender and scratching the finish.)

The Perforated Board. The dimensions of the circuit board are determined by the cabinet—it must be smaller than the front panel to be able to fit into the cabinet easily. The easiest way to mount the phenolic board is to attach it to the meter terminals. The perforated board is light—even with all the components on it—and its weight will not damage the meter. To mark the positions of the meter terminal screws the meter *must* first be mounted on the front panel of the cabinet—make sure there is enough clearance around the perforated phenolic board and that none of the components can short to the case or make it difficult to insert, or remove, the circuitry from the cabinet.

All the electronic components are mounted on the phenolic board—except the switches and the meter. The switches are wired separately and then connected to the board.

Once the meter and switches have been mounted on the front panel it is an easy matter to the leads from the switches to the appropriate points on the phenolic board.

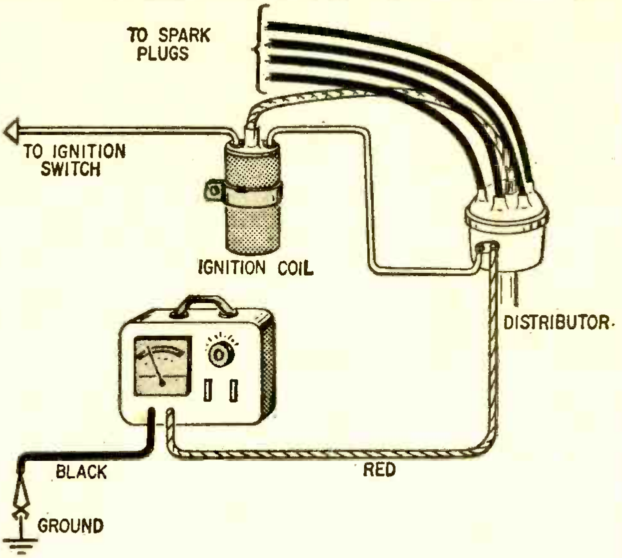


Control panel of Dwell/Tachometer is simple and neat. Meter scale has been relettered. Switches have decals.

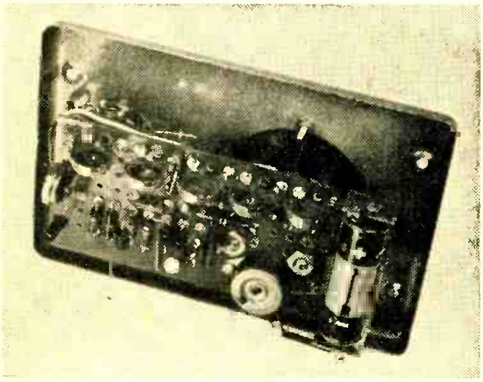
PARTS LIST FOR DWELL METER/TACHOMETER

B1—1.35 volt mercury cell (Mallory RM12R or equiv.)
C1, C2—.01 mf., 600 V ceramic disc capacitor
D1—1N457 switching diode
M1—0-200 microampere panel meter
Q1, Q2—2N404 or 2N408 transistor (or equiv.)
R1—5,600-ohm, ½-watt, resistor
R2, R3, R4—6,000-ohm potentiometer (Mallory MTC63L1 or equiv.)
R5—2,700-ohm, ½-watt, resistor
R6—15,000-ohm, ½-watt, resistor
R7—27,000-ohm, ½-watt, resistor
R8—56,000-ohm, ½-watt, resistor
R9—47-ohm, ½-watt, resistor
R10—8,200-ohm, ½ watt, resistor
R11, R12, R13—1,000-ohm potentiometer (Mallory MTC13L1 or equiv.)
R14—27,000-ohm, ½-watt, resistor
R15—2,200-ohm, ½-watt, resistor
R16—15,000-ohm, ½-watt, resistor
R17—100-ohm, potentiometer (Clarostat series 39 Humdinger or equiv.)
S1—3-pole, 5-position rotary switch (Mallory 3236J or equiv.)
S2—3.p.d.t. slide switch (Continental-Wirt G369 or equiv.)
S3—D.p.d.t. slide switch
Misc.—Chassis box (Bud 2107A or CU729 or equiv.), perforated phenolic board, battery holder, eyelets, wire and hardware.

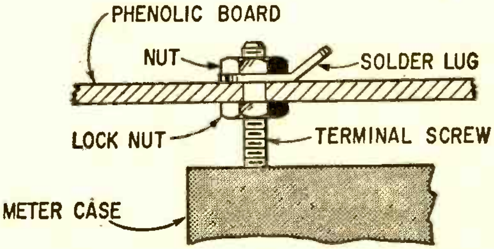
Estimated cost: $20.00
Estimated construction time: 6 hours



The Dwell-Meter and Tachometer connections for negative-ground battery system. Red lead may be connected to terminal on the coil if it is easier to get to. For a positive-ground system the red lead is grounded and black lead goes to breaker-point terminal on coil or on distributor. Tester does not draw power from ignition battery—only pulses are used to trigger the circuits.



Rear view shows calibration potentiometers along top of perforated board. Voltage adjust "pot" is near cell.



Phenolic-board chassis mounts only on meter terminals. Meter is mounted on front panel first—without board.

Leave the leads from the switches extra long. After the switches are mounted and the phenolic board positioned they can be trimmed to exact length just before they are soldered to the eyelet terminals in the perforated phenolic board. After all the switch leads are soldered the phenolic board can be mounted on the meter teminal screws—double nuts are used on the terminal screws as shown in the illustration.

Battery Adjustment. A 3600-mah, 1.35-volt mercury cell (Mallory) provides the best service. Due to the nature of the mercury cell the output voltage remains essentially constant throughout its useful life. When the cell becomes depleted there is an abrupt drop in voltage output—unlike the zinc-carbon (Leclanche) dry cell, whose voltage output slowly tapers off.

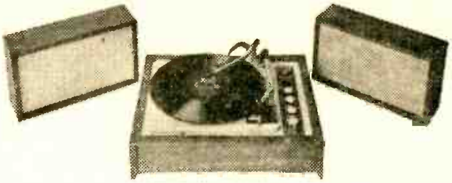
For the initial adjustment, the 100-ohm *battery-adjust* potentiometer (R17) should be set for slightly less than maximum resistance. With a fresh mercury cell to power the circuit M1 should indicate full scale when S1 is set to the ADJUST position. If full-scale reading cannot be obtained with any setting of R17, resistor R10 should be reduced in value—it should not be necessary to use a value below 6200 ohms. (Try wiring 68K, 62K, 56K, 51K or 47K resistors in parallel to 8.2KR10.) It is not essential that a full-scale reading be obtained but it is easier

(Continued on page 112)

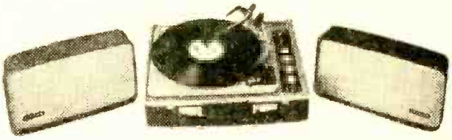
RADIO-TV EXPERIMENTER LAB CHECK

SINGER MODELS HE-911 & HE-912

Portable and Table-top Stereo Compact Phonographs



Singer Tabletop Phonograph HE-912



Singer Portable Phonograph HE-911

■ When the stereo disc using a single groove for both left and right channels finally made the scene, the manufacturers fell over each other in their rush to add a stereo pickup and a second speaker to *a pepped up* portable phonograph. Though the sound was strictly fourth rate, a big sticker, usually in bright gold, proclaimed *STEREO HI-FI,* and the uninformed public couldn't wait to plunk down a hundred bucks or more for a thirty dollar phonograph *upgraded* to stereo.

But instead of dying a natural death the stereo phonograph actually was improved, and today it's known as the *Dormitory Special*—the hottest thing going in Hi-Fi gear—especially on the college campus and with the teen set.

What Is It? A *Dormitory Special* is a Stereo Compact in approximately the $150 to $250 price range. It's compact, lightweight, and easily carried from place to place; so convenient that it's high up on the list of items a college student packs for his trip back to school—hence the term "Dormitory Special". And of course, back from school the student generally sets it up in the bedroom or den as a secondary Hi-Fi system, so in a sense it is still a *Dormitory Special.*

What differentiates the *Dormitory Special* from the rest of the stereo compact line is that it's not really Hi-Fi. A Hi-Fi stereo compact can pack 70 or more watts and a record changer into a small cabinet, has two large "bookshelf" speakers, and can deliver outstanding sound; but it would take three trips to carry the system out of the car—let alone manage it on a train or plane. The *Dormitory Special* is a scaled-down compact usually with two small speakers, a moderate quality record changer, and just enough power to fill a 12x15 foot bedroom or playroom with reasonably loud volume. Since the small speaker enclosures and speakers in themselves limit the *Dormitory Special's* sound quality, the overall response is tailored to deliver exceptionally clean *balanced* sound —no outstanding window rattling bass or shimmering highs, rather a decidedly pleasant sound comfortable in a modest sized room.

A typical *Dormitory Special* is Singer's— the same outfit that makes sewing machines —Compact Stereophonic Phonograph, which is available in a utility "portable" case, Model HE-911, or wood with a walnut finish, HE-912. Both units are electrically identical.

The base contains the amplifier and a Garrard changer equipped with a Pickering V-15 cartridge. The two detachable speaker enclosures utilize 3-inch highly compliant speakers. Since individual performance of each component is related to the total performance we'll discuss them individually.

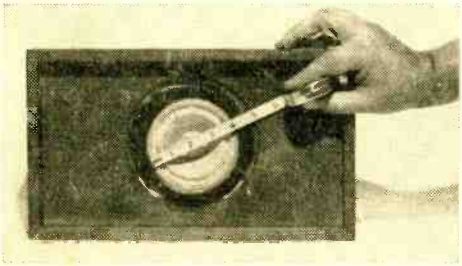
What You Get. First off, the changer's mounting is excellent. The usual springs that float the changer on the cabinet are damped with plastic foam. The effect is similar to shock absorbers on a car. The foam quickly dampens changer vibration such as caused by jolts to the cabinet or floor, and the needle stays in the groove under rather severe shocks. Even a roomful of dancing teenagers failed to cause the arm to skip even though the changer was placed on the floor.

The four-speed changer will automatically index intermixed 7, 10 and 12 inch discs as long as they all play at the same speed. Manual operation is also provided. One feature we particularly liked was an oversize, *accessible* adjustment screw for the arm indexing. Often, the indexing—the ability of the arm to automatically come down on the beginning of the record—gets knocked out of adjustment if the changer gets a severe *"bouncing"*; on the Singer the adjustment can be made by the user with a standard screwdriver.

The V-15 cartridge is an outstanding performer, and is reflected in the notably clean final sound. Tracking force between just one record on the platter and up to six remained at essentially 4 grams.

Test Report. The amplifier has a maximum capability of five watts steady-state tone (rms), 20-watt peak per channel (music power), and this is the *absolute* maximum. Above five watts the sound tears apart. The overall gain has been set so that with the volume control wide open a high level LP disc will just about deliver the full output power. Though the total available power is small by modern standards—where 35 watts is not unusual in a low power amplifier—the Singer's power output is more than adequate for the intended purpose, since, when feeding its own speakers, only a ½ watt of music power per channel is needed to fill a 12 x 15 foot room with a moderate sound level. While the Singer can be pushed to the maximum of 5 watts (steady-state tone, rms) per channel it can only be done with the tone controls in the flat position as either bass or treble boost pushes the amplifier above 5 watts, into high distortion. The THD (total harmonic distortion) is less than 1% at 5 watts.

The phono input is internally connected; a set of jacks provides an auxiliary input for a tuner or tape recorder. The AC power switching is automatic; when the function switch is set to *phono* the changer's operating lever turns the power on and off. When the function switch is set to *Aux* the power is applied automatically through the function switch. A mode switch provides for stereo or mono output, while a balance control adjusts the sound level ratio of the speakers.



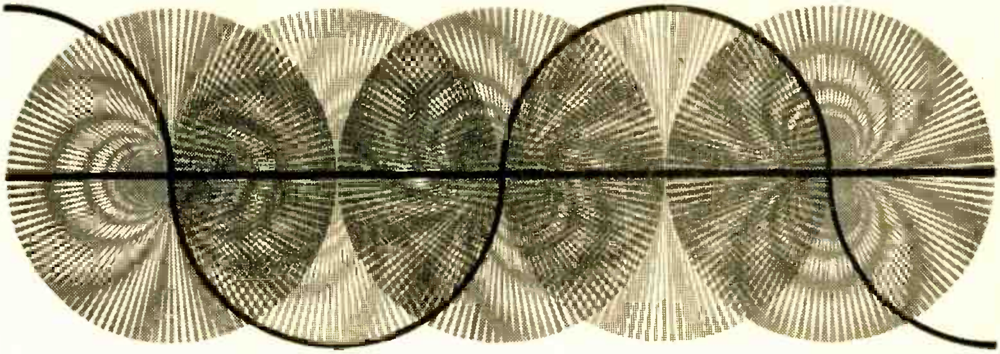
The Singer Company claims their speakers used in the HE-911 and HE-912 are only 3-inches in diameter. Photo proves that cone is 3-inches, but can be called a 4-inch job if you wish to include suspension material. Some manufacturers are a bit more liberal by including the metal basket—normal industry measurements would be 4½-5 inches minimum.

Stylus brush at tip of pencil is located to sweep stylus clean at start of every automatic record play. Changer clamps down by twisting screws to avoid transport damage.

The 3-inch KLH speakers do a creditable job considering their size. Sound output starts at about 80 cycles and cuts off at 15 kc. Though sound is apparent at 80 cps it doesn't really come up till 110 cps, and it is often necessary to apply some bass boost (contrary to the instructions) to avoid an overly bright sound (typical of small speakers). Even with full bass boost the sound is exceptionally clean even at moderate output levels. But keep in mind that it's a *balanced* sound—not real Hi-Fi; the thunder of the cannons in the 1812 Overture sound more like a recoilless rifle than a Howitzer.

Our Views. So now you have the picture of a *Dormitory Special.* Adding up the good and the bad we come up with decent balanced sound at moderate power levels suitable for small rooms, flexibility in terms of utilizing the amplifier for an optional tuner or recorder, reasonably low in cost, and finally, real portability—for not everything with a handle is portable. The HE-912 (oiled walnut) is priced at $209.95 and is available at Singer Centers throughout the country. Drop in your nearby Singer Center (check the phone book for address) and inspect the HE-912 yourself. While you are at it check the Singer Model HE-911 ($199.95)—it comes in a vinyl case. ■

Theoretical explanations and some practical experiments with circuits.



Two Novel Oscillators

By A. J. Cote, Jr.

■ Just about every child of three who has managed to find enough time to pick up four or more years of electronics background has heard of the Colpitts and Hartley oscillator circuits. And those of lesser experience have probably encountered them without realizing it. They are circuit classics found in almost every book that pretends to treat electronic circuits.

But how many of you have ever heard of the Y-type and Z-type oscillators?

Well, I'll introduce you to these two circuits and show you why they are fundamentally just as basic as the Hartley and Colpitts configurations. And we'll also point out why these little known wonders apparently weren't discovered until about ten years ago.

We'll begin by briefly reviewing some important aspects of oscillators and refresh your memories as to the form of the Hartley and Colpitts circuits. We will also review what components are important in determining the frequency of oscillation and frequency stability of all four oscillators. Then we'll move to the workbench, breadboard a couple of the Z-type circuits and discuss their performance.

Basic Ingredients. Every component in an electronic circuit is there to perform a particular function which will contribute to the overall performance of the circuit. Sometimes a component will do extra duty and handle more than one job. But they generally have only one primary mission.

In any oscillator circuit, there are three functions that must be fulfilled. One group of components will combine to insure proper feedback conditions and also determine the frequency at which the circuit oscillates. Another will provide the necessary power gain. And the third group will determine the operating conditions of the circuit. Since this third group is found in all types of circuits, we'll ignore it initially, because it will detract from our focus on the conditions that influence oscillator performance.

Some Basic Oscillators. There are so many ways to build an oscillator that it sometimes appears that there is little rhyme or reason to the various approaches. But actually it is possible to categorize many of these circuits into one of five basic types shown in Fig. 1. Note that each type consists of two "black boxes." One contains the power gain components and the other contains the feedback and frequency determining components. The difference between the oscillator types is due to the way the boxes are interconnected.

This is not the only way you could "typecast" oscillators, but it is a convenient one when conducting theoretical studies of oscillators. It saves a lot of work, because by analyzing just these few circuits, it is possible to come up with results that can explain the operation of a large number of other circuits.

Feedback Oscillators. The first four types of oscillators are sometimes called feedback oscillators. The power-gain components are generally some type of amplifier, while the frequency is determined by the box through which the amplified signal is fed back toward the input. If you were to insert a signal into the amplifier box, a portion of the amplified output would find its way back to the input via the feedback box. If the circuit is to oscillate, the components in this latter box must be selected so as to insure that the returned signal has the proper phase and amplitude. In short, certain starting conditions must be satisfied. And the components in the feedback box must also be selected to insure that the circuit oscillates at the desired frequency.

Although there is no apparent feedback in the configuration in Fig. 1E, it is also a class of oscillator. It exploits the concept of a *negative* resistance such as obtained in components like tunnel diodes, four-layer diodes, neon tubes, etc. But that's another topic that we don't want to get into here.

Fig. 2 shows some examples of Y-type oscillators and you can see that the Colpitts, Hartley, and Clapp circuits are among the members of this category. Fig. 3 shows examples of the Z-type oscillators. Although we can't consider them here, one example of the G- and H-type oscillators is the Wein Bridge circuit that is the heart of many commercial audio generators.

But now let's get down to brass tacks by looking more closely at the Hartley, Colpitts, and two Z-type circuits shown in Fig. 4.

Oscillation Frequency. The oscillation frequency of each of these circuits can be predicted using the equations in Table A. The terms $\triangle z$ and $\triangle y$ are numbers computed from a knowledge of the properties of the transistor and its bias components. But we can ignore this computation for the most part if we take advantage of the fol-

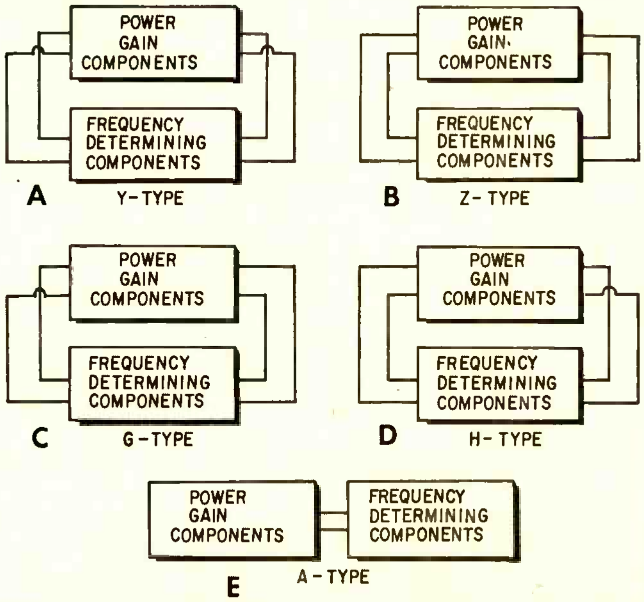


Fig. 1. The basic black-box concept of oscillator circuits shows how two divisions of required circuitry can be interconnected. For this basic concept the power connections are ignored since they remain just about the same for all the amplifier circuits.

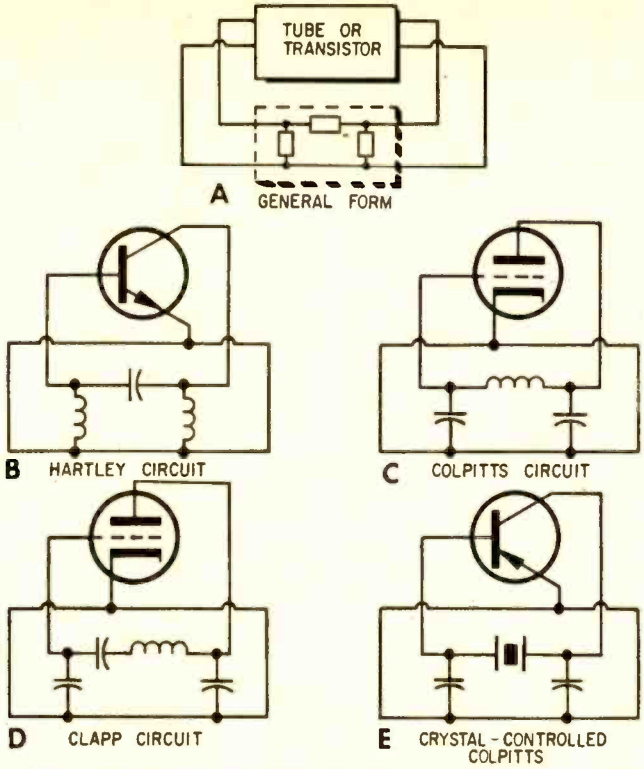


Fig. 2. Basic Y-type oscillator circuits using vacuum tubes and transistors. Only the signal paths are shown. DC paths and the blocking capacitors are not shown in this AC simplification.

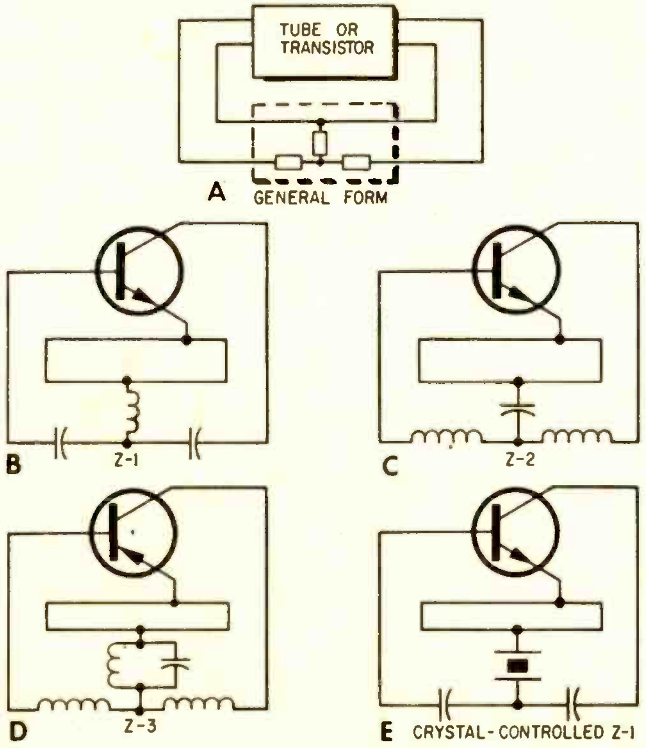
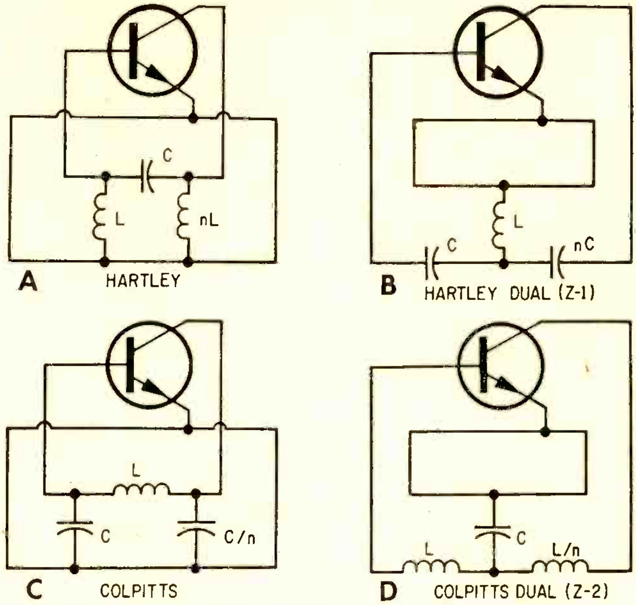


Fig. 3. Examples of basic Z-type oscillators using transistors as the amplifying element. Box-like wiring in emitter circuits is a common loop carried over from black-box concept (A) at top.

Fig. 4. The Pi-type networks in these schematics are just a new presentation of the more well-known tapped-coil Hartley (A) and split-capacitor Colpitts (C) circuits. The dual of the more standard circuit is just the reverse—the Hartley dual (B) has a split capacitor while the Colpitts dual has a tapped inductor.



lowing fact brought out by the equations. Proper selection of the values of *L* and *C* will enable us to insure that the term containing the △ is much less than one in value. Under these conditions, the equations for frequency simplify to the forms shown in the right hand column.

Incidentally, in using these equations, the capacitor values must be expressed in farads and the inductor values in henries. The frequency will then be in cycles per second. The term *n* is just a number which expresses the ratio of the appropriate pair of components in each circuit.

The simplified form of the two equations brings into evidence another aspect of the two circuits. The equations show that the frequency of a Y-type oscillator is the resonant frequency of the *series* combination of the three frequency determining elements. And for the Z-type oscillators, the *parallel* combination of the three determines the resonant frequency.

Starting Conditions. We could also find equations that tell us something about the starting conditions of the oscillators. But to employ them, we'd have to know quite a bit about the properties of the transistor or tube employed in the oscillator. For example, the transistor could actually be represented by an equivalent circuit which would approximate the device's behavior. Whether or not the oscillator will work will be dependent on the relative values of the components of the equivalent circuit and the frequency determining feedback components. By making certain measurements on the transistor, we could find the equivalent circuit component values and then solve equations for the feedback component values which will permit oscillations to take place. These are the starting conditions.

Although this sounds like a nice sophisticated engineering approach to the problem, it really isn't too practical. For oscillator applications, the transistor equivalent circuit isn't much good and is only a crude approximation. So in the real-life world, you go to the workbench and build your oscillator circuit using the equations for starting condition only as a very rough guide. Then with an oscilloscope, and some trial and error, you succeed in getting the circuit to operate in a reasonable fashion.

That's what I've done here and we'll consider the results in a minute. The significant aspect of the equations is that they take a form that makes it evident that the Z-type and Y-type oscillators are close relatives. Even in Table A, we can see the similarity in form between the equations of the Hartley and the Z-1 circuits, and the Colpitts and the Z-2 configurations (and the circuits in Figs. 1 and 2). The *C* and *L* are interchanged. Such similarities are even more apparent in the equations for starting conditions. When such similarities are found in pairs of circuits, engineers call the pairs *duals*.

