Electronics World

AUGUST, 1964
50 CENTS

SPECIAL ISSUE

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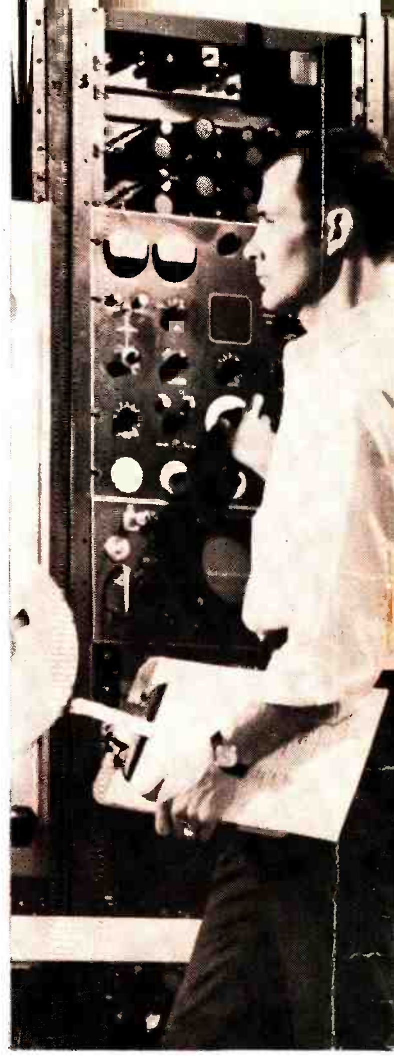

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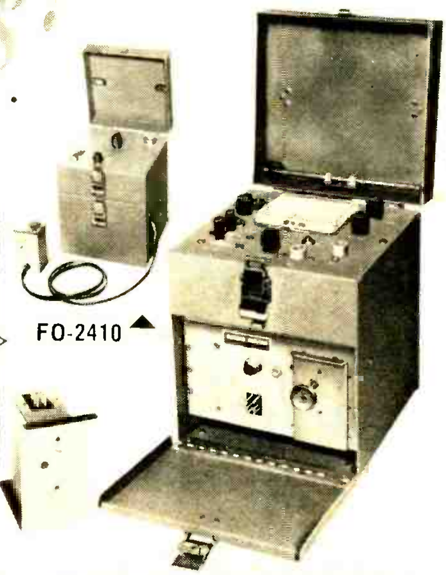

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Crystals for C-12M (specify frequency) $5.00 ea.

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Electronics World

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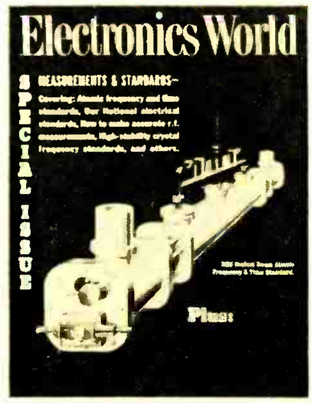

OUR COVER is a somewhat simplified illustration of the National Bureau of Standard's "atomic clock." This is the primary standard for the measurement of frequency and time in the United States. Cesium atoms are shot through the long cylinder into which radio waves are injected. When the radio waves match the vibration-per-second rate of the cesium atoms (9192.63177 mc.), absorption occurs and a near absolute standard is available. A clock, controlled by this instrument might vary no more than one second, loss or gain, after running continuously for 3000 years. (Illustration: Otto E. Markevics.)

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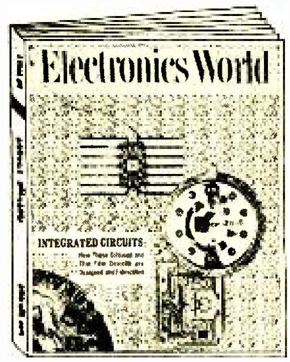

INTEGRATED CIRCUITS
New fabricating techniques permit the production of multi-transistor circuits so small that a 28-component device can pass through the eye of a sewing needle. How they are made, how they are interconnected, and a description of the various types of devices are included in this industry-wide survey.

SELECTING AN H.F. TRANSISTOR
Roy Hejhall and Darrell Thorpe of Motorola explain how the selection of high-frequency transistors can be simplified. Since different parts catalogues quite often use different parameters in specifying these units, two simple nomograms are included to permit easy interconversion.

CLIP-ON D.C. CURRENT PROBE
Three engineers from Hewlett-Packard describe a technique which permits the measurement of d.c. current in a circuit without either opening or loading down the test circuit.

DESIGNING THE I.F. CIRCUIT
It is common knowledge that the design parameters of circuit components vary with frequency. The article describes more than the reasons—it covers the degree of change in resistors, capacitors, and inductors when operating at these various radio frequencies.

CAPACITANCE TRANSDUCER SYSTEMS
Many modern instrumentation and control systems use the principle of capacitive variation to sense mechanical changes and convert them into corresponding electrical signals. The article describes how these transducers are being used in the precise measurement of fluid pressures of gas, oil, steam, and hydraulics materials as well as determining the moisture content of soils, paper, and related products.

PIANO-TUNING—THE ELECTRONIC WAY
Frederick Van Veen of General Radio explains how you can put a piano "on key" with the aid of a test instrument that picks out the correct harmonic and beat note. The technique described involves a tuned amplifier and null detector plus a "universal counter."

SCA BACKGROUND-MUSIC DEMULTIPLEXER
Details on a transistorized adapter designed to be used with FM tuners for the home reception of background music from "storecast" transmissions.

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ELECTRONICS WORLD is published monthly by Ziff-Davis Publishing Company at 434 South Wabash Avenue, Chicago, Ill. 60605. (Ziff-Davis also publishes Popular Photography, Popular Electronics, HiFi/Stereo Review, Popular Boating, Car and Driver, Flying, Modern Bride, Amazing, and Fantastic.) Subscription rates: one year United States and possessions $5.00; Canada and Pan American Union countries $5.50; all other foreign countries $6.00. Second class postage paid at Chicago, Illinois and at additional mailing offices. Authorized as second class mail by the Post Office Department, Ottawa, Canada and for payment of postage in cash. August, 1964. Vol. 72, No. 2.

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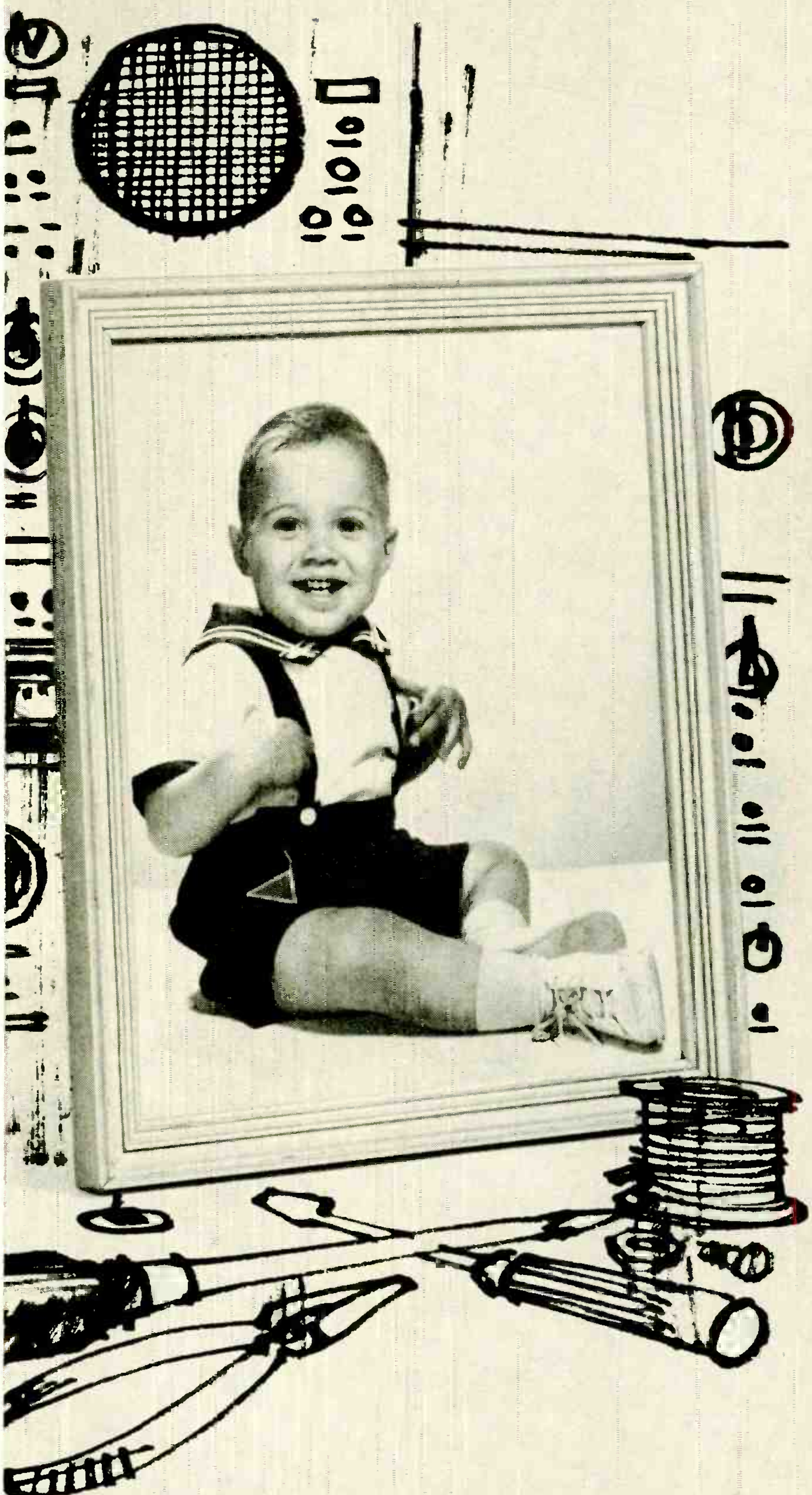

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For the record

WM. A. STOCKLIN, EDITOR

THE ELECTRONIC PARTS SHOW

THE "Electronic Parts Distributor Show" in Chicago is supposedly the "show of the year" for all manufacturers and distributors of electronic components. It is their only show and, if one were to judge the success of this year's performance solely by attendance, no one would doubt that it was a failure. Exact attendance figures are impossible to come by but we were able to walk through aisles from exhibitor to exhibitor without the customary pushing and shoving. In most cases booth attendants were readily available for discussion. To the newcomer this probably would not seem unusual but the old-timer remembers past years when one had to wait thirty minutes just to get on an elevator.

Times have changed—so have the industry and people in it. Ten years ago television was still young and manufacturers were working on new circuits, new components, and were making use of new test equipment. Dealers were excited about the potential growth of the industry and this was reflected at the Show. There was a lot of excitement and everybody in the industry attended.

Since that time we have seen the development of the CB and high-fidelity industries and they have helped to maintain some of this earlier enthusiasm. However, within the past few years the industry has generally standardized on circuits and components. Even test equipment is much the same as it was in previous years. Sure, there were new products; almost every exhibitor had something new or different to show, but in many cases it was a matter of restyling or a new form of packaging. The really new items—those capable of generating special excitement—were hard to find.

The Parts Show, however, is not just a showcase for new products. The component industry is a billion dollar market and, like most other industries, it is plagued with problems. The over-all sales of electronic components through parts distributors has increased only 1.8% in 1963 over 1962. This is the smallest gain in the last 8 years. The problems are obvious: community antenna systems are cutting heavily into antenna and tower sales; foreign imports of electronic parts are rising each year; there are more and more parts to handle; profit margins are decreasing while operating costs are rising. Just imagine what effect integrated circuits alone will have on the sale of individual components.

These are problems of both manufacturer and distributor and there is no better place to review them than at the Show. Obviously they cannot be eliminated but, at the same time, they cannot be ignored. One must learn to compete even against these odds.

This, in essence, was the real theme of the Parts Show: new marketing plans, sales aids, and profitability were subjects under major consideration among manufacturers, their reps, and distributors.

For those manufacturers who planned their programs ahead of time, planned meetings, and pre-arranged personal appointments, the show proved profitable. We talked with many exhibitors and nearly everyone, although not all, mentioned that they were extremely pleased with the results.

The Show Committee, like that for any show, can only set the stage and arrange the time and place. What the participants get out of the Show is in direct proportion to their own efforts. For astute businessmen who have the foresight to plan, the Show will continue to be a profitable venture year after year.

Sure, it is nice to have a large attendance but simply counting noses isn't a true measure of success. The importance of the Show lies in the caliber of the people who attend and, from what we saw, those that "counted" were there. ▲

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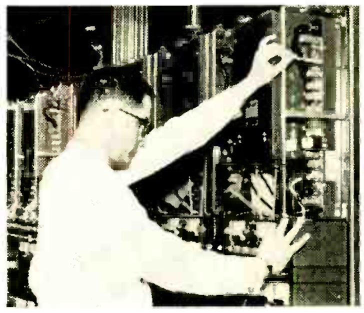

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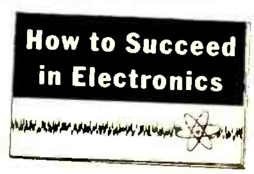

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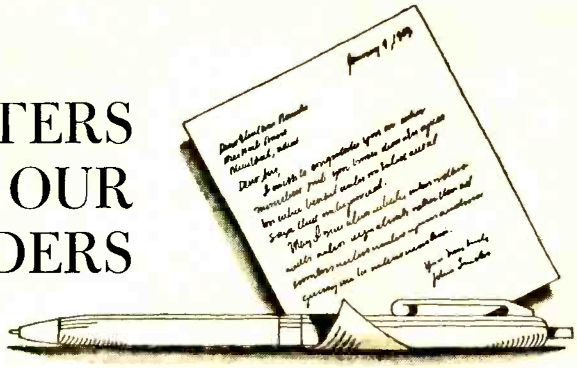

CONSTRUCTION HELP

To the Editors:

You recently ran a construction story entitled "Unusual D.C. to D.C. Supply" (May, 1964 issue). I cannot seem to get the circuit to operate properly although I followed the article carefully. The only change I made was in the type of transistor used.

Assuming you can help me to get the supply working, I would like to know how to modify the circuit to give 150 volts output. Also, do you have any additional information showing the layout of the parts and giving me some construction details?

JAMES B. YOUNG
Rochester, N.Y.

The above letter is fairly typical of a large number we receive every week on some of our construction projects. The performance described in any of our articles will be obtained only with the exact parts specified. We cannot give information on the circuit changes that would be needed with substitute parts. Also, we cannot design specific equipment or suggest modifications in our projects. A look through our Annual Index (December issue) might disclose a circuit that would be closer to your needs. Finally, we do not have pictorials or additional information on the articles other than that which has been published.

We like to hear about interesting experiences of our readers, particularly those pertaining to any of the stories we run. We also would like to know about circuit improvements or possible errors. Such information is always published just as soon as we hear about it.—Editors.

° ° °

TRANSISTOR IGNITION SYSTEM

To the Editors:

Last fall I constructed a transistor ignition system according to the instructions by Mr. Mayfield, as described in June, 1963 and revised in the September, 1963 issue.

The system has been working very satisfactorily since I rewired the car. I neglected to record the mileage when I installed it, but I estimate I have driven about 6000 miles since I installed it. Starting seems to be somewhat better and I am sure the acceleration has improved, even in the low-speed range where I usually drive.

The trouble I experienced upon installing the unit may be of some interest to others contemplating such systems. I installed it on a warm afternoon with the engine warm. After setting the coil current, it fired right off. I then opened the plugs to .055 and again it fired right off. Later that evening, with a cold engine, it wouldn't start until I increased the coil current. Checking the next day I found that the voltage at the unit was very low, about 4½ v. (from the 6-v. battery). Until I could install a relay I carried a jumper so that I could short out part of *R2* when starting it. When I installed a headlight relay, I was able to get 6 v. at the unit.

A few days later, on a rather cool morning, it wouldn't fire until I released the starter switch. That told me that the starter was pulling the voltage down. I overcame this by installing another movable contact on *R2* and connecting it to the other contact through a relay. This relay is controlled by the starter. The main contact was set to give a coil current of 7 amp. and the auxiliary contact set for about 10 amp. Under reduced voltage during starting the coil current is still about 7 amp. The relay used in the starting circuit is a modified horn relay.

DAVID H. MCGOUN
Pensacola, Fla.

Although the 10-amp. setting is too high for normal operation, if this setting is made in warm weather, operation should be normal in cold weather when the battery voltage drops during starting.—Editors.

° ° °

SIMPLE TRANSISTOR TESTER

To the Editors:

The "Simple Transistor Tester" article by J. E. Content and B. K. Morse in your May issue was interesting. The increasing number of transistors in use creates a high demand for such a field tool, and typical transistor failures justify this type of testing.

We have put together a similar item that is even simpler, both in content and in operation. We use it in conjunction with the safe ohmmeter in our Model 300 Digital Passive Scaler. A terminal post, a s.p.d.t. push-button, a d.p.d.t.

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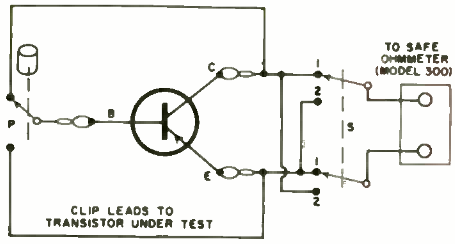


toggle switch, and three clip leads are needed. The ohmmeter, which is power-limited, supplies the voltage. The circuit is shown here.

Ohmmeter connection polarity and whether the device is *n-p-n* or *p-n-p* are immaterial. The base clip lead is a different color from the other two leads. The user needs to know which terminal of his device is the base. With this item and the safe ohmmeter, he observes transistor action by noting an appreciable difference in the resistance indication on the ohmmeter (at least a 30 percent deflection of the meter pointer) as push-button *P* is depressed for both positions of switch S. He can also determine very readily if any open or short circuits exist by observing that no appreciable resistance change, the same 30 percent, occurs as the push-button is depressed for both positions of switch S.

The ohmmeter used here presents a maximum voltage of 50 mv. on the X1 through X1k ohms ranges with a maximum current of 20 μa. on the X10k and X100k ohms ranges to any circuit under test. The X100k range is used for the transistor checker. The maximum power transferred is 25 μwatts. Use of this test with a conventional ohmmeter, as contained in a v.o.m. or v.t.v.m., can be disastrous to the device being tested.

Edward W. Rummel
Western Reserve Electronics, Inc.
Cleveland, Ohio

If the characteristics of the ohmmeter are known accurately, such as the maximum voltage and current on the various ranges, and if these do not exceed the ratings of the transistor being checked, such meters can be used for quick, non-quantitative checking.—Editors.

° ° °

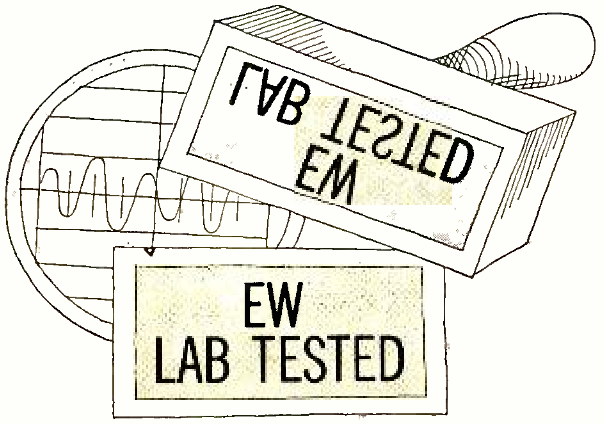
BACK ISSUES OF EW

To the Editors:

I have been a subscriber to Electronics World for several years and have accumulated approximately 80 copies of back issues, some dating back to 1952. Do you ever have any inquiries for back issues, or do you know whom I should contact to determine if there is an interest in these copies?