Because of this duality relationship, the Z-type circuits actually deserve to be considered on a par with the Hartley and Colpitts oscillators as fundamental circuits. So how come nobody built Z-type oscillators before the mid-1950's?

It's because vacuum-tubes are no darn good! . . . at least as far as Z-type oscillators are concerned. The vacuum-tube has properties that make it extremely difficult to use in the Z-type circuits. But not the transistor. It was shortly after the transistor came along that somebody at RCA built one of the first Z-type oscillators by using transistors.

But so much for the background. Let's see what we can learn about them by adding bias components and firing them up.

What You'll Need. In the following experiments, what you learn about these oscillators will be somewhat dependent upon what test equipment you have available. Ideally, you should have an oscilloscope for observing the waveforms at various points in the circuit and an audio generator for determining its frequency. But if you don't have access to these instruments, we'll show you how to survive with less as we go along.

You will also need a couple of capacitor decade boxes (or a variety of capacitors beyond those in the parts lists) for most of the experiments.

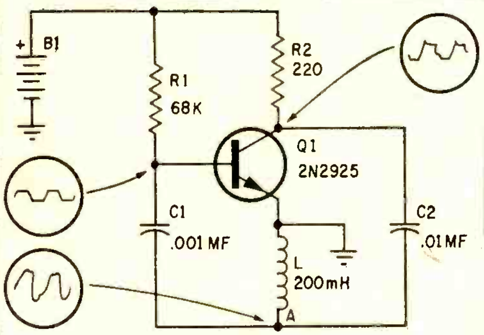


Fig. 5. Hartley-dual circuit has C1, C2 in series as a split capacitor from base to collector.

PARTS LIST

C1—0.001-uf capacitor (Cornell-Dubilier WMF1D1)
C2—0.01-uf capacitor (Cornell-Dubilier WMF1S1)
L—200-mh (Miller 9008 adjustable inductor)
Q1—2N2925 transistor (General Electric)
R1—68,000-ohm, ½-watt resistor
R2—220-ohm, ½-watt resistor
B1—6-volt lantern battery (RCA VS040S screw)
Misc:—Perforated phenolic board, terminals, hook-up wire, solder.

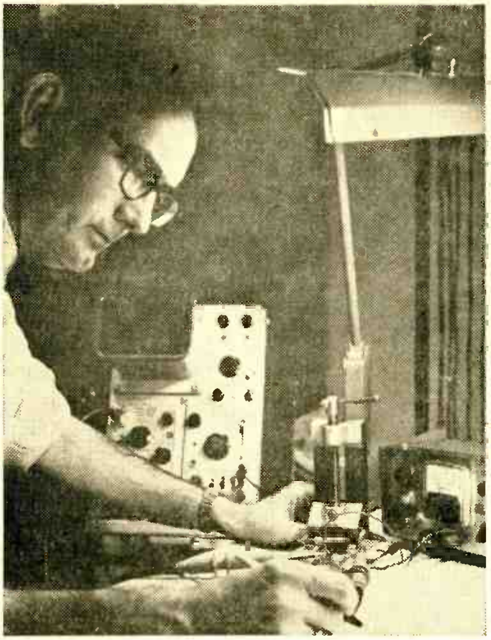
The Hartley Oscillator Dual. Let's begin with the simple circuit of Fig. 5 in which we've drawn the oscillator in the more conventional form of schematic diagrams. Note that C1 here corresponds to C in Figure 4(b), and C2 is *n* times bigger than C1.

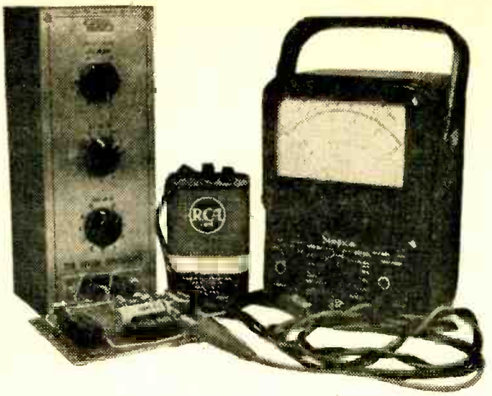
There should be no problem in laying these components out on a terminal board. The board was cut from a larger one and it's approximately 3 by 5 inches—more than enough. If you plan to dismantle the circuit and salvage the components after experimenting with it, you can solder in the components without clipping their leads. All you lose is neatness. And it's a good idea in experimental work not to wrap the leads around the terminals, because you may want to change some of the components later. If you don't wrap, they'll easily lift up as the solder melts when you try to remove them.

The transistor is one of those inexpensive plastic jobs, but it's supposed to have a β (beta) between 237 and 470, so it's not exactly a piece of junk. However, the relative position of the emitter, base, and collector terminals on these devices is somewhat different. If you look at it from the bottom end, and so that the flat side faces upward, the base is at the right, the collector in the *middle*, and the emitter at the left.

The coil shown in the parts list is actually adjustable over a range from 65 mh to 300 mh, but for this experiment it was set at 200 mh. If you don't have a bridge available to set it to this value, adjust the slug about halfway. Or, you can use a fixed 200 mh inductor instead if you have one handy.

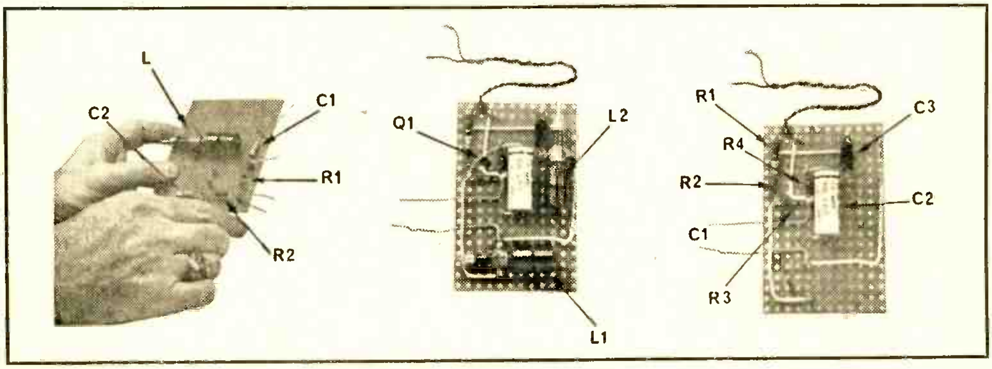
Although a six-volt lantern battery is indicated in the parts list, tests with a variable power supply indicate that the circuit oscillates with supply voltages ranging from less than three to over nine volts. It's also good practice to twist the leads running from the battery to the terminal board to minimize hum pick-up.





Variable-voltage power supply, in front of author (left), powers circuit board held in drill-press vise for convenience. Operation is checked by high-quality DC scope which can also measure DC voltages while looking at waveforms. Simple setup (above) is all that you need to perform the basic experiments in the text.

The parts layout on the phenolic chassis is not critical for the oscillator circuits. For an experiment it is more usual to see parts tacked in with just a drop of solder without squared and clipped leads. Shortened leads often make unused capacitors and resistors useless for other projects that require full-length leads.



After you've wired the circuit and connected the battery, you'll want to know the answers to two questions. Is the oscillator working? And, what is the frequency of oscillation? How you go about finding the answer to these questions depends on what equipment you have available.

If you have an audio amplifier, take the lead that normally goes to the phonograph and connect the shield to the minus terminal of the battery (or to the emitter terminal of the circuit). Turn the volume control on the amplifier all the way down. Then attach a high resistance (greater than 100K) to the circuit at the junction of the two capacitors and the coil (point A in Fig. 5). Connect the inner conductor—the signal input lead of the amplifier—to the other end of this resistor and slowly turn the volume up. You should hear a tone pitched at about 3400 cps for the component values shown in Fig. 5—if the circuit is oscillating.

If it isn't, it's either because you employed a different type of transistor or else a 2N2925 of somewhat different characteristics, try the following changes, *one at a time!*

Increase R1. But if this doesn't work, put it back at its original value and try decreasing R2. This should put you in business.

Of course if the transistor's no good, or the battery's dead, or you wired the circuit incorrectly, you could change those two resistors until you're blue in the face and the circuit will probably never oscillate.

But now that it's working, let's measure the frequency.

If you have a piano or organ available, you can estimate the approximate frequency of the oscillator by comparing the tone to that of the various keys on one of these musical instruments. Fig. 6 shows the relations between key position and frequency. And if you don't have access to either one, you can buy a pitch-pipe at a local music store for less than five dollars. But then you'll also have to lower the frequency of the oscillator by changing components to bring it within the more limited range of the pitch-pipe.

Should you only have a voltmeter available and no amplifier, you won't be able to measure the circuit's frequency. But you will be able to tell whether or not the circuit is working. With the meter set to the ac scale, you should read about 6 volts, if the circuit is oscillating. Otherwise there'll be a big fat nothing and you'd better troubleshoot as indicated above.

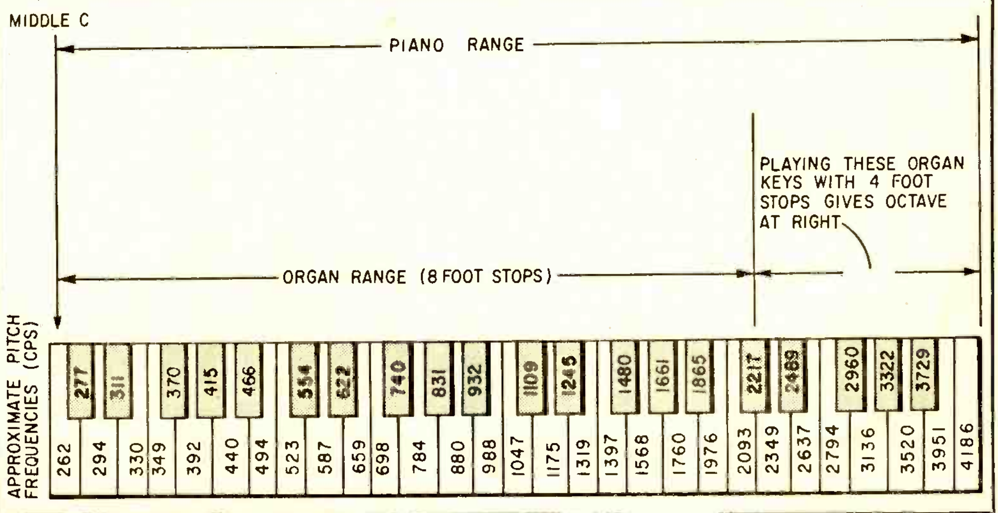
Of course, if your lab has an oscilloscope and audio generator available, you can compare the periods of the generator and the oscillator circuit, by using Lissajous patterns. And if you have this equipment, you probably know how to use it in this manner, so I won't go into that here.

If the scope is available, the approximate waveforms at the key points in the circuit are as shown in Fig. 5. Although the cleanest waveform is found at point A, that is also the point where loading is most severe. If you attempt to drive another circuit with this oscillator, make sure that the other circuit has a high-impedance input. Or if you can settle for a poor square wave, take the signal from the collector. In either event, employ a coupling capacitor.

Changing the C/L Ratio. Let's suppose you succeeded in building an oscillating oscillator. Now you'll need a VOM (voltohmeter) or VTVM (vacuum-tube voltmeter). It will also be helpful if you have a couple of capacitor decade boxes. If not, you can substitute capacitors individually. Solder each in place to be sure you maintain a good connection. (If you notice erratic behavior while conducting these tests, check your solder joints, because sometimes a lead will spring loose before the solder cools and as a result make only intermittent contact.)

What we want to determine in this experiment is what effect the C/L ratio has on the oscillator's performance. So we want to vary the value of the capacitor connected to the base of the transistor (C1), while simultaneously keeping the inductance unchanged. But so that we don't confuse the issue by also changing the frequency, we'll also have to alter the value of the other capacitor (thus effectively changing n in our equation for the frequency). Because the frequency of *this* oscillator is determined by the resonance of the coil and the *sum* of the two capacitors, whenever we decrease (or increase) one capacitor, the other should be increased (or decreased) by the same amount. If this is done, the frequency won't change, but the C/L ratio will.

Fig. 6. Keyboard of piano or organ showing approximate frequencies of keys for use as a frequency standard.



NOVEL OSCILLATORS

So let's replace the two capacitors in Fig. 5 with the decade boxes, initially adjusted so that the base capacitor is set to 5000 Pf ($\mu\mu$f) and the collector capacitor is set to 5600 Pf. (Thus n = 5600/5000 = 1.12) Since the coil is set to 200 mh and the sum of the capacitors is 10,600 pf, the approximate frequency equation in Table A indicates that the frequency of the oscillator will be about 3400 cps.

Now connect the battery to the circuit, and place the ac probe of the voltmeter on point A (the junction of the two capacitors and the coil). If you're using a voltohmeter, the exact voltage reading you obtain will depend on which scale the voltmeter has been set to. This is because of the sensitivity of point A to loading. With the voltmeter on the 2.5-volts (full-scale) range, you should read about 1.2 volts. All of these conditions are summarized in the first row of Table B.

Disconnect the battery and change the capacitor settings so that C = 4000 pf and *nC* = 6600 pf. Now reconnect the battery and you should read an increased voltage at point A. In my case it was up to 1.5 volts. (See the second row of Table B.)

In a similar fashion, disconnect the battery each time and change the capacitor values through the ranges shown in Table B. You'll find that the voltage at point A will increase with each change until you reach a value, for C1, of about 1000 pf. Then as you decrease C1 further, the voltage will start to fall off and you'll eventually reach a value of C for which the circuit will not oscillate when you connect the battery.

Now, which is the best value of C to employ in this oscillator?

Well, ideally, it would be the smallest value for which the circuit will oscillate (C = 600 pf in Table B), because at that value, the C/L ratio is smallest, and therefore the effect

TABLE A—Formulas Used To Determine Frequency

	Frequency Equation	Approximate Form
Hartley Circuit	$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC\left[1 + n\left(1 + \frac{L}{C}\Delta_y\right)\right]}}$	$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC\left(1 + n\right)}}$
Hartley Dual (Z#1)	$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC\left[1 + n\left(1 + \frac{C}{L}\Delta_z\right)\right]}}$	$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC\left(1 + n\right)}}$
Colpitts Circuit	$f = \frac{1}{2\pi}\sqrt{\frac{1 + n\left(1 + \frac{L}{C}\Delta_y\right)}{LC}}$	$f = \frac{1}{2\pi}\sqrt{\frac{1 + n}{LC}}$
Colpitts Dual (Z#2)	$f = \frac{1}{2\pi}\sqrt{\frac{1 + n\left(1 + \frac{C}{L}\Delta_z\right)}{LC}}$	$f = \frac{1}{2\pi}\sqrt{\frac{1 + n}{LC}}$

TABLE B—Changes of C/L Ratio of Components

Column	①	②	③	④	⑤	⑥	⑦	⑧	⑨
Quantity	C1	C2	n	C+nC	L	C/L	freq.	voltage	meter scale
How Computed	—	—	①/②	① + ②	—	①/⑤	—	—	
Units	uuf	uuf	—	uuf	mh	$x10^{-7}$	cps	volts	volts
Test 1	5000	5600	1.12	10600	200	25	3400	1.2	2.5
Test 2	4000	6600	1.65	10600	200	20	3400	1.5	2.5
Test 3	3200	7400	2.31	10600	200	16	3400	3.0	10.0
Test 4	2000	8600	4.30	10600	200	10	3400	4.3	10.0
Test 5	1400	9200	6.56	10600	200	7	3400	5.6	10.0
Test 6	1000	9600	9.60	10600	200	5	3400	6.2	10.0
Test 7	600	10000	16.68	10600	200	3	3400	5.0	10.0

of the transistor on the oscillation frequency is also the smallest. But practically, this choice is too close to the borderline of oscillation, so it's better to increase C slightly to the value that will also give us the strongest output signal. In this case, that's either 1000 pf or 800 pf.

Another interesting aspect of this experiment is the waveform seen at point A, if we observe the signal with an oscilloscope. For the higher values of C (hence C/L ratio), the sinewave is badly distorted. But as we decrease C, the waveform improves considerably—becoming almost a pure sinewave just prior to the value of C for which oscillation can't be obtained.

It should be noted that the numbers presented in Table B were those for a particular transistor. You'll probably encounter somewhat different values, but the general trend should be the same. You should be able to find an optimum value of C which will maximize the signal at point A.

Changing the Frequency. Now that we have an idea of how the C/L ratio affects the output signal measured at point A, let's see what we can do about changing the oscillator's frequency. We'll maintain the ratio of the two capacitors (*n*) at 9, and start varying C. Keep the voltmeter connected to point A to indicate the voltage and, if it's a VOM, set it at the 50 volt scale to minimize the loading. Unless you have a means of monitoring frequency, you'll just have to take my word for it that it does change.

Set the C (C1) decade box at 7000 pf and the *nC* (C2) box at 63000 pf.

Connect the battery to the circuit.

You'll find that the circuit oscillates at about 1250 cps and the voltmeter reads about 4 volts. This is not the most accurate way to read that low a voltage, but we'll sacrifice accuracy to minimize loading. Besides, we're only interested in the trend rather than the actual value. If you compute the frequency using the approximate equation for this circuit in Table A, since C + nC = 7000 + 63000 = 70000 pf and L = 200 mh, you'll see that the circuit should be oscillating at 1350 cps. This is close enough to the 1250 cps measured value.

Now decrease the values of the two decade boxes to 5000 pf and 45000 pf as noted in the second row of Table C. The computed frequency is (50000 pf in resonance with 200 mh) about 1600 cps. I measured about 1560 cps and a voltage at point A of about 5 volts.

If we continue to decrease the capacitor values and take measurements each time, we'll find that the frequency varies as shown in Fig. 7. The graph shows both the computed and measured values for the circuit tested.

Now we've seen that we can change the frequency of this Z-type oscillator in a predictable manner. Although we only varied the capacitors, changing the inductor could also do the trick. But we'll leave the verification of that statement as an "exercise for the student."

Let's now turn our attention to the other basic Z-type oscillator, the Colpitts dual.

The Colpitts Dual. The schematic for this circuit is shown in Fig. 8. We've employed a different biasing arrangement in this circuit. Although it contains more components, its operation will be less critical—less dependent upon the transistor's characteristics.

Capacitors C2 and C3 have been selected

TABLE C

Changes of frequency-determining components while maintaining C/L ratio.

Column	①	②	③	④	⑤	⑥	⑦	⑧	⑨
Quantity	C1	C2	n	C+nC	L	C/L	freq.	voltage meter	
How Computed	—	—	①/②	① + ②	—	①/⑤	—	—	scale
Units	uuf	uuf	—	uuf	mh	x 10^{-7}	cps	volts	volts
Test 1	7000	63000	9	70000	200	35	1250	4	50
Test 2	5000	45000	9	50000	200	25	1560	5	50
Test 3	4000	36000	9	40000	200	20	1670	6	50
Test 4	3000	27000	9	30000	200	15	2000	7	50
Test 5	2000	18000	9	20000	200	10	2440	8	50
Test 6	1000	9000	9	10000	200	5	3570	10	50
Test 7	700	6300	9	7000	200	3.5	4160	11	50
Test 8	400	3600	9	4000	200	2	5550	12	50
Test 9	300	2700	9	3000	200	1.5	6250	12	50
Test 10	200	1800	9	2000	200	1	8000	12	50
Test 11	100	900	9	1000	200	0.5	Won't start		

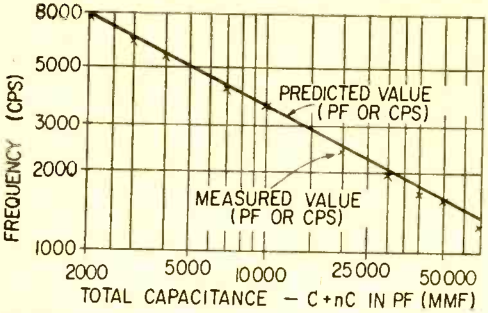


Fig. 7. Frequencies generated by the Hartley dual with calculated (line), measured values (crosses) shown.

to approximate short circuits at the oscillation frequency. The frequency determining components are C1, L1, and L2. The last two correspond to the L and L/n components of Fig. 4c.

If you have a bridge available, L1 and L2 should be set to the values shown in Fig. 8; but if no bridge is handy, set L1 so that the screw protrudes about 5/16-inch from the top of the coil form, and set L2 so that the screw extends about 11/16-inch from the top. This will get you in the right ball park even if the inductance is a little off value.

If the oscillator doesn't start, try lowering the value of C2. When this component value is too large, the oscillation takes place in evenly spaced bursts, or in extreme cases, not at all. This effect is observed most conveniently with an oscilloscope, but it shouldn't be encountered with the components shown.

The approximate formula for the frequency of oscillation given in Table A indicates, that for the values employed in Fig. 8, oscillation should be about 1.9 kc. But the circuit actually operates at about 2.5 kc! If we had employed the more exact equation, however, (assuming we knew the value of Δz) we would find that the computed frequency would be closer to 2.5 kc.

There would have been a closer agreement between the measured value of frequency and that computed using the approximate equation, if larger values of L1 and L2 had been employed in combination with a smaller C1 value.

But let's settle for these values of L1 and L2, and vary C1 to see how the circuit performs. Again, a capacitor decade box is convenient, but you can wire in different capacitor values to accomplish the same thing. I tested the circuit with 14 different capacitor

(Continued on page 113)

PARTS LIST

- B1—6-volt lantern battery (RCA VS040S screw)
- C1—0.07-uf capacitor (Cornell-Dubilier WMF1S68)
- C2—1.0-uf capacitor (Cornell-Dubilier WMF1W1)
- C3—10.0-uf capacitor (Kemet K10C35K)
- L1—300-mh (Miller adjustable inductor 9008)
- L2—150-mh (Miller adjustable inductor 9008)
- Q1—2N2925 transistor (General Electric)
- R1—1500-ohm, ½-watt resistor
- R2—22,000-ohm, ½-watt resistor
- R3—22,000-ohm, ½-watt resistor
- R4—2200-ohm, ½-watt resistor
- Misc:—Perforated phenolic board, terminals, hook-up wire, solder

TABLE D
Capacitance Affects Frequency and Voltage

Column	①	②	③
Quantity	C1	freq.	voltage
Units	uf	kc	volts
Test 1	0.1	2.17	2.5
Test 2	0.07	2.50	2.5
Test 3	0.04	3.03	2.5
Test 4	0.02	4.00	2.5
Test 5	0.015	4.75	2.5
Test 6	0.010	5.25	3.0
Test 7	0.007	6.25	3.2
Test 8	0.004	8.33	4.0
Test 9	0.002	11.1	5.0
Test 10	0.0015	12.5	5.2
Test 11	0.0010	15.4	5.8
Test 12	0.0007	17.8	6.0
Test 13	0.0004	22.8	6.2
Test 14	0.0002	28.6	5.8

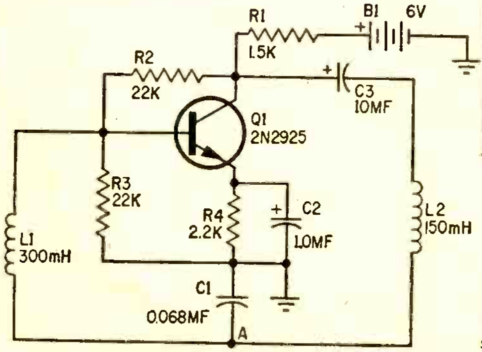


Fig. 8. Although two separate inductances are used in the schematic diagram the effect is similar to normal Hartley tapped inductance.

Solid-State Crystal Calibrator

by A. A. Mangieri

With known frequencies, and their harmonics, you can do an accurate calibration job on most equipment!

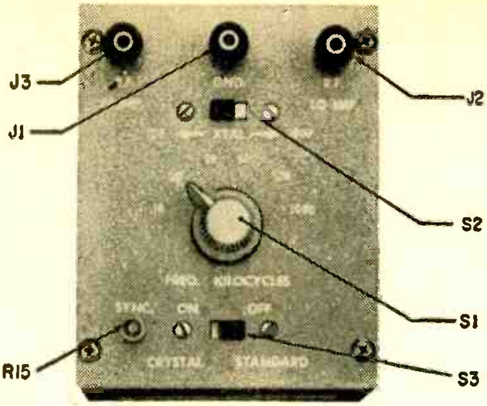
■ Do you ever wonder about the calibration accuracy of your VFO, receiver, or signal generator? Are the dials of that VFO or all-band receiver you just built lacking calibrated scales? Do you operate your ham transmitter near the edges of the band but lack reliable frequency check points? If so, you need this precision frequency standard. Hams, experimenters, technicians, and shortwave listeners alike will find the standard indispensable.

Compact standard provides frequencies of 10, 20, 25, 50, 100, and 1000 kc with harmonics extending well beyond 34 mc. The standard uses a 100-kc and a 1000-kc crystal in a three-transistor circuit. Construction costs are low and particularly so if you have either or both of the crystals on hand. High stability and very low battery drain are additional features of this standard.

The Circuit. Transistor Q1, in the schematic operates as a blocking oscillator. Transistor Q2 operates as a crystal oscillator at either 100 or 1000 kc. Transistor Q3 is the output amplifier. In the blocking oscillator, transformer T1 provides regenerative feedback to the base of Q1 through selectable capacitors C1, C2, C3 and C4. Bias resistors R1, R2, R3 and R4 set the transistor operating points for proper synchronization. Sync potentiometer R15 allows some adjustment to compensate for component aging.

The blocking oscillator is synchronized only with the 100 kc crystal. Sync voltage is taken from the collector of Q2 and fed to the base of Q1 through C8 and R11. A lower frequency blocking-oscillator voltage at the base of Q1 is fed to the base of Q2 through C9 and R12. Mixing action takes place in Q2. At the 100 and 1000 kc positions of S1, the blocking oscillator is inoperative.

In the crystal oscillator, Q2, a mixer-type transistor, has either L1 or L2 connected in its collector circuit as selected by S2. These inductors provide regenerative feedback through their respective crystals to the base of Q2. Trimmer capacitors C14 and C15, in series with their respective crystals, are



Front panel of calibrator contains two switches and a control. R15 is a screwdrive adjustment for sync.

used to zero beat the crystals with NBS station WWV.

Output amplifier transistor Q3, which is not biased, provides very strong harmonics at output jack J3. Output jack J2 provides a lower level marker signal.

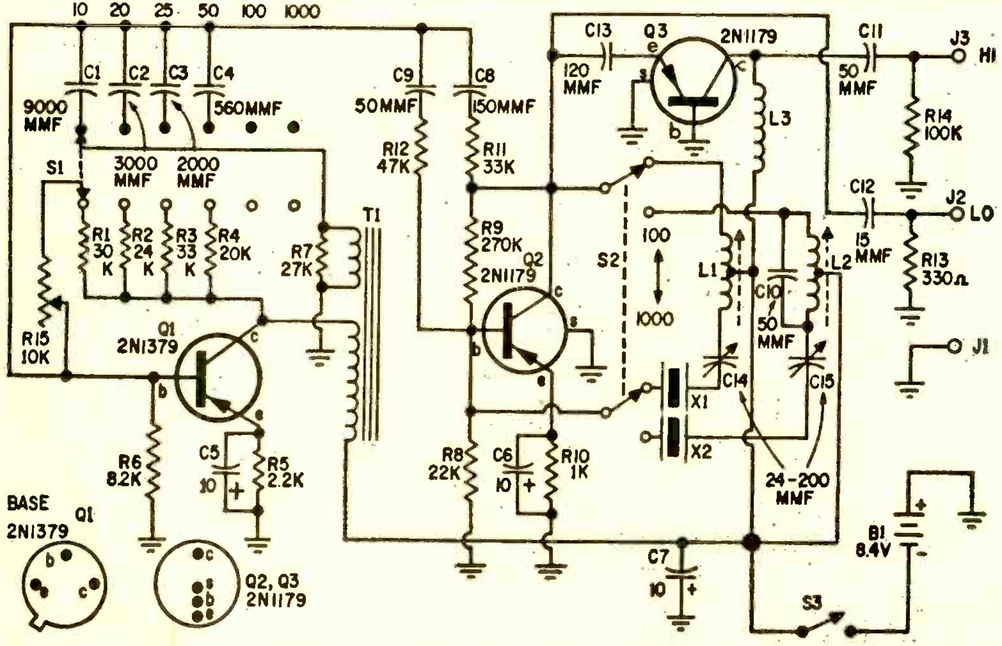
The pulse-like fundamental waveforms of 10, 20, 25, and 50 kc in the blocking oscillator are not observable or available separate from the predominatting 100 kc waveform at the output terminals provided. A scope display will show little change in waveform as S1 is rotated.

If you need the low-frequency pulses for checking scope sweep frequencies or other purpose, they can be taken from the collector of Q1 through a 100-pf capacitor connected in series with a high resistance for isolation.

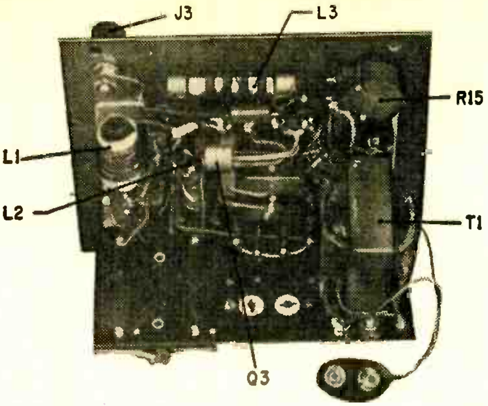
Let's Build It. Construction details are shown in the photographs. Use a $3 \text{x} 4\frac{1}{8} \text{x} \frac{3}{32}$ inch sheet of perforated phenolic board for the chassis along with flea-clip terminals. Mount all parts solidly and wire neatly using insulated solid hookup wire. Trial fit all parts beforehand and allow clearance for the case flanges. Make two L-shaped brackets of $\frac{1}{16}$-inch aluminum to mount the chassis to the panel.

You can omit the crystal sockets by securing the crystals with suitable brackets. Use slip-on terminals removed from an octal socket for terminals.

Wire the chassis removed from the panel as far as possible. Solder trimmer capacitors C14 and C15 on flea clips or use brackets. Slip thin spaghetti insulation on all bare leads that are apt to short. Use long-nose pliers as a heat sink when soldering the transistors and other small parts. Mount Q1 and Q2 on the



Most expensive components are the crystals (X1 and X2) that control the 100 and 1000-kc calibrator frequencies. Accuracy of the 10, 20, 25 and 50-kc signals depends on stability of resistors and capacitors tied to S1.



Internal view of calibrator with crystals removed from sockets shows close spacing of wiring—use spaghetti.

chassis and Q3 on a lug strip located near S1 as shown. Do not install bias resistors R1, R2, R3 and R4 at this time. Wire S2 so that it selects L1 and X1 when switched to the left.

Use fiber shoulder washers to insulate J2 and J3 from the case. Ground J1 to the case. R15, as specified, requires a small knob (a shaft-locking type that was on hand was used here). Mount the battery at any available location within the case using a bracket. Label the panel. Locate and drill screwdriver access holes for adjusting L1, L2, C14, and C15. Check all wiring for errors.

Calibration. Make all initial adjustments with the case removed. Twist four to eight turns of insulated wire (gimmick) around the receiver antenna lead and connect to J3. Connect J1 to receiver ground. Set S1 and S2 to 1000 kc and close S3 to turn power *on*. Set the core of L2 almost fully in and adjust C15 for maximum capacitance. Turn *on* the receiver BFO (beat-frequency oscillator or CW switch). Check for a marker signal at 2, 3, or 4 mc while snapping power switch, S3, *on* and *off*. If absent, re-adjust L2 and recheck.

Tune in WWV at 5 or 10 mc and switch the receiver's BFO off. Adjust the receiver antenna trimmer (adding one externally if necessary) to receive WWV at about S8 (strong). Adjust the gimmick connecting the frequency standard to the receiver antenna for an equally strong signal. Wait for the no-tone period when WWV is transmitting just the one second interval ticks. Decrease the capacitance of C15 slowly and listen for the heterodyne or beatnote whistle. The beatnote will first fall in pitch, pass through zero beat, and rise in pitch as C15 is decreased. Should oscillations cease, re-adjust L2.

Observe the S-meter carefully near zero beat. The needle will vibrate rapidly at first and then slowly fluctuate up and down scale

PARTS LIST FOR CRYSTAL CALIBRATOR

B1—8.4-volt mercury battery (Burgess H146, Mallory TR146)
C1—9000 pf, 500-volt, 5% mica capacitor
C2—3000 pf, 500-volt, 5% mica capacitor
C3—2000 pf, 500-volt, 5% mica capacitor
C4—560 pf, 500-volt, 5% mica capacitor
C5, C6, C7—10-mf, 16-volt electrolytic capacitor (Sprague TL)
C8—150 pf, 500-volt, 10% mica capacitor
C9, C10, C11—50-pf, 500-volt, 10% mica capacitor
C12—15 pf, 500-volt, 10% mica capacitor
C13—120 pf, 500-volt, 10% mica capacitor
C14, C15—24-200 pf trimmer capacitor (Allied 17U082)
J1, J2, J3—5-way binding posts
L1—variable inductor, two windings, 5-40 mh, 2.5-7 mh (J. W. Miller 6316)
L2—variable inductor, tapped, loop antenna, 35-300 microhenries (J. W. Miller 2002)
L3—2.5 mh rf choke (National R-100)
Q1—2N1379 transistor (TI)
Q2, Q3—2N1179 transistor (RCA)
R1—30,000-ohms (see text), ½-watt composition resistor
R2—24,000-ohms (see text), ½-watt composition resistor
R3—33,000-ohms (see text), ½-watt composition resistor
R4—20,000-ohms (see text), ½-watt composition resistor
R5—2,200-ohms, ½-watt composition resistor
R6—8,200-ohms, ½-watt composition resistor
R7—27,000-ohms, ½-watt composition resistor
R8—22,000-ohms, ½-watt composition resistor
R9—270,000-ohms, ½-watt composition resistor
R10—1,000-ohms, ½-watt composition resistor
R11—33,000-ohms, ½-watt composition resistor
R12—47,000-ohms, ½-watt composition resistor
R13—330-ohms, ½-watt composition resistor
R14—100,000-ohms, ½-watt composition resistor
R15—10,000-ohms midget pot. (Mallory Type VW-10K)
S1—2 pole, 6 position rotary switch (Mallory 3226J)
S2—D.p.d.t. slide switch (Wirt G326)
S3—S.p.s.t. slide switch (Wirt G323)
T1—blocking oscillator transformer, 1:4.2 ratio (Stancor A-8111)
X1—100-kc crystal (James-Knight H-93)
X2—1000-kc crystal (James-Knight H-93)
Misc.—3 x 4 x 5-inch aluminum box (BUD AU-1028-H.G.) 50k pot., perforated board, flea clips, knobs, hardware, etc.
Estimated cost: $25
Estimated construction time: 12 hours

as dead zero beat is approached. In the absence of an S-meter, listen for the rise and fall, or swishing, of the intensity of the background noise. One fluctuation or swish per second at 10 mc means that the error is only one cycle in ten million cycles or 0.00001 percent.

Next, set the core of L1 to about midposition, C14 at maximum capacitance, and S1 and S2 at 100 kc. Now zero beat the 100-kc crystal with WWV as was done with the 1000-kc crystal. Adjustment to one fluctuation per second or less is adequate for both crystals.

It may be necessary to select more-accurate values for bias resistors R1, R2, R3 and R4, yet to be installed, to account for parts tolerances. Connect a 50k pot to S1 (using small clip leads) in place of R4. Set R15 to the midrange position, S1 to 50 kc, S2 to 100 kc, and S3 to *on*. Disconnect the receiving antenna and couple the standard to the receiver using a gimmick. With the BFO *on,* tune the receiver from 600 to 700 kc or from 1.8 to 1.9 mc.

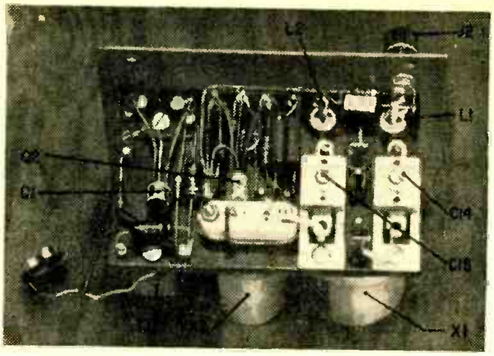
Adjust the 50k pot until the marker signals are received every 50 kc. Then rotate R15 over its range and reset the 50K pot, if necessary, so that synchronization is held over all or most of the range of R15 at 50 kc. Measure this adjusted value of the 50k pot to determine R4.

When not in sync, the blocking oscillator produces a bedlam of unstable whistles on the receiver. When in sync, the signals are equally spaced and perfectly stable in tone.

Similarly, shift the clip leads on S1 terminals to find the resistance settings of the 50k pot which provides frequency intervals of 25, 20, and 10 kc. If you use ten or twenty percent tolerance capacitors for C1 through C4 and are unable to obtain synchronization at the proper frequency intervals, increase the selected capacitor to decrease the frequency and vice versa.

After installing the chassis in the case, retune the crystal adjustments for zero beat with WWV.

Calibrating a Receiver. Set the XTAL switch to 100 for the 10 to 100 kc output and to 1000 for the 1000 kc output. Use post J3 (HI) for a very strong signal and J2 (LO) for a moderate signal. Connect J1 to ground. Use a small trimmer or gimmick between the output terminal and the receiver to reduce signal strength to avoid blocking the receiver with excess signal. Frequently, a short length of wire connected to J3 will provide enough signal with no connection to the receiver.



Bottom view of calibrator. Holes in side of case will allow final adjustments to be made after closing unit.

Use only enough coupling to provide an S7 to S9 signal. Otherwise, depending on the selectivity of your receiver, you will find image signals on the receiver dial at odd frequencies, particularly on the high bands. Good receiver shielding and good grounding of the standard and receiver will prevent stray signals from getting into the receiver IF amplifiers.

If the marker signals are swamped by QRM (noise), remove the antenna lead from the receiver when spotting the dials. If the 10 kc intervals are too crowded on the 10-meter band, simply switch to the larger intervals provided for this purpose. To avoid operator errors, always use the largest interval suited to the intended purpose. Note that the 25 kc interval provides precision marker frequencies not available from the 10 kc interval.

Before using the standard, check zero beat adjustments with WWV. In the following, zero beat by audio tone. That is, tune the signal to the midpoint where the audio tone disappears. The error will be about fifty cycles provided the crystals are previously adjusted by the S-meter method. This error can be ignored for most purposes.

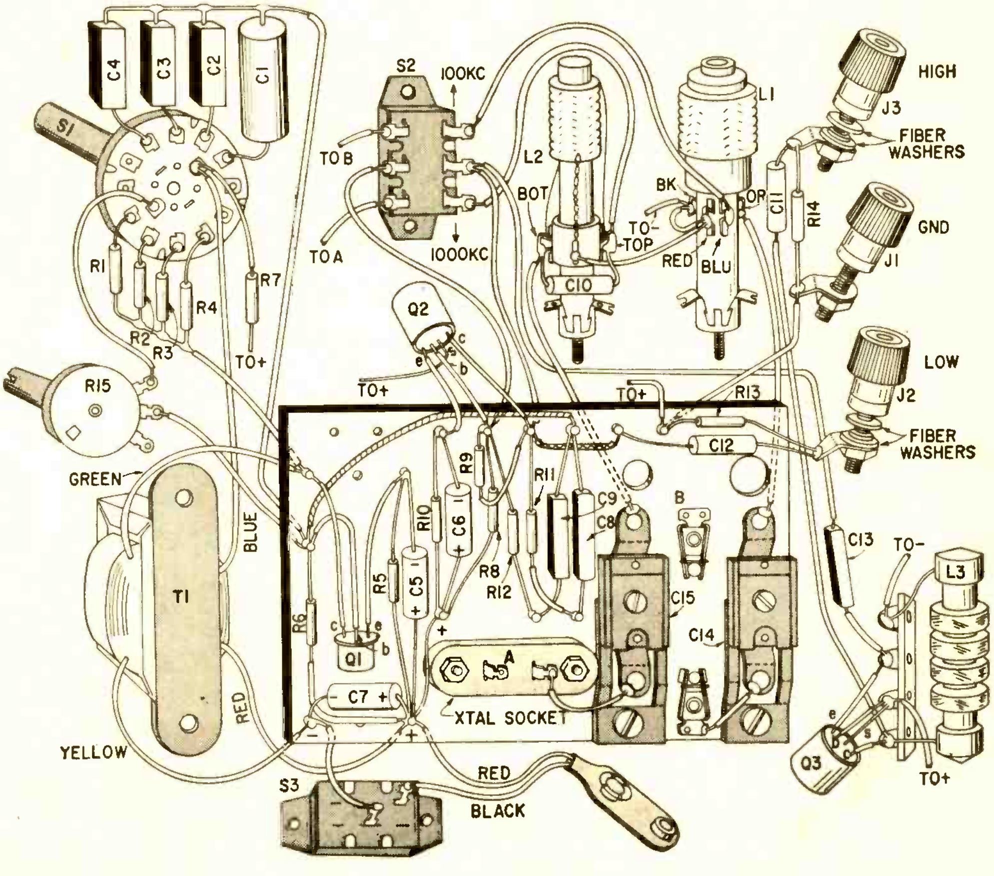
To either spot or check the calibration of the dials of a receiver, always start with the 1000 kc markers and work downwards to the desired interval. With the BFO OFF and selectivity set at a medium value, tune for maximum signal on the S-meter. In the absence of an S-meter, tune for maximum sig-

Completed unit can be stashed in any corner of work-bench; put on a shelf—it's smaller than some VOM's.

nal as indicated by receiver hiss. Then turn on the BFO and set it to zero beat. Allow the BFO to remain at that setting as you tune in the other markers.

To calibrate an unmarked receiver dial, use the above procedure. However, it is necessary to know one frequency on the dial to allow positive identification of the marker frequencies. Any calibrated VFO or signal generator can be used to supply a known point on the dial. Then use the 1000 kc markers which can be identified with respect to the one known point and follow up with the smaller intervals. There is no need to interpolate any of the subdivisions on the dial as the standard provides all required intervals at precise frequencies.

Many SWL's use a general coverage receiver which has a bandspread calibrated for the ham bands. In many cases, it's quite simple to provide a new calibrated scale covering one or more of the shortwave broadcast bands. The new scale may be of heavy paper and attached to the present scale or may be



Pictorial diagram supplements schematic and makes wiring easier for builder laying out phenolic chassis.

made of a suitable plastic to replace the present scale. The settings of the main dial, corresponding to each of the new bandspread scales may be marked on the new scale or recorded. The calibration procedure is the same as that used to calibrate an unmarked receiver dial previously detailed.

Align a receiver by the usual methods or follow manufacturers instructions. Use the harmonics from the standard in place of the fundamental frequencies usually specified. Since the marker signals are not modulated, use the S-meter as an output indicator. Or, connect a VTVM set to a low DC range across the second-detector diode-load resistor. Since odd IF frequencies of 455 or 465 kc are not available from the standard, use a standard signal generator to align such IF amplifiers. Use the 50-kc marker to align a 50-kc IF stage. Use the harmonics of the 100-kc marker to align a 1600 or 1700-kc IF stage which is already close to the correct frequency. Or, use a standard signal generator first and follow up with a signal from the standard for much greater accuracy.

Having aligned all IF stages, proceed to the RF and oscillator sections. Using the broadcast band as an example, adjust the local oscillator so that the 100-kc markers fall exactly on 600 and 1600 kc and nearly so every 100 kc across the dial. Adjust the oscillator padder or coil slug (core) at the 600 kc point and the oscillator trimmer at the 1600 kc point. Next, proceed to the mixer and RF amplifier sections again adjusting corresponding inductors at the 600 kc point and trimmer capacitors at the 1600 kc point. A double conversion all-band receiver with IF frequencies of 1650 and 50 kc was completely realigned using the standard.

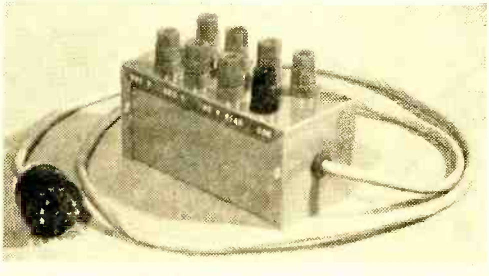
The VFO or RF Generator. To calibrate the unmarked scales of a VFO, you'll need a receiver which covers the frequency range of the VFO. Allow the receiver and VFO to warm up for 15 minutes or more. Then spot the receiver bandspread dial accurately using the standard. Couple about equal signal strengths from both the VFO and the standard, using gimmicks, to the receiver antenna terminal. Tune the receiver to a given known marker signal. Receiver BFO should be OFF. Then tune and zero beat the VFO with the marker by audio tone. Proceed similarly to the next known marker and follow along with the VFO dial. The VFO scale can be marked with pin pricks and finally inked and numbered.

For the Transmitter. If you operate your transmitter near the edge of a ham band or subdivision, use the standard for precise reference points. First, spot the receiver dials precisely in the desired portion of the band using the standard. Turn the BFO OFF. Tune the receiver to the transmitting frequency and note its position with respect to the known markers. When the transmitting frequency is close to the marker frequency, a beatnote will be heard. As an example, if the beatnote tone is 2000 cycles, the transmitting frequency is 2 kc above or below the marker frequency as the case may be. ■

SNATCH-VOLT BOX

PLUG IT IN and pick 'em off when you need 'em. There's no reason why you shouldn't make a slight modification to your TV so you can use the voltage from its power transformer for your experimental work. All you have to do is mount a socket on the TV chassis and build this "snatch box."

Make up a power cable terminating in a plug to match the TV socket on one end, and terminating in a utility box on the other end. Use multi-purpose binding posts (Allied 41H368) which will accommodate banana jacks, test prods or bare wire to be able to quickly and easily connect power to test circuits. Mark the voltages on the box and start making your work easy. If you wish, add a few electrolytic capacitors to the plate voltage terminals in the Snatch-Volt Box to eliminate voltage spike pickup from the TV. ■



An 11-prong plug is shown here, but you can use any plug and socket combination that is available, and has sufficient prongs to give you a good range of voltages.

Tooling Up

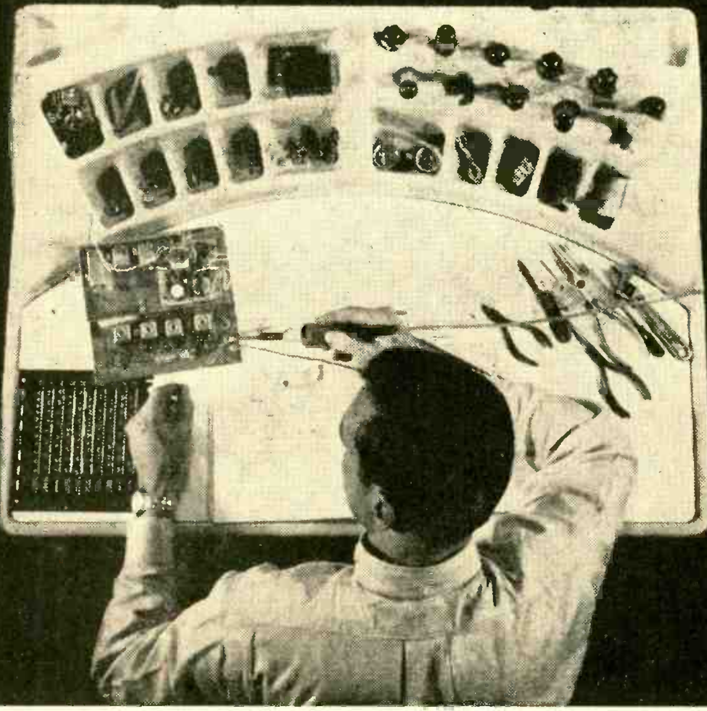
by Herbert Friedman

W2ZLF

It doesn't take a ton of tools to build electronics projects—but specialized tools make things easier.

■ There is nothing that equals the pride and general feeling of satisfaction one gets when he completes a kit or project—and it works the way it should right off the bat. Trouble is, modern kits, and even projects, have become so complex that it's often difficult to build them, let alone get them working.

Think back just a few years, remember the early kits and magazine projects? They had a handful of parts, used simplified circuits, and generally were assembled on a chassis large enough to park two Lincolns and a Volkswagen. As for getting them working, the most complex project was a four-tube oscilloscope, and not much could go wrong other than sloppy connections. In fact, all kit manufacturers claim that the majority of complaints stem from incorrect or sloppy connections. Okay, you claim you're the world's neatest wirer; well, that's not the answer to getting modern kits and projects working. Unless you've kept your shop up-to-date with the latest tools and



e/e TOOLING UP

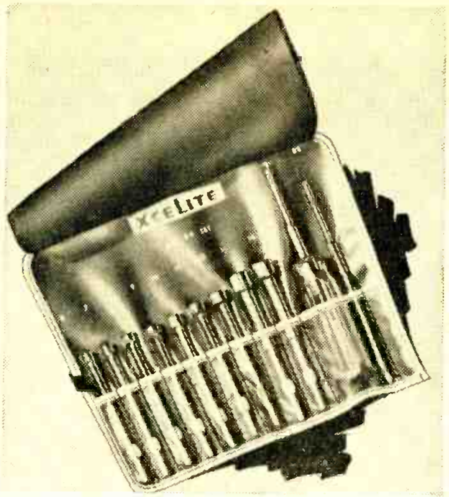
techniques a modern kit or project may turn out to be a lifetime of troubleshooting.

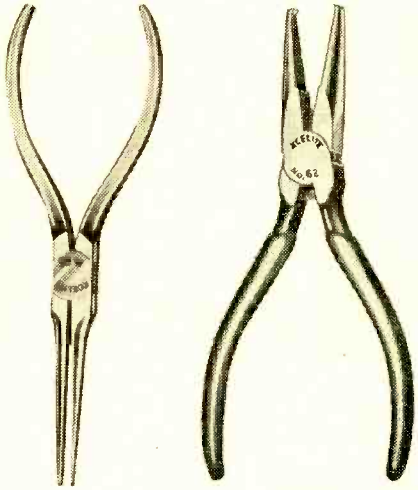
Take a look at the modern kits. First off, they're no longer especially simplified for the inexperienced builder. The latest kits (and projects) are often part-for-part copies of complex wired equipment. And they're not spread out on a gigantic chassis. Most likely, the kit uses a few printed-circuit boards with miniature components—and the whole thing is slightly larger than a postage stamp. Of course, you might get lucky and select a metal chassis kit—two thousand components on a 2 x 3-inch chassis. Another thing going against you is the hardware and the total number of components. No longer do you get a bag with some machine screws and nuts; you get a small hardware store, like five different lengths of #6 screws, four sizes of nuts, pulleys, split, "C" and internal tooth lockwashers; angle brackets; chassis brackets; pulley brackets; and on, and on, and on. In fact, the modern kit is primarily *a hardware kit*, and the question is: Which is more difficult, locating a #6 5/16-inch screw in a pile of #6 quarter-inch screws, or locating a single 22-ohm resistor out of assorted values like 220, 2200, 22,000 and 220,000 ohms.

Add up the problems of miniaturization, critical wiring for complex circuits, and infinite hardware and components—you'll see that now you can no longer dump the contents of a shipping box on a table, grab the trusty old *thumb burner*, and then hope everything works out. Modern kits and projects require modern techniques if you expect to get the performance you paid for.