I would prefer to sell all back issues to one address, or to break them up into no less than a calendar year's group to any one address.

John Oezer
7865 Jolain Dr.
Cincinnati, Ohio 45242 ▲



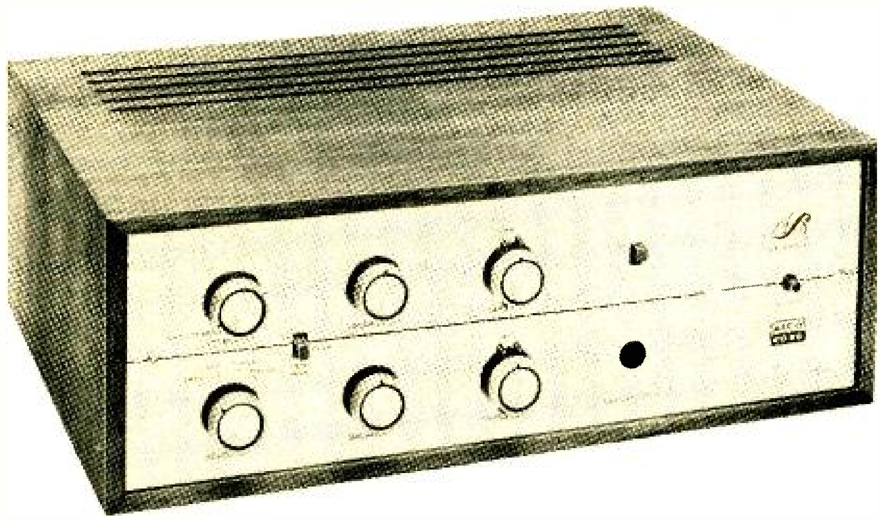
HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Eico Model 2036 Stereo Amplifier
Electro-Voice EV-2 Speaker System

Eico Model 2036 Stereo Amplifier

For copy of manufacturer's brochure, circle No. 52 on coupon (page 9).

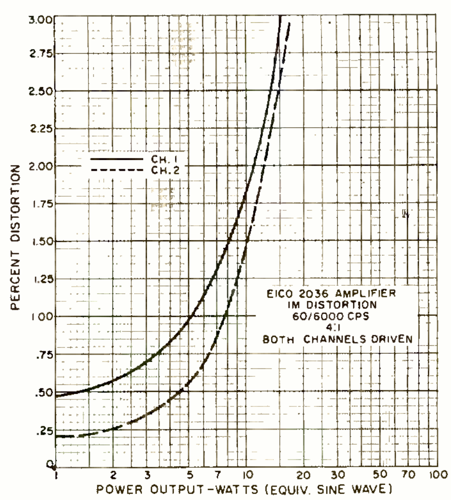


THERE is a current trend toward deluxe, highly styled, high-fidelity equipment kits which are designed for the utmost ease of assembly. These might better be termed "semi-kits," since all sockets, terminal strips, and transformers are pre-mounted on the chassis, and all critical circuits are pre-wired and pre-aligned. The builder, in return for the moderate effort required to complete the kit, gets a handsome piece of equipment which usually cannot be distinguished in performance or appearance from much more expensive factory-wired units.

The new *Eico* "Classic Series" of kits represents the firm's entry into the deluxe kit field. The kits come with three spiral-bound manuals: a two-color construction figures manuals, a construction steps manual, and an operating manual. Folding easels are supplied to support the construction manuals while working on the kits. The construction process is broken down into wiring steps, with not more than 20 components to be wired in each step. All the parts for each step are packaged as a group, and a separate figure is used for each step in the construction manual The kit may be replaced in its case in a partially completed state and taken out at a later time without the necessity of searching for parts or otherwise getting organized.

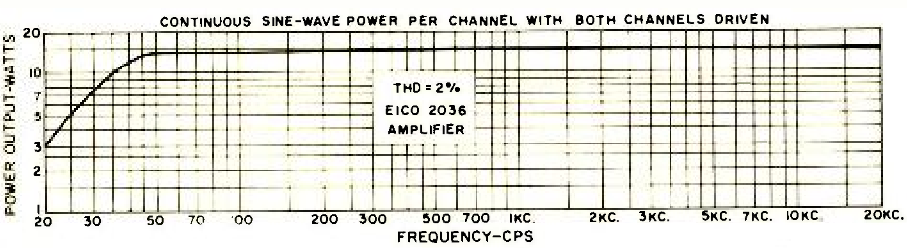
The "Classic Series" comprises several integrated amplifiers, mono and stereo receivers, and an FM stereo tuner. We tested the Model 2036 stereo amplifier, rated at 36 watts music power output. Other amplifiers are available with music-power ratings of 50 watts and 80 watts. The Model 2036 is designed for the wide market of users who are looking for good sound with a minimum of expense and gadgetry. It is rated at 28 watts continuous output (both channels) at 2% IM distortion, with a frequency response of ±1 db from 15 to 40,000 cps. It has inputs for tape preamplifier, high-level auxiliary, tuner, and magnetic phono.

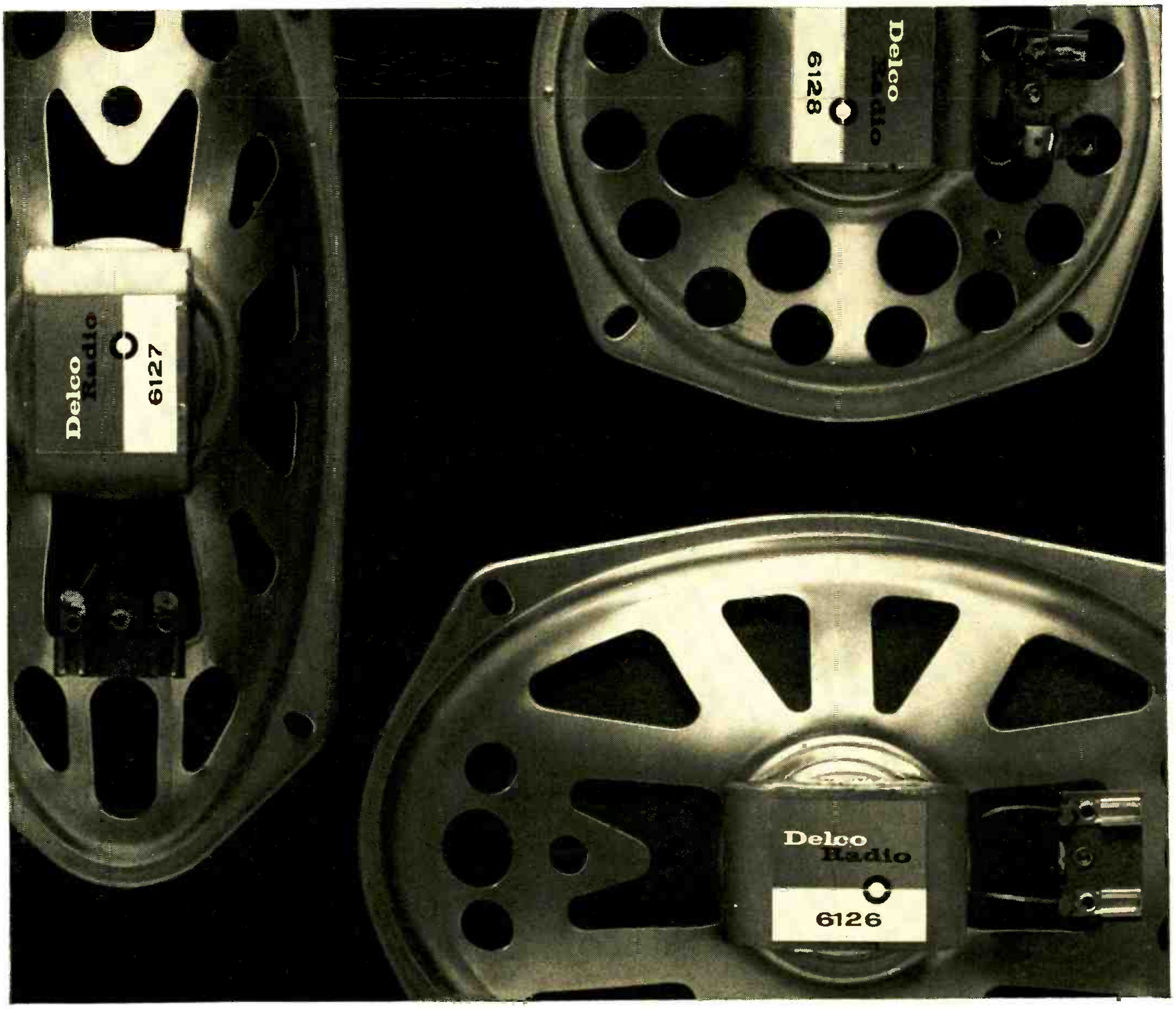
Each output stage uses a pair of 6BQ5/EL84 pentodes, driven by a 12DW7/7247 triode as a voltage amplifier and phase splitter, with over-all negative feedback. There are 8-ohm and 16-ohm outputs, selected by a slide switch on the rear of the chassis. A feature of the Model 2036, not often found



in amplifiers of its price class, is the provision for connecting two independent pairs of speakers, selected by a front-panel switch.

The "basic-amplifier" section is preceded by a 12DW7/7247 tone-control amplifier. The tone controls are of the negative-feedback type, with the desirable variable inflection point characteristic of this circuit. This allows appreciable correction at either end of the spectrum without affecting the mid-range response. The tone-control stage is preceded by a ganged volume control and followed by a balance control. Another front-panel control blends the two





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channels smoothly to provide any mode of operation from full stereo, through a partially blended condition, to full mono. The phono preamplifier is a 6EU7 dual triode with negative-feedback equalization circuits. Tape-output jacks supply the selected input signal to a tape recorder, unaffected by volume- or tone-control settings. A front-panel tape-monitor switch allows off-the-tape monitoring when a machine with separate recording and playback amplifiers and heads is used. There is also a front-panel stereo headphone jack.

Our laboratory measurements confirmed the manufacturer's performance specifications in all significant respects. The power response at 2% harmonic distortion was flat at 14 watts per channel from 40 to 20,000 cps, with both channels driven. As is the case with most amplifiers in this price class, the low-frequency power response falls off considerably, but there is plenty of power to drive any of the moderate-efficiency speakers likely to be used.

The IM distortion was less than 0.5% for power outputs up to a few watts per channel, rising to about 2.5% at 15 watts per channel. The basic frequency response, with tone controls set at their mid-points, was flat within ±0.5 db from 20 to 20,000 cps. RIAA phono equalization was also very accurate, within ±1 db from 30 to 15,000 cps. The maximum tone-control range was +13 to −14 db at 50 cps and 10,000 cps, with mid-range response unaffected by tone-control settings. The ganged volume control sections tracked within 1 db over a 35-db range.

The input voltage required to drive the amplifier to 10 watts per channel output was 0.2 volt on high-level inputs and 1.7 millivolts on phono inputs. Unused inputs are shorted out, eliminating any possible crosstalk from the tuner when listening to phono. The hum was an inaudible −75 db on high-level inputs, and −41 db on phono, referred to 10 watts. The front-panel tape-monitor switch picked up a slight hum when the hand was brought near it. This hum, while not very loud, would be recorded on a tape being made and would come directly over the reproducing system.

In listening to the unit, we found it to be free from any audible faults. It was clean-sounding, with excellent tone-control characteristics and complete freedom from the input-circuit crosstalk and switching transients which mar so many otherwise satisfactory amplifiers. A minor criticism could be directed against the labeling of the volume control as a "loudness" control. This implies that it is compensated for the Fletcher-Munson characteristic, with bass boost at low volume levels. Actually, the volume control is uncompensated.

With a host of operating niceties and a set of honest specifications, the Model 2036 deserves serious consideration from anyone looking for a moderate-priced stereo amplifier. It sells for $79.95 in kit form, or $109.95 factory-wired. An oil-finish wooden cabinet is available for $19.95, and a metal cover for $7.50. ▲

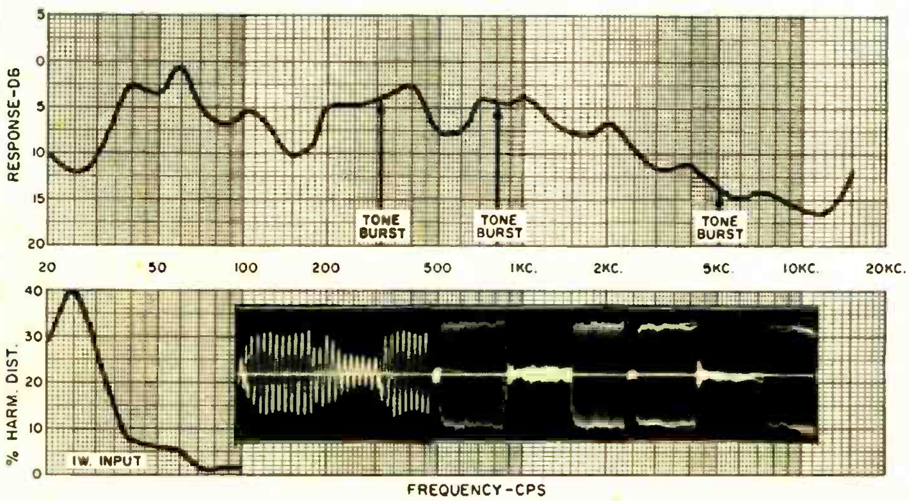
Electro-Voice EV-2 Speaker System

For copy of manufacturer's brochure, circle No. 53 on coupon (page 9).

ALTHOUGH *Electro-Voice* has long been noted for its efficient, horn-loaded speaker systems, it is now also producing speakers of quite different design. An example is the Model EV-2. This compact, bookshelf-type speaker system combines a low-efficiency acoustic-suspension woofer with a horn-loaded, compression-type tweeter. The enclosure, which is available in oiled-walnut or mahogany finish, measures 14"x 25"x 13½" and weighs 43 pounds.

The woofer is a 12-inch diameter driver with a heavy die-cast frame and a ceramic magnet. The 8-ohm voice coil is wound with edgewise ribbon on a glass-fiber form. The compliant suspen-

(*Continued on page 75*)



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New 3" Portable Scope

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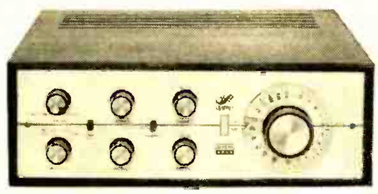
Eico 369 TV/FM Sweep generator, with built-in post injection marker adder. Kit $89.95; wired $139.95.

New CB Transceiver

Eico 777 dual conversion 6 crystal-controlled channels, 5-watts. 3-way power supply. Kit $119.95; wired $189.95

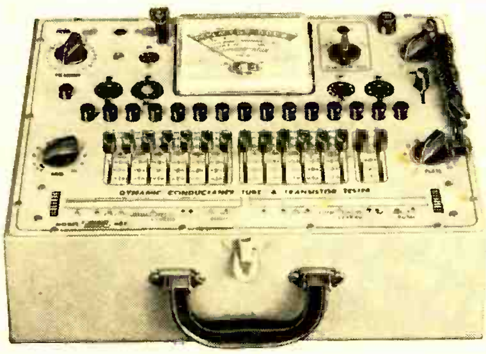
New Stereo Rcvrs.



Eico Classic 2536 36-watt FM-MX Stereo Receiver. Kit $154.95; wired $209.95 (Incl. F.E.T.)
New Stereo Tuner Eico Classic 2200 FM-MX Stereo Tuner. Kit $92.50; wired $119.95 (Incl. F.E.T.)

New Stereo Amplifiers Eico Classic 2036 36-watt. Kit $79.95; wired $109.95. Eico Classic 2050—50-watt stereo. Kit $92.50; wired $129.95. Eico Classic 2080 80-watt stereo. Kit $112.50; wired $159.95.

New Tube Testers



Eico 667 Dynamic Conductance Tube & Transistor Tester. Kit $79.95; wired $129.95. Eico 628 Tube Tester. Kit $44.95; wired $59.95

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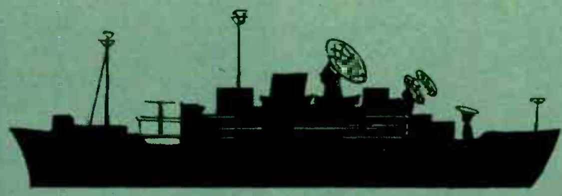
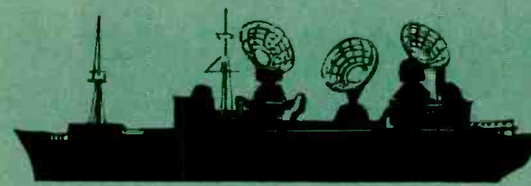


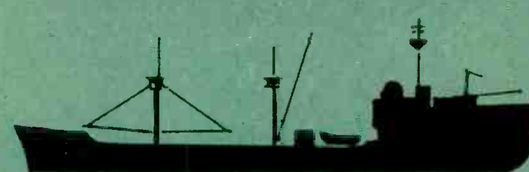
AMERICAN MARINER

TWIN FALLS

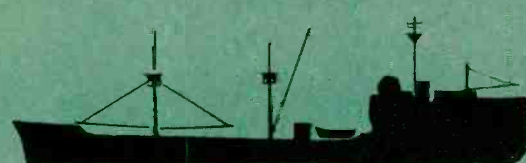


GENERAL HOYT S. VANDENBERG

GENERAL H. H. ARNOLD



COASTAL CRUSADER



SAMPAN HITCH

TIMBER HITCH

SWORD KNOT

ROSE KNOT

COASTAL SENTRY

FLOATING SPACECRAFT TRACKING STATIONS

By RICHARD LaCOSTE

Spacecraft tracking stations are not always located on hard ground. In fact, a pair of the most highly sophisticated stations are mounted on two specially equipped ships that can be located on any ocean.

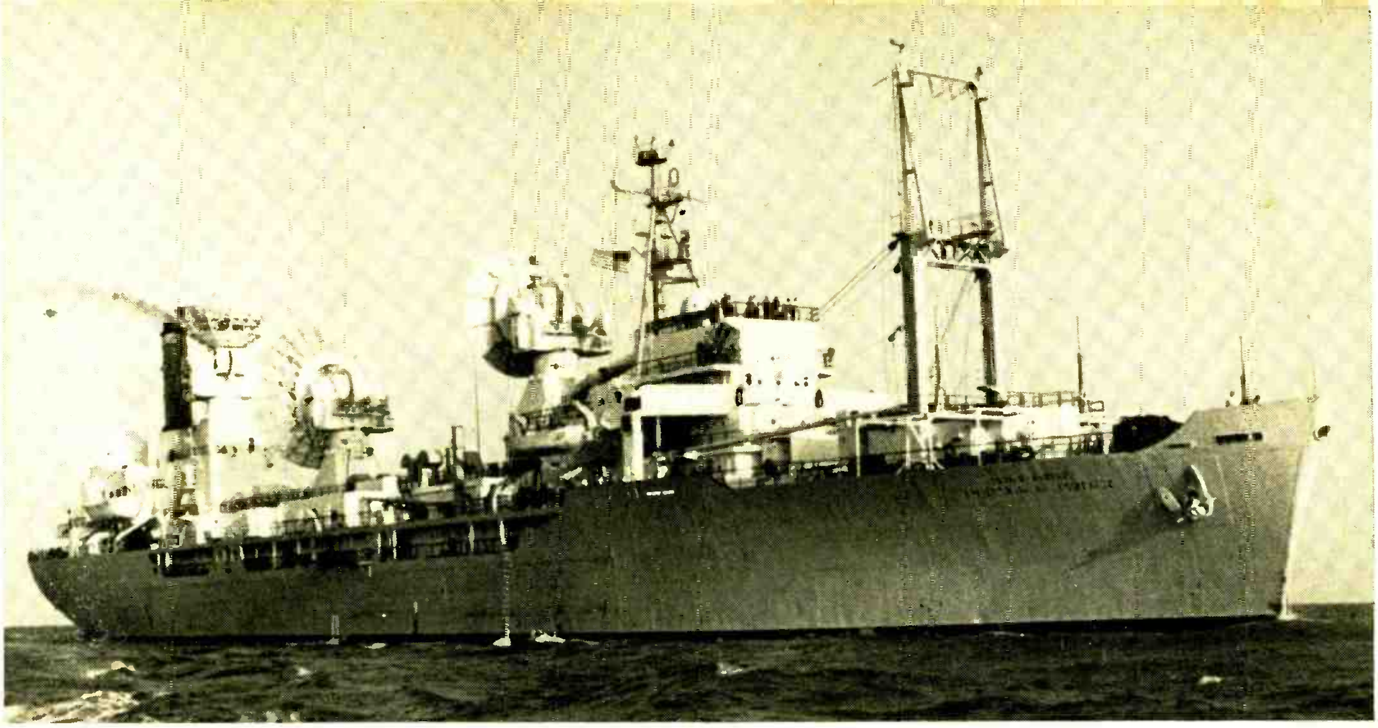
THE Atlantic Missile Range (AMR) extends from Cape Kennedy, Florida, to the Indian Ocean, some 10,000 miles away. This range is used to provide exact data on all phases of a missile's performance from launch to termination of flight.

To accomplish its mission, the AMR has established ground tracking stations at Grand Bahama Island, Eleuthera Island, Trinidad, Ascension Island, and Pretoria, South Africa.

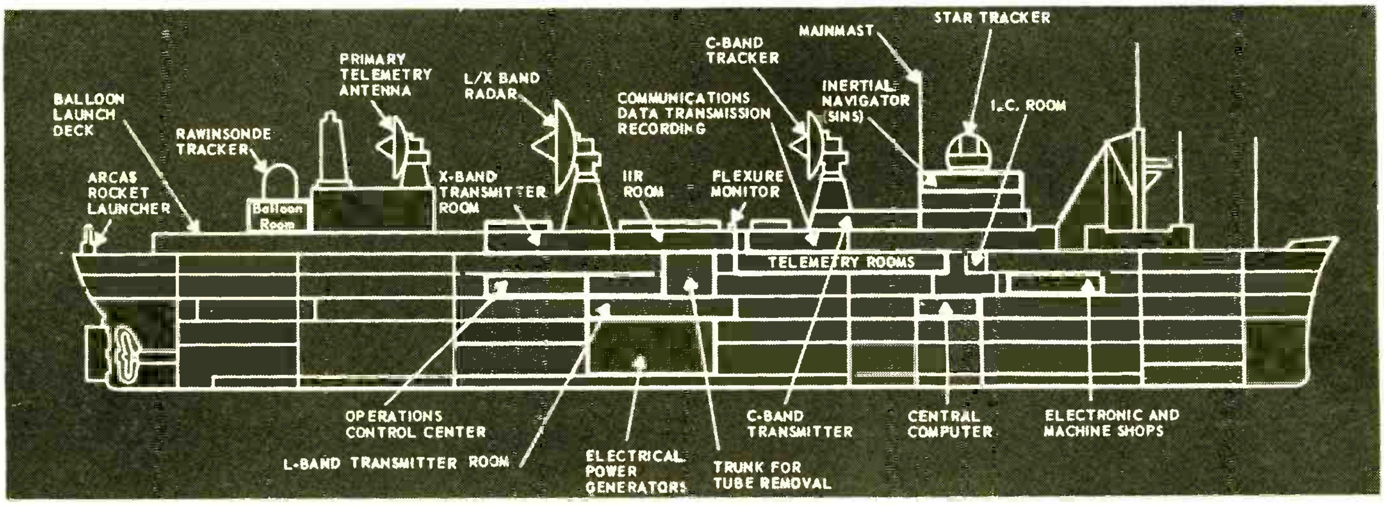
Another network for use in manned space operations is the former Mercury Ground Communications Network, now part of the Manned Space Flight Network controlled from Goddard Space Flight Center, Greenbelt, Md. This network also has ground-based tracking stations scattered around the earth.

Both of these tracking networks also require the use of a pair of floating tracking stations that can be stationed at sea in any part of the globe to cover otherwise empty sectors of the missile's planned flight path.

This is the purpose of the Advanced Range Instrumentation Ships (ARIS), the "General H. H. Arnold" and the "General Hoyt S. Vandenberg." These two vessels, part of a fleet of 10 ships, carry the very latest in electronic equipment for reception and recording of spacecraft teleme-



The "General H. H. Arnold" is a converted troop transport and is the world's largest and most heavily instrumented missile and space tracking ship. The interior arrangement shows how bulk of the electronic equipment is arranged in the vessel.



try, tracking, and voice communications in the case of manned flights. Navigation equipment on board these ships is capable of placing its position within yards relative to Cape Kennedy, many thousands of miles away.

ARIS instrumentation is divided into eight subsystems: operations control center; integrated instrumentation radar; stabilization; navigation; communications/data handling; telemetry; meteorological; and timing.

Operations Control Center

This center functions as the command post during tracking missions and systems tests. The centralized control facility provides for smooth internal operation and assures proper integration of the ARIS station into AMR operations.

During missions, center personnel coordinate with other AMR stations, aircraft and ships; review system and subsystem status; assure correctness of ship's position, speed and heading; monitor and countermand subordinate decisions; and select the source of sensor designate information.

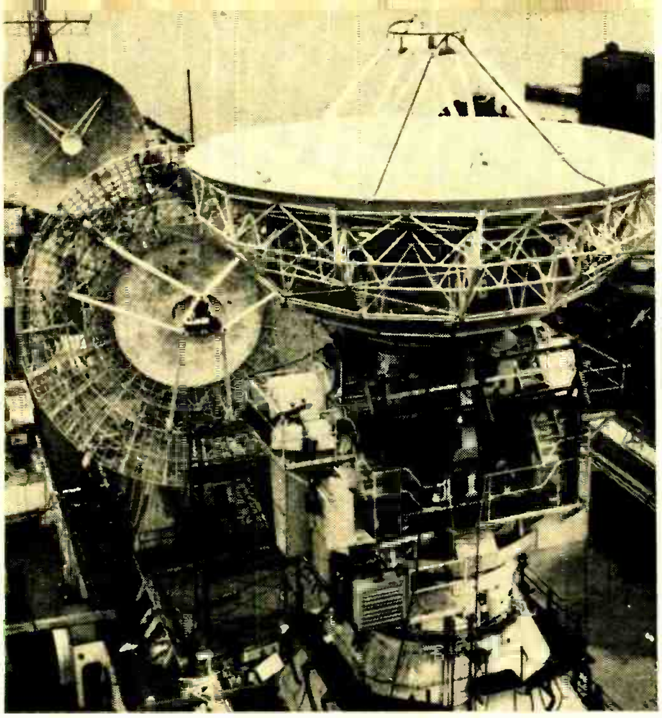
Integrated Instrumentation Radar

This consists of three radars operating at C (5.7-6.2 kmc.), L (.39-1.55 kmc.), and X (5.2-10.9 kmc.) bands. The primary tracking device is the C-band radar using a parabolic reflecting antenna thirty feet in diameter. Precision has been stressed in the construction of the antenna. The radar provides complete tracking data on re-entry bodies from the launching of the missile to its impact. Similar to C-band radar is the L/X-band radar. This uses a dual-frequency antenna forty feet in diameter. The center 18 feet are used for X-band radar and the remaining portion for the L-band radar. These radars also provide data on re-entry.

Stabilization and Navigation

The exact location of the ship must be known if the received satellite tracking data is to be of any value. A complex navigation system continuously supplies this information on the ship's position, heading, speed, and vertical reference. The system consists of: SINS (Ships Inertial Navigation Systems), a navigation control console; a water speed-measuring system (E-M log); a star-tracker; and a Mk-19 gyro-compass and sonar bench mark equipment.

The heart of the system is SINS. It contains three gyros and two accelerometers. Because of gyro drift, this inertial system develops errors that increase with time. The drift or precision error is determined by a star fix. A star-tracker measures star altitude by locking onto the star's position, then a computer solves the celestial problem and a navigation fix is made. Sonar bench marks also are used as a navigational aid for updating SINS' accuracy. The bench mark is dropped over the side in a known position. It has an acoustic transponder mounted on a buoyant tank which is anchored by a



Three radar and telemetry antennas are used on the larger ships. In the foreground is the 30-ft. telemetry antenna.

battery container. When the sonar set is triggered, a reply is received from the transponder. The elapsed time, as a function of range, is measured to each beacon thus locating the ship with respect to the bench marks.

Communications

The highly sophisticated communications system is designed to meet all external and internal needs. It includes one of the most powerful radio communications systems ever installed on board a ship. One 10,000-watt and two 2500-watt high-frequency transmitters provide complete long-range voice, teleprinter, and high-speed data communications up to 10,000 nautical miles from Cape Kennedy. An interior communication network has been developed for use by the

Integrated instrumentation radar room of the "General H. H. Arnold." This system uses alternate polarization of three radars to gather 3.6 million bits of data per minute about the trajectory and impact point of the incoming vehicle.

Navigation area of the "General H. H. Arnold." Accuracy of this system is such that it can locate the ship within yards of Cape Kennedy although vessel is thousands of miles distant.

instrumentation personnel. This network consists of three types of intercom stations, each varying in channel capacity, which link key shipboard instrumentation personnel.

Data Handling

The data handling system consists of the central data conversion and control equipment and a *Univac* 1206 stored-program digital computer. The conversion equipment has two main purposes: to serve as an interface between the major systems (SINS, C-band radar, L/X-band radars, telemetry) and the *Univac* 1206 computer, and to store all trajectory and non-trajectory data collected during a mission. The over-all accuracy of the data conversion equipment is 0.4 percent. All stored information is in digital form, having been transformed by the conversion equipment. The data processing needs are met by the *Univac* 1206 digital computer. This is a general-purpose machine of small size and high resistance to shock, vibration, and unusual climatic conditions. The computer performs such functions as system checkout, target acquisition, target tracking, data format, data transmission, navigational fixing, and information updating. Most information is stored on magnetic tape.

Telemetry

The telemetry system is used for acquiring, tracking, receiving, and predetection recording of telemetry data from

An inflated bag is secured to an Atlas nose cone after it has landed in the ocean. This particular nose cone flew 5000 miles.

the re-entry vehicle. It is capable of either independent or integrated operation with other sensors, or it can be used to aim other tracking sensors to a proper angle of acquisition, and it can be slaved to the C-band radar or computer for position information. A 30-foot parabolic antenna is used for reception of telemetry signals.

Meteorological

To aid in the analysis of missile performance and the scheduling of tests, the ARIS vessels provide data on atmospheric pressures, density, wind direction, and speed of sound. This is accomplished through surface weather equipment, weather balloons, and high-altitude ARCAS rockets.

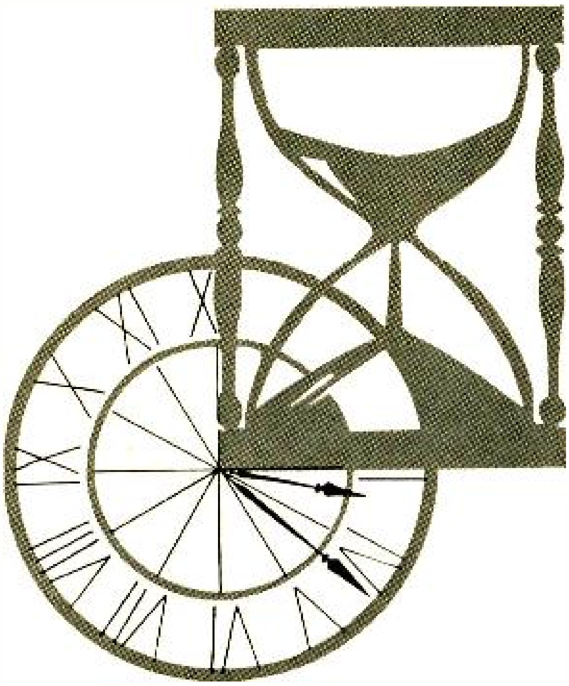
Timing

The timing system provides real-time codes and indexes for time correlation of pertinent data. These codes are distributed in various digital serial formats throughout all the systems for accurate time correlation of all recorded data. The time code and indexes will maintain time correlation, relative to Cape Kennedy timing, within 10 microseconds at distances up to 10,000 miles. Two radio systems provide this synchronization.

The general operational procedure of the ARIS ships will be as follows:

1. The ships will sail prescribed courses in the vicinity of the expected impact points, (*Continued on page* 56)

FREQUENCY & TIME STANDARDS



By GEORGE E. HUDSON, Asst. Chief
Radio Standards Physics Division, National Bureau of Standards

The work of the NBS on atomic frequency standards and their accuracy. Included is a description of the U.S. Frequency Standard, which can control clocks that could run 3000 years without gaining or losing over a second.

IN recent years, the National Bureau of Standards has been conducting developmental research on the precise measurement and generation of frequency and time. For radio communications, the tracking of satellites, the control of long-range rockets, and astronomical observations, timing accuracies of one part in a billion or better will be required in the future.

Many scientific and engineering activities rely on regular radio transmissions of standard frequencies from Bureau stations WWV, WWVB, WWVL, and WWVH and from the Navy's NBA to provide high accuracies. These broadcasts are based, in part, on astronomical observations related to the earth's rotation as made by the U. S. Naval Observatory. However, to meet the ever-increasing need for even greater accuracy, the Bureau has been investigating atomic frequency standards, which are a thousand times more precise for time-interval determinations than the earth's rotation.

A Frequency-Time Standard

Let us first consider a device which actually realizes the limits of accuracy with which we are able to generate and determine frequencies—and times—for the present. This is the United States Frequency Standard, illustrated on the cover and in the various accompanying pictures and diagrams. It is located in Boulder, Colorado, in the Radio Standards Laboratory of the Institute for Basic Standards—one of the four Institutes which now comprise the National Bureau of Standards.

For some time now the primary standard for frequency in the United States has been an atomic one. Up until now the most precise such standard has used a cesium beam, undergoing a hyperfine dipole structure transition using magnetic resonance as its controlling element. In effect, the cesium atoms are constantly spinning in such a way as to produce magnetic poles having a certain orientation. Under certain conditions of excitation, the atoms appear to suddenly "flip over" or reverse their spin direction and the magnetic poles reverse.

The cesium beam frequency standard is essentially an atomic beam spectrometer which emits a signal only when the frequency of radiation introduced through a waveguide into the cavity through which the beam is passing is precisely equal to the resonance transition frequency. This frequency is actually in the microwave region. The presence or absence of the signal indicates whether the frequency of the radiation, itself generated by a quartz-crystal oscillator driving a frequency multiplier chain, is within the allowable tolerance limits.

In practice, the quartz signal generator is manually or automatically varied over a narrow band to find the "center" frequency. When the spectrometer output is at a peak, the signal generator frequency is known within ± 0.1 cps or 1.1 parts in 10^{11} (a hundred billion). Automatic equipment is used to control the signal generator so that the spectrometer output stays at the maximum. This provides a signal of known and nearly constant frequency for as long as the device can be kept running. As the separations of the quantum states of an isolated atom are fundamental constants of nature, they provide a stable, reproducible standard of frequency and time interval when the atomic beam resonance technique is used.

Previously, the most uniform time-intervals available were those derived from astronomical observations of the rotation of the earth relative to the fixed stars. This was corrected to the orbital motion of the earth about the sun. The orbital motion of the earth at 12 hours (noon, E.T.) on January 0, 1900 (December 31, 1899) is the basis of what is called Ephemeris Time (E.T.). In 1956, the second of Ephemeris Time was adopted as the fundamental unit of time by the International Committee of Weights and Measures (CIPM) and this action was confirmed by the General Conference on Weights and Measures in 1960.

Steps were taken by the Conference toward the adoption of an atomic standard for time-interval. In early December of 1963, the Consultative Committee for the Definition of the Second of the CIPM met in Paris. This committee recommended, among other things, that the cesium frequency should serve as an international provisional standard on which the atomic second of time should be based. Research, of course, should continue as to the best atomic standard, but it recommended that the astronomical second be dropped except as needed for celestial mechanics.

A time scale approximating Ephemeris Time can be made immediately available by the use of atomic standards, quartz-crystal oscillators, and counters. In terms of the ephemeris second, the frequency of the cesium transition has been experimentally determined to be 9,192,631,770±20 cps. The probable error, ±20 cps (or 2 parts in 10^9), results from the limitations on the precision of the astronomical measurements. Consequently, it is common practice now, and in line with the policy that the atomic frequency transition studied at the Bureau of Standards is the primary one for the United States, to take the frequency of the transition to be exactly at 9,192,631,770 cps (or 9192.63177 megacycles).

To avoid inconsistency, we must regard the error quoted of 2 parts in 10^9 to be the error in determination of the ephemeris second in terms of an exactly defined atomic second. Such a definition is being currently considered. If the cesium transition is adopted for this purpose, one second of atomic time will consist of 9,192,631,770 cycles of the electromagnetic radiation absorbed or emitted by a cesium atom in changing its state. The physical picture in this particular case is that the magnetic dipole moment of the cesium atom changes because of a spin transition.

Measurement of a frequency or a time-interval in terms of the cesium transition can be made with a typical precision of 1 part in 10^{12} and is not limited by the instrumental difficulties involved in astronomical observations. See Fig. 1. Until official action is forthcoming it can not, however, supplant the present definition of a scale for time based on the non-uniform apparent motion of the sun.

It seems natural to base the standard of time-interval on the physical process that provides the most uniform and most accessible interval. The precision of measurement for the atomic standards is a hundred times better over a 15-second period than astronomical measurements made over a period of 3 years.

Also under investigation as a standard of frequency is the thallium atom, which has certain significant advantages over the cesium atom in this application. However, thallium may have some disadvantages in practical use. A thallium beam is now in operation at the Boulder Laboratories to determine which of the two atomic systems is more suitable.

Radio Transmissions

At the present time, radio transmissions controlled by the Bureau's master quartz-crystal oscillators are being monitored with cesium beam frequency standards. Corrections for the 60 and 20 kc. standard frequency broadcasts from NBS radio station WWVB and WWVL at Boulder, Colorado, are being made regularly and are available on request from the Broadcast Service Section of the Bureau's Boulder Labs.

The time generation system now employed at the Boulder Laboratories comprises the most accurate clock that man has ever known. Fig. 2 is a schematic diagram of this system, which generates the NBS-A time scale. W. Atkinson, L. Fey, and J. Barnes have been chiefly responsible for its development.