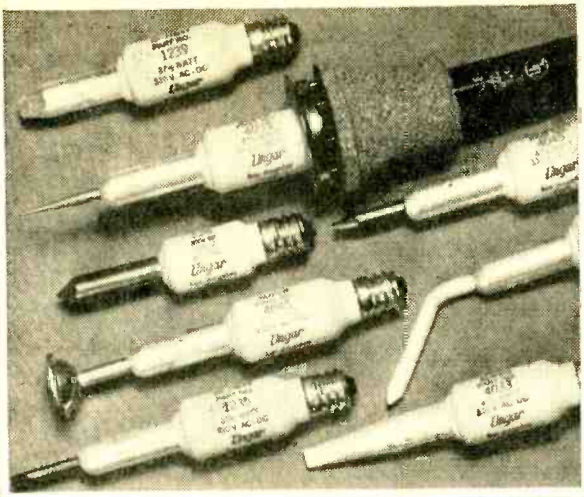
Organization. Modern construction starts with organization; you can't sort the parts on dishes and cups cause you'll have nothing to eat off—there are just too many parts. So the first thing is to sort *and store* the components so you can get the correct one without confusion, and the best sorter to come along in years for the builder is the D.E.C. Associates' *Opti-Man Hobby Center* shown on our cover.

The *Hobby Center* is made of plastic—it's 27 inches deep and 36 inches wide—just the right size for a table or desk. As you can see, it consists of many large storage compartments, tool racks angled so the hand

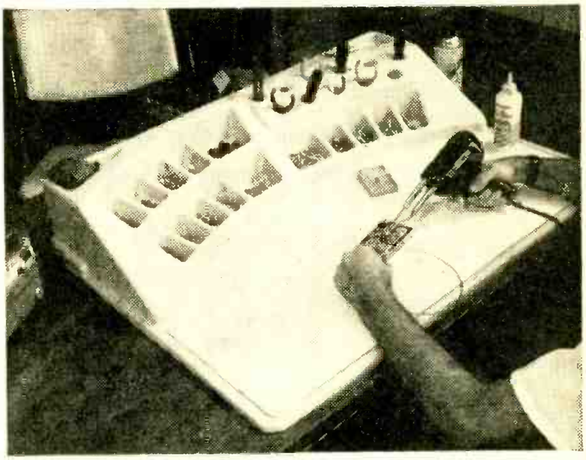




Tool roll (top) contains most popular sizes of nut drivers (socket wrenches) as well as two sizes of the regular and Phillips screwdrivers on double-ended blades. A single handle fits all — it takes up less room where storage space happens to be limited. Needle-nose pliers (center, left) are just an extra-thin long-nosed chain plier. The end-cutters (above) make it easier to trim off lead ends after soldering. They are a specialized electronics tool as are the chain-nose cutter combination pliers at left.



Plastic handle accepts a variety of screw-in tip and tiplets. Chisel tip and element with thread-in pencil tiplets are most popular for electronics soldering. This lightweight soldering tool is used on many production lines. Soldering gun (below) heats up and cools rapidly. It's great for those quickie soldering jobs that are completed fast. Chassis or knockout punch (lower left) come in a great number of sizes and shapes—round, square, D-shaped and notched or keyed for special sockets. Most hobbyists can get by with the few sizes needed for tube sockets—the 7,9-pin miniatures and octal sockets are the most frequently used in projects. Hobby-Center (below) provides smooth top for work area while protecting the table and providing bins for components, hardware and hand-tool storage.



can easily grab the tools, and a white work area (you can't lose a part dropped on a white background). The storage compartments are of varying sizes, and except for large chassis parts you can store practically all switches, pots, etc. used in virtually any kit or project. The compartments are rather deep, so there's no problem of the components spilling out. But the best part of the *Hobby Center* is that you don't have to spend half your time packing and unpacking the project. When you're finished working you simply pick up the entire assembly—storage compartment and attached work top —and slip it all into the closet, with everything right in place when you're ready to start work again.

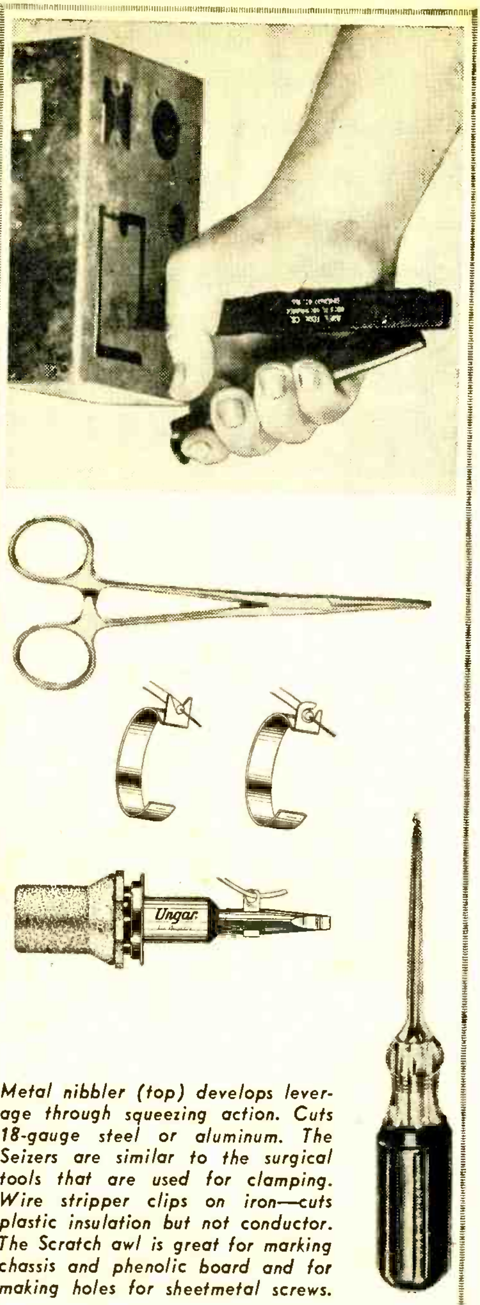
Construction. Next, it's on to the actual construction. First thing you'll notice about the new components for home-brew projects (not necessarily in kits) is the large number of imported components with nuts that fit none of the sockets of American made wrenches. True, you can crank away with long nose pliers until you've got a round nut but you can also ruin a five-buck meter that way. Best idea is to run down to Honest Harry's Auto Supply Shop and latch onto a set of *metric-size wrenches*—wrenches sized to the European metric system. And don't worry about wasting money on wrenches you'll use only once a year, for with metric size wrenches you'll be able to tackle service jobs on imported auto and home radios, and tape recorders (among other items). You'll find that Honest Harry's metric-size wrench kits—which are priced at least three times what they're worth—don't include the miniature sizes needed for the miniature headphone and recording jacks used on transistor radios and tape recorders; but these sizes are available at your local dealers from standard stock.

Another special hardware tool you'll need is a *holding screwdriver* for the screws the kit manufacturers pack into the tightest corners. Best bet here is the split-blade type, where you push down a collar that expands the tip.

For routine assembly you'll need only the standard tools: a full socket-wrench set (from 1/8 to 1/2 inch; three screwdrivers, one with a 1/8-inch blade, one with 1/4-inch and one with 3/8-inch (if you're going to tackle a big transmitter better add a heavy-duty screwdriver for mounting the power transformer); a pair of long nose (needle nose) pliers and heavy duty side cutters like electricians use.

If you're going to specialize in transistor projects, you'll need special needle nose pliers, and diagonal cutters. The average needle-nose plier, will not grasp the fine leads used on modern transistors and diodes, so add a plier whose jaws *you can see* (don't get this one mail order) come flat together. Then add a very small set of tip cutting pliers that won't mash a handful of components when worked into a tight corner. Don't overlook tweezers and other surgical-type instruments.

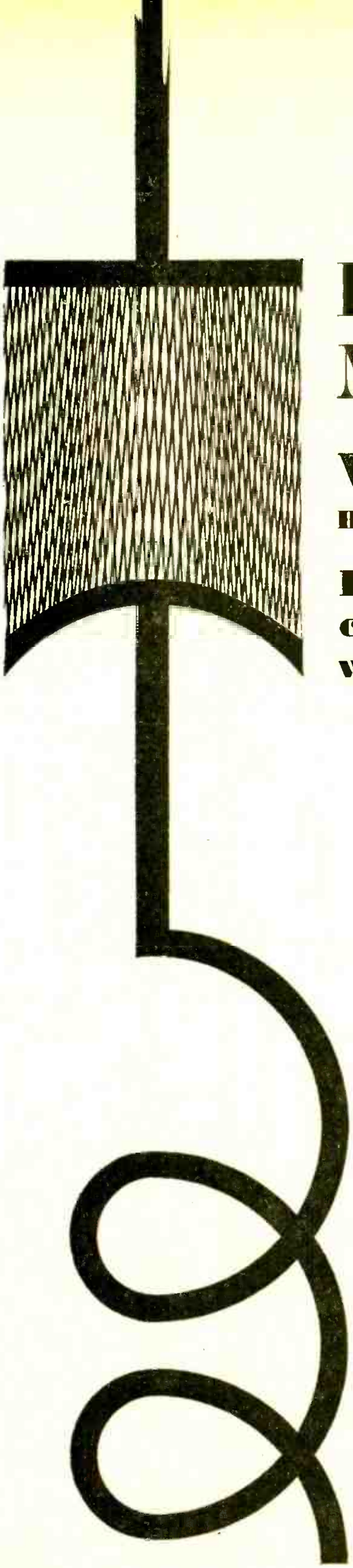
You'll need *two* soldering irons: one for building the kit and one for servicing. All modern projects use tie points for connections so you'll never need a heavy iron to "mash" components to the chassis. More than likely you'll be working with printed-circuit boards and solid-state devices, both of which are easily damaged by excess heat. So chuck that old *thumb burner* and latch onto one of the new pencil-tip irons rated about 50 watts. For repairs, forget about heating a connection till everything runs like molten metal—that's a sure way to either burn up a few transistors or accumulate enough solder on a printed-circuit connection so it runs and short circuits a few printed leads. The modern way to desolder is with a *solder shlurper*—a pencil-size iron with a hollow tip attached to a rubber suction bulb. You place the hollow tip on the joint, release the bulb, and *all* excess solder is *shlurped* off the connection. It even leaves an empty lead hole on a printed-circuit board.



Metal nibbler (top) develops leverage through squeezing action. Cuts 18-gauge steel or aluminum. The Seizers are similar to the surgical tools that are used for clamping. Wire stripper clips on iron—cuts plastic insulation but not conductor. The Scratch awl is great for marking chassis and phenolic board and for making holes for sheetmetal screws.

While the above can be considered a basic tool kit for building kits and projects there are several low-cost items which take all extra effort out of construction. First, there's our old friend, the 1/4-inch electric drill—which is a lot more useful than for just drilling holes. Equipped with a miniature grinding wheel you can deburr chassis cut-outs,

(Continued on page 114)



LC Measurements with a GDO

By Donald E. Bowen

Find small inductance and capacitance values easily with two simple test jigs!

■ All too often, an experimenter becomes discouraged and leaves a project half finished because his test facilities are inadequate. This is especially true of RF projects, because RF test instruments are specialized and expensive. In fact, most well equipped hobbyists have little more in the way of RF test equipment than a grid-dip oscillator (GDO), a service-quality signal generator, and possibly a home-brew frequency meter, a vacuum-tube voltmeter (VTVM) with a set of probes, and perhaps an oscilloscope complete the list.

Testing RF circuits and components is easier than you think. Expensive instruments are not required to perform satisfactory tests. In fact, by building a few simple test fixtures to be used with existing test equipment, you can perform almost any test you can imagine.

Among the more common tests are measuring small values of inductance and capacitance frequently found in RF circuits, and measuring circuit Q. This article describes a simple test fixture for use with a GDO to perform tests. Nomographs accompanying the article minimize the need for grinding out arithmetic, each time for the final result.

How It Works. Capacitance and inductance in parallel form a resonant circuit. Frequency of resonance (*f*), inductance (*L*), and capacitance (*C*) are related by the formula $f = \frac{1}{2\pi\sqrt{LC}}$ An *LC* circuit will absorb power from any nearby RF source (such as an oscillator) operating at the resonant frequency. This is the principle of the absorption wavemeter and grid dip oscillator. The indicating frequency meter operates on a similar principle, that of measuring the voltage induced in the resonant circuit. Both principles are employed in the RF Test Fixture.

The Capacitance Test Mount uses a fixed inductance of known value with the unknown capacitor, as the resonant circuit. The circuit is coupled to the GDO coil. Tuning the GDO for a dip indicates resonance. Substituting the known values for *f* and *L* in the resonance formula provides the value of *C*. However, since the value of *L* is fixed, *C* and *f* have a fixed relationship. The nomograph showing this relationship eliminates the arithmetic.

The Inductance Test Set uses a calibrated variable capacitor with an unknown inductance, as the resonant circuit. A detector circuit used with a VTVM indicates the voltage induced by the GDO. A peak voltage reading indicates resonance. Substituting the values of *C* and *f* (at resonance) in the resonance formula provides the unknown value of *L*. *Q* measurements require values of *C* for resonance (C_r), for the low-frequency half-power point (C_{max}), and for the upper-frequency half-power point (C_{min}). Substituting these values in the formula $Q = \frac{2Cr}{C_{max} - C_{min}} = \frac{2Cr}{\Delta C}$ provide the unknown parameter *Q*. The *Q* Nomogram contains the solution to this formula for all values of *C* within the range of this test fixture.

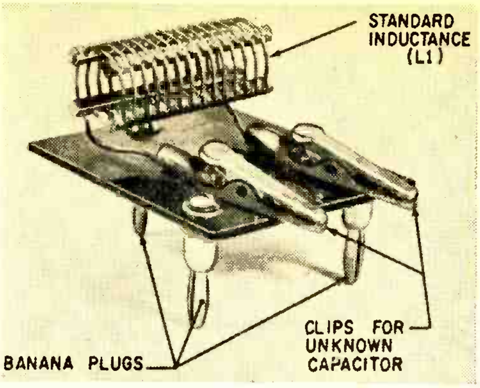
Start Building. Made from a scrap of wood, a few small pieces of sheet metal, miscellaneous screws and nuts, and no more than a dozen components from the junk box, this test fixture is easy to build.

The test fixture is actually three separate items. The Capacitance Test Mount, the Inductance Test Mount and a base—to hold them and the GDO. The base, (see photos), is the foundation to which the GDO and one of the test mounts are attached when tests are being made. Side brackets center the GDO with respect to the test mount. A retaining spring holds the GDO rigidly to the base. You'll have to make some changes if you have a different make GDO. Test mount fittings mate with prongs on each of the test mounts. No electrical connections are made to these fittings.

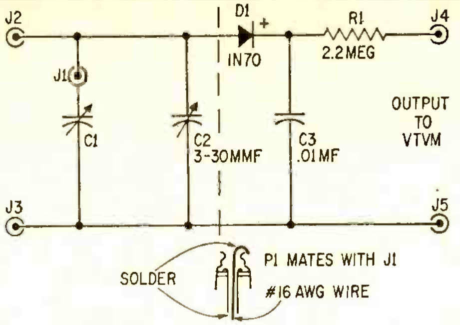
Capacitance-Test Jig. Capacitor tests are performed using the Capacitance Test Mount. This is a standard inductance attached to a mounting plate, which contains prongs that mate with the test mount fittings on the base. Alligator clips are connected to the standard inductance.

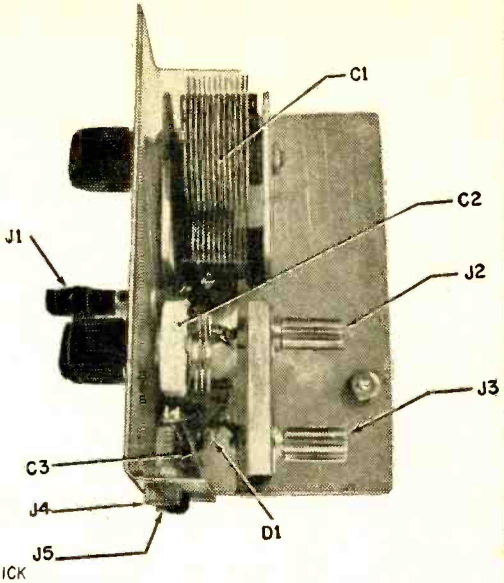
Inductance-Test Jig. The Inductance Test Mount is more complex. It includes a terminal block with J2 and J3 and a panel assembly comprising high-C capacitor C1, low-C capacitor C2, capacitor shorting plug assembly (J1, P1), and RF detector circuit (D1, C3, R1, J4 and J5). The terminal block and panel are attached to a mounting plate, which contains prongs to mate with the test mount fittings on the base.

Base Construction. Basic details of the base and Capacitance Test Mount are evident from the photographs. The base is ½-inch thick wood cut to match the width of GDO. Side brackets are perforated aluminum, used because it was handy and is easy to work with. The retaining spring is a material such as that used for drive belts on 16 MM motion picture projectors. This spring material is available in small quantities (approximately 6-foot lengths) under the

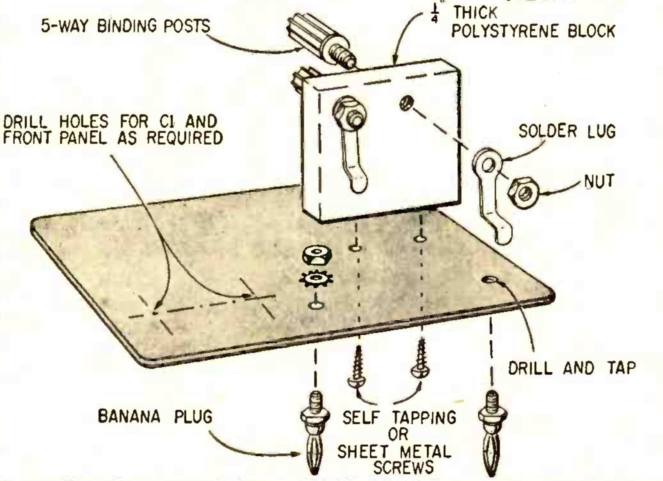


This rigidly mounted air-core inductance can be used to adapt GDO for small-capacitance measurements.





The circuit (above) is quite simple. Standard capacitors C1 and C2 form a parallel-tuned circuit with the unknown inductance. J1 and P1 are used as a simple low-capacitance switch to disconnect or connect C1. The components to the right of the dotted lines are the detector-filter circuitry. Inductance test jig (left) has aluminum panel for shielding. Unknown inductance connects to J2 and J3; VTVM probes connect to J4, J5.



Assembly of the Standard Capacitance is not critical as long as no changes are made after it has been calibrated. If threaded banana plugs cannot be obtained standard type can be drilled and tapped. Thin phenolic board is drilled and tapped to serve as a locknut—preventing plugs from working loose. Stack phenolic for inductance and capacitance jigs and board for base and drill pilot holes through all pieces to assure proper spacing of the holes. A drop or two of cement on the jacks and plugs will be one way to keep them from becoming loose later and getting lost.

trade name Makes-A-Belt, among others. (Also check your local hardwware store's housewares department). Sleeving over the spring protects the GDO from scratches. Test mount fittings are banana jacks.

Capacitance Test Mount. The mounting plate is linen-base phenolic, 1/16 to 3/32-inch thick. The prongs are banana plugs. Replace the colored insulating boot on each plug with a nut—to hold the plugs in the mounting plate. Be sure that the prongs have the same pattern as the fittings in the base.

Use alligator clips for test clips. Attach the clips to the mounting plate with screws. Solder the standard inductance to the test clips as shown. This inductance is 1.2 microhenrys—14 turns of number 18 AWG wire, 3/4-inch diameter, 1 3/4 inches long.

(Continued on page 86)

PARTS LIST

C1—10 to 365-pf., (minimum) variable capacitor (Connect sections of 2-gang in parallel for greater tuning range.)
C2—3 to 30-pf., variable capacitor (E. F. Johnson type 160-130)
C3—.01-mf., ceramic disc capacitor
D1—1N70 or equivalent
J1—Phono jack (must be insulated from front panel)
J2, J3—Binding post (5-way type)
J4, J5—Pin jack (1 red, 1 black) to mate with VTVM test leads
L1—1.2 microhenrys (B & W 3010 Miniductor—see text)
P1—Phono plug—to mate with J1
R1—2.2-megohms, 1/2-watt composition resistor.

Misc—Phenolic stock 1/16 or 3/32 thick; 1/2-inch lumber for base; aluminum stock for panel; spring; knobs and assorted hardware.

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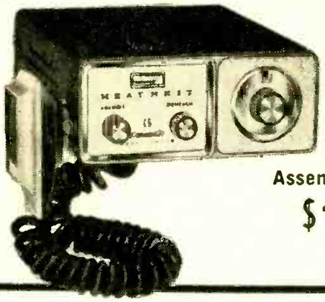
New 23-Channel 5-Watt All-Transistor CB Transceiver



Kit GW-14

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23 crystal-controlled transmit & receive channels for the utmost reliability. Low battery drain . . . only .75 A transmit, .12 A receive. Only 2⅞" H x 7" W x 10½" D . . . ideal for car, boat, any 12 v. neg. gnd. use. "S" meter, adjustable squelch, ANL, built-in speaker, PTT mike, aluminum cabinet. 8 lbs. Optional AC power supply, kit GWA-14-1, 5 lbs . . . $14.95.

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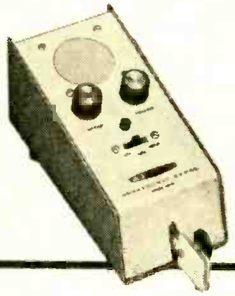

Kit HD-10

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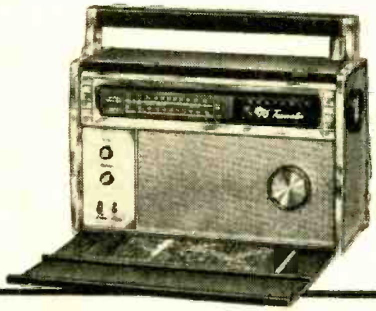
All-transistor circuitry. 15-60 words per minute. Solid-state switching—no relays to stick or clatter. Convertible to semi-automatic operation. Built-in paddle. Self-completing dashes. Variable dot-space ratio. Built-in sidetone. Keys neg. voltages only, such as grid-block keying. Transformer-operated power supply. Fused. 6 lbs.

New All-Transistor, 10-Band SWL Portable



Kit GR-43

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10 bands tune longwave, broadcast, FM and 2-22.5 mc shortwave. 16 transistors, 6 diodes, 44 factory-built & aligned tuned circuits. Two separate AM & FM tuners, two built-in antennas, 4" x 6" speaker, battery-saver switch. Operates anywhere on 7 flashlight batteries or on 117 v. AC with optional charger/converter GRA-43-1 @ $6.95. Assembles in 10 hours. 17 lbs.

New Deluxe 5-Band SSB Ham Transceiver

Kit SB-100

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Full SSB-CW transceive operation on 80-10 meters. 180 watts PEP SSB—170 watts CW. Switch select for USB/LSB/CW operation. Operates PTT and VOX; VOX operated CW with built-in sidetone. Heath SB series Linear Master Oscillator (LMO) for true linear tuning. Mobile or fixed operation with appropriate power supply. 23 lbs. . . Accessory mobile mount, SBA-100-1 . . . $14.95.

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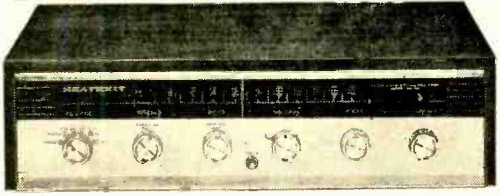
New 30-Watt Transistor FM Stereo Receiver



Kit AR-14 $\$99^{95}$ (less cabinet)

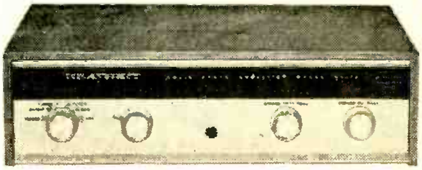
31 transistors, 11 diodes for transparent transistor sound; 20 watts RMS, 30 watts IHF music power @ ±1 db, 15-60,000 cps; wideband FM/FM stereo tuner, two pre-amplifiers, & two power amplifiers; compact 3⅞" H x 15¼" W x 12" D size. Assemble in around 20 hours. Mounts in a wall, or optional Heath cabinets (walnut $9.95, beige metal $3.95). 16 lbs.

Best Hi-Fi News of '66 . . . New Low Cost Transistor Stereo Twins!

New Transistor FM/FM Stereo Tuner

Assembles in only 4 to 6 hours! 14 transistor, 5 diode circuit; 5 uv sensitivity; less than 1% distortion; phase control for best stereo; 4-stage IF; filtered outputs; automatic stereo indicator light; preassembled & aligned "front-end". Install in a wall or either Heath cabinet (walnut $7.95, beige metal $3.50). 6 lbs.

Kit AJ-14 $\$49^{95}$ (less cab.)



Matching 30-Watt Stereo Amplifier

Assembles in 10 hours! 17 transistor, 6 diode circuit 20 watts RMS, 30 watts IHF music power @ ±1 db from 15-50,000 cps; Handles tuner, phono, auxiliary. No audio transformers . . . assures lower distortion, minimum phase shift. Install in a wall, or either Heath cabinet (walnut $7.95, beige metal $3.50). 10 lbs.

Kit AA-14 $\$59^{95}$ (less cab.)

Deluxe 6-Transistor AM Portable!

Kit GR-24 $\$28^{25}$

Surpasses miniatures in performance and economy! Boasts large 4" x 6" speaker for a crisp, bold sound; slide-rule dial; "thumb-touch" controls; smooth vernier tuning; tuned RF stage & double-tuned IF stage for greater sensitivity and selectivity; big ½" diameter rod antenna for distant station pickup; handsome black simulated leather case. Build in 4 to 6 hours. Uses long-life "D" size flashlight batteries (not included). 5 lbs.

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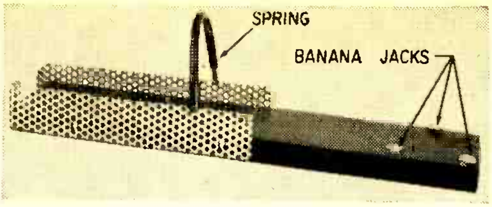
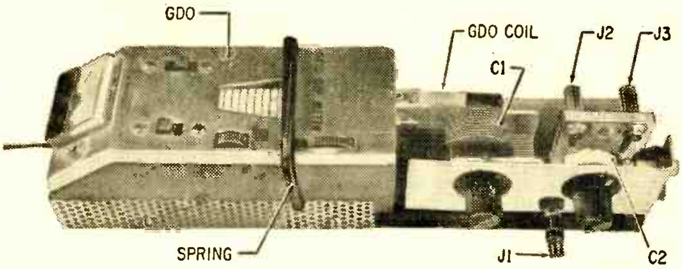
IC MEASUREMENTS

Continued from page 81



Base construction (left) may be modified to accommodate variations in construction of GDO models.



Standard capacitance mounted on the base (left) with EICO Grid-Dip Meter in position to make measurements of millihenry and microhenry inductors of unknown value. Winding your own coils and chokes becomes easy when you need not rely on winding data alone. Measurements are limited only by the frequency limits of grid-dip oscillator.

Inductance Test Mount. Since the accuracy of inductance measurements depends on such factors as stray capacitance and inductance in the test circuit, construction requires extra care. Use large-diameter wire (16 AWG or larger) for interconnections. Keep lead length to an absolute minimum. Use low-loss material such as polystyrene for the terminal block. Although we modified a banana jack for the shorting plug assembly, a standard phono jack and plug can be used as can a low-capacitance switch.

No dimensions are given since they depend on the particular GDO used.

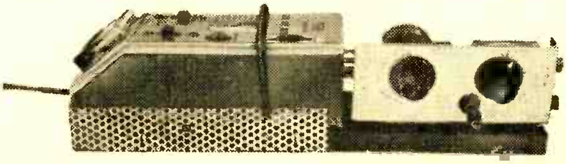
GDO Calibration. To ensure accuracy in making capacitance measurements, just check the GDO for calibration. One way to do this is to spot-check frequencies against a radio receiver of known calibration. For convenience, mark correction factors on the Capacitance vs Frequency chart. This will serve as a calibration chart.

Inductance Calibration. To calibrate the Inductance Test Mount, place the GDO along with the Capacitance Test Mount, in position on the base. Connect the test clips on the Capacitance Test Mount to the terminals on the Inductance Test Mount. Be sure the shorting plug is in place. Set C2 at mid-range. Mark this point 0 on the scale. Set C1 to maximum capacitance. Connect a VTVM to J2 and J3. Tune the GDO to between 6 and 8 megacycles and watch for a peak-voltage indication on the VTVM—this indicates resonance.

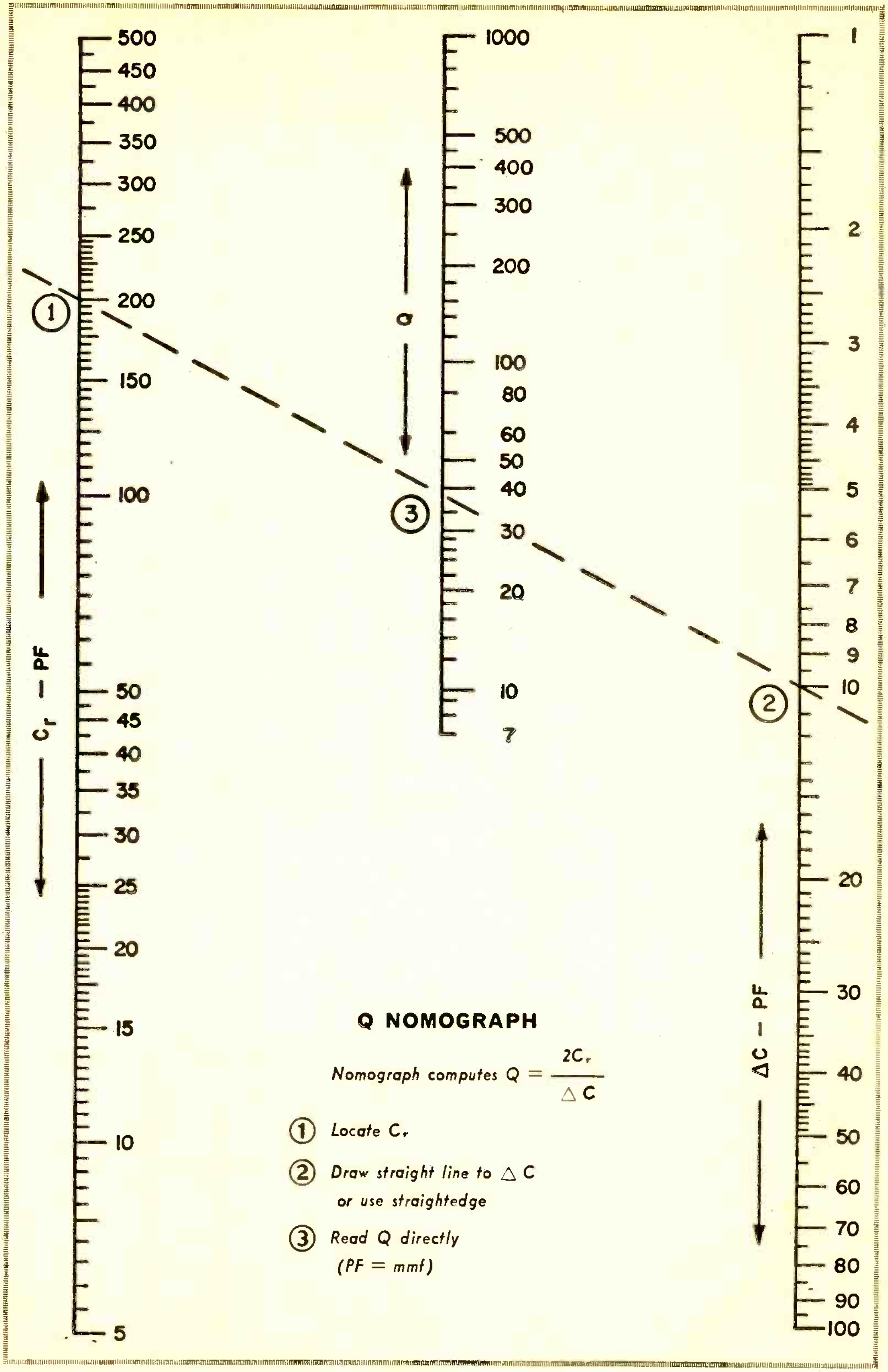
At resonance, check the value of capacitance shown on the Capacitance vs. Frequency chart. Mark this capacitance value on the scale. This is the maximum capacitance for C1. From the Capacitance vs. Frequency chart, determine the frequency required for 10 pf less than the previous value, and readjust the GDO to that frequency. Rotate C1 for resonance. Mark this capacitance value on the scale. Repeat this procedure until the minimum setting of C1 is determined. As the capacitance decreases, increase the incremental change. This is necessary because the frequency-capacitance ratio is nonlinear, unless a capacitor with a *straight-line capacitance* characteristic can be obtained.

To complete high-frequency (HF) calibration, rotate C2 in increments of 1 pf (mmf) in each direction, using the same procedure of supplying the required frequency, resetting the capacitor, and marking the scale. With the shorting plug in place, C1 and C2 are in parallel; therefore, a change in the setting of C2 is either added to or subtracted from the minimum value of C1, depending on which direction C2 is rotated from the zero (midrange) value. Values thus marked for C2 represent an incremental change in the total circuit capacitance. This completes HF calibration.

To calibrate for VHF, remove the shorting plug and rotate C2 to maximum capaci-



Layout of completed unit can be changed to suit your GDO and operating convenience. Vernier dials will make tuning easier but will increase the cost considerably if the most expensive, large-scale units are used.



Q NOMOGRAPH

Nomograph computes $Q = \frac{2C_r}{\Delta C}$

① *Locate* C_r

② *Draw straight line to* ΔC
or use straightedge

③ *Read Q directly*
(PF = mmf)

tance. Tune the GDO until resonance is indicated on the VTVM. Determine the capacitance from the Capacitance vs. Frequency Chart and mark this value on the second scale. As previously outlined, mark this scale for C2 in increments of 1 pf until the lowest value is reached. When this operation is complete, C2 should have two sets of scale markings, one showing incremental values plus and minus from midrange (0), and one showing actual capacitance values from some minimum to some maximum value.

Capacitance Measurements. To measure capacitance, plug the Capacitance Test Mount into the base and set the GDO in position as shown in the photograph. Place the leads of the unknown capacitor in the test clips. Tune the GDO until a dip is observed. Check the frequency at which the dip occurs and read capacitance opposite that frequency on the Capacitance vs. Frequency Chart.

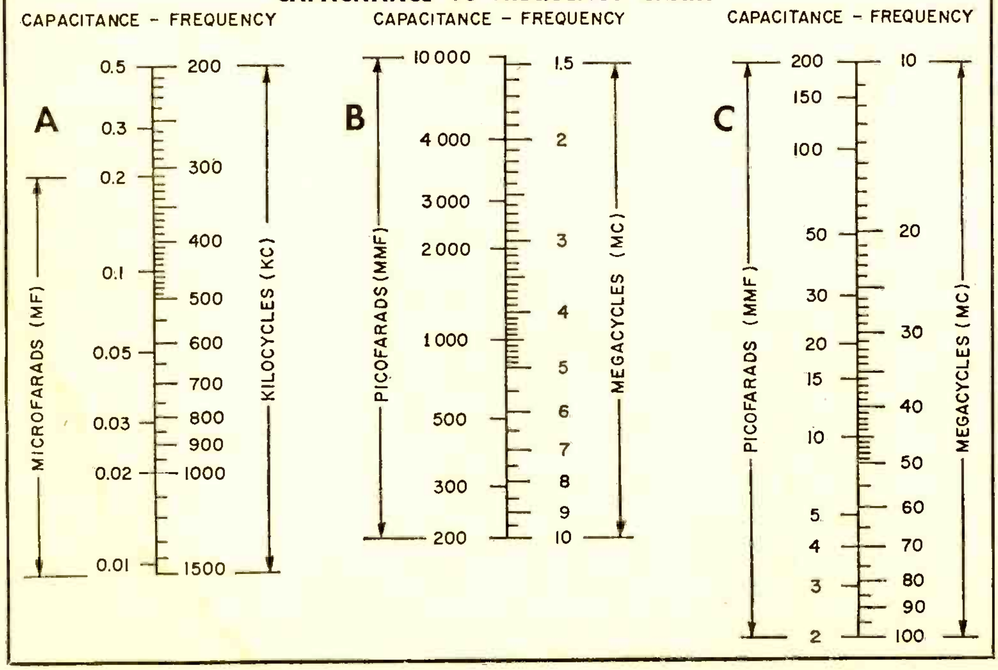
Inductance Measurements. To measure inductance, plug the Inductance Test Mount into the base and place the GDO in position as shown in the photograph. Connect the unknown inductor across the terminals on the block, orient the inductor so that it is in line with the GDO coil. Connect a VTVM between J2 and J3. (Either the approximate frequency at which the inductor will be operated, or the capacitance with which it will be used is usually known. Thus, either operating frequency or tuning capacitance can be selected for the test, leaving the other as a variable.) With either the GDO or the calibrated capacitors (C1, C2) tune until resonance is indicated on the VTVM. Substitute frequency *(f)* and capacitance *(c)* in the formula $f=\frac{1}{2\pi\sqrt{LC}}$ and solve for L.

Q Measurements. This test set employs the delta-C method for measuring Q. One of the advantages of this method over the delta-F method commonly used with a GDO is the fact that measurements are independent of frequency. Also, the variable capacitance used to measure Q is more stable than the signal generated by the GDO. Thus, neither the calibration accuracy nor the stability of the GDO affects the accuracy of Q measurements. To make the job easier, the Q Nomogram eliminates calculations.

Always measure circuit Q at or near the frequency at which the components will operate in the final circuits. To measure Q at frequencies *below 25 megacycles,* use the inductance test mount and the GDO on the base. Connect a VTVM between J2 and

(Continued on page 116)

CAPACITANCE VS FREQUENCY CHART



TUNE IN ON HIDDEN WIRES

by Herbert Friedman

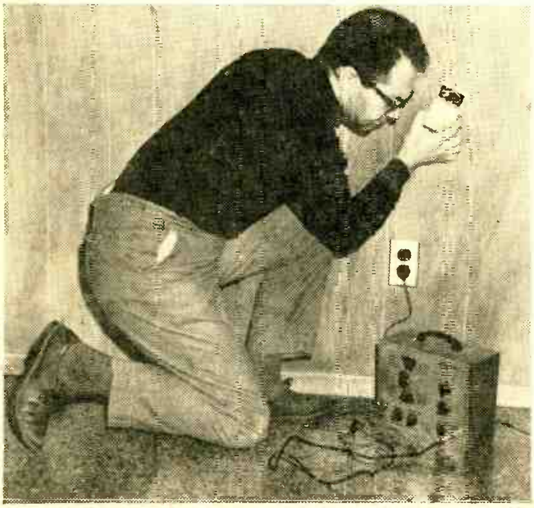
W2ZLF-KBI9457

All you need is a signal generator and a sensitive transistor radio to ferret out the hidden wires for AC power, bell wiring and heating system thermostats

■ You're ready to install an in-the-wall air-conditioner or heater—but where's the electric wiring? Will you cut into the wall only to find you've cut through a cable? Or a circuit goes dead and you want to trace it back to the source—how do you find the cables without chopping the walls? The answer? With a transistor radio and a borrowed signal generator you can trace a "road map" of the house wiring.

Just connect a signal generator—set to any quiet spot on the broadcast band—to a "dead" outlet and tune in the signal with the transistor radio. Now reduce the generator's output level till the signal can just barely be heard when the radio is next to the generator. Place the generator against the wall and sweep it slowly back and forth. When the radio is directly over an electric cable the signal will suddenly increase sharply. (The received signal is the 400-cycle tone from the generator.) By moving the radio along the wall the wiring can be "mapped" with reasonable accuracy.

Keep in mind that even though the outlet is "dead"—whether by removing the fuse or opening a circuit breaker—the signal is transferred to all the house wiring through the junction boxes via the common wire. For example, if the generator is connected to a "dead" basement outlet it will be received in the "live" attic wiring as well as the



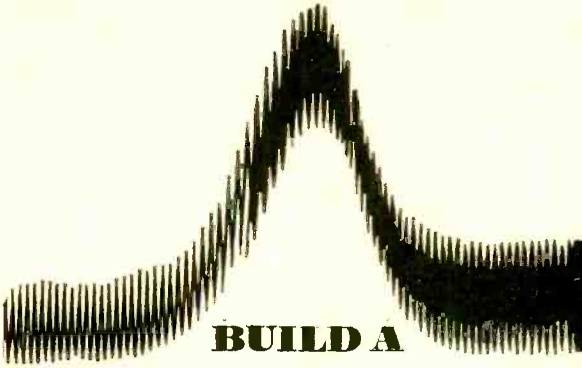
overhead power lines carrying the power to the home and even in the neighboring building.

Remember the signal pickup from wires in conduit and BX cable will be weaker than the signals obtained from wires in Romex and similar nonmetallic sheathed cables. Sometimes the signals will be so well shielded or the transistor radio so insensitive that little or no signal will be picked up from the sheathed wiring.

Before turning *off* the power you should check the outlet to see which opening of the wall receptacle is the grounded contact. The "hot" lead of the generator output cable is connected to one prong of a male plug (top photo)—make sure that the shield braid does not short to the same metal prong when the connections are made to the "hot" generator lead.

If the signal is too weak remove all wall plugs and turn *off* all the switches of appliances and lights that might be permanently connected to that branch of the power wiring. This will reduce the loading on the generator even though the capacitive loading (between the two wires and ground) cannot be reduced.

Connecting the generator to the "hot" lead through the male plug, as shown in the center photo, will reduce the signal to the other branch circuits when you want to trace the wiring as shown below. ■



DC from 150 to 400 volts powers most vacuum-tube circuits easily

BUILD A Regulated DC Supply

by John Potter Shields

■ Here is a bench-top power supply for your experimental projects. It will furnish a continuously variable output voltage with excellent regulation and low ripple. The unit will supply up to 400-volts DC (depending upon load current) with an output-voltage regulation of 1% or better. At its maximum output current of 120 ma. (milliamperes), the supply's output-ripple voltage is a very small 20 mv. (millivolts), peak-to-peak. With a load current of 10 ma, the ripple voltage is less than 5 millivolts. Output terminals on the supply offer both the regulated high voltage and 6.3-volts AC at 2.9 amps. The entire supply is protected against overloads by a self-resetting circuit breaker. Separate switches are provided for the 6.3-volts AC and high-voltage DC outputs so that heater current alone may be applied to the tube in the device being powered by the supply. This feature saves the time normally required waiting for tube heaters to reach operating temperature each time the supply's high voltage output is switched *on* and *off* to make minor circuit changes.

The Series Voltage Regulator. The circuit in the schematic diagram is basically that of a feedback-controlled, series voltage regulator connected to the output of a conventional full-wave rectifier. Before examining the power-supply circuit in detail, let's take a moment to go over the basic operation of the feedback-controlled series voltage regulator.

Fig. 1 illustrates the basic operation of the series-regulator portion of the complete feedback controlled series regulator. The *series pass* tube (V1), has its plate connected to the positive DC-output terminal of the unregulated power supply, and its cathode connected to the external load. The control grid of V1 is connected to the slider of a potentiometer (R1) which is connected in parallel to the bias battery (B).

When R1 is set so that V1's control grid is at the same potential as its cathode there is no control-grid bias and as a result, V1 can conduct maximum plate current with minimum voltage drop from plate to cathode. This will allow almost maximum voltage of the unregulated supply to appear across the external load.

In Fig. 2, the slider of R1 has been adjusted to apply a small amount of negative control-grid bias to V1. The effect of this

Fig. 1. With slider of R1 at the cathode end of its rotation zero bias is applied to V1 and minimum voltage drop appears across V1. (Whenever current flows through V1 some IR drop will occur since V1 will never present zero resistance from plate to cathode.) V1 is just a variable-resistance component that changes value automatically to maintain the output voltage.

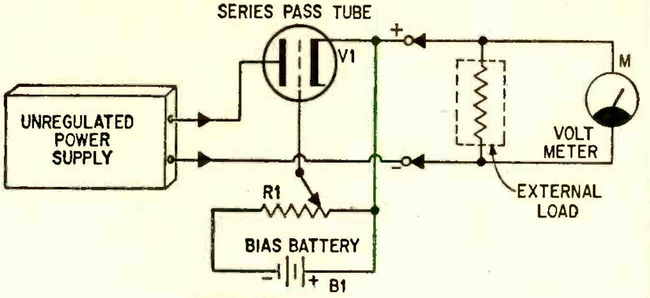
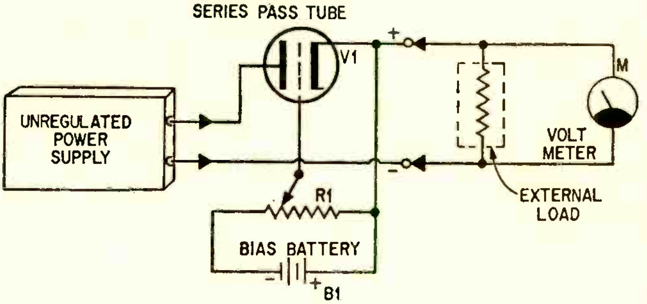
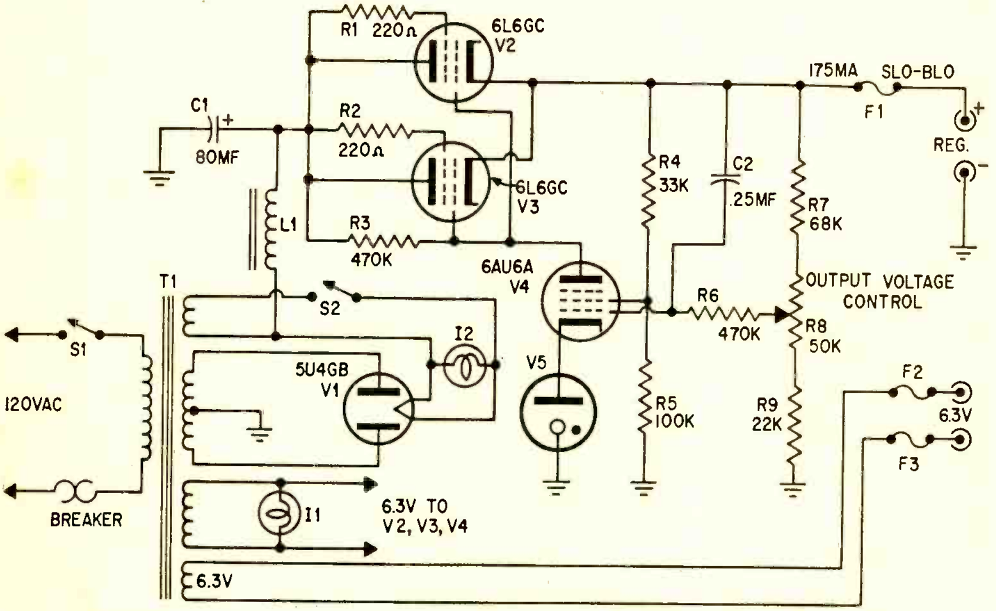


Fig. 2. With slider of R1 at the negative bias-battery end of its rotation maximum negative bias is applied to V1 and minimum output voltage will appear across the external load because V1 has now become a high-resistance element and maximum voltage drop will now occur between the plate and cathode of tube V1.





Transformers with centertapped windings connect L1 to tap on 5U4GB winding—6.3 winding's to its own binding post.

negative bias is to decrease V1's ability to pass plate current and less voltage will appear across the external load—V1's internal resistance has increased. As the negative control-grid bias is increased still further, V1 will pass even less plate current and the voltage across the external load will decrease further as the voltage drop across V1 increases. In effect then, V1 is a variable resistance, in series, between the output of the unregulated power supply and external load . . . the value of V1's resistance being

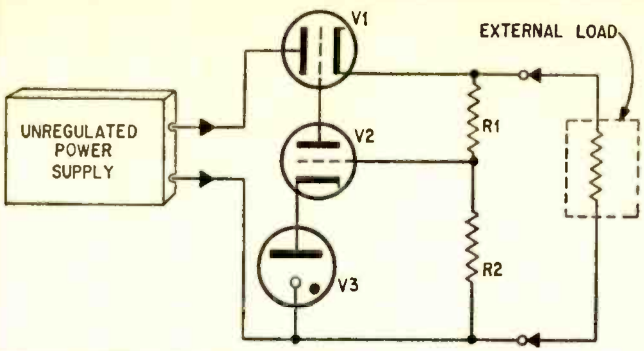


Fig. 3. Voltage-amplifier tube V2 controls power-amplifier tube V1 voltage drop to maintain constant voltage output to external load. Gas-filled regulator tube maintains cathode of V2 at a high positive voltage—slightly higher than that at the grid of V2 which varies with voltage change across bleeder R1, R2 and load.

determined by the amount of control-grid bias.

In the schematic of a simplified feedback-controlled series voltage regulator (Fig. 3, the voltage appearing at V1's cathode is applied to the external load and the voltage divider (consisting of R1 and R2). The voltage at the junction of these two resistors is applied to the control grid of V2—a DC amplifier. Voltage at the cathode of V2 is maintained at a constant value by the gaseous voltage-regulator tube (V3).

Let's now say that, due to a decrease in external-load resistance the voltage across the external load decreases. Since the voltage divider, R1, R2, is directly connected across the external load, the voltage appearing at the junction of R1 and R2 will also drop. This, in turn, will cause V2's control-grid voltage to become more negative (less positive) with respect to its cathode. In turn, this will lower V1's effective internal resistance and more voltage will be supplied to the external load, bringing it back up to its original value.

If the voltage across the external load should increase, the voltage at the junction of R1 and R2 will increase proportionally. This will cause V2's control-grid voltage to become less negative (more positive) with respect to its cathode. In turn, V1's control-grid voltage will become more negative with respect to its cathode and V1's internal resistance will increase, dropping the voltage across the external load back down to its original value.

How It Works. With this basic theory under our belts, let's run through the operation of the actual unit. The DC output of the choke-input filter, full-wave power supply (at the junction of L1 and C1) is applied to the plates of the parallel-connected series-pass tubes, V2 and V3. The cathodes of V2 and V3 are connected to the *Regulated* + output binding post. Voltage divider R7, R8, and R9 is connected across the regulated output of the supply. The *Voltage Control* potentiometer, R8, selects the amount of voltage fed to the control grid of the DC amplifier (V4), and hence, the value of the regulated output voltage. V4's cathode is maintained at a constant voltage by the gaseous voltage-regulator tube, V5. Proper screen-grid voltage is supplied V4 by the voltage divider (R4 and R5).

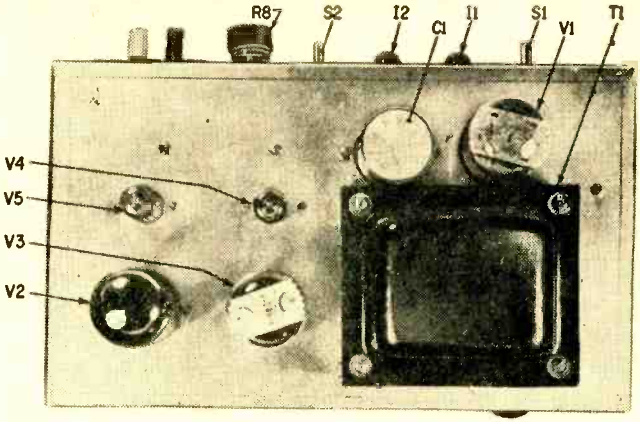
PARTS LIST

C1—80 mf., 500-volt electrolytic capacitor
C2—.25 mf., 400-volt paper capacitor
F1—175 Milliampere Slo-Blo fuse
F2, F3—1 to 5 amps depending on transformer
I1, I2—pilot lamp, 6.3 V, 150 ma. (#47, 1847 or equiv.)
L1—2-henry, 200 ma filter choke (Allied Radio 61-Z-481 or equiv.)
R1, R2—220-ohm, ½-watt resistor
R3—470,000-ohm, ½-watt resistor
R4—33,000-ohm, ½-watt resistor
R5—100,000-ohm, 1-watt resistor
R6—470,000-ohm, ½-watt resistor
R7—68,000-ohm, 1-watt resistor
R8—50,000-ohm potentiometer (linear taper)
R9—22,000-ohm, ½-watt resistor
S1, S2—S.p.s.t. toggle switch (Allied Radio E33-B-542 or equiv.)
T1—Power transformer (see text) 800VCT @ 175 ma; 5V @ 3A; 6.3 @ 2.5A; 6.3 @ 2.5A (Stancor P-4004 or equiv.)
V1—5U4GB
V2, V3—6L6GC
V4—6AU6A
V5—OC2
Breaker—2-amp. Minibreaker (Sylvania) (Allied Radio 34-B-076)
Misc. Tube sockets, Pilot lamp assemblies, wire, solder, 5-way binding posts, chassis, tie strips, fuse holders, etc.