Recent comparisons with other time scales—such as those of Essen in England and particularly Bononomi in Switzerland—the so-called TA_1 time scale—have shown agreement to within 1 part in 10^{11} over about a two-year period. This means that these time scales diverge at the rate of 1 second in 3000 years.

One of the time scales that is computed at the Naval Observatory from astronomical observations is designated as UT-2. It is an approximation to Ephemeris Time and represents an average scale obtained by correcting the earth's

Fig. 1. Simplified block diagram of the frequency measuring system which utilizes the cesium beam U.S. Frequency Standard.

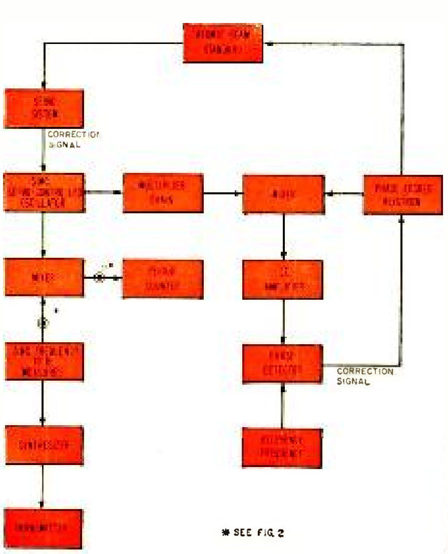
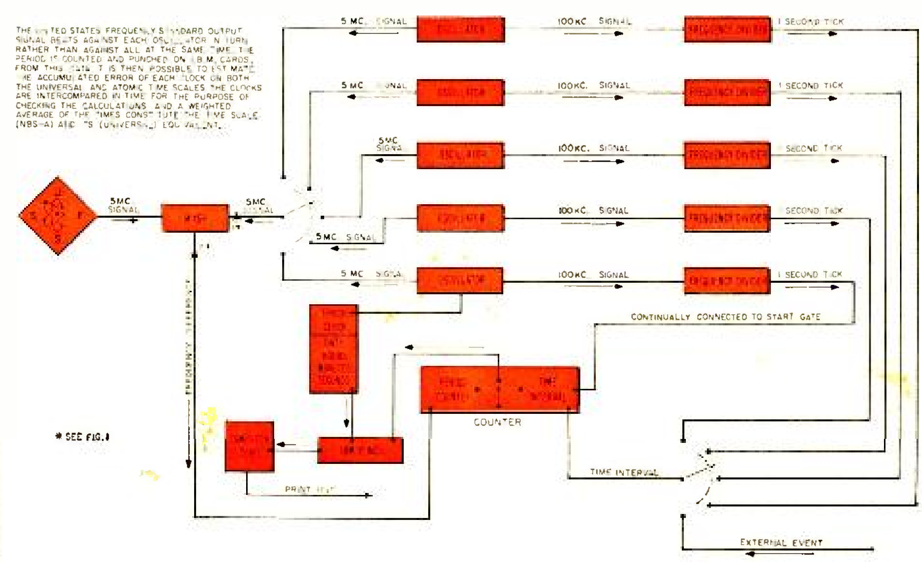
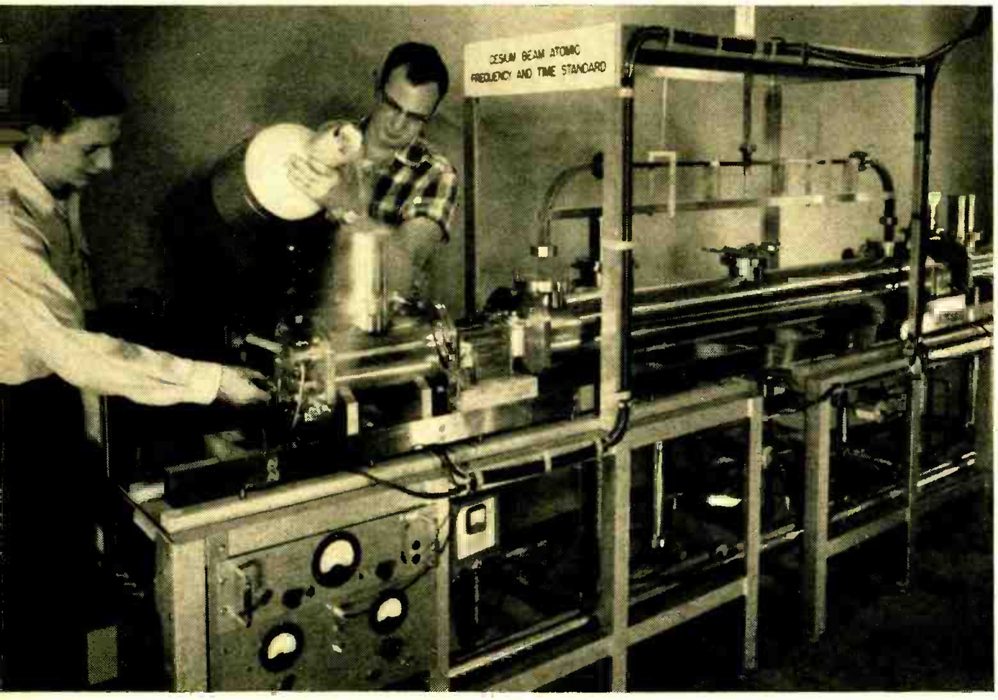


Fig. 2. A simplified block diagram of the NBS-A atomic time-scale generator. The U.S. Frequency Standard, shown in Fig. 1, beats against each of the five oscillators in turn. After a time intercomparison, a weighted average is used.





Scientists are shown above pouring liquid nitrogen (at a temperature of −320° F) from a Dewar into one of the cold traps in the NBS "atomic clock" at the Boulder Laboratories. The nitrogen lowers the temperature in the evacuated tube and causes stray gas molecules and other impurities to condense around the cold end of the trap. This reduces the chance of collision between the cesium atoms and molecules of air, thus improving the vacuum and increasing cesium-beam accuracy.

period of rotation on its axis. After correcting for longitude effects on the astronomical observations which yield UT-0 directly, one obtains UT-1. Then correcting for seasonal variations in rotation speed one obtains UT-2. The U. S. Naval Observatory obtains a composite "atomic" time scale—known as A1, by taking a weighted average of various atomic standards from the United States and European laboratories. The average is obtained from broadcast transmissions. However, propagation effects lead to many technical questions which remain to be investigated. The Naval Observatory publishes the difference between A1 and UT-2 regularly.

On the basis of the NBS-A atomic scale which has been kept continuously since the Fall of 1957, it is known that the UT-2 scale, which really is simply an average representation of the earth's rotation, shows that the earth has slowed down by about 2.9 seconds in this time. It is clear that the uniform atomic time scale NBS-A generated at the Boulder Laboratories and based on the atomic frequency standard must be heavily relied on for the serious business of accurate time-keeping. It is also clear that the United States is maintaining its eminence in this field.

Principles of Time Keeping

The principle of keeping time with an atomic clock is simple. If one has a continuous record of the frequency, f, of any oscillator and a concurrent record of the number of cycles of vibration, or phase of the oscillator, then the time interval between two given phases can be calculated. If one plots the quantity $1/2\pi f$ *versus* the phase, the time interval is just the area underneath the curve between the two phase values.

Now to do this one must have a continuously running oscillator, or several oscillators (for redundancy and to increase statistical reliability) and measure their frequencies periodically by comparison with the atomic standard. Then one must also count the cycles generated by the oscillators with a suitable counting circuit. The NBS-A time scale is generated essentially in just this way. To account for the tiny variations in frequency of the oscillators used (four quartz ones and one rubidium one) intensive studies have been and are being made of their physical and their statistical characteristics.

The result is a clock whose accuracy in keeping time is only limited by the accuracy of the U.S. Frequency Standard itself. There is not one but five complete time keeping systems in the fail-safe setup shown in Fig. 2. A weighted average of the five leads to the NBS-A atomic time scale.

Signals from this system control the broadcast frequencies and time furnished by the Bureau, under the direction of Mr. D. Andrews. A recent innovation utilizing a phase-lock system insures that the time signals emitted by WWV are in phase with the NBS-A scale to within 25 microseconds. It is only at certain intervals, as the earth gradually changes its rate of rotation, that shifts must be broadcast so that all the signals simultaneously are kept in agreement with UT-2 furnished by the Naval Observatory. Between times, the rate of time ticks is atomically controlled. Thus the Bureau of Standards must maintain two time scales simultaneously under its NBS-A system.

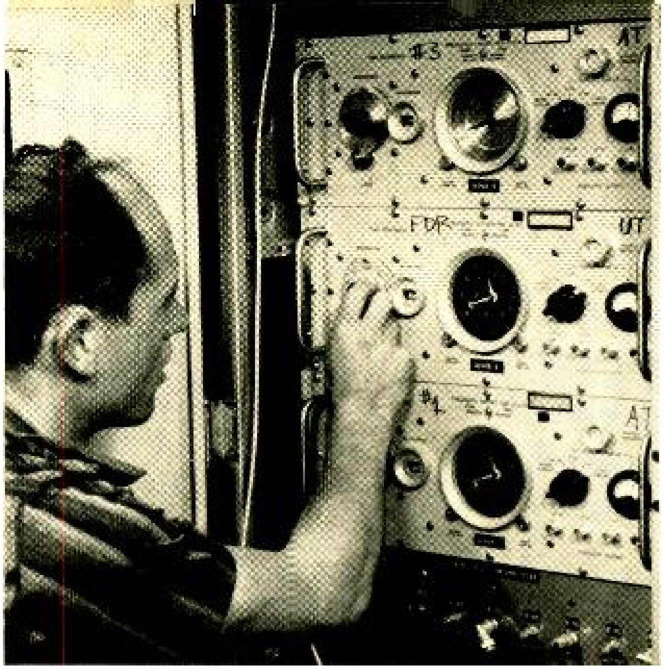
Atomic Beam Spectrometer

The atomic beam spectrometer, which is the heart of our frequency and time measuring system, is shown in cross-section in one of the photos. Neutral cesium atoms effuse from the oven and pass through the non-uniform magnetic field of the deflecting magnet. As the atoms act as miniature bar magnets (they are said to have a magnetic dipole moment), a transverse force will act upon them in this non-uniform field. The magnitude and direction of this force depends upon which of the energy states the particular atom is in. Of all the atoms effusing from the oven, suppose those with nuclear and electron spins in the same direction, say up, have their trajectories bent toward the axis. Atoms on the other side of the center line with spins in opposite directions, with the net being down, will have their trajectories bent toward the axis also. Note that atoms with upward spins and those with downward spins experience forces in opposite directions. The upward-spin atoms and the downward-spin atoms will cross the axis at the collimator slit, pass through the slit, and enter the region of the B deflecting magnet.

As the B magnetic field is exactly like that of the A magnet, it exerts the same transverse force on the atoms as does the A magnet field. The upward-spin atoms will experience a downward force as before and the downward-spin atoms will be acted on by an upward force, as before. As the two sets of atoms are now on opposite sides of the center line of the evacuated tube (compared to their previous positions), these forces make their trajectories more divergent.

However, if a radiation field is applied at just the proper frequency (which matches the energy separation of the two quantum states), transitions between the two states will occur in the region between the A and B magnets. The spins will be reversed in the two beams, and a quantum of energy will be either emitted or absorbed. Since the sign of the magnetic moment has changed in moving from the A magnet to the B magnet, the force on these atoms will reverse its direction and the atoms will be re-focused onto the axis at the detector. Thus, as the exciting radiation is swept in frequency, the detected signal will increase and reach a maximum at the critical frequency, and then decrease as the radiation frequency is varied on either side.

An NBS scientist is shown retarding by 0.1 second on April 1, 1964 the clock which maintains Universal Time (UT) at the Boulder Laboratories. This 100-millisecond adjustment was necessary due to changes in speed of rotation of the earth, as determined by astronomical observation. Center clock (being adjusted) is kept in close agreement with UT-2 (GMT). The top and bottom clocks, which are controlled by the U.S. Frequency Standard and which are not adjusted, maintain atomic time and were in agreement with UT-2 on Jan. 1, 1958, as determind by the U.S. Naval Observatory. Since that time, the clock maintaining UT has lost about 2.9 seconds relative to atomic time. Since UT-2 is determined by the earth's rotation (which is slowing down), the center clock must be retarded periodically and progressively loses time (150×10^{-10} sec./sec. for 1964).



We have tried to furnish some notion of the intense activity which is now current at the Boulder Radio Standards Laboratory of the National Bureau of Standards' Institute of Basic Standards. Highly accurate atomic standards exist at the Bureau—but they are constantly being improved and modified as the state of the art progresses.

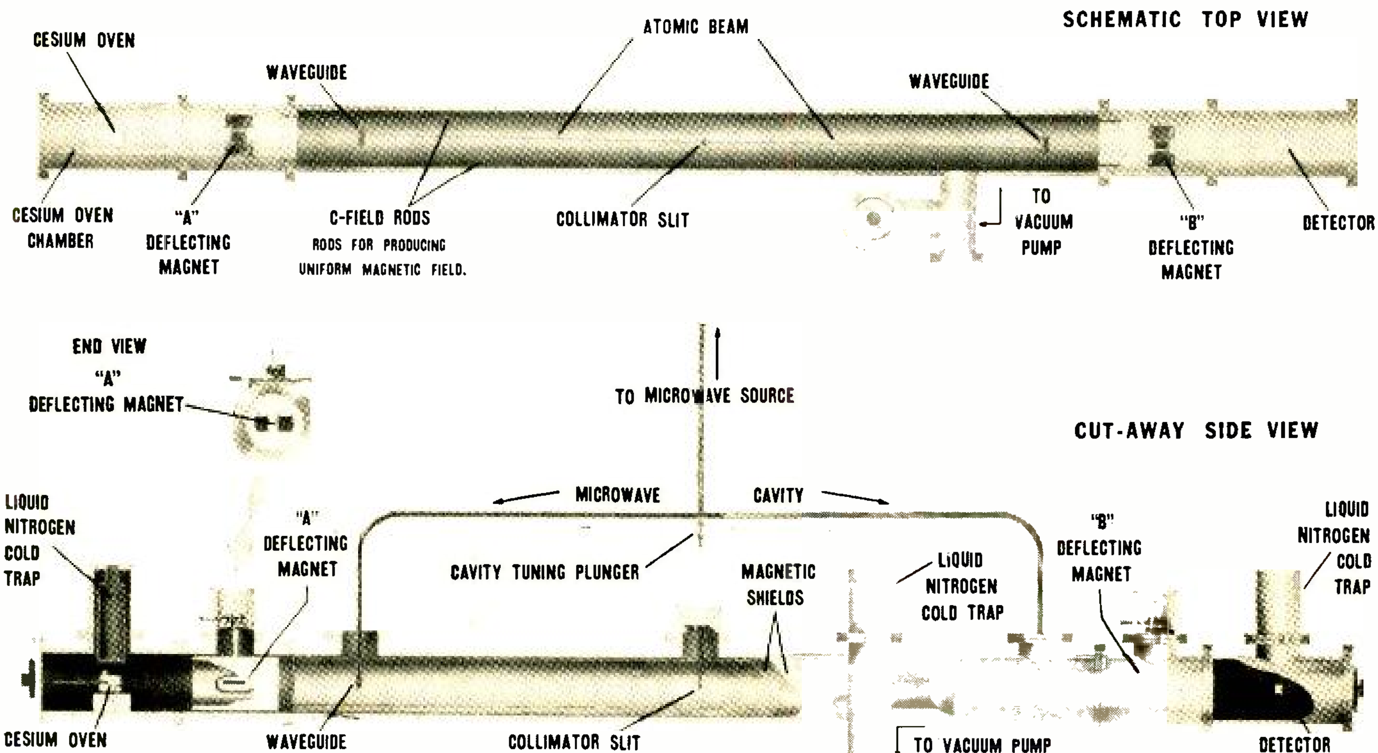
A hydrogen maser is under development and will soon be ready for comparison with the cesium beam frequency standard. Commercial varieties are now available which hold considerable promise of being at least competitive with the presently used standard.

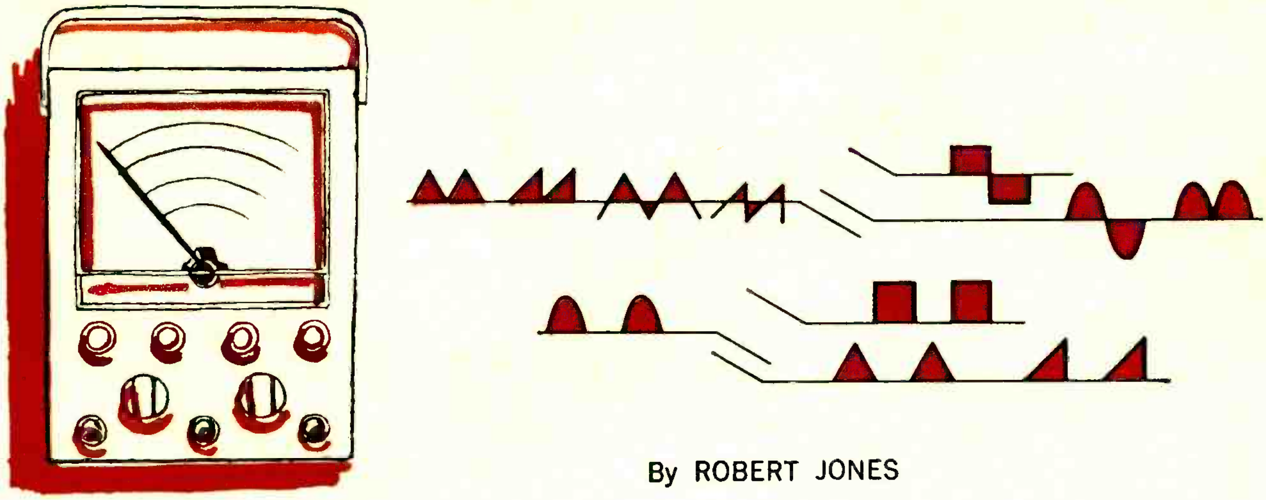
The adoption of the definition of the atomic second as the international standard of time seems to be in the immediate offing. The NBS atomic frequency standard itself controls the rate of the very accurate atomic time scale and the broadcast information, whereby industry and the scientific community can feel confident that it is receiving the best and most up-to-date services available in the area of frequency and time.

The author wishes to express his thanks for and acknowledgement of the contributions made in the writing of this article to his associates at NBS (BL). ▲

Cut-away scale drawing of the NBS cesium beam frequency standard, or "atomic clock," shows the location of the cesium oven at the left end where the cesium atoms are emitted; the deflecting magnets at each end which bend the beam and direct it through the collimator slit to the detector; the microwave cavity and waveguide, which introduce the microwave frequency; the three liquid nitrogen cold traps used to remove, by condensation, impurities not removed by the vacuum pump; the magnetic shields, designed to eliminate the influence of terrestrial and other outside magnetic fields; the hot-wire detector at far right end where the beam impacts and is detected. This equipment is essentially an atomic-beam spectrometer excited by a crystal oscillator driving a frequency-multiplier chain. The radio waves, oscillating at a frequency close to the vibration-per-second rate of the cesium atoms (9192.63177 mc.), are tuned slightly so that they match the atomic rate. When they match, the radio waves are absorbed; the radio frequency is then the same as that of the cesium atoms—and a near absolute standard is available. The device can measure an unknown frequency with an accuracy of 1.1 parts in 10^{11} (one hundred billion). This is equivalent to measuring the width of the United States with less error than the thickness of this page. Its stability is even higher—at least a few parts in 10^{12} per year—and at the present time these figures represent one of the best achievements in this field in the entire world.