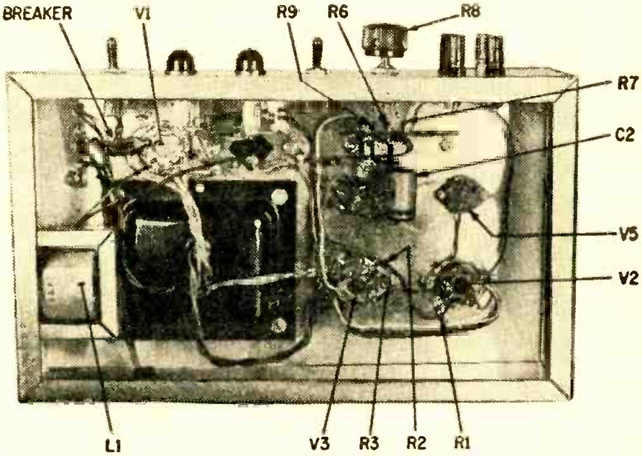
Estimated construction cost: $32.00
Estimated construction time: 5 hours

The plate of V4 is connected to the grids of V2 and V3, with R7 serving as V4's plate-load resistor.

Notice that V4's control grid is connected



Top view of the power supply. It won't hurt anything to leave more space between T1 and C1. V1. V2 and V3 are both 6L6GC's—but by different tube makers. For protection, completed unit should have a cover of expanded or perforated metal. V1, V2 and V3 get hot—glass breaks easily.



Bottom view shows major components. Bottom half of transformer shell was removed for this installation—it makes a neater looking sheet-metal job since cutout is concealed. Rough metal edges can scrape unprotected insulation or winding.

Output voltage control cannot be calibrated in volts because output voltage changes with different loads.

to the slider of R8 through an isolating resistor, R6, and that C2 is connected from the *Regulated* + output of the supply to the control grid of V4. This AC signal coupling greatly reduces the percentage of ripple voltage appearing in the supply's output by coupling the 120-cycle ripple voltage appearing at the cathodes of V2 and V3 back to the control grid of V4. V4 "sees" this ripple voltage as a rapid alternate increase and decrease in load current, and treats it in just the same way.

The power supply is protected from heavy overloads and short circuits by the self-resetting circuit breaker placed in the primary circuit of the power transformer (T1).

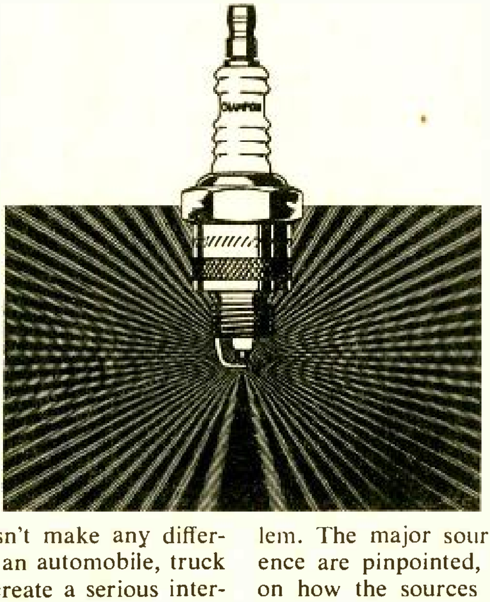
Let's Build One. As shown in the photo, the power supply is assembled on a standard metal chassis. Parts placement is not particularly critical so you can use your own judgment here. As far as component value

(Continued on page 116)

Stamp out ignition hash and generator whine! Don't blame your rig —check your car!

Quieting Ignition Interference

By John D. Lenk



■ Radio-frequency and audio-frequency interference, created by an engine's ignition and electrical system, have been around for a long time. The problem is becoming worse because of engine design changes and increased receiver sensitivity. And it doesn't make any difference if the engine is in an automobile, truck or a boat. It can still create a serious interference or noise problem. Equipment manufacturers have taken steps to combat this noise problem. Some have added shielding and electrical filters to the sensitive portions of the receivers. Most have incorporated squelch and automatic noise-limiter circuits. Effective as these circuits are, they serve only to reduce the noise level — make it bearable. Weak signals below this level simply do not get through the noise and communication range is reduced.

This article provides a "shirt sleeves" approach to the problem. The major sources of engine interference are pinpointed, along with some hints on how the sources may be located. Then conventional remedies to reduce or eliminate such noise or interference sources and how to use the special noise elimination components or kits.

What Is Interference? It can be *any* electrical disturbance that causes an undesirable response, or a malfunctioning of communications receivers or other electronic equipment.

Noise in a receiver is the most common form, but interference may also show up as misleading readings on a boat's depth finder, or as other undesirable signals. Interference can be caused by sources other than the engine, but this is the major problem.

Engine ignition interference can be broken down into two classes or types according to the method by which the interference reaches the receiver.

Radiated interference is unwanted electrical energy broadcast. It is generated by the combined actions of the spark plugs, the distributor, the ignition coil, and the spark-plug wires themselves. This energy can be transferred either by radio waves or magnetic fields. Normally, it is picked up by the receiver antenna.

Conducted interference is noise carried through the electrical wiring and conducted into the receiver by the wiring.

It is not always easy to tell the difference between these two basic types of interference. Quite often the two are mixed. Any wire carrying conducted electrical interference serves as an antenna and radiates this interference. Likewise, nearby wires can pick up radiated electrical interference, and conduct it just as though they were physically connected to the line.

What Causes Interference? The chief culprit in most interference is *sparking*. In the early days of radio the spark-gap was used in radio transmitters. Radio waves were created when an electrical spark jumped across a gap. These waves were picked up by the receiver. By carefully timing the duration of the spark, and the interval between spark, a code was transmitted without the use of wires between the transmitter and receiver.

A gasoline (internal combustion) engine is jammed full of spark-noise sources. Spark plugs, distributor points, distributor contacts, generator brushes, and voltage-regulator contacts all have gaps that electricity jumps in the normal operation of the engine. These parts are divided among three circuits.

First is the high-voltage ignition-coil secondary circuit, consisting of spark plugs and distributor cap contacts. (See Fig. 1.) This circuit is the source of the worst radio interference.

Next is the low-voltage primary ignition

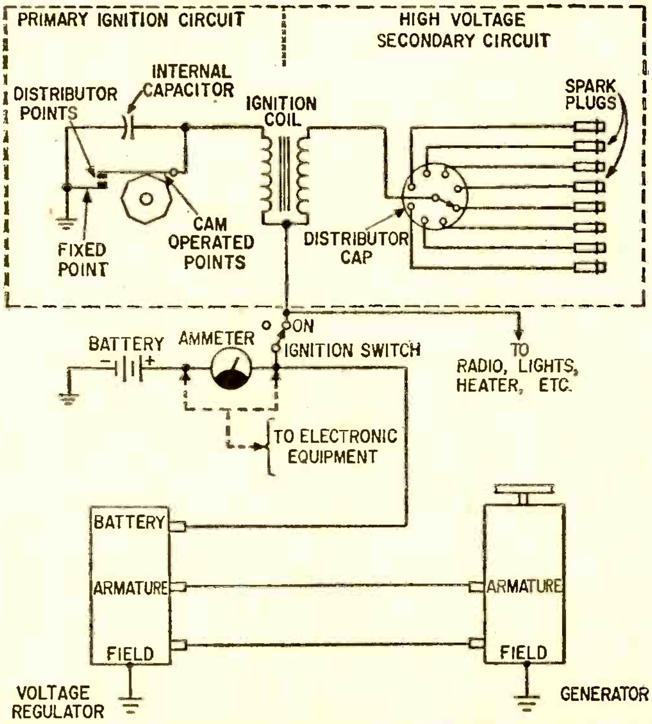


Fig. 1. Basically the circuit of the automotive ignition system has not been changed in 30 or more years. The recent switching to the alternator is greatest change. Electronic equipment connected at point between battery and ammeter will not show as discharge on ammeter. With connection made to ignition switch side, high drain can burn out ammeter.

coil circuit that consists of the distributor cam-operated points, and internal capacitor (condenser).

Finally, there is the battery, generator and voltage-regulator circuitry.

How They Work. The distributor points are opened and closed by a cam at a rate determined by the engine speed. When the points are closed current from the battery (or generator) flows through the ignition switch, distributor points, and primary winding of the ignition coil. There is no current in the secondary circuit at this time. When the points open, the magnetic field in the ignition coil collapses. This induces a high voltage in the secondary winding of the ignition coil.

The coil secondary has many more turns than the primary. A ratio of 50:1 or 100:1 is not unusual. When the distributor points open, the sudden collapse of the magnetic field induces a voltage across the secondary winding that is not proportional to the ratio of turns in the coil. The resulting 10,000 volts passes through the contacts in the distributor cap, and discharges through one spark plug. Consequently, there are two high-voltage arcs or sparks each time the distributor points open—a major one at the spark plug (to fire the gasoline) and a lesser one in the distributor cap.

Radio waves are created whenever a spark jumps between two contacts. In the engine, radio waves are generated in the secondary ignition circuit. They are picked up by most sensitive electronic gear and appear as noise or interference in the speaker or other output.

The primary ignition circuit also produces noise. There is a spark when the breaker points first open. You have probably noticed that a noise (or "pop") is produced in your home radio each time a light or appliance is switched *off* or *on*. In an engine this same noise is duplicated by the distributor points which constantly are being opened and closed. Although the primary-power source of the engine is only 12 volts (against the 120 volts of home wiring), it is direct current which has a much stronger tendency to arc across switches as they are opened.

The specific details of the generator and voltage-regulator circuits vary from engine to engine, but the basic operation of all of them is essentially the same. The generator is driven by the engine, producing a continuous output of direct current (with the help of a commutator) at approximately the same voltage as the battery. The voltage-regulator contacts control the current flow through the generator's field winding. Each time the voltage output falls below the correct operating point, contacts close and short out a resistance in the generator field circuit. The increased current flow increases the generator voltage to normal. The rapidly opening and closing voltage regulator can be a source of noise due to arcing across the contacts.

Generator noise is caused by the spark that occurs between the generator brushes, and the commutator on the armature. Although this spark is normal for any generator, the spark amplitude increases when the commutator segments are worn or dirty, or when the carbon brushes are worn or improperly seated. Naturally, the greater the spark, the more interference will be generated.

Some late-model autos and boats have alternators instead of generators. In this case, the alternator is driven by the engine, producing alternating current instead of direct current. The alternating current is then rectified for use by the battery and the ignition system. An alternator uses brushes and slip-rings instead of commutator segments to make contact with the rotating armature. This results in less sparking and, consequently, less noise interference. However, the ignition system (voltage regulator, distributor and spark plugs) create the same interference whether an AC alternator or DC generator is used.

This comment on dirty carbon brushes and slip-rings brings up the first rule in controlling engine interference. *Keep the electrical and ignition system in top condition.* A well-adjusted and carefully tuned engine creates some radio interference, but a defective or "borderline" ignition system will surely add to the problem. If spark plugs, distributor points, and rotor contacts are fouled, worn, or pitted, there will be more sparking (or a longer spark) that will create more noise. The same is true if generator brushes are dirty, if the spark plug gap has widened, if alternator slip rings are dirty, or if the voltage-regulator points are burned or pitted.

Getting Rid of Noise. Electric arcs (sparks) from any source start undesirable radio waves that can be radiated or conducted into electronic gear. Of course, you could get rid of the interference by stopping the engine or cutting off the generator each time the electronic equipment is used. But this is hardly practical. The problem must be attacked at its source—the engine itself. Four basic methods can be used: arc suppression, filtering, bonding and shielding. We will cover each of these in turn. But before going into the details, let us see how to tell if you have a noise problem.

Making A Noise Test. The easiest way to make a noise or interference test on any engine is to check the noise level of a receiver with the engine running, then check it under identical conditions with the engine off. Try to make the test away from any external noise source such as other engines, power lines, neon signs, fluorescent lights, etc. Turn off the squelch and any other noise-limiter circuits. Adjust the receiver gain until you hear a steady noise level on the speaker. If there are any signals on the air, select a weak signal and adjust the gain until it is barely audible. Then turn off the engine and see if the noise level drops noticeably.

If there is no great change in background noise when the engine is turned off, you do not have an engine interference problem. All is well. Forget the whole thing and count yourself among the fortunate. If you do not note any appreciable change, you may as well start looking for another cause of the noise interference.

Arc Suppression Techniques. Arc-suppression methods are based on three facts: (1) Although it takes a high voltage to make a spark jump across the gap of a spark plug, very little current is needed. (2) The amount of radiated interference is proportional to the current. (3) A high resistance placed in series with the spark plug and the distributor will limit the current to practically nothing without lowering the voltage. Thus, a high resistance in the spark circuit does not affect the spark for firing the engine, but it does reduce the radiated noise in proportion to the reduction of current. In actual practice this is accomplished by installing a suppressor on each spark plug. One is also added in the coil circuit at the distributor.

There are a couple of drawbacks to using suppressor resistors.

First, if sufficient resistance is added to a circuit (by means of suppressors) to eliminate all objectionable interference, current may be lowered to the point where the timing or ignition of the engine may be impaired. Yet the maximum resistance that can be added may not be enough to eliminate all objectional interference.

Another problem with suppressors is that most late-model engines have resistance wire to connect the spark plugs to the distributor cap, and often use suppressor-type spark plugs as well. When suppressors are added to this built-in resistance the net effect is too much resistance, and the ignition system is impaired. So before you install any suppressors, check out the ignition wiring and spark plugs.

The resistance of suppressor-type plugs varies, but should be between 10,000 and 18,000 ohms. If it is much higher than 18,000 ohms, it is possible that the resistance element in the spark plug is defective, and the plug should be replaced. Check all of the plugs, if in doubt.

The resistance of ignition wiring also varies, but is in the general area of 3000 to 7000-ohms per foot for HTLR (high-tension low-resistance) and 6000 to 12,000-ohms per foot for HTHR (high-tension high-resistance) wire. Check all of the leads between distributor caps and spark plugs.

The main point to remember is that *if you already have both resistance plugs and resistance ignition wiring, it is a good bet that suppressors will not do the trick,* and could cause ignition problems.

Once you have decided that suppressors are needed, the next step is to select the right type and give them a try. Various forms of resistors are used to suppress ignition noise. The suppressor shown in Fig. 2 is inserted in the ignition lead; the lead is cut in two, and the ends are twisted into the suppressor resistor. Suppressors that mount on the spark plugs are also available. Such a suppressor is shown in Fig. 3. Installation is quite simple. You only need to pull the ignition lead from the spark plug, place the suppressor on the spark plug, and connect the lead to the suppressor.

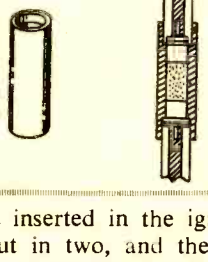


Fig. 2. In-line suppressor makes connection through a screw-type projection that is threaded into cut ends of ignition wire. Defective contacts here can be difficult to find—noise levels are increased and engine-performance degradation are symptoms.

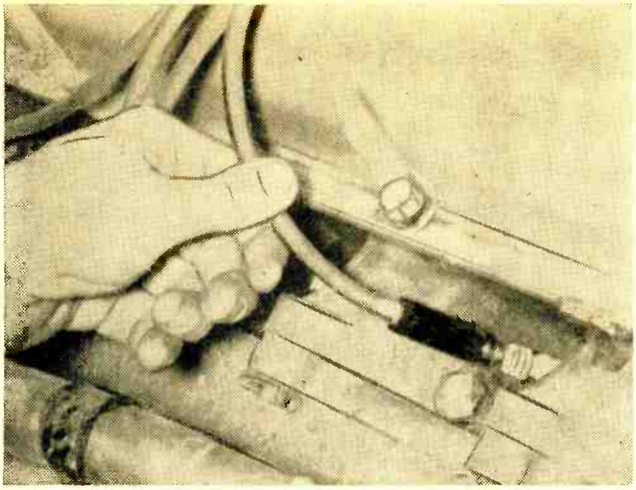


Fig. 3. Plug-in suppressor is easy to install and remove (left) if they are suspected of being defective. Right-angle suppressor fits into top of coil (Fig. 4, above). Rubber covers are removed.

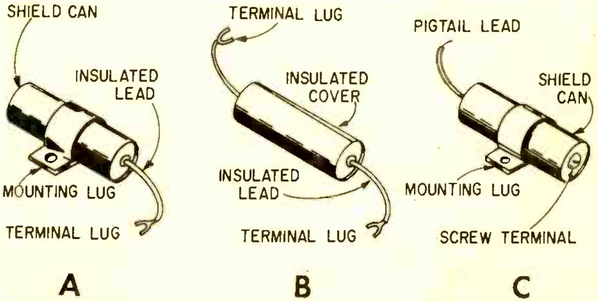
The lead connecting the coil to the rotor of the distributor radiates the most noise. Often adding a suppressor to just this one lead eliminates most ignition interference. Fig. 4 shows such a suppressor installed at the coil end of the lead. Usually, it is more effective to install the suppressor at the distributor end of the lead (this is where the spark takes place), but frequently it is not as convenient to fit it to the distributor cap connector.

Suppressor resistors are available as separate components, and as part of kits. We will discuss suppression kits later on.

Capacitors. Bypass or filter capacitors (or condensers, as most old timers call them) are the most common method of noise elimination. And, except in special cases, are the most effective. A capacitor will remove electrical interference because of its reaction to the presence of electrical currents. So let us indulge in some basic theory. A capacitor of any type has the property of passing both alternating current and fluctuating direct current, but it will not pass pure direct current. If a capacitor is connected between an electrical line and ground, it will provide a low-resistance path to ground for alternating and fluctuating direct currents. Since these are the types of currents produced by the electric sparks, all interference will be routed directly to ground, while the pure direct current will be passed to the battery and power wiring in the normal manner.

The three most common types of capacitors used for filtering are shown in Figure 5. Usually these filter capacitors are in a tubular case and have a capacitance value between 0.1 and 0.25 mf. In the noninsulated type (Fig. 5A) the wire lead is for connection to the hot side of the circuit, and the mounting lug is fastened to a ground screw on the generator, regulator, engine block, etc. To be effective, the mounting lug must make firm contact with clean bare metal (paint or grease removed) and the head of the mounting bolt. The insulated type of capacitor (Fig. 5B) has two leads: one for ground and one for the hot lead. It should be mounted rigidly—not just by the leads. This type of capacitor has lost popularity in mobile systems because it lacks mechanical strength.

Fig. 5. The most common type of capacitor (condenser—at auto parts stores) has a single lead terminated in a lug (A). Ground connection is made through metal case and bracket. Types without mounting lugs (B) are subject to lead breakage from constant vibration and jouncing. The pigtail lead (C) can be fitted with any of the various lugs for proper fit to screw-type terminal on unit.



A feed-thru capacitor (Fig. 5C) is generally used in conjunction with shielding where it is necessary to pass a DC line out of a shielded area. For example, one could be used at a voltage regulator that has a metal shield. The lead to the battery terminal of the voltage regulator could be removed and connected to screw terminal of the capacitor. The pigtail lead would then be connected to the voltage regulator battery terminal. With this connection the current flows through the capacitor from the screw terminal to the pigtail lead—they are internally connected to the ungrounded electrode of the capacitor. The other electrode of the capacitor is connected to the metal-tube shield that is grounded, in turn, to the voltage regulator cover.

One strong word of caution on installing filter capacitors. *Never* connect a capacitor's leads to the field terminal of the generator or voltage regulator. This damages the voltage regulator contacts. There will usually be a tag or decal on the generator stating this. However, the other end of this lead is not usually tagged at the regulator end. As a last resort (if this lead requires filtering), a resistor and capacitor can be connected in series to the field terminal as shown in Fig. 1. The resistor should be 4 to 7 ohms, while the capacitor value should be about 200 pf (mmf).

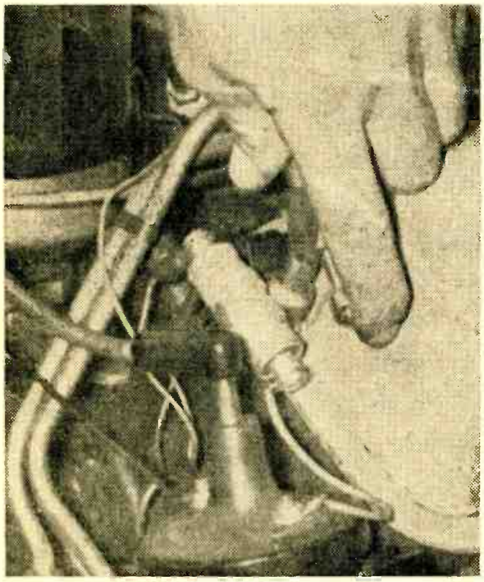


Fig. 6. This feed-through capacitor has screw terminals on both ends—be sure to use toothed lockwashers.

Installing a 0.5 feed-thru capacitor at the battery terminal of the ignition coil (as shown in Figure 6) and another placed at the accessory terminal of the ignition switch have been quite effective in a great many cases. In fact, many installations require only minor noise-suppression measures, such as a suppressor resistor in the distributor-to-coil high-voltage lead (Fig. 4) and a feed-thru capacitor at the ignition coil (Fig. 6). In other cases, a complete set of suppressor resistors and filter capacitors as shown in Fig. 1 are required.

Low-Frequency Interference. In some isolated cases it is produced in the primary circuit of the ignition system. It is coupled directly into the electrical system. This interference is low in frequency, and is caused by the current pulses drawn by the primary of the ignition coil. The pulses appear on the battery lead (to the receiver) because the voltage on the wire is common to it and the ignition coil. The only cure for this particular problem is a 1000 mf (or more) electrolytic capacitor, which happens to be quite expensive.

Since this particular interference is low in frequency, it is picked up in the audio section of the receiver rather than the RF section or the antenna. It is easily identified because the volume control has no effect on it. However, this symptom could also indicate a defective receiver. (An open filter capacitor could be letting the noise reach the audio system, for example.) You would do well to check for this condition before you spend the money on an expensive external bypass capacitor.

If the installation is new, and you know the receiver has been checked and is proven to be in good condition, a 1000 mf electrolytic capacitor can be installed at the ignition coil to cure the problem. A basic installation is shown in Figure 7.

Connections and Interference. Low-frequency noise may be the result of a faulty power connection. There are two schools of thought on connecting mobile communications equipment of any kind to the power source. One school says to run the power lead directly to the battery, thus minimizing the effect of conducted noise from the ignition system. The other says that connecting directly to the battery may cause trouble

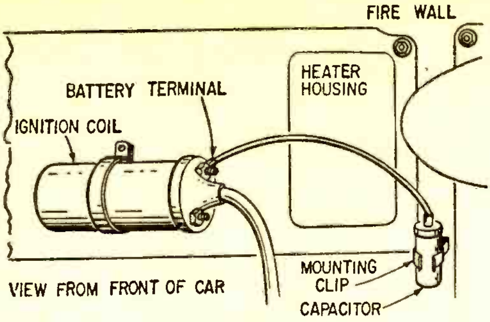


Fig. 7. Spring-type mounting clip is a suitable mechanical mounting. Use separate wire for grounding can.

since the power lead would then be exposed to the radiated noises present in the engine compartment. Try both methods as part of any noise-suppression program. Use the method which gives the least noise in your particular situation. In many installations it is effective to install a bypass or feed-thru capacitor at the point where the power lead is connected. In that case, special units that include the necessary power lead and connectors, are often convenient to use. Typical examples of such assemblies are shown in Figure 8.

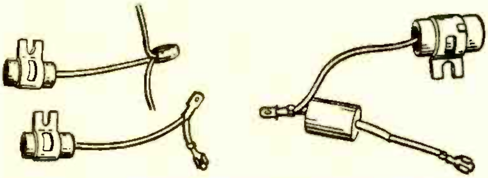


Fig. 8. Use spaghetti sleeving to insulate slip-fit connections. All crimped connectors must be soldered.

Radio-Frequency Chokes. Some of the early noise-suppression systems used RF chokes. If you are not already familiar with the operation of an RF choke, it can be summed up by saying that it has the opposite effect of a capacitor. It restricts alternating current and fluctuating direct current, while it passes pure direct current. Consequently, choke coils are connected in series with the electrical line they are supposed to protect. They are not used frequently for interference suppression in present-day systems since the chokes used in radio and TV are not usually designed to handle the heavy currents in engine use. Quite often chokes can be made by winding coils of heavy wire on an experimental basis. These may prove useful in some cases, but it is pretty much of a hit or miss proposition.

Wave Traps. Wave traps are used primarily to suppress generator spark interference. They are more difficult to install than filter capacitors and some types require adjustment after installation. However, their operation is quite simple to understand. Wave traps are nothing but a coil and capacitor combination (tank circuit) that is tuned to either the frequency of the spark interference, or to the operating frequency of the electronic gear. They act to reject or trap interference of this frequency just like a wave traps in an antenna system. Their major drawback is that they can be tuned to only one frequency although spark noise is often generated on several frequencies at once. They can be effective in the case of extreme generator interference on a few channels.

You can make a wavetrap. But there are basic snags. First, the coil must be capable of carrying all of the current in the line, so a very heavy-gauge wire (that is difficult to handle) must be used. More important, the completed LC circuit must be tuned to the correct frequency, and this involves the use of extra test equipment.