ATOMIC BEAM FREQUENCY STANDARD





By ROBERT JONES

METER READING CONVERSION NOMOGRAMS

CONVERSION of meter readings for different waveforms aids in checking equipment against a diagram's reference voltages when limited test equipment is available. There are many meter types ranging from the hot-wire ammeter to the vacuum-tube voltmeter. Each of these instruments may have a slightly different reading when used on waveforms which are not pure sine waves. The problem becomes more bewildering when some meters respond to one value of a waveform (for example, the average) and the scale supplied with the instrument reads another value (for example, the r.m.s.). In this case the calibration is always performed on a sine wave, but the scale reading will be correct only for this particular waveform.

The picture becomes more complicated when a square wave is applied to this same instrument, as it will now be found to be reading high by 1.15 times the true r.m.s. value of the wave. To further complicate matters, the reading error changes with each change of waveform from sine waves to isoceles waves, sawtooth waves, square waves, and pulses.

Average-Responding Meters

Meters responding to the true average value of a waveform are quite common. A typical example is the pocket type of meter or the a.c.-reading v.o.m.'s. In fact, any meter using copper oxide, magnesium copper sulphide, selenium, silicon, or a crystal diode as a rectifier, either as a half-wave or full-wave rectifier and without a capacitor across the output of the rectifier, responds to true average values for any waveform. The scale provided with common commercial instruments reads in r.m.s. values. This means the true average value can be found by multiplying the meter scale by 0.903 in order to obtain the correct average value for any other waveform that we might be interested in.

R.M.S.-Responding Meters

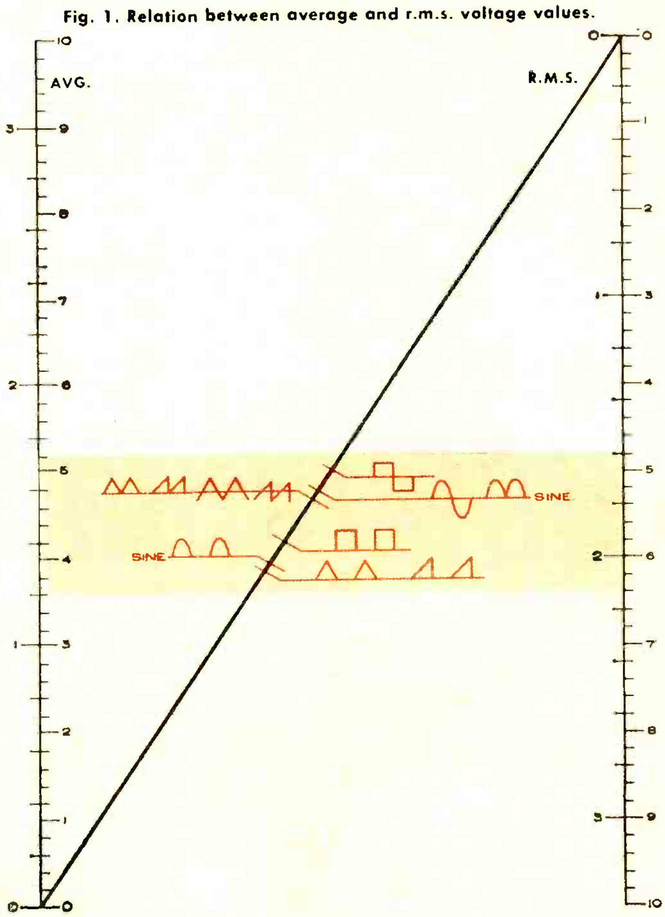
These meters include the moving iron-vane meters, thermocouple meters, hot-wire meters, electrodynamometer meters, and electrostatic meters. For this group of meters the meter scale, if r.m.s., matches the meter movement and the instrument will read true r.m.s. values for any waveform.

Peak-Responding Meters

Peak-responding instruments include the slide-back vacuum-tube voltmeter, cathode-ray oscilloscopes, rectifier-type instruments with a capacitor across the output of the rectifier, and some types of v.t.v.m.'s. The response of these meters is true peak for any waveform and most will have scales calibrated in peak values. These meters give correct readings for any waveform except for pulses of short duration compared to the repetition frequency.

If the meter scale is calibrated to read r.m.s., then the true value can be found by multiplying the scale value by 1.414. If, however, the scale is calibrated to read average

Fig. 1. Relation between average and r.m.s. voltage values.



values, then the scale reading must be multiplied by 1.571 to give true peak value of the waveform being measured.

Vacuum-Tube Voltmeters

The determining factor in this type of meter is the bias supplied to the tube or transistor which does the detecting or rectifying. The bias sets the operating point and by this means the conventional v.t.v.m. becomes peak, average, or r.m.s. responding. Hence, the common v.t.v.m. without a special input circuit cannot usually be relied upon to read true values when anything but a true sine wave is applied. Consider the waveform as applied to the meter from the detector. The amplitude is dependent on the amplification provided by the tube and on the bias supplied to the control grid, while the waveshape or distortion at the cut-off end of the tube characteristic curve is dependent only on the bias setting. Since tubes of the same type vary from tube to tube and with usage, any given bias setting cannot be relied upon to make the conventional meter read the true value of peak, average, or r.m.s. This does not reduce the usefulness of the v.t.v.m.—being calibrated on sine waves and reading sine-wave values—but it does make it difficult to correct for other waveforms that we must measure.

True Values & Corrections

Once the true values of a voltage or current are known, be it average, root-mean-square, or peak, the remaining two values can be computed provided the waveshape is known. For example, if we have a sine wave and know the r.m.s. value, then we can find both the average and peak values by simply applying appropriate correction factors. This same approach can be applied to many waveforms, but of course the correction factor changes with each different waveshape.

The ratio *r.m.s. to average* values is generally called the *form factor* of a wave. This ratio is different for each waveshape, being 1.11 for sine waves and 1.00 for square waves. Another ratio, *peak to average,* is known as *field form factor* and is 1.57 for a sine wave and 1.00 for a square wave. The *peak to r.m.s.* ratio, known as the *peak* or *crest factor,* is 1.414 for a sine wave and 1.00 for a square wave.

Fig. 1 shows the relationships between average and r.m.s. values for various waveshapes. Fig. 2 relates r.m.s. and peak values for various waveforms. Fig. 3 relates average and peak values. In all cases the peak, r.m.s., and average values are measured true values.

These charts are used by placing a ruler or straightedge from the known value in one column through the known waveform to the required answer in the second column. In using the charts, be sure that you read values on the same sides of the various voltage scales. Also, all scales can be extended by dividing or multiplying by 10, 100, 1000, etc.

The technician without a particular type of test instrument called for in a service diagram, can forecast the value that would be measured by the proper meter. This, of course, requires that the diagram show the waveform or that the technician be able to forecast the probable waveshape at the point of measurement. If a scope is the measuring instrument, then both waveform and true peak values are available and the charts can provide conversion. ▲

Charts permit the conversion of peak, r.m.s., and average meter readings so that existing meters can be used to check a variety of applied waveforms.

Fig. 2. R.m.s. and peak voltage values for various waveforms.

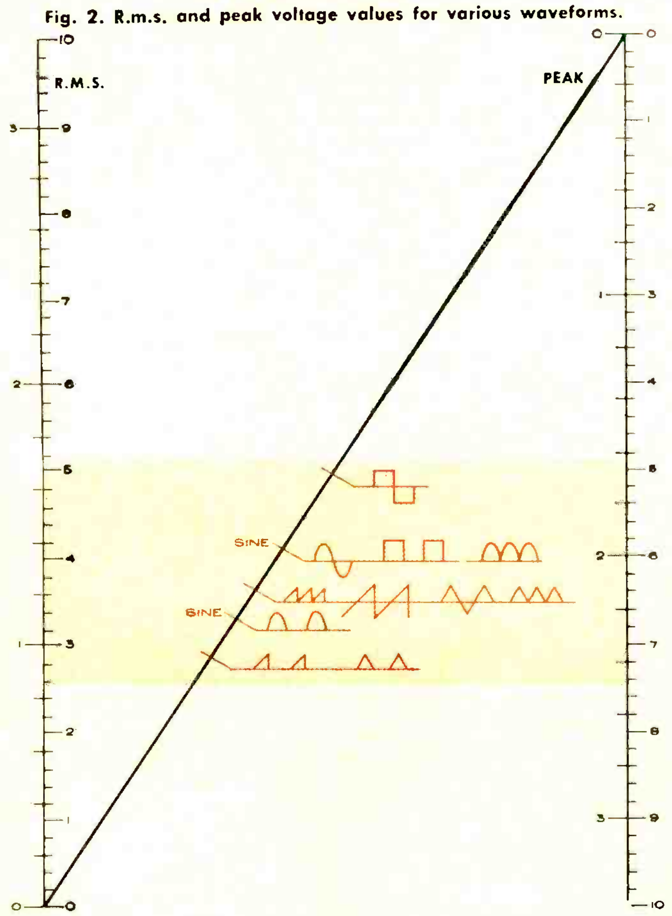
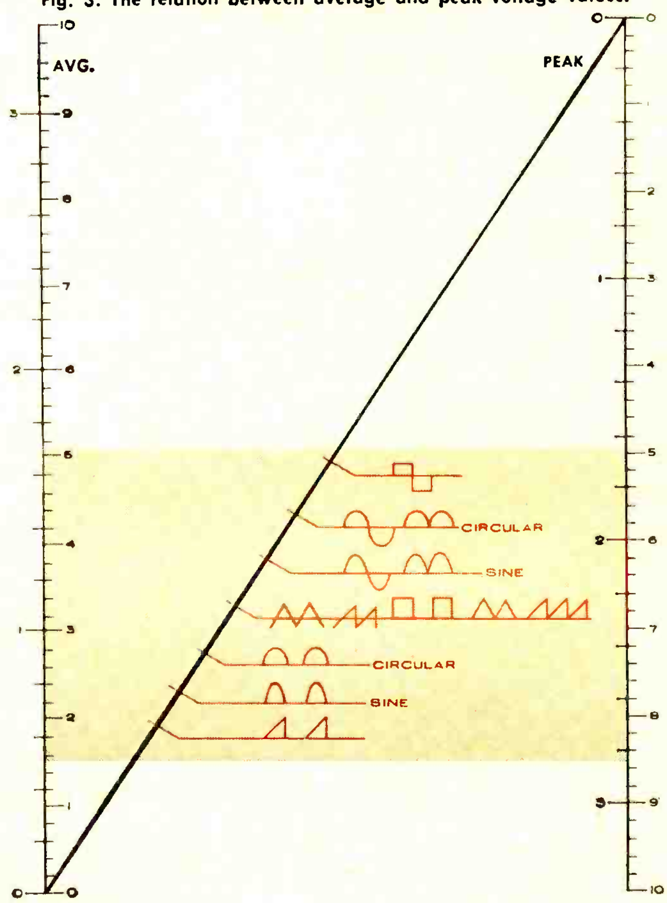
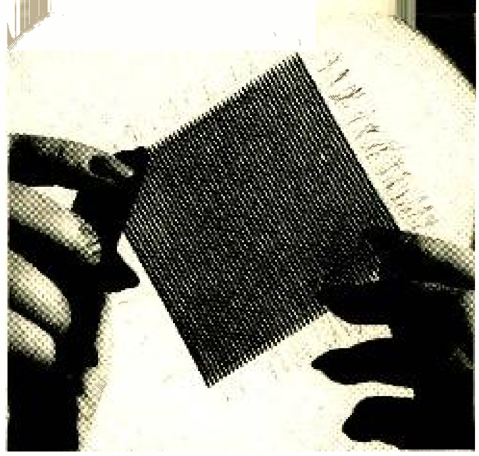


Fig. 3. The relation between average and peak voltage values.

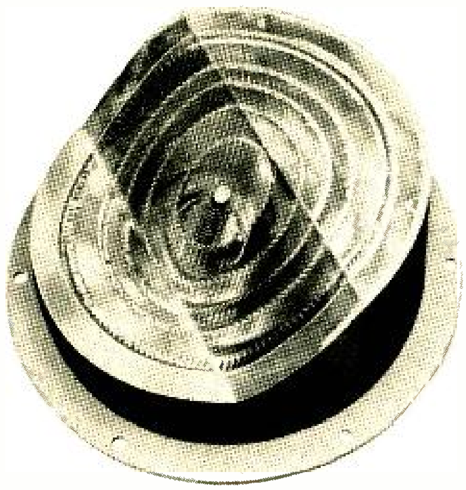


RECENT DEVELOPMENTS in ELECTRONICS



Molded Memory for Computers. An experimental "flute" memory array has been made by molding tiny magnetic ferrite tubes over a mesh of fine wires. The name of the IBM-developed array is derived from the flute-like appearance of the individual magnetic tubes. This experimental array can store 5000 bits of information. A bit, either a "1" or a "0," can be stored by changing the magnetization direction of the ferrite material at the intersection of any two wires.

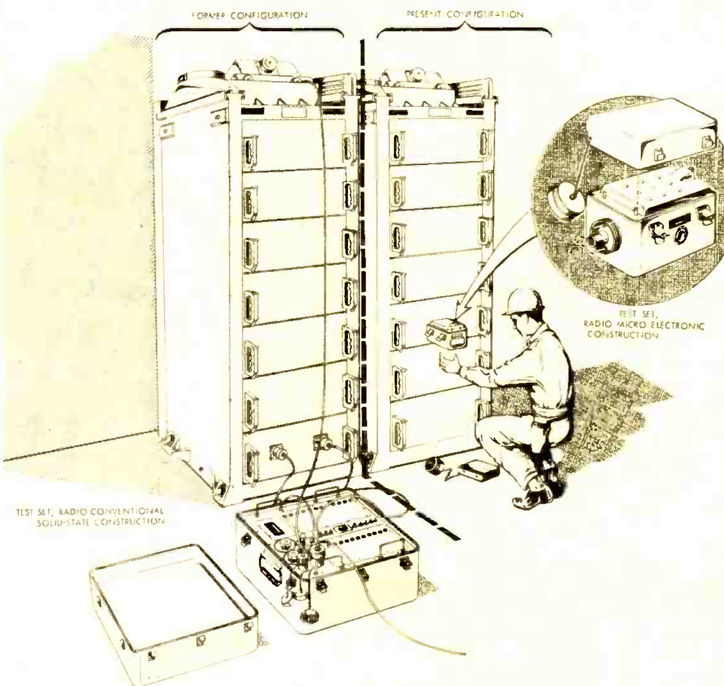
Thermoelectric Cooler. A compact thermoelectric cooler for epoxy cements and other fast-setting compounds has been introduced. The unit draws less than 45 watts and is completely solid-state, having no moving parts or cooling fans such as would be used in a mechanical refrigeration system. The material to be cooled is placed in a disposable 4-oz. aluminum cup which fits into a block of foam insulation. The cooler has two temperature settings: one cools 10-15 degrees C below room temperature, the other 28 degrees C below room temperature. The device sells for approximately $100 from Carter-Princeton Co.

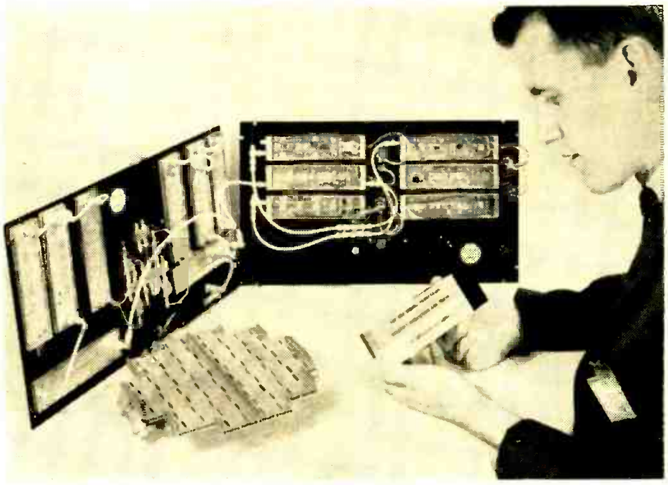


Electron Multiplier Tube. A cutaway view of a five-stage electron multiplier tube shows a pentode structure surrounded by five dynode electrodes. This tube uses secondary emission, such as is used in photo-multipliers, to achieve high gain and fast response. One of these Tung-Sol tubes can replace complete multistage amplifiers in microwave systems. They are also used to supply trigger pulses for traveling-wave tubes and klystrons with a total input to output time delay of only 20 nanoseconds. The tube can supply a pulse of 4 amps peak at 600 volts peak.

Laser-Beam Deflector. A scientist at the General Telephone & Electronics Labs is shown with a newly developed device which electronically deflects laser light beams. The bending occurs when the beam is directed through a crystalline bar just above his hand. The index of refraction of the crystal varies in direct proportion to an applied electric field. This changing refraction causes the beam to sweep back and forth as much as 30 times the beam angle. Such deflection would permit an earth-based laser to sweep 900 sq. mi. over the moon's surface in search of a receiver.

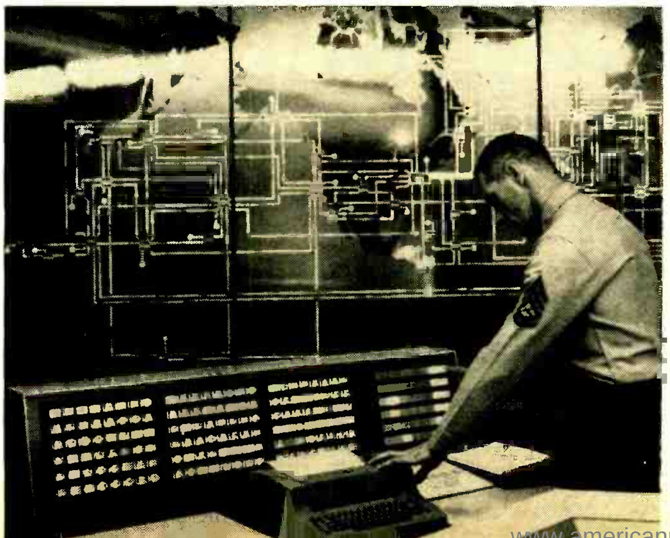
Integrated-Circuit Tester for Minuteman. A shoebox-sized unit for testing ground electronic equipment for the Minuteman missile has been developed. The test set uses integrated circuitry to achieve smaller size and lighter weight than the previously used steamer-trunk-sized tester (at left in the illustration). Where previously two technicians were needed to move the bulkier test equipment into position, and cables and connectors were used to attach it to a rack of electronics equipment, the new 12-lb. Sylvania unit is handled by one man and plugs directly into the rack. The tester first tests itself and then performs a series of tests on the equipment. Light panels give immediate indication of equipment performance. Entire test cycle takes 20 seconds.





Molecular Electronic Radar. An X-band doppler radar using molecular electronic functional blocks for all receiver and signal-processing circuits has been developed by Westinghouse. The entire system, except for the antenna array (center), servo motors, and gyros, can be packaged in the 2"x 2"x 6" mock-up being held in the photo. The only non-molecular device included, besides these items, is a solid-state local oscillator.

Experimental Picture Telephone. An experimental telephone that transmits a caller's picture along with his voice was demonstrated at the N.Y. World's Fair by the Bell System. The video bandwidth of the system is 500 kc., scanning is 275 lines per frame interlaced, and there are 30 frames or 60 fields per sec. A person using the system can control whether he wants to be seen, whether he wants to see himself or the person being called.



Computer Monitors Defense Communications. A new status reporting and control complex is being used to monitor the Defense Communications System's 19-million mile network of communications channels. A display board, activated by IBM computers, shows the status of the various circuits and identifies trouble anywhere in the system. Landlines, high-frequency circuits, microwave links, ionospheric and tropospheric scatter circuits, and other channels, are indicated with varicolored lights. Military commanders can monitor the entire network or any selected portion of it.

DISTORTION IN PHONO CARTRIDGES

By JAMES H. KOGEN / Chief Engineer, R&D, Shure Brothers, Inc.

By matching the playback stylus vertical angle with that of the cutting stylus, distortion is reduced.

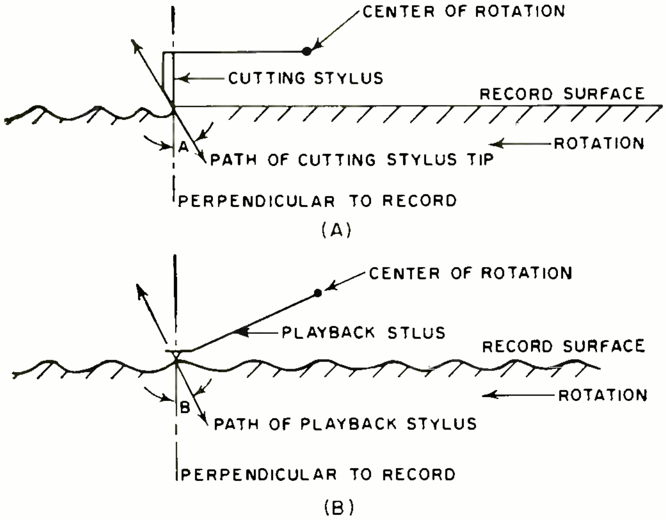


Fig. 1. (A) Motion of the cutting stylus on the master record. (B) The motion of the playback stylus with respect to record.

THERE are many factors which can contribute to distortion in a phono cartridge. Assuming that any good cartridge design will eliminate the flagrant sources of distortion, we can still cite at least five significant contributors.

1. *Lateral tracking error.* Lateral tracking distortion occurs when the center of rotation of the playback stylus is not on a line tangent to the record groove at the point where the stylus makes contact. Distortion from this source is minimized by proper geometrical configuration of the tonearm. Lateral tracking error in all good tonearms, properly mounted, is less than 5°—and the resultant distortion is quite small.

2. *Vertical tracking error.* Vertical tracking distortion is caused when the playback stylus moves in a different vertical arc than that which is cut in the record.

3. *Tracing error.* Tracing distortion results from the fact that the round playback stylus differs in shape from the wedge-shaped cutting stylus.

4. *Dynamic distortion.* Dynamic distortion results from the fact that the playing surface of the record is not infinitely hard and is, therefore, indented to some extent by the playback stylus.

5. *Rattling in the groove.* This distortion occurs when the needle loses contact with the groove wall. Such a situation can happen during very highly modulated passages.

Vertical Tracking Error

The cutting stylus used in making the master record follows a motion as depicted in Fig. 1A. It has been known for years that distortion will result if the playback stylus does not have the same effective center of rotation as the cutting stylus. Formulas have been developed from which the expected distortion can be calculated. The significant variable in the formula is the vertical tracking angle error, defined as the difference between the effective cutting angle *A* (Fig. 1A) and the effective playback angle *B* (Fig. 1B).

Although this theoretical information had been used for some time, something seemed to be amiss. Measurements consistently showed distortion to be considerably higher than we would expect from the theory. Late in 1962, engineers at both the *CBS* and *RCA Laboratories* discovered at least one major cause for the discrepancy. It had previously been assumed that the effective cutting angle of the record could be determined by measuring the free motion of the cutting stylus. Precise measurement proved, however, that the effective angle at which the record is cut differs from this free motion by as much as 21°, a startling difference.

The reasons for this difference have not been thoroughly proved as yet, but at least two major contributors are known. One factor is the bending of the cutting stylus as it slices through the surface of the master disc. A second factor is the so-called "springback" of the record material as it is being cut. Although this material is literally being cut, there is a certain amount of springiness in the record material which results in a slight alteration of the groove modulation after the cutting stylus passes.

Clearly the way to eliminate this source of distortion is to eliminate the tracking-angle error. To do this, it is necessary that the cartridge manufacturer have a single target to shoot at. This means that the record companies must standardize on a vertical cutting (recorded) angle. Such a standard has been proposed as 15° by several standardizing organizations both in the United States and abroad. Many of the major recording companies are now cutting records at this angle. The way is now clear and cartridge manufacturers are designing pickups to match this standard.

The dramatic decrease in harmonic distortion that can be obtained by matching the playback stylus tracking angle to that on the record is shown in Fig. 2. This curve was drawn from measurements made with the *CBS Labs'* test record STR-160 and the *Shure* M44-7 cartridge, designed for a 15° vertical tracking angle. This curve shows that a significant reduction in distortion can be obtained when the angles are matched. A considerable increase in distortion can be noted when the tracking angle error is 20°, which was the best match possible for most of the older style high-fidelity cartridges and records.

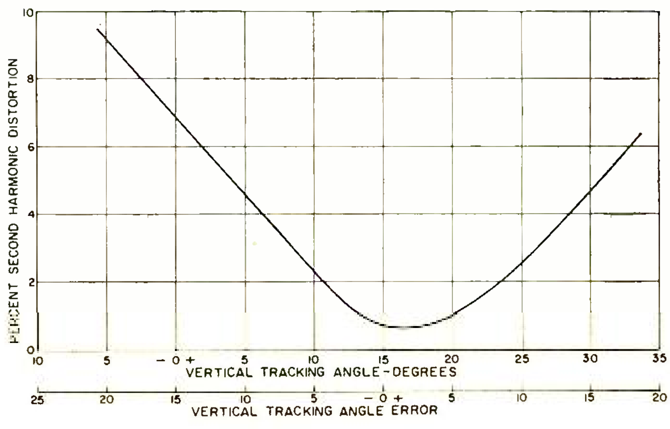
To guarantee a continued reduction in distortion, therefore, it is imperative that:

1. The recording industry agree on standard measuring methods for determining vertical tracking angle.

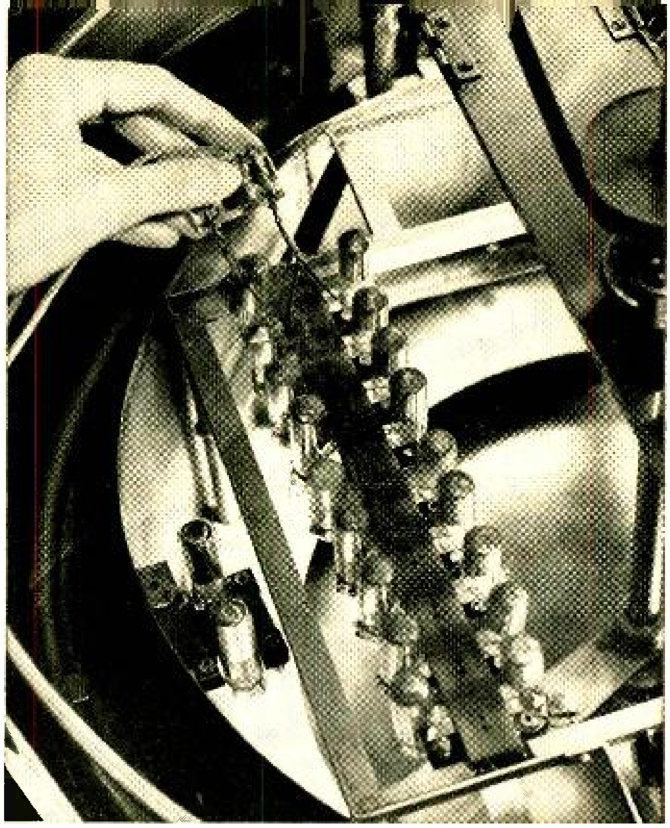
2. Recording companies standardize on a single vertical tracking angle, preferably 15°.

3. Playback cartridges be designed to match the recording standard. ▲

Fig. 2. Distortion characteristics of Shure M44-7 cartridge at 2 grams tracking force on CBS Labs STR-160 test record.



UNITS and STANDARDS of ELECTRICAL MEASURE



The practical standard for d.c. voltage is provided in this country by saturated standard cells forming National Reference Standards. These cells are extremely stable, but sensitive to change in temperature. Both the reference cells and cells sent to the Bureau for calibration are kept in a circulating oil bath whose temperature is electrically controlled to within a few thousandths of one degree of 28 degrees centigrade.

Examination of our National Standards, their derivation, maintenance, and accuracies, and an assessment of the present state of the art.

By FOREST K. HARRIS
Chief, Absolute Electrical Measurements Section
National Bureau of Standards

IF we wish to say how large some physical quantity is, our description of its size has two parts—a unit and a number. The *unit* is a defined reference amount of the quantity; and, if our statement is to be understood, everyone who is concerned must agree on the size of the unit. The *number*, which completes our statement, tells how much bigger or smaller is the quantity we are discussing than the defined unit quantity. The size of the unit can be fixed by definition, quite independently of any measurement, and therefore can be exact. We can arrive at the numerical part of our statement only through measurement—this number is subject to the errors of the measuring process by which we obtain it, and therefore can never be exact.

Thus if a statement of quantity is to have meaning, there must first be agreement on the size of the unit. Next, there must be acceptable reference standards to represent the physical embodiment of the defined unit or some multiple of it; and it is through such reference standards that measurement errors are controlled.

Reference standards form the basis for the calibration of measuring devices and systems; and, to the extent that their assignment derives from National or International Standards, they can also serve to coordinate measurements made at different times and places. It will be the purpose of this article to examine our National Standards of electrical measure, their derivation and maintenance, and, in addition to these items, to assess the present state of the art in just a few of the important areas of electrical measurements.

History of the Electrical Units

In the years following the promulgation of Ohm's Law (1827), many suggestions were made regarding a standard (and unit) of resistance. Examples were: (1) a foot of copper wire weighing 100 grains; (2) an English mile of No. 16 copper wire; (3) a kilometer of iron wire 4 mm. in diameter; and (4) a column of mercury 100 cm. long and 1 mm. in cross-section at 0°C. The last of these units was used for a time in Germany, and was known as the Siemens unit. It is interesting to note that it differs from today's resistance unit by a little more than 6%. During this same period the e.m.f. of the Daniell (zinc-copper) cell was widely used as the unit of voltage.

By the middle of the 19th century the work of Gauss and Weber had shown that electric and magnetic quantities could be measured in terms of mechanical units. Then in 1861, the British Association for the Advancement of Science formed a Committee on Electrical Units and Standards with Maxwell as chairman. This committee realized the value of a correlated system of electrical and mechanical units based on the metric system—which was already familiar to scientific workers through the world; and in 1863 (just over a century ago) the committee recommended a set of "absolute practical" units that were decimal multiples of the centimeter-gram-second electromagnetic units. By "absolute" was meant that the unit was defined directly in terms of mechanical units; and "practical" signified that the unit was of a convenient size for practical engineering measurements. The following is a list of the British Association recommendations:

Absolute practical unit		Equivalent in c.g.s. electromagnetic units
1 coulomb	=	0.1 c.g.s. unit of charge
1 ampere	=	0.1 c.g.s. unit of current
1 volt	=	10^8 c.g.s. units of potential difference
1 ohm	=	10^9 c.g.s. units of resistance
1 joule	=	10^7 ergs
1 watt	=	10^7 ergs per second

These units were accepted on an international basis in 1881 by the Paris Electrical Congress and have been formally recognized as the electrical units in the United States by Congressional acts. (The most recent such act is Public Law 617 of the 81st Congress.) The choice of 10^9 as the conversion factor between ohms and c.g.s. units of resistance brought the size of the new unit close to that of the existing German unit (the Siemens unit, smaller than the ohm by about 6%). Similarly, with 10^8 chosen as the factor between the volt and the c.g.s. unit of e.m.f., the new unit did not differ greatly from the Daniell-cell unit (within about 20%). Having fixed the values of these two conversion factors, the others are all fixed by the simple relations—such as Ohm's Law—that exist between the units.

The wisdom of the BA committee's choice will be seen when we consider that if the e.m.f. of the Daniell cell had been chosen as an electrical unit together with one of the suggested units of resistance (a mile of No. 16 copper wire), the electrical and mechanical units of power and energy would have differed by a factor of about 25, whereas with the chosen units they are identical.

The BA committee sponsored "absolute" experiments that resulted in the assignment of values to a number of wire standards that were distributed to various laboratories in the interest of international agreement. These standards were not

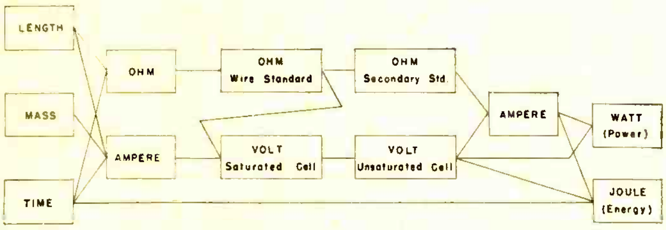


Fig. 1. Present absolute electrical units, used since 1948.

completely stable, and the assigned value of one was found by Rowland in 1878 to differ by 1.5% from its intended absolute value.

At that time there were no national laboratories where standards could be checked; and there was a need for "reproducible" standards that could be set up in any laboratory to duplicate the units. In 1893 the Chicago Electrical Congress fixed on a mercury column 106.3 cm. long and with a cross-section of 1 sq. mm. to represent the ohm at 0° C. In 1892 the British Association adopted as a "reproducible" ampere, the current that would deposit silver from a silver nitrate solution under specified conditions at the rate of 0.001118 gram per second. The apparatus used for this measurement was called a "voltameter."

National Laboratories

During the closing years of the 19th century and the beginning of the 20th, national laboratories were organized in a number of countries including the United States, to preserve and disseminate the units of measure; and in 1910 representatives of the national laboratories of Germany, France, Great Britain, and the United States met in Washington to compare standard resistors and standard cells whose values had been assigned in terms of their national units, and to resolve differences among the various silver voltameters. As a result of this meeting each representative returned to his own national laboratory with a group of resistors and standard cells whose values were assigned in terms of a mutually acceptable "International" ohm and volt, realized through the "reproducible" units.

During the next four decades, the various national laboratories maintained their electrical units more or less in terms of these groups of resistors and cells; but by 1930 it was quite generally argued that the mercury ohm and silver ampere, on which the "International" system of units was based, were not reproducible with sufficient accuracy for scientific and technological purposes—in short, the techniques of measurement were outgrowing them; and also, unacceptably large discrepancies were showing up in comparisons between the national standards of some countries. So it was agreed that "absolute" ohm and ampere experiments would

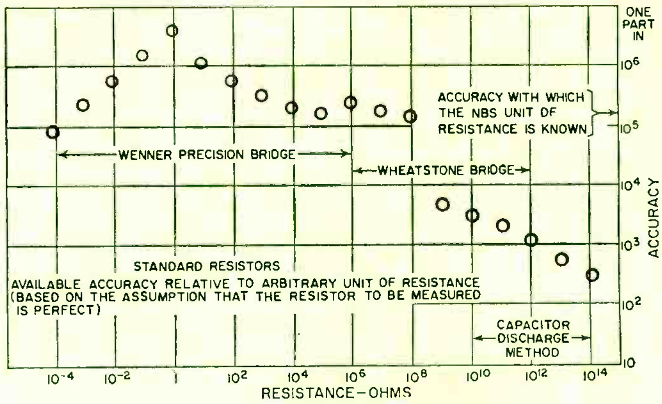


Fig. 2. Available accuracy of various standard resistors.

be performed at some of the national laboratories, and that the results of these experiments would be used to re-assign the various national units on an "absolute" basis. At an international meeting in 1935 it was hoped that the transition to the "absolute" units could be made on January 1, 1940; but the outbreak of war in the summer of 1939 interfered with this plan.

The transition was finally made on January 1, 1948, with changes amounting to a few hundredths of a percent. For example, the "International" ohm as then maintained at the National Bureau of Standards was stated to be 1.000495 absolute ohms, and the "International" volt, 1.000330 absolute volts. Conversion factors for the remaining electrical units can be derived in terms of these two factors and the simple relations that exist between the units.

It should be noted that if the meter, kilogram, and second

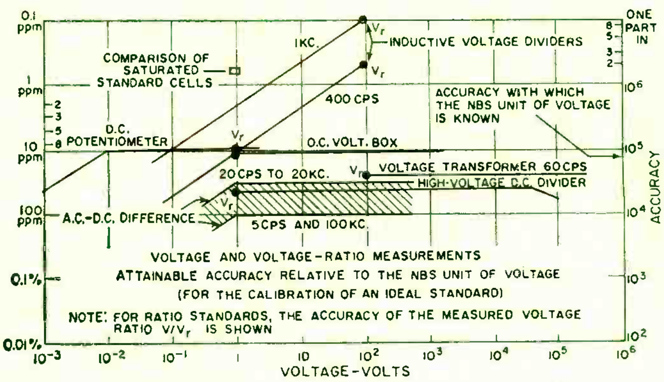


Fig. 3. Present voltage and voltage-ratio accuracies.

are used in place of the centimeter, gram, and second as mechanical units, and if the permeability of free space is assigned the value 10^{-7}, the absolute system of electrical units becomes identical with the practical system. Alternatively, since four arbitrarily chosen quantities can be used to define a system of electrical units, it has been suggested that the meter, kilogram, second, and ampere be used as the basis of the defined system of units, the m.k.s.a. system. This was adopted by the General Conference of Weights and Measures in 1960 as a part of the general system to be known as the Systeme International d' Unites (which is commonly abbreviated SI).

Experimental Realization of Units

Section 12 of the Public Law that defines the electrical units contains the following statement: "It shall be the duty of the National Bureau of Standards to establish the values of the primary electrical units in absolute measure; and the legal values for these units shall be those represented or derived from National reference standards maintained by the National Bureau of Standards."

Two types of "absolute" measurements have been used in assigning numerical values to our basic electrical standards in terms of the mechanical units. The *ohm* is evaluated in terms of *length* and *time;* the *ampere* in terms of *length, mass,* and *time*. (See Fig. 1.)

The *absolute-ohm* determinations on which our "legal" ohm are based were performed in the National Bureau of Standards and in the national laboratories of other countries. These determinations have involved an inductor (either self or mutual) of such construction that its value can be computed from its measured dimensions together with the conventionally assigned permeability of the space around it. This inductance is supplied with a periodically varying current and its reactance at the known frequency is, in effect, compared with the resistance of a standard resistor.

A similar experiment could involve the comparison of a capacitive reactance and a resistance; and such a determination would have the advantage that the electrical field of a capacitor can be completely confined by a shield so that the capacitance value is independent of anything outside the shield, whereas the magnetic field of an inductor cannot be limited to be free from proximity effects. However, it is only within the past few years that a practical capacitor geometry capable of simple measurement and computation has been described in terms of a new theorem in electrostatics—the Thompson-Lampard theorem. The value of such a capacitor can be assigned with sufficient accuracy to make attractive an *absolute-ohm* determination in terms of capacitance; and such determinations have been made, although their results have not yet (1964) been incorporated into the "legal" ohm.