It is also possible to use commercial wave traps. Such traps are pretuned to the operating frequency of the communications equipment, usually at the approximate center of the band. Stock filters are available for the 11-meter Citizen's band as well as the 2- and 6-meter amateur bands.. Other filters can be obtained to cover just about any frequency from 15 to 180 mc. The pretuned filters should not be adjusted after they are installed. The tuning adjustment (a trimmer capacitor) is set and sealed during manufacture.

Tracking It Down. Half the battle in eliminating ignition interference is in locating the source of the interference. In some cases this is fairly simple, while in others it is very difficult.

The source of interference can be identified by the sound that comes from a receiver (if you are lucky that is!) Here are the characteristics. Ignition intereference is a popping sound that is synchronized with the speed of the engine. Generator noise (or alternator noise) can generally be identified as a whine that starts only when the engine is speeded up. If there is doubt as to the noise source, temporarily remove the generator leads (or slip the generator belt off) and check the noise level with the engine running. If the noise is still there, it originates in the ignition circuit. If the noise is eliminated by disconnecting the generator, the interference originates in the generator. A voltage regulator will usually produce a rough, rasping sound.

If you can't locate the noise source by identification of sound, the next step is to use some form of electronic tracer. Connect a pair of long, shielded leads to the vertical input of the scope, and attach a pickup coil (for radiated noise) or a probe (for conducted noise) to the shielded leads. The scope can be connected through an isolating capacitor to possible points of conducted noise (power leads into the receiver, generator output, ignition-switch hot lead, dashboard instrument hot leads, etc.) instead of using a standard probe. A signal tracer can also be used to check various points for conducted noise.

If instruments are not available you can use the receiver itself. It can be converted into a noise tracer by connecting a pickup coil to the antenna input terminals. A suitable pickup coil consists of 50 turns of insulated wire wound into a 2-inch coil and taped to the end of a broom handle. (Figure 9). The coil is connected to the receiver antenna through ordinary lamp cord or any suitable insulated wire. Of course, the receiver antenna must be disconnected. If the receiver has a coaxial input, it will be necessary to make up a coax adapter in order to connect the coil.

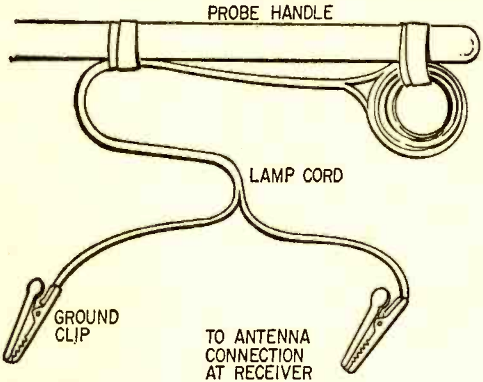


Fig. 9. Use adapters to connect lamp-cord lead to the various antenna connectors used on equipment chassis.

No matter what instrument you use, the basic procedure for locating radiated noise is as follows:

1. Operate the engine and hold the pickup coil near the distributor. Listen or watch for a change in the noise level.
2. Move the pickup coil along each spark-plug lead from the distributor to the individual spark plugs.
3. Move the pickup coil along the high-voltage lead from the distributor to the ignition coil.

One of the simplest and most practical devices to pinpoint conducted noise is a bypass capacitor, to which two alligator clips have been soldered. A large alligator clip is attached to the mounting bracket of the capacitor shell, and a smaller clip is attached to the lead (Fig. 10). To use the capacitor for noise tracing, connect the small clip to the circuit at a terminal near a suspected source of noise. Then connect the large clip to the nearest ground point. If there is any noticeable reduction in noise level with the bypass capacitor connected, install a permanent capacitor at that point. Use the same value for the permanent capacitor as is used for the test capacitor. It should be between 0.5 and 1.0 mf for best results.

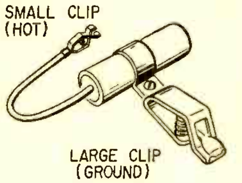


Fig. 10. Large battery clip will grasp most hex heads and brackets to make ground connections while a smaller clip attaches to lug on pigtail lead.

Suppression Kits. Thus far, we have talked about installing individual suppressors or filters to cure a specific noise problem. You may be better off using a complete noise-suppression kit that provides all of the components necessary for the usual suppression techniques. They supply suppressors for each of the spark plugs, a suppressor for the distributor, and filter capacitors for various points throughout the ignition system. Shielding for the generator (or alternator) and voltage regulator wiring is also included.

Figure 11 shows the schematic of a typical ignition system with all the components of a noise-supression kit installed at the proper points. While this particular kit is manufactured by E. F. Johnson Company, it is typical of many kits now available (manufacturers are listed at the end of the article).

No matter what kit you choose, its effectiveness will be determined to a large extent by the amount of care taken, and how closely the instructions are followed. Most kit instructions are well prepared, but *you* must do a careful job or the kit will not suppress

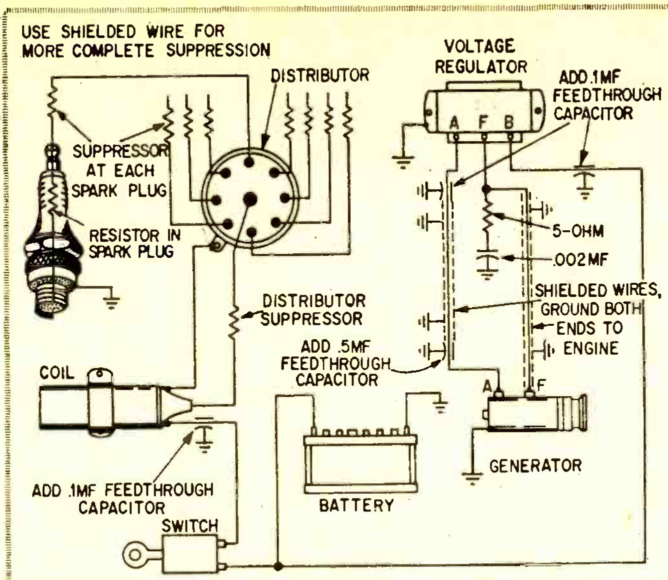


Fig. 11. Typical automotive ignition circuit with suppressors, feed-through capacitors and the shielded wires indicated. The A (on voltage regulator and the generator) refers to armature or ARM terminals, B to BATT or the battery and F to field terminals.

noise. Even worse, the ignition system may not operate properly with a poorly installed kit. It is especially important that all surfaces used for ground connections are free of grease, dirt, and paint. If necessary, they should be scraped with sandpaper, a knife, or other suitable tools and wiped clean with a rag. All ends of the shielded braid must be kept as short as possible. All connections to ground should be tightened securely. Care should be taken to insure that all wires removed from terminals are reconnected to their proper terminals. It is best to work with only one wire (or the set of wires from one terminal) at a time to prevent confusion. It is easy to make a mistake. One of the battery terminals should be removed to prevent any damage that might result from the accidental short circuits caused by dropped tools or dangling wires. A dangling hot lead can create quite a mess!

We will repeat the detailed instructions supplied with the various kits. However, Figs. 12 through 14 show how the major ignition components (generator, voltage regulator, and coil) are modified by installation of the kit.

The original bypass capacitor is removed from the generator and replaced by a 0.5-mf coaxial feed-thru capacitor. The armature and field leads to the voltage regulator are covered with braid shielding.

The braid shielding in Figure 13 is grounded to the voltage regulator ground lug to prevent radiation of noise. Both the battery and armature terminals of the regulator have 0.1-mf coaxial capacitors. A *regulator*

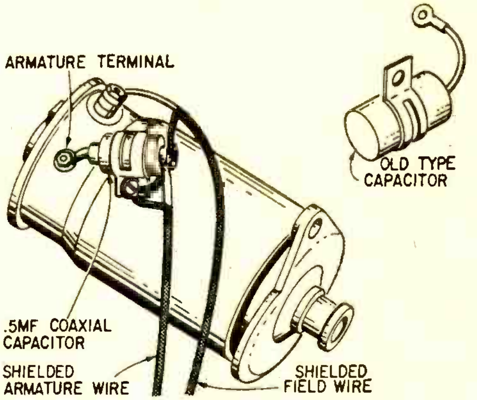
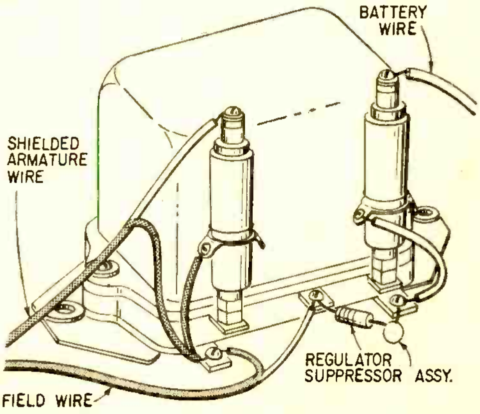


Fig. 12. Old-type capacitor is discarded and replaced by coaxial or feed-through capacitor and generator leads shielded with braid or shielded wire installed.

Fig. 13. Feed-through capacitors are attached directly on voltage regulator terminals; regulator suppressor assembly (RC network) from field to ground terminals.



suppressor assembly (a series resistor and capacitor) is connected between the field terminal of the regulator and ground lug of the regulator.

The battery terminal of the ignition coil (Figure 14) is also provided with a 0.1-mf coaxial capacitor. As shown in Fig. 11 each spark plug and the coil-to-distributor lead are provided with suppressors. These are similar to those shown in Figs. 3 and 4.

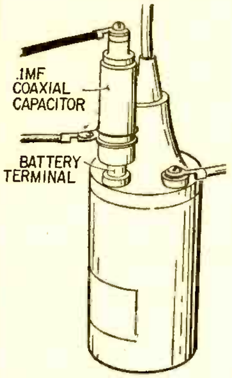


Fig. 14. Coaxial or feed-through capacitor is threaded on coil terminal. If a suitable adapter is not supplied you can make your own—just cut the head off a machine screw or use a section of threaded rod of same thread.

Bonding. After installing a complete suppressor kit and the engine noise persists, there are only two courses of action available—bonding and shielding. Bonding is the easiest, so let's talk about it first.

Bonding provides an easy route for radiated interference to reach ground. The term bonding, as applied here, means connecting two metal objects with a metallic conductor, so that there is a good electrical path between them. For example, both the hood and the frame of an auto are made of metal (except on some sports cars). This metal acts as a shield for containing interference radiated from the engine. However, if the hood is not connected electrically to the frame, the shield is not complete, and interference signals can be radiated through or around the hood. With proper bonding the interference grounded.

Direct bonding occurs when two metals are connected directly, surface to surface. To be effective, the metal surfaces must be in constant contact; they must be physically clean, and they must be unpainted. In most cases it is necessary to join the surfaces with screws or bolts. Bonding can be improved by using toothed washers (internal or external). These washers cut into the metals through any paint or insulating surface; they should be used at both ends of the screws so that both metal surfaces are in contact with the washers and screws.

Strap bonding is by connecting the two metals with an electrical conductor, usually with a braided strap with lug fasteners at the ends. Braid is used because it is flexible and will not break easily with constant movement. Quite often the two metals to be bonded will move in relation to each other when the auto is in motion. This motion could break an ordinary solid electrical wire. As a side effect, the rubbing of two surfaces can produce static electricity that creates interference under some conditions. When the parts are bonded together, the static electricity has a constant discharge path through the strap.

Bonding Points. Some typical bonding points on an automobile are:

Corners of the engine to the frame.

The exhaust pipe to the frame and the engine.

Both sides of the hood.

Both sides of the trunk lid.

The coil and distributor to the engine and fire wall.

The air cleaner to the engine block.

Battery ground to the frame.

The generator to the voltage regulator frame.

Front and rear bumpers to the frames on both sides.

The tail pipe to the frame at the rear.

An automobile engine is mounted on rubber shock absorbers that insulate it from the body and the frame. Since the ignition system centers around the engine, the entire engine will radiate ignition noise if it is not grounded. The auto manufacturer grounds the engine in a manner that is satisfactory from an operational standpoint. However, this ground still may offer a high impedance to radio frequencies, leaving the engine only partially grounded as far as interference is concerned. When a good radio-frequency ground is made, the engine acts as a shield and absorbs a good part of the ignition system radiation.

A braid bonding strap can be installed between the engine and the firewall of the auto (Figure 15). This is effective and adequate in a great number of installations. In some cases, however, a bonding strap between the engine and chassis will work better,

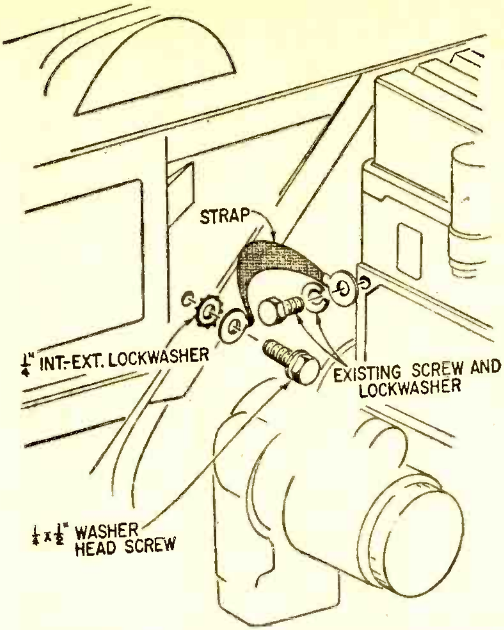


Fig. 15. If you have the braid you can custom-make any bonding strap—just solder ends and drill holes.

and in extreme cases, both may be required.

In many instances the hood hinges do not provide good electrical contact between the hood and body. Braid bonds can be used to bypass the hinges and provide the needed ground. Painted surfaces also prevent good electrical contact between the hood and body, so it is necessary to use metal wipers with sharp points to provide the needed contact. Such wipers are shown in Figure 16.

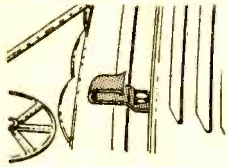


Fig. 16. The bonding wipers dig through paint. The eventual rust spot makes very poor contact in metal.

These are often installed at the cowl to contact the underside of the hood and provide good grounding near the antenna. There are various types of hood bonds available for locations where clearance exists between the body and the bond.

A coating known as anti-squeak is often used by auto maufacturers to eliminate rattles and squeaks. It does an excellent job of this, but it can also do an excellent job of insulating such things as fenders and instrument panels. These floating sections can help radiate the interference unless they are grounded. Toothed washers can be used on the screws that hold the sections together. However, braid bonding straps are usually much more effective.

Heater ducts, control cables, and other parts that extend into the engine compartment often transfer noise to the receiver. Ducts may give the appearance of being grounded to the firewall while they actually are poorly grounded or insulated when contact is not made because of a painted surface. Sometimes good grounds can be made by inserting toothed washers under the bolts or studs that mount the ducts to the firewall. If this is not practical braid bonds should be used.

Sources Of RF Noise Suppression Devices

The following companies manufacture or supply ignition interference suppression products:

Allied Radio Corporation
(Suppression Kits)
100 N. Western Avenue,
Chicago, Ill. 60680

Ben N. Bartlett Co. (Wave Traps)
1815 W. 85th Street,
Los Angeles, Cal. 90016

Champion Spark Plug Co.
(Suppression Components)
P.O. Box 910,
Toledo, O. 43601

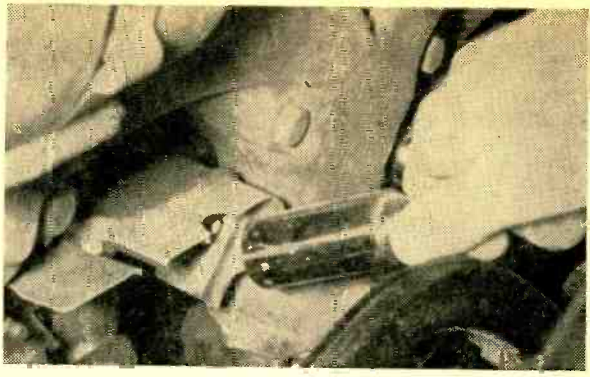
Estes Engineering Co.
(Shielding Kits)
1639 W. 135th Street,
Gardena, Calif. 90249

Hallett Manufacturing Co.
(Shielding Kits)
5910 Bowcroft Avenue,
Los Angeles, Cal. 90016

E. F. Johnson Co.
(Suppression and Shielding Kits)
Waseca, Minnesota 56093

Lafayette Radio Electronics Corp.
(Suppression Kits)
111 Jericho Turnpike,
Syossett, L. Is. N.Y. 11791

Motorola Consumer Products Inc.
(Suppression Components)
9401 W. Grand Avenue,
Franklin Park, Ill. 60131



Spark-plug wires being inserted into distribution-cap shield (left). Spark-plug shield (above) can be a bit difficult to install on some engines. Coil-to-distributor lead connects easily to shielded ignition coil.

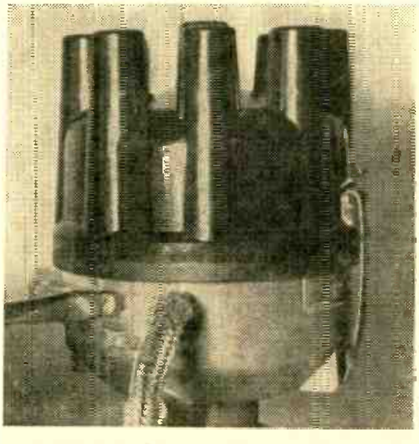
Cables, (such as the choke control and the hand brake) can be grounded by using a cable clamp that connects to the firewall through a short braid.

Most mobile communications units have a metal case that shields from radiated interference. It will be most effective when the case is properly bonded to the auto frame. In fact, most equipment manufacturers recommend that you bond the mounting rack of the radio to the frame. Either bonding straps or mounting straps can be used.

Shielding Systems. When all else fails, the only means of combating extreme radiated noise problems is to shield the ignition wiring. This is especially true where there is a minimum of natural shielding. Two classic examples of this are on motorboats (outboards especially) and sports cars with molded plastic bodies. In either of these cases, a completely shielded ignition has the same effect as surrounding the engine with a metal shield. Radiated noise is confined and grounded. Conducted noise associated with radiated noise can be eliminated with bypass capacitors and filtering.

There are two ways to do shielding—the home-brew system found in the do-it-yourself articles, or the commercial kits.

While the home-brew systems provide some measure of shielding (some of them work quite well in that respect), they may also impair the operation of the ignition system. When an ignition system is shielded



Braid shield of lead from ignition coil is grounded at distributor. Shield slips over top of existing cap.

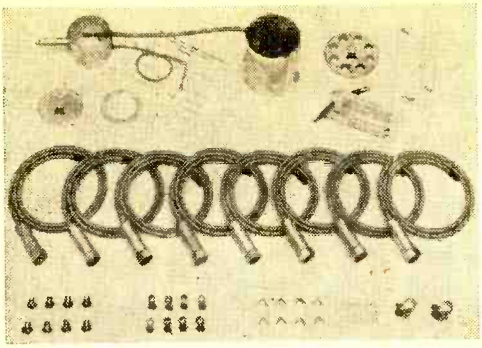
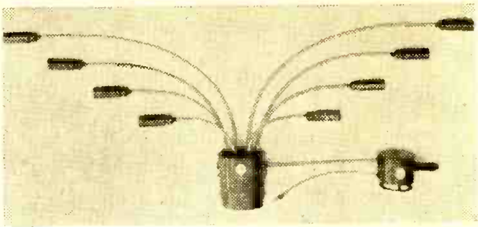


Fig. 17. Semi-assembled kit (left) must have leads cut to proper length before connectors can be attached.

Fig. 18. The fully-assembled ready-to-install kit has factory cut ignition wires to fit individual engines.



with *any type* of cable shield (kit or home brew), the voltage produced by the ignition coil is reduced at the spark plugs.

The commercial-kit shielding systems are designed to offset this condition. They use insulating materials that will not lose their dielectric properties—even under the extreme heat of the average engine. (The home-brew systems usually ignore this factor completely.) With any shielding the ignition system must be in good shape—with plenty of reserve voltage available to the plugs. A borderline ignition system should not be shielded. Some shielding kits also include a replacement ignition coil which supplies increased voltage for the spark plugs. While a new coil is not always necessary, it can be the answer when you install a shielding system that cures your noise problem, but creates an ignition problem.

Kits available for shielding automobile and marine engine ignition systems fall into two broad categories—the semi-assembled kits (Fig. 17), and the fully-assembled ready-to-install kits (Fig. 18). Both kits supply a shield for the distributor cap (Fig. 19), the individual spark plugs (Fig. 20), and the ignition coil (Fig. 21). Flexible metal sleeving for the high-voltage leads is also included.

The difference in kits lies in the manner of assembly. The semi-assembled systems require that you cut the spark-plug wires to the proper length and attach the shielded

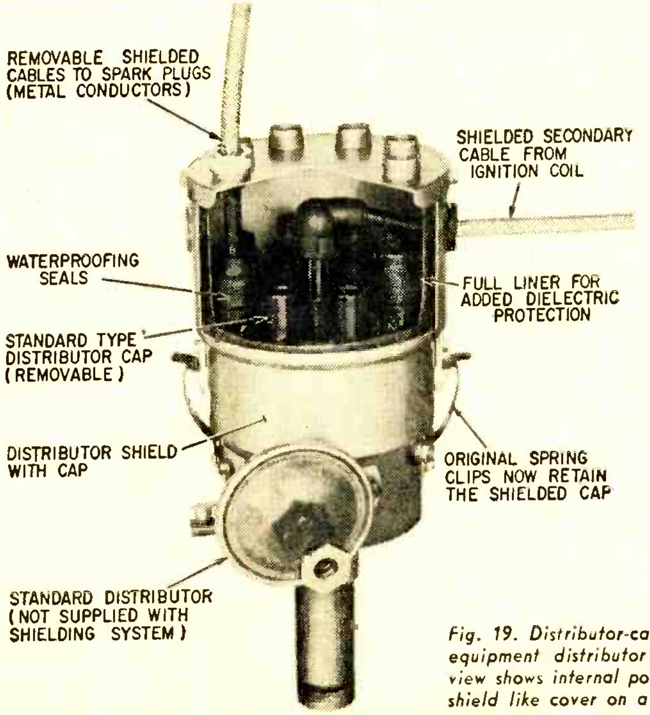


Fig. 19. Distributor-cap shield fits over the original equipment distributor and cap assembly. Cutaway view shows internal portions remain same. Top fits on shield like cover on a canister—fittings grip shields.

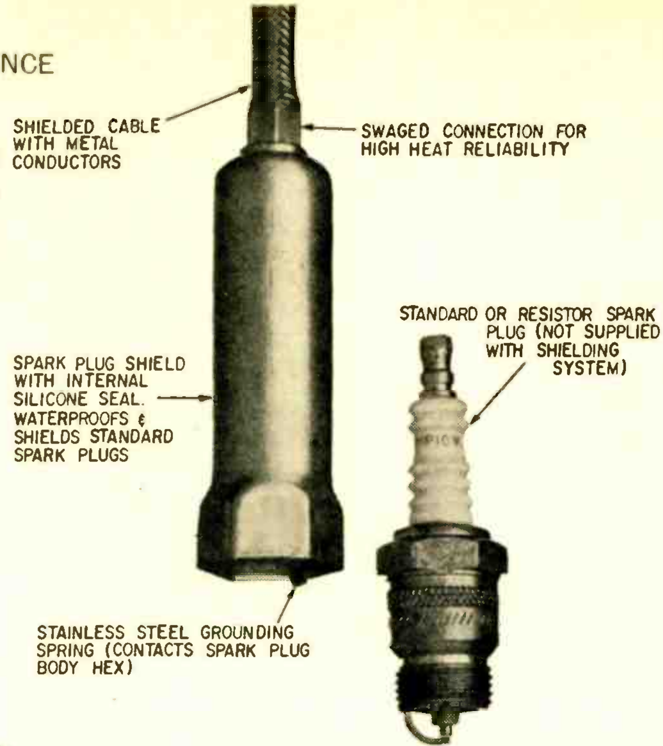


Fig. 20. Shielding prevents the radiation of noise from plug and wiring. Braid is crimped or, as indicated, swaged to plug shield. Solder would reduce flexibility of braid — stainless steel and aluminum used for plug shields do not accept solder readily.

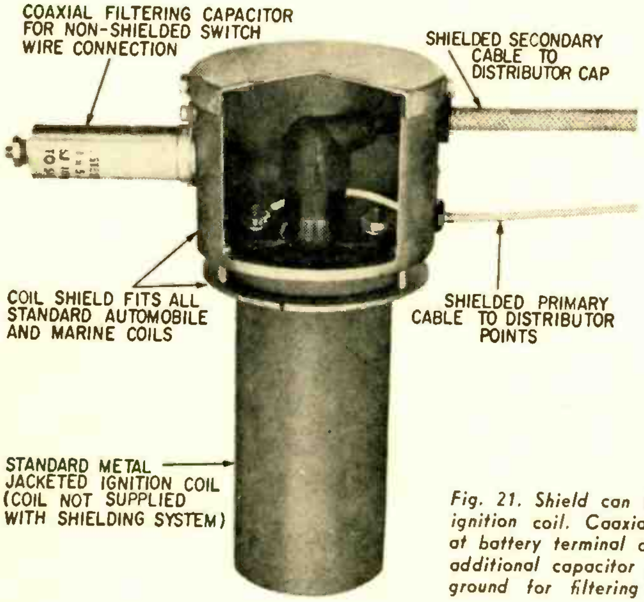


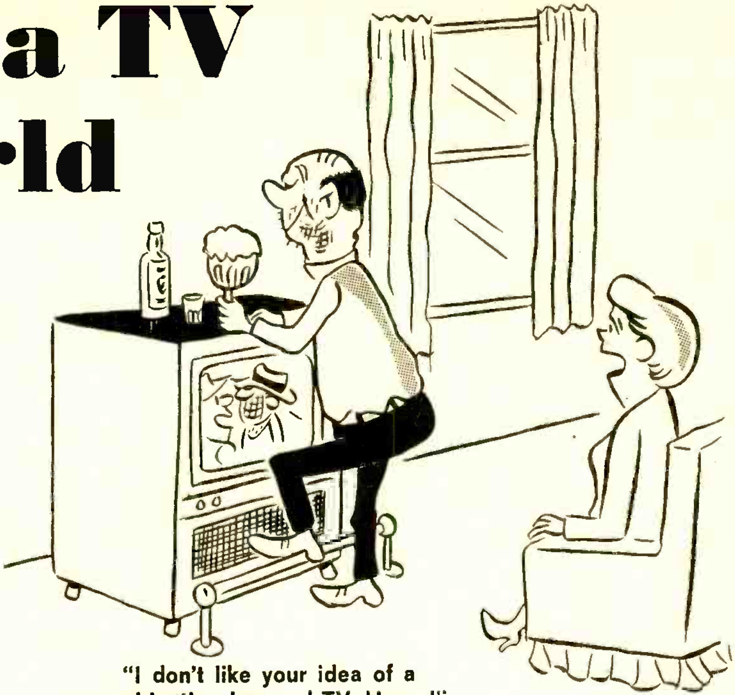
Fig. 21. Shield can fits around original equipment ignition coil. Coaxial capacitor provides filtering at battery terminal of ignition coil. Never connect additional capacitor from distributor-point lead to ground for filtering — it upsets ignition system.

distributor cap, the spark plug shields, and the coil shield. Sometimes existing wiring is used, the braid is passed over the wires. With the fully-assembled kits, the old ignition wiring is removed, and pre-assembled items are installed.