In an *absolute-ampere* determination, a pair of coils is arranged so that the force between them when they carry current can be measured in terms of the force of gravity acting on a known mass—thus the units of measure are *length, mass,* and *time*. The current, measured in *absolute* amperes, is passed through a standard resistor whose value is known in *absolute* ohms. The resulting voltage drop is compared to the electromotive force of a standard cell, and its value is assigned in terms of *absolute* volts.

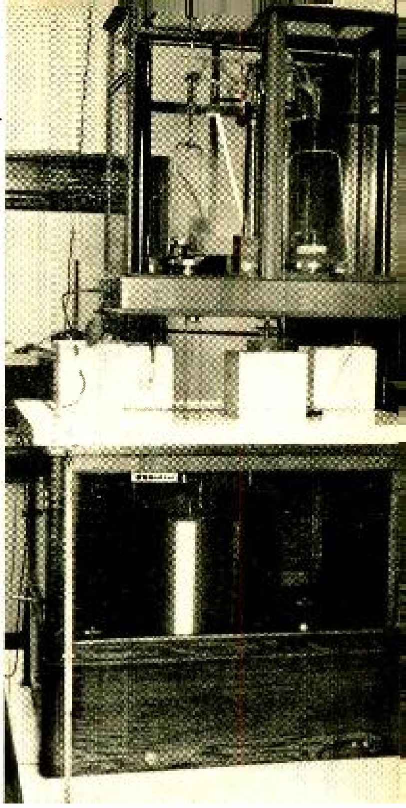
"Legal" Electrical Units

The absolute measurements on which are based the assignment of the National reference standards are time consuming and require great care and skill. Their occasional repetition, to maintain surveillance on the constancy of the national standard, is desirable. But for the purpose of providing a continuing measurement capability, groups of wire-wound resistors and of standard cells constitute the National reference standards and form the basis of the "legal" electrical units.

The National reference standard of resistance for the United States is a group of ten 1-ohm resistors of special construction. Their values were assigned on January 1, 1948, in terms of an international agreement based on the results of the various *absolute-ohm* determinations. The "legal" unit of resistance is preserved in terms of their group average, which is assumed not to have changed since the 1948 assignment. The resistors of the group are regularly intercompared to about a part in 10^7. In addition, our *national standard* is compared at regular intervals, through measurements made at the International Bureau of Weights and Measures in Sevres, France, with the standards maintained by National laboratories of other countries.

The maximum net change in any of the group with respect to the group average has been a little over 2 ppm (parts per million) in the 30 years that have elapsed since the group was first set up. In the international comparisons over the past decade, the differences between our unit of resistance and that maintained by the International Bureau have never been greater than 1 ppm; and in only one instance was the difference greater than 0.4 ppm. It is believed very unlikely that the "legal" ohm—maintained in terms of the average

Over-all view of the NBS helical-coil balance. In the center of the coil (bottom) is a small movable coil which is attached to the arm of the precision balance. This arrangement measures change in force on the small current-carrying coil when current in the two parts of the outer coil is reversed. From the change in force and the dimensions of the coils, the exact current value in amperes is found.

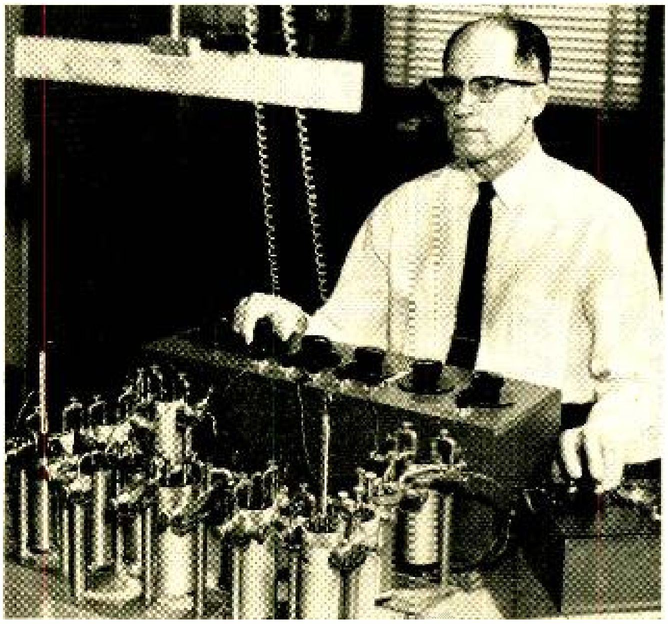


This large, double-walled standard 1-ohm resistor is used to maintain the standard unit of resistance.

of this group of ten resistors—differs from the defined *absolute* ohm by as much as 4 ppm; and there is evidence in terms of recent absolute-ohm determinations (capacitive) that the difference is no more than 1 ppm (Fig. 2).

The *National reference standard of e.m.f.* is a group of 44 saturated standard cells (commonly referred to as Weston cells), maintained continuously at a temperature of 28 ±0.01° C, and held at 28 ±0.001° C during intercomparisons. Eleven of the cells have been in the reference group since 1906; of the remainder, 7 made in 1932 and 26 made in 1949 were added to the group in 1955. New cells are made periodically of carefully purified materials, and are kept under the same conditions as the reference group and compared with it regularly. Thus a cell having a known history of constancy is always available for replacement, if one of the National reference group fails. The cells of the reference group are intercompared regularly and their average value is assumed to be constant. It is in terms of this group average

The 100-ohm-per-step dial of a universal ratio set is being checked against one of the group of 100-ohm reference standards.



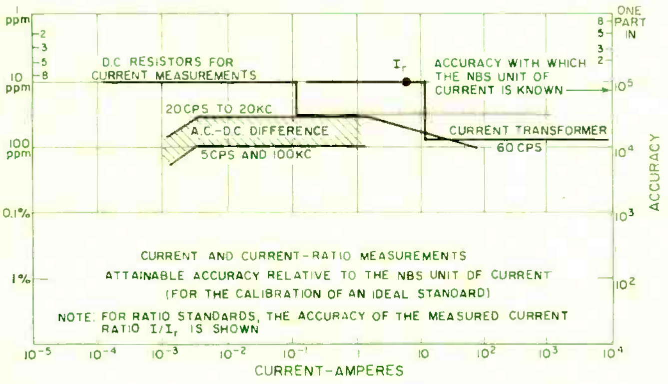


Fig. 4. Present current and current-ratio accuracies.

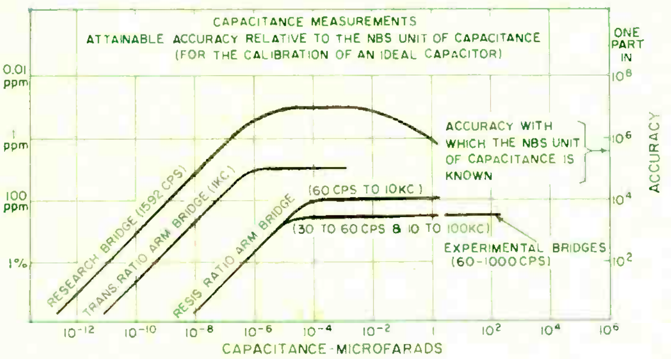


Fig. 5. The accuracy of capacitance measurements.

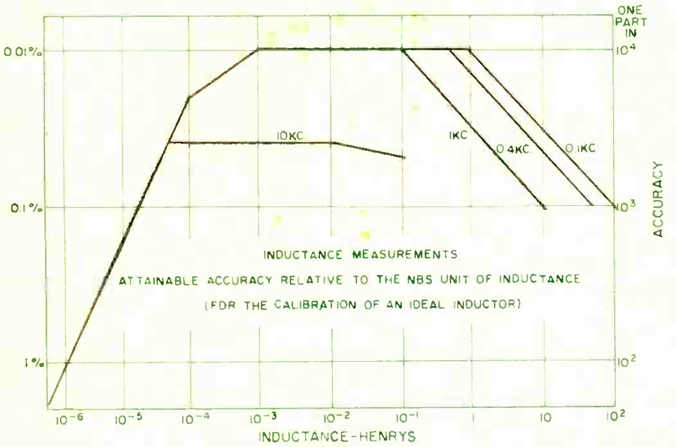
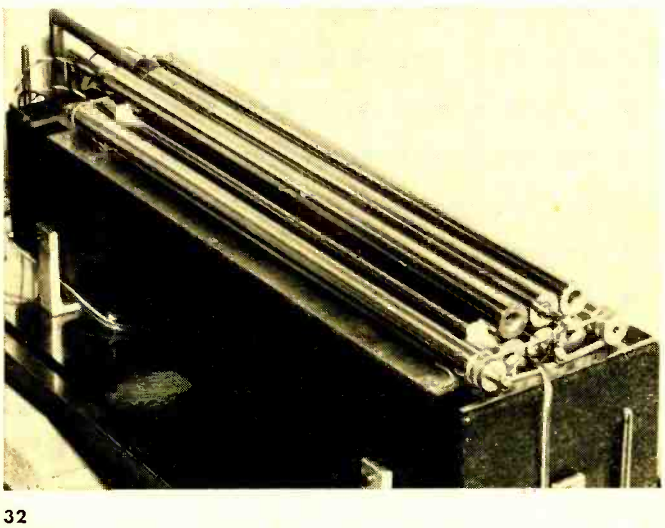


Fig. 6. The attainable accuracy of inductance measurements.

Improved standard of capacitance. This design, based on a recently discovered theorem in electrostatics, allows capacitance value to be calculated directly in terms of length.



and its 1948 assignment that the "legal" volt is maintained.

This unit is regularly compared with those of other countries at the International Bureau. Over the past decade the differences between our unit and the one maintained by the International Bureau have generally been less than 2 ppm, although on one occasion (1953) the difference amounted to about 3 ppm (Fig. 3).

Recently an additional means of checking the constancy of our National electrical units has become available by using a natural physical constant—the gyromagnetic ratio of protons in a sample of pure water. These elementary charged particles are continually spinning like miniature tops. Because of this spin and their electric charge, they behave like magnets and tend to align their spin axis in the direction of the ambient magnetic field. When they are thus oriented and then disturbed, they precess about the direction of the magnetic field, just as does a spinning top or gyroscope in the earth's gravitational field. This precession frequency, which we can measure very accurately, can be used to measure the strength of the field.

In our experiment, the field is set up within a precisely made solenoid and can be computed from the coil dimensions and the measured current in the coil. This current is measured by comparing the voltage drop it produces in a standard resistor to the e.m.f. of a standard cell. If the measured precession frequency is constant we know that the current has not changed and therefore that the ratio of the National volt to the ohm has not changed—strong evidence that neither has changed, since it is quite unlikely that they would both drift in such a way that their ratio would remain constant. A series of measurements over the past four years indicate that the Bureau's ampere has been constant over that interval, the maximum departure from the mean value being 0.4 ppm (Fig. 4).

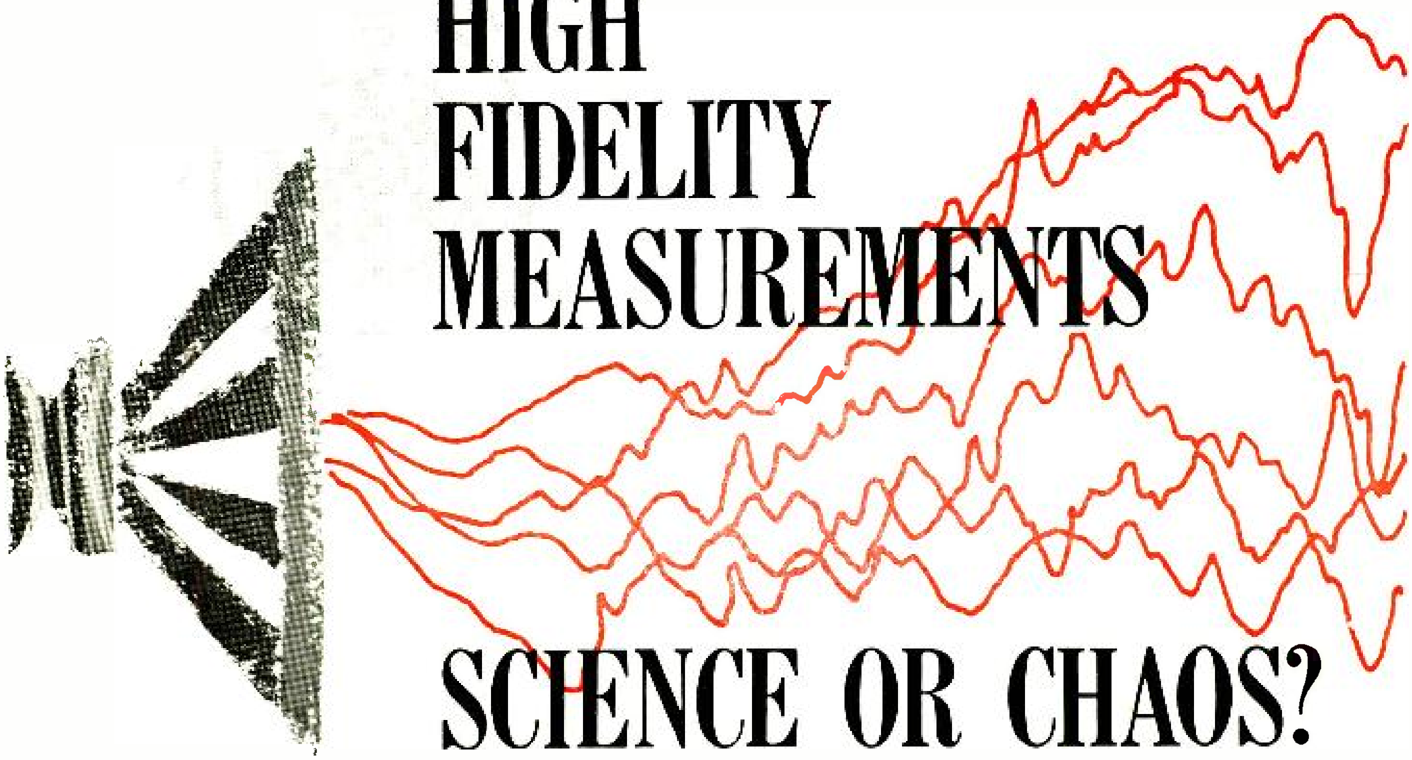
While all available data indicate constancy of the National reference standard of e.m.f., there is evidence—both from absolute-ampere determinations and from consideration of internal consistency of the assigned values of various atomic constants—that the "legal" volt (maintained in terms of the National reference standard) differs from the defined absolute volt by about 10 ppm. Certainly there is need for further absolute measurements, and there is now under consideration an *absolute-volt* determination directly in terms of the amount of force that is associated with a potential difference between the electrodes of a capacitor.

Capacitance and Inductance

There are no national reference standards for capacitance and inductance in the pattern used for the National reference standards of resistance and e.m.f. However, the 1-pf. computable capacitor used in the *absolute-ohm* determination can be set up and measured without great difficulty; and the assignment of its value is believed to be correct within 1-2 ppm in terms of the defined absolute unit. Studies are in progress to develop stable capacitance standards in the range 1-10^3 pf.; and in this range, the values of "ideal" capacitors can be compared within 1-2 parts in 10^7. In this context, the term "ideal" means a standard which is completely stable and whose value is independent of ambient conditions. For values of capacitance greater than 10^3 pf., the attainable measurement accuracy falls off, and is less by a factor of about 10 at the 1-μf. level of capacitance (Fig. 5).

Inductances are regularly measured at low frequencies in terms of capacitance and resistance, for example in a Maxwell-Wien bridge. In the middle range of inductance (1-100 millihenrys) and at a frequency of 1 kc., an "ideal" inductor can be measured in terms of real capacitors and resistors to about 0.01%. Measurement accuracy falls off at higher and lower values. In fact, if one were to plot measurement accuracy for any kind of quantity against magnitude, the typical shape of the curve would be a (*Continued on page* 55)

HIGH FIDELITY MEASUREMENTS



SCIENCE OR CHAOS?

Is objective testing possible? Do some tests have reliability but no validity? Can a device measure well but sound bad? Here is the viewpoint of a speaker designer with examples in his own field.

By EDGAR VILLCHUR
Acoustic Research, Inc.

THE problem of testing, which is so crucial to design work, is one that a good many engineers know less about than they should. In schools, the techniques of testing have for the most part been the concern of the social-science discipline. I first learned about the basic principles of testing—the difference between reliability and validity, and the use of controls—from courses in psychology, sociology, and statistics, not from engineering courses.

We will consider here matters which are more often discussed in classes of social science than of physical science, but they are matters that you should be masters of.

Objective Testing in Audio

Objective tests of reproducing equipment—for frequency response, distortion, transient response, etc.—have been criticized from two widely different points of view, one scientifically legitimate and the other scientifically childish. I will discuss the latter first to get it out of the way.

It is an accepted principle among some of the hi-fi writers who advise the public on the mysteries of sound reproduction that high-fidelity components, and particularly loudspeakers, cannot be tested objectively. The reasons given usually relate to hearing differences in different individuals, differences in room environment, and differences in taste.

If we think of a high-fidelity system as a new musical instrument, a creator rather than a reproducer of sound, these reasons have relevance. But if we consider that the function of a high-fidelity system is to recreate with maximum accuracy sound whose character has been determined previously, they are irrelevant.

Differences in individual hearing have no more to do with comparing a copy to its original than differences in vision affect the objective accuracy of a matching color sample. The same hearing aberrations come into play in listening to both the live and the reproduced sound, and they do not affect the process of matching.

Room environment profoundly affects the final acoustic output of a sound reproducing system; this simply means that the room is one link in the chain of reproduction. Compensation for the effects of room environment (other than power requirements) must be sought in the flexibility of controls, not in design idiosyncrasies of the reproducing equipment.

Taste may determine whether a listener prefers a Stradivari violin to a Guarneri, but it cannot affect the objective determination of the accuracy of reproduction of either. Taste can only be involved where a choice must be made between different kinds of inaccuracy, for example, a given amount of distortion *vs* restricted frequency response.

These experts often tip their hand by an interesting contradiction. Knowing that audio design laboratories have invested in elaborate and expensive test equipment, and suspecting that this amount of cold cash would not be spent for useless measuring devices, they hedge. Sometimes hi-fi writers state that while objective measurements cannot provide a basis for the evaluation of high-fidelity equipment, measurements do serve as a useful tool for the designer. It should be clear that any measurements that do not have precisely the significance denied by these writers are as useless to the designer as to the consumer.

A kind of scientific know-nothingism is all too common in the field of high-fidelity testing, and it is necessary to bring some order into this chaos. What is needed is an understanding of the basic principles of testing, and particularly the difference between *reliability* and *validity*. Most engineers understand the term "reliability"; however, they are quite often not sufficiently familiar with the term "validity."

Reliability

The reliability of a test is an index of its accuracy, an index of the extent to which we can expect the test results to be repeatable.

Let us suppose that we have a device with two electrical terminals, that we put the prods of a meter across these terminals, and read 53.8 volts. The reading is the same the next day with a meter of another make, which conforms to the specifications that we have laid out. It is the same in a testing laboratory in Alaska. Apparently we have specified the conditions of this test sufficiently so that we can expect the same reading each time. We have a *reliable* test. Note that I can call it reliable before I know what meaning, if any, the test has.

A live versus recorded concert with the Fine Arts Quartet at a moment of changeover from live to reproduced sound.

Let me give you an example of an unreliable test of this same device. A low-impedance meter may affect the circuit that we are measuring, but we fail to mention this in our description of the test procedure. With a vacuum-tube voltmeter we measure 53.8 volts. Someone comes along with a low-impedance meter and he reads only 32.6 volts. He may conclude that the voltage across the terminals is erratic and cannot be depended on for anything, but his analysis is wrong. It is the test procedure that is unreliable.

Validity

Now we come to the real crux of the matter, validity. What does that 53.8 volts mean—is it good, bad, high, or low? Is this voltage an index of some quality of the device?

The validity of a test is that key quality which tells us whether the test measures what it is designed to measure. We say that a given test measurement is, or is not, a valid index of a given characteristic.

There are test techniques surrounded by all kinds of quantitative controls, techniques that give us beautiful, accurate results, but which do not give us the information that we think they do. They are reliable but invalid. It is such test techniques that have given rise to the legitimate criticism of objective audio testing to which I referred. Sometimes a device is described as measuring well but sounding bad. When this is so, it is obvious that someone has measured the wrong things, however accurately.

I can give you an example from my own field of specialization, loudspeakers. As in other components of a high-fidelity reproducing system, the frequency response of a loudspeaker is of prime importance. We are concerned with how even the response is over the range, and we are also concerned with how great that range is compared to the audio spectrum.

Now it is generally accepted in the audio field that the way to measure the frequency response of a loudspeaker is to place the speaker in an anechoic environment, put a microphone in front of it, run a sweep signal into the loudspeaker, and measure the output of the microphone at different frequencies. About twenty years ago Standards were published by RETMA (now EIA) and the American Standards Association, introducing the controls necessary to make this speaker testing technique reliable. If these Standards are followed in testing a given loudspeaker, you will get the same curve without significant difference every time.

But this on-axis curve does not represent what it purports to represent—loudspeaker frequency response. Two loudspeakers with almost identical curves made in this way may sound entirely different in terms of whether they are bright or dull, smooth or rough.

The output of an electronic amplifier appears across definite terminals. Whatever comes out of the amplifier will be sensed by test prods across the terminals, and complete information on the amplifier output can be provided through the prods.

The output of a loudspeaker, which is acoustical rather than electrical, appears in quite a different way. This output is thrown out into the room in all directions, and the frequency distribution of the energy radiated directly in front of the loudspeaker is not the same as that of the energy radiated to the sides. It is also true that when we listen to a loudspeaker in a normally reverberant room we hear a combination of direct sound from the speaker and reverberant sound reflected from the walls, floor, and ceiling. The *major* part of what we hear is due to the sound field created by the reflected sound.

Thus, we respond more to the integrated power output of all those pencil-rays of sound that are radiated in an infinite number of directions than to the pressure of a particular ray between the loudspeaker and our ears. Even if we sit directly in front of a loudspeaker, the frequency response that we are affected by is not represented by the on-axis response curve. The test microphone was in an anechoic environment and did not sense any off-axis reflected sound.

To know the frequency response of a loudspeaker as it relates to non-anechoic environments, then, we need to know how much total energy the loudspeaker will radiate at one frequency compared to another, and the shape of the response curves at various angles to the speaker axis. This information is contained in a family of curves of the response at different angles from the axis of the loudspeaker, from 0 to 90 degrees. If the horizontal and vertical dispersion are not the same, we need to know both.

I have said that two loudspeakers can have almost identical on-axis response curves and yet sound completely different. This can occur in two ways. The off-axis response of one may drop severely at high frequencies compared to the other, giving the former a much duller character; or the off-axis response of one may be much more ragged than the other, giving it a rougher quality. (See Figs. 1 and 2.) These differences between the two speakers would be apparent from any listening position, including one directly on-axis.

The conclusion that we must draw is that the test technique of measuring only the on-axis frequency response of a speaker is not a valid one. The single curve does not represent the frequency response of the speaker, let alone serve as an index of its quality. But the conclusion sometimes drawn is that objective measurements are therefore useless when it comes to high-fidelity loudspeakers.

If I now say that we must not rely on the on-axis response curve but take a family of curves at different angles, and then take distortion curves *vs* frequency curves and tone-burst data (we do actually use this particular gamut of tests at my company), what proof do I have that these measurements give us meaningful information? We can't just invent tests in our heads and then apply them. There must be validation of test techniques.

If we wanted to develop tests for the evaluation of printing equipment designed to reproduce paintings, the method of validating a proposed test would be obvious. We would see whether our test predicted the degree of accuracy of the reproduction, and we would check the accuracy in a direct comparison between the reproduction and the original painting.

In 1936, New York's Museum of Modern Art staged a "high-fidelity" show, an exhibition of color reproductions of paintings. The original paintings and reproductions of the paintings were hung side by side on the walls of the Museum, the reproductions in exactly the same sizes and in matching frames. One judged the success of the reproduction by direct comparison with the original. One didn't look at the reproduction and say, "The color is too dull." If the color was accurate compared to the original, dull or no, then the reproduction was a good one. All of the psychological and perceptive variables that would normally be operative in evaluating reproductions were under control. The control was the presence of the original.

Similarly, the validation of test techniques for audio equipment lies in a showdown display—the reproduced sound compared directly to the original live sound.[1] If a test technique predicts well the degree of similarity between the live and reproduced sound it is valid; if test results do not correlate well with the results of the comparison, however involved the quantitative controls of the test, it is invalid and useless.

Several companies in high-fidelity manufacturing, including my own, have staged or participated in what we call "live *vs* recorded" concerts, in which live and reproduced sound are alternated. We have used a string quartet and a pipe organ, as has G. A. Briggs of *Wharfedale*. The validation of test techniques, or the evaluation of equipment directly, can then be made with guesswork reduced to a minimum.

These public concerts serve a dual function for us—they are part of a serious validating and evaluation program, and they are also part of an advertising program. In serving the former function the concerts have certain disadvantages. We can't have the Fine Arts Quartet travel to *AR* every time we want to test a design variation, or validate a new test technique, or compare a group of loudspeakers. There is also a human element involved—the musicians may not be playing exactly the same way during the test as they played to make the original tape. So we have worked out a technique in which we use this live *vs* recorded approach, but instead of a quartet we use a mechanical sound generator, and instead of music we use white noise (or a portion of the white noise spectrum) as the live sound.[2]

You all know what white noise sounds like—if you have never heard a white noise generator you've heard FM interstation hiss. It is neutral, without musical pitch. Any aberration or coloration in its reproduction is even more evident than in music, and so its use makes the test more sensitive. Our reproduction of white noise has never been so close that it could not be distinguished from the original, whereas we were able to reproduce a pipe organ or string quartet well enough so that most of the switchovers from live to reproduced sound would not be detected if one's back were turned.

We make an anechoic recording of this white noise and then play it back, switching back and forth between the original live white noise and the reproduced white noise. When we listen we pay no attention to whether we like the reproduced white noise or don't like it, whether it soothes us or jangled our nerves, whether (*Continued on page* 54)

[1]The analogy to the reproduction of paintings is not perfect, since reproduced music is usually heard in a changed acoustical environment, but it does work. Accurate high-fidelity equipment can re-create musical timbres either raw or as they are molded by the concert hall, depending on the recording technique. If the character of these sounds is to be changed purposely for living-room listening, such a change will have to be brought about by composers and musicians, not by design engineers.

[2]Villchur, E.: "A Method of Testing Loudspeakers with Random Noise Input." Journal of the Audio Engineering Society, October 1962, Vol. 10, No. 4, pp. 306-309. Reprints are available from Acoustic Research, Inc., 24 Thorndike Street, Cambridge, Massachusetts. 02141.

Fig. 1. Family of machine-run frequency-response curves on a commercial tweeter, from on-axis to 60 off-axis. Based on on-axis curve alone, response could be described as ± 3.5 db from 3 kc. to 20 kc., leading one to expect outstanding performance. An examination of the off-axis curves, however, shows that total power radiated is badly peaked at 3.2 kc. and high-frequency response is greatly attenuated off-axis. It is the latter characteristic that shows up in listening test, whether or not the listener involved is seated on-axis.

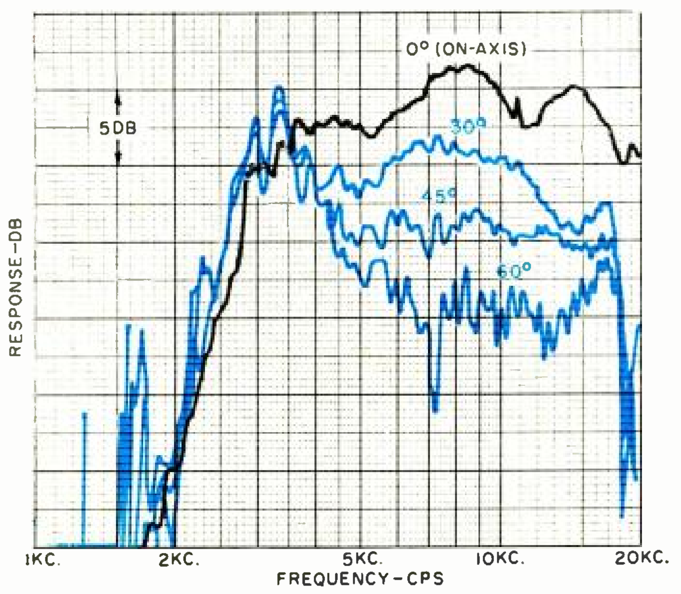
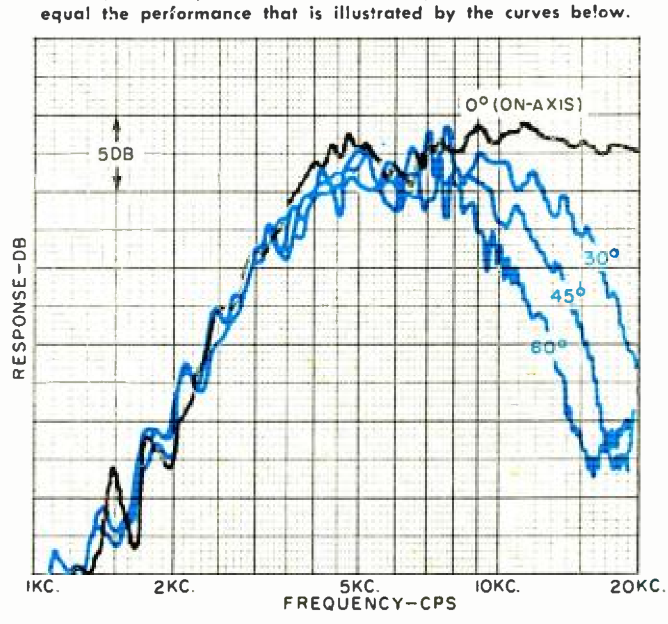


Fig. 2. Family of machine-run frequency-response curves on a super-tweeter, from on-axis to 60 off-axis. As in Fig. 1, a reading of the on-axis curve alone would give misleading information, since there is far less power radiated at higher frequencies than this curve would suggest. While the off-axis curves remain fairly smooth, there is clearly room for improvement in high-frequency dispersion. At the present state of the art, however, author knows of few speakers that will even equal the performance that is illustrated by the curves below.



DATA FLOW IN DIGITAL COMPUTERS

By ED BUKSTEIN / Northwestern TV and Electronics Institute

Step-by-step description of how computer is programmed in order to perform simple calculations automatically.

ACCORDING to a popular belief, the outstanding characteristic of the modern digital computer is its amazing speed. Although it is true that the computer operates with electronic swiftness rather than the motor-and-gear speed of the desk-type adding machine, this is not its most outstanding characteristic. It is the *automatic* sequencing of its internal operations that makes the computer something more than just a king-size adding machine. What would be the use of a machine capable of thousands of mathematical operations per second if it were not automatic? Could an operator punch the keyboard fast enough to keep the computer supplied with data and to control the internal operations? Obviously not. The automatic digital computer must, therefore, contain a memory unit capable of holding large amounts of data and instructions, and these must be automatically extracted from memory as they are needed.

Because computers employ two-state ("on-off") type of circuits, data and instructions must be handled in binary form. The binary system of notation employs only two symbols, 0 and 1, and various combinations of these symbols are used to represent numerals and letters of the alphabet. Several such representations are shown below:

001001=9	010111=X
110101=E	001011=%

Each numeral, letter, etc. is represented by a unique group of six bits (binary digits). There are a total of 64 different six-bit combinations—more than enough to represent all the letters of the alphabet, the numerals from 0 through 9, punctuation marks, and other special symbols. A code recently adopted by the American Standards Association employs seven-bit groups. Since there are 128 seven-bit combinations, this code handles all the alphabetic and numeric characters and special symbols, and leaves many other combinations to be used for special control purposes.

Computer Words

Two types of information are stored in the memory unit of the computer: *data words* and *instruction words*. Data words comprise the information to be operated on—the "given" information in a mathematical calculation, for example. Instruction words indicate the types of operations to be performed (addition, subtraction, etc.) and also specify the location in memory of the data words to be added, subtracted, etc. The composition of typical instruction and data words is illustrated in Fig. 1. Decimal digits are shown but, as described previously, each digit is represented in the computer by a group of binary bits.

As indicated in Fig. 1, the data word uses one digit position to indicate sign (plus or minus). A five-digit number is shown but most computers employ longer words for greater precision. Data words are not always numerical. In business data processing, for example, they often contain alphabetical characters to represent customer names, street addresses, and similar material.

An instruction word consists of two parts. The *operation* code specifies the type of operation to be performed (multiplication in the example shown in Fig. 1). The *address* part of the instruction word specifies the location in memory of the data word to be used. The instruction word in Fig. 1 therefore means that the data word located in address 1306 is to be multiplied (times the number already in the arithmetic section of the computer).

Operation codes are selected rather arbitrarily by computer designers. The code for multiplication, for example, may be 32 in one computer, 61 in another, and 07 in still another. In Fig. 1, the code is 25. A list such as shown is a *repertoire of instructions* and most computers have a repertoire of 50 to 150 instructions. Not all operation codes specify arithmetic operations. Typical non-arithmetic operations are: clear the memory, clear the arithmetic section, transfer the data from arithmetic section to memory, write on magnetic tape, examine the contents of the arithmetic unit to determine if it is plus, minus, or zero.

The Program

In the memory section of the computer, the location of each word is identified by an address number. If the memory can hold 10,000 words, for example, the addresses can be identified by numbers ranging from 0000 to 9999. All of the instruction words needed to perform a particular data processing job are known collectively as the *program* and these instructions are stored in successively numbered addresses in the memory. If the program requires 500 instruction words, for example, these could be stored in addresses 0000 to 0499. The remaining addresses, or as many as are needed, would then be available for holding the data words. All of the data and instruction words are loaded into the memory at the start of the program, and the instructions are then read out one at a time. This establishes the basic rhythm or machine cycle: obtain an instruction from memory, perform the operation specified by the instruction, obtain the next instruction from memory, and so on.

A list of instructions necessary for performing a relatively simple calculation is given below. Actually, a computer would not be used for the solution of such a simple calculation, but the principles are the same. Suppose that it is desired to calculate M in the following equation:

$$M = \frac{XZ + Y^2}{R}$$

REPERTOIRE OF INSTRUCTIONS

OPERATION CODE	MEANING
14	ADD
22	SUBTRACT
25	MULTIPLY
67	DIVIDE
51	STORE (TRANSFER INFORMATION FROM ARITHMETIC SECTION INTO MEMORY)
05	CLEAR (ERASE CONTENTS OF ARITHMETIC SECTION)
38	JUMP (GO TO INDICATED ADDRESS FOR NEXT INSTRUCTION INSTEAD OF TAKING INSTRUCTIONS IN NORMAL SEQUENCE)
49	HALT

Fig. 1. Data and instruction words are stored in memory of computer. Instruction words are those that are employed to determine which operations are performed on the data words.

The numerical values of X, Z, Y, and R are stored as data words in the memory. Assume that they are stored at addresses 1500, 1501, 1502, and 1503 respectively. The following list of instruction words would also be stored in the memory and, when performed in sequence, will yield the solution to this equation. In each instruction word, the first two digits represent the operation code as listed in Fig. 1.

1. 050000
2. 141502
3. 251502
4. 511600
5. 050000
6. 141500
7. 251501
8. 141600
9. 671503
10. 511601
11. 490000

The first instruction (050000) therefore serves to clear the arithmetic unit of any data which may remain from a

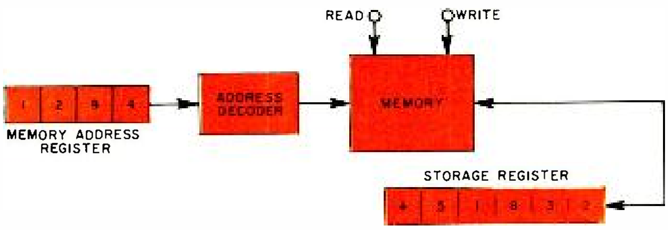


Fig. 2. Information can be transferred to or from memory. Address register and decoder determine which word is transferred.

previous calculation. The second instruction adds the value of Y from the storage address 1502 into the arithmetic unit. Instruction number three causes Y from the address 1502 to be multiplied by Y in the arithmetic unit. The contents of the arithmetic unit is now Y^2, and this value is stored (instruction four) in storage address 1600. Instruction five now clears the arithmetic unit. The sixth instruction brings X from address 1500 into the arithmetic unit. Instruction seven causes multiplication by Z so that the arithmetic section now contains the product XZ. The eighth instruction causes the addition of Y^2 from address 1600, and the arithmetic unit now contains $XZ+Y^2$. Instruction nine divides by R, and the arithmetic unit now contains the value of M. This value is stored by instruction ten at address 1601. Instruction eleven then halts the machine completely.

Memory Operations

In addition to its main memory, the computer contains several one-word storage units known as *registers*. Information can be transferred from a register to the memory or *vice versa*. A read-from-memory type of operation is illustrated in Fig. 2. When a pulse is applied to the "Read" terminal, one word is transferred from memory to the storage register. The *memory address register* and the *address decoder* determine which word will be transferred. In Fig. 2, the memory address register is set to 1294. The "Read" pulse therefore transfers the word from this address to the storage register. As indicated, the word is +51832. A *store* instruction (write-into-memory) is accomplished in a similar manner except that the pulse is applied to the "Write" terminal instead of the "Read" terminal. This pulse will cause the word in the storage register to be transferred into memory (at an address determined by the setting of the memory address register).

Fig. 2 illustrates the general technique of moving words into or out of memory. Data words are generally transferred into arithmetic registers, and instruction words are transferred into the instruction register. An instruction register is illustrated in Fig. 3. After an instruction word has been

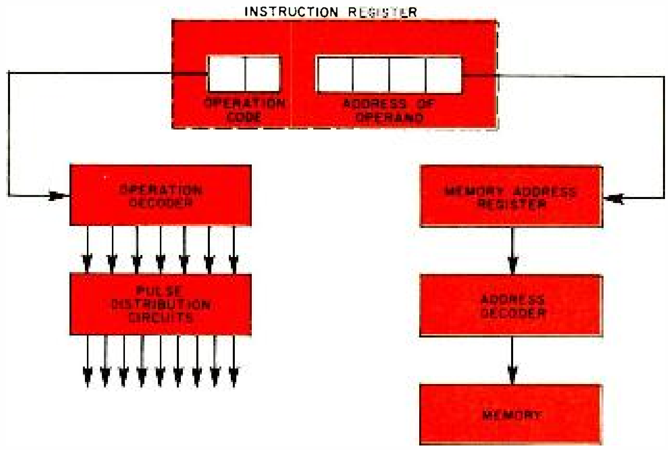