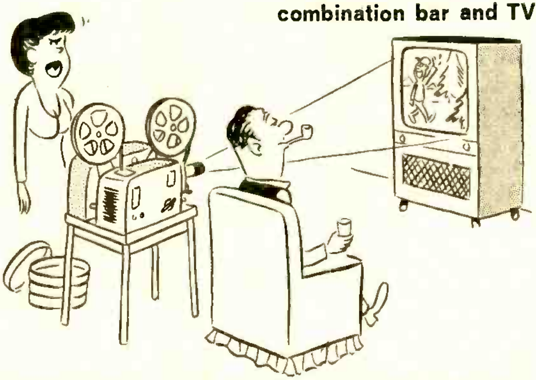
Do It Yourself. Why not check your mobile rig for possible ignition interference, noise that may be affecting your communication? Start by making the *engine-on, engine-off* test. If you have noise, try to identify it by the sound. Then eliminate it in step-by-step order—suppression, filtering, bonding, and shielding, in that sequence. Even in extreme cases, there is no reason to suffer the annoyance of ignition interference. ■

It's a TV World

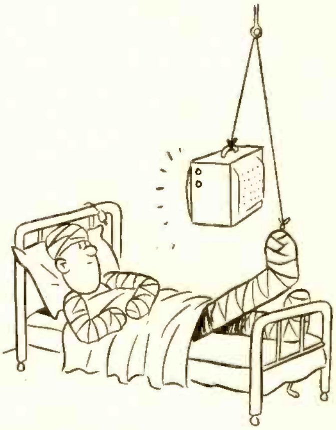
by
Marvin
Townsend



"I don't like your idea of a combination bar and TV, Henry!"

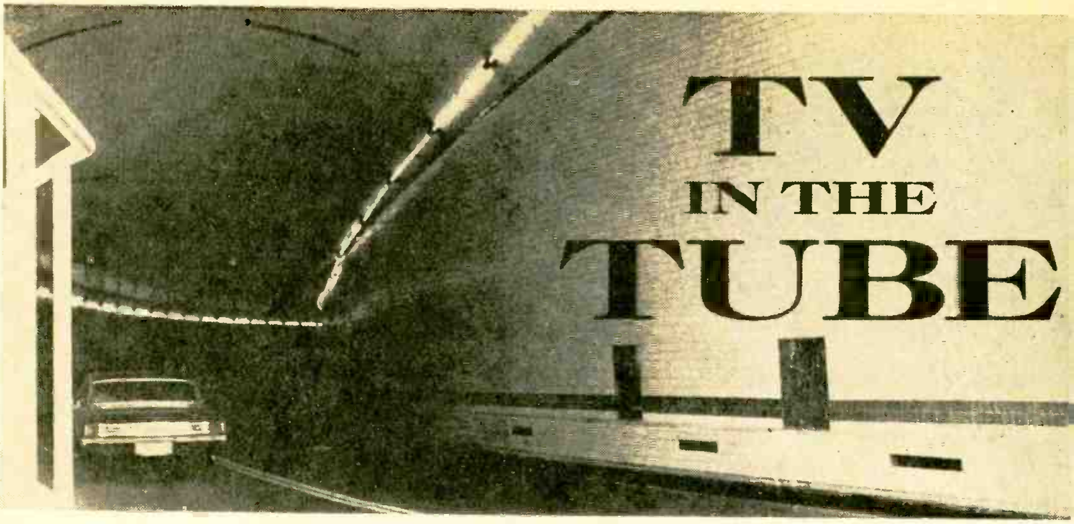


"When are we going to have our TV repaired? I'm getting tired of seeing these old vacation films!"

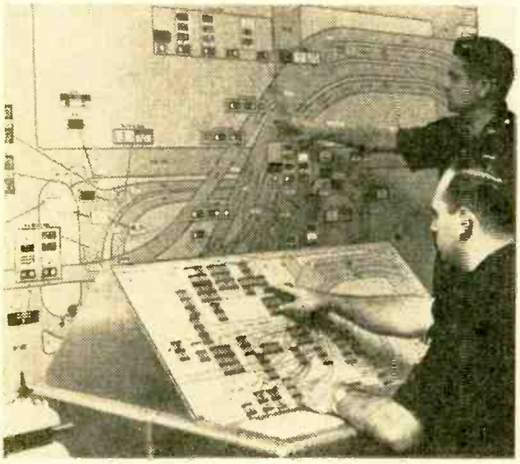


"Are you sure this guy knows his business?"

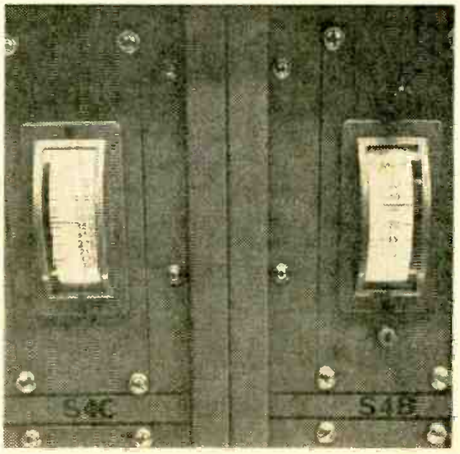
TV IN THE TUBE



At the Lincoln Tunnel control Center in Weehawken, a police officer watches traffic flowing through the South Tube. Each screen shows condition for 480 feet of the tube, which carries traffic to N. Y.

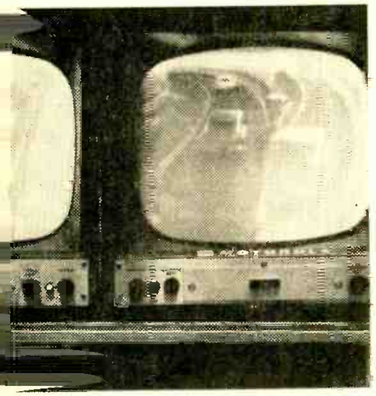


The numerous traffic signs and signals on the complex bus ramps connecting the Lincoln Tunnel with the Port Authority Bus Terminal in Manhattan are controlled from this console in the Control Center.



Photocells at 480-foot intervals in the roadway of the South Tube activate these drive meters at the control center. Meter S4C shows hourly traffic flow rate at one point in the tunnel; S4B indicates speed of vehicles.

Gasoline-powered vehicles, 20 inches wide and guided by a unique single-rail system on a catwalk, enables tunnel police to speed to any part of Lincoln's South Tube.



Closed circuit TV cameras at nine locations show traffic flow. Each camera provides split image of traffic approaching on right and leaving on the left due to the reflection from a mirror placed in the camera housing.

Emergency tractors equipped to lift loaded trailer trucks are stationed immediately adjacent to exit portals of the tunnel. The tractors have a short wheel base to permit rapid turnaround inside the tunnel.

In New York's Lincoln Tunnel, traffic is now televised to keep it flowing swiftly and smoothly under the Hudson River. The tunnel has three tubes connecting various New Jersey highways with midtown Manhattan. Down the full length of the tunnel's South Tube are various devices to expedite traffic: systems which measure traffic flow, radio-equipped catwalk cars for police to speed to disabled vehicles, and closed circuit television.

Candid Camera. Nine cameras, each equipped with mirrors so views can be taken of traffic on either side, are installed. Both views are relayed, via split images, to nine TV monitors in the traffic control center in the Lincoln Tunnel Administration in Weehawken, and an observer thus has a complete view of traffic from one end of the tunnel to the other. Additional screens are visible to police officers in two catwalk booths inside the tube. Each camera, and monitor, covers a specific section of tunnel.

Flow indicators. Another system registers speed and flow in each of six tube zones. Under the roadway at 18 points in each lane are photoelectric vehicle detectors, which relay traffic speed and spacing to a console at the control center. When a car passes over a detector at less than 5 mph, an amber light flashes on the console, indicating a potential stop. An actual stop in traffic causes a red light to flash on the console and an accompanying bell to ring. The low flow indicator operates on the basis of a time lapse between vehicles passing over the detector. The expected interval is automatically adjusted according to the volume of traffic. When the alarm rings, a glance at the monitor determines the cause.

To the Rescue. Emergency vehicles can be dispatched when a breakdown is observed. The tube has four catwalk cars that can zip to the scene of the tieup. Other vehicles can reach the scene to remove disabled automobiles.

These vehicles plus the electronics in the tube combine to form an efficient system to keep the traffic moving. Chances are, the system will be used in the other tubes of the tunnel and in the Holland Tunnel as well. Last year alone 30,352,000 vehicles sped through the Lincoln tubes. As you can imagine, a mere flat tire can create a monstrous, exasperating traffic jam unless police know immediately where it is, and can act to relieve it. ■

Dwell-Meter/Tachometer

Continued from page 56

than putting an additional mark on the meter scale as a reference point to indicate mercury cell aging. Slight aging can be compensated for by adjusting meter reading with R17.

The circuity operates on less than 2 milliamperes in either the dwell meter or tachometer positions so the mercury cell should provide between 1500 and 1800 hours of useful operation.

Dwell-Meter Calibration. With the cylinder selection switch (S1) in the ADJ position and function switch (S2) in the DWELL position short the two leads together. Set the *Battery Adjust* control—meter pointer must be set exactly to the reference mark on the meter scale if calibration is to be meaningful in the future.

Set S1 (cylinder selection switch) to the 6-cylinder position and adjust R3 for a full-scale reading—60-degrees of dwell angle.

In the 4-cylinder position, R4 is adjusted for a reading of 45-degrees of dwell angle. (The reading obtained in the 4-cylinder position is actually one half the actual value—that is for a 45-degree meter reading the actual dwell angle is 90 degrees.)

Potentiometer R2 is adjusted for a meter indication of 45 degrees with the cylinder selection switch in the 8-cylinder position.

Tachometer Calibration. Set S2 to the tachometer position. The cylinder selection switch (S1) is set to the 8-cylinder position and the 1000-5000 RPM selector switch (S3) is set to the 1000 RPM position. Connect the Dwell-Tachometer to the calibration test set-up (see schematic). Adjust R11 for a 900 RPM indication on the 1000 RPM scale of the meter.

Switch to the 5000 RPM position of S3. The meter should now indicate 900 RPM on the 500 RPM scale. (If meter pointer does not indicate 900 exactly meter shunt R9 can be adjusted to give a more exact reading. If the meter reading is too low, too much current is being passed by the shunt and R10 must be increased in value—substitute a 51-ohm value.

Too high a meter indication means that not enough current is being passed by the shunt resistor and its value must be decreased. Additional resistors can be added in parallel to R9—try values like 470 ohms, 510 ohms and 560 ohms.

With the 900 RPM point set on the 5000 RPM scale switch cylinder selector switch S1 to the 6-cylinder position and adjust R12 for a meter indication of 1200 RPM.

Finally, rotate switch S1 to the 4-cylinder position and adjust R9 for an indication of 1800 RPM on the meter.

Now you're all set to tune up the engine—just remember that the *red* (+) lead is connected to ground for positive-ground battery systems and the *black* (−) lead is connected to ground with negative-ground systems. Most cars built in the last few years use a negative-ground system. ■

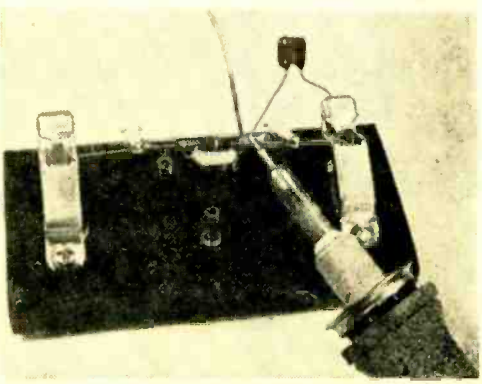
THIRD HAND/FOUR CLAWS

■ Two alligator and two battery clips on a scrap of lumber are handy to hold small parts for soldering or cementing. Since the battery clips are insulated from each other and from the alligator clips this little stand can also be used as a base for a "hay-wire" circuit or network.

The battery clips are held rigidly in place with screws—nuts are countersunk into the wooden base. The alligator clips are soldered to a U-shaped section of 3/16-inch rod which is fastened to the base by two cable clamps and can pivot up and down.

A hole drilled into the board is used to hold pin tips in a vertical position for easier soldering. Two concentric holes are drilled—one to fit the pin tip and the other to take an aluminum eyelet to cover the rough edges of the wood around the drilled hole.

—*Howard S. Pyle* ■



Novel Oscillators

Continued from page 68

values and measured the frequencies shown in Table D. The voltage measurements were made at point A with a voltohmeter set to the 50-volt ac scale to minimize loading effects. Again we sacrifice accuracy to minimize loading.

In Fig. 9, I've plotted the predicted frequency (using the approximate equation) along with the measured points. At the lower frequencies, the points stray further from the curve due to the Δz effect just mentioned. But the points also stray at the higher frequencies as well! ! And we can't use the Δz excuse up there.

But there is a plausible explanation for that discrepancy also. All the measurements were made with the voltohmeter connected to the circuit. And it's connected essentially across C1. Therefore the value of C1 employed in computing frequency should include not only the value of the decade box setting, but also the capacitance of the meter and its leads. Or else the meter should be disconnected from the circuit when measuring the frequency. You'll find that when the meter is removed, the measured points agree with the computed values. ■

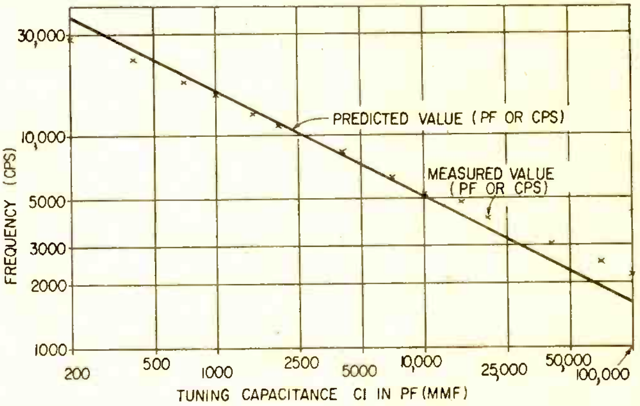


Fig. 9. A line drawn through the values measured (crosses) show an equal deviation of about 20% above and below the calculated values indicated by the straight line. The deviation of ±20% is suitable for many applications in electronics.

Heath-kit GR-43 Receiver

Continued from page 44

to slide over, rather than rotating the pulleys. The sliding caused aluminum powder to flow onto the dial cord—essentially lubricating the cord—and after several hours turning the tuning control did absolutely nothing in the way of selecting stations. We therefore suggest that before you even string the dial cord you apply a *single drop* of graphited radio dial oil (such as made by G. C.) to each pulley shaft—then spin the pulley several times. Make certain the oil goes between the pulley and the shaft. If just a *smidgen* of oil gets on the pulley itself, wipe it off with carbon-tet or else the dial cord will slip. Oiling the pulleys well result in a smooth-as-silk tuning with absolutely no backlash, and you'll be able to tune 21 mc. signals as easily as with bandspread. Heath has since included dial cord drive lubrication instructions in the GR-43 manual.

The completed kit is rather handsome in appearance and fully protected by magnetic latch, black anodized, aluminum front and back doors; with the front cover closed it looks like a small piece of airplane luggage. For those who are newcomers to short-wave listening, Heath provides an excellent guidebook to short and longwave stations, their frequencies and their approximate time of reception. Included are also tips on how to locate stations (such as the FAA weather stations) and a section for your own notes.

While the GR-43's price tag of $159.95 might appear somewhat high for a transistor portable, keep in mind that it is not a transistor radio in the ordinary sense. The GR-43 is more akin to a communications receiver as far as performance is concerned, and dollar for dollar it offers at the least (if not more) the performance of a communications receiver without FM at the same general price—with the exception that the GR-43 is *really* portable. For additional information, write to Heath Company, Dept. EB, Benton Harbor, Michigan. ■

Tooling Up

Continued from page 78

cut rectangular slots for switches and even smooth the edges of home-brew printed-circuit boards. Use a rotary cutter and you can cut a hole of any shape in the heaviest chassis, even steel. Mount a coil form in the drill chuck, reduce the speed with an SCR motor-speed control and you can wind "factory made" coils. (Add a tachometer to your shop equipment and you can accurately measure the speed of the drill and you can wind coils of several hundred turns accurately, and easily.)

Ever crumple a thin aluminum chassis when you bashed the center punch?, of course you have; but you can make nice clean marks with an automatic center punch. An automatic punch has an adjustable spring-loaded tip that "fires" when hand pressure is applied. And it fires with just enough force to mark the metal without caving in the whole surface. And speaking of chassis, don't forget a *metal nibbler;* you drill a ½-inch hole, stick the *nibbler* through, and then literally nibble away at the metal-forming any shape hole you desire.

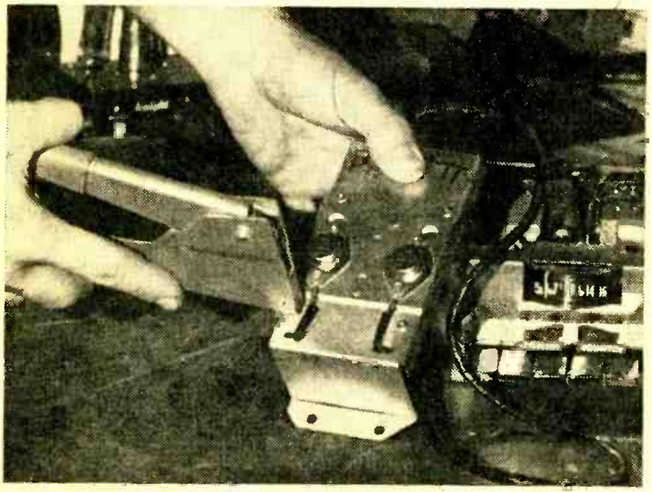
Ever try to tack several wires together while you hold the iron in one hand and the solder in the other? Sure, it can be done if you can get your toes to hold a pair of pliers. An easier way is to grasp the connection with spring-loaded tweezers or *seizers*. They also double as a third hand for holding components upright on the table—like when soldering a microphone plug. They also make dandy heat sinks when soldering transistor and diode leads.

And don't forget wire strippers. Sure, many of us can grip the wire with pliers and then strip the insulation with cutters, but in a tight corner most of us also wind up cutting through the wire.

While we could write an endless list of tools, the ones covered are just about the minimum needed to take the strain out of the boring details of project and kit construction. As you go along you'll naturally find more tools that will simplify construction even further. But avoid the *two-for-one pitfall;* don't try to buy two tools for the price of one by cutting down on quality—it can't be done; either the tools will break down or they won't do what they're supposed to do. For example, the solid-state builder using a cheap pair of poorly machined long nose pliers won't be able to grasp transistor leads—so what good is the cheap tool.

You'll find you get most for your money when you buy moderately priced electronics tools from an electronic distributor. Generally speaking, he can't afford to alienate his customers by selling junk (though admittedly, some do).

All the tools we've mentioned, with the exception of the *Hobby Center*, are sold by electronics distributors. The *Hobby Center*, which is priced at $24.75 in styrene (model 603S) and $34.95 in Polyethylene (model 603P), is available from D.E.C. Associates, 3774 Catalina Street, Los Alamitos, California, 90720. ■



Hand riveter is a noiseless way to secure sockets, tiepoints or myriad other items. It is not necessary to work on both sides of surface—rivets can be set into sides of tubes or boxes without any backing tool needed.

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LC Measurements

Continued from page 88

J3. Connect the unknown inductor to the terminals on the block. Orient the inductor for loose coupling with the GDO coil. Adjust the GDO to the test frequency. Be sure that jumper plug P1 is inserted in J1. Set capacitor C2 at midrange (0); adjust C1 for resonance, as indicated on the VTVM.

Note the value of C1. This is C_r. Increase C2 until the reading on the VTVM drops to 70.7% of the value indicated at resonance. Note the change in capacitance required to reduce the VTVM reading. This is C_{max}. Now, decrease C2 until the reading drops to 70.7% of the peak reading on the other side of resonance. Note the total change from C_{max} to the new value, C_{min}. The total change is delta-C. To find Q, locate the value of C_r on column 1 of Q Nomogram. Locate the value of delta-C on column 2 of the Q Nomogram. Using a straight edge, connect (1) and (2) on the nomogram. Read Q directly from column 3 of the nomogram.

To measure Q at frequencies *above 25 megacycles,* remove P1, but otherwise use the test set as described in the preceding paragraph. Determine resonance by adjusting C2. The value of C2 at resonance is C_r. Next, increase C2 until the VTVM reading drops to 70.7% of the original value. The capacitance of C2 at this point is C_{max}. Now, tune C2 back through resonance to the point where the VTVM reading again drops to 70.7% of the value at resonance. The value of C2 at this point is C_{min}. Delta-C is C_{max} minus C_{min}. To find Q, locate C_r and delta-C on the Q Nomogram, as previously outlined, and read Q from the nomogram.

Although this method for measuring Q is not as convenient as the circuit magnification method (used in most laboratory instruments) it will provide accurate Q measurements if the test fixture is constructed and calibrated properly, and if readings are taken carefully. The same applies to measuring values of capacitance and inductance. There is no substitute for understanding the nature of the measurements and knowing the capabilities of the test equipment used. And one of the best ways to be well versed in these matters is to construct your own test instruments, especially when it can be done so easily and economically! ■

Regulated Supply

Continued from page 94

substitutions are concerned, a variation of ±20% is perfectly all right. If desired, a single 6L6GC can be used in place of the two shown. However, the supply's maximum-output current rating will be cut in half.

Even the power transformer is not critical. The one used here is from a discarded TV set. A transformer with two 6.3-volt filament windings is preferred—a separate filament transformer can be used in place of the extra winding and can be controlled by a separate on-off switch. Be sure to obtain your transformer(s) first—then buy your chassis. Do not crowd the chassis. When operated for long periods of time it can get quite warm and nothing will shorten the life of electronic components, or break down electrical insulation like heat. The more space between tubes, transformers and electrolytic capacitor the longer the trouble-free life or your power supply will be.

(*While the thermal circuit breaker will protect the AC line fuse the regulated + and 6.3-volt ac outputs should be protected individually. A fuse should be used in each output of the 6.3-volt supply if a grounded center tap is used on that winding. These additional fuses—not shown in the photographs—will protect the power supply from the accidental short circuits that so often occur in experimental chassis and breadboards.*

—The Editors.)

Test and Operation. When the power supply is completed and thoroughly checked for wiring errors, connect a DC voltmeter from the *Regulated* + and − (common) binding posts and apply operating power. After allowing time for the tubes to reach operating temperature, rotate the *Output Voltage Control* (R8) knob. With no load connected to the supply, the output voltage should range from less than 150 volts to over 400 volts as R8's knob is rotated.

When using the supply, you will find that the maximum output voltage, obtainable from it, will depend upon the load current; the maximum output voltage decreasing as the load current is increased.

Well, there you have the details on the regulated power supply. Why not assemble one as I'm sure you'll find it a worthwhile addition to your lab. ■

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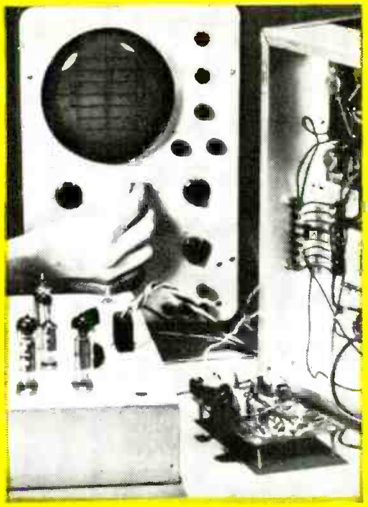

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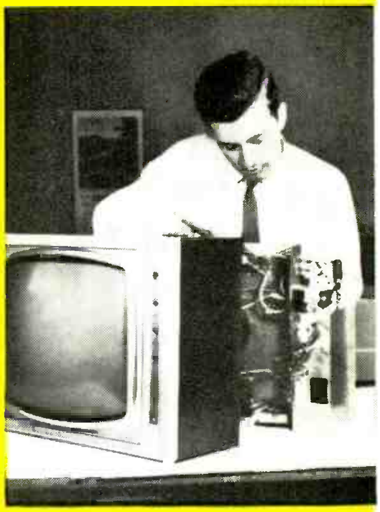

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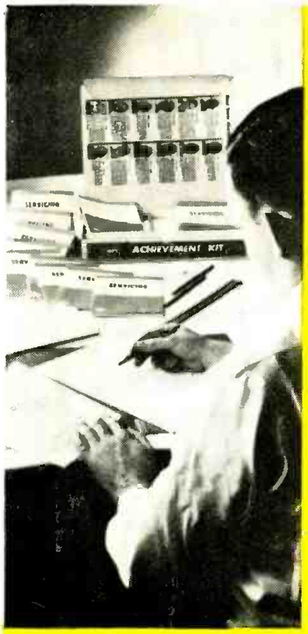

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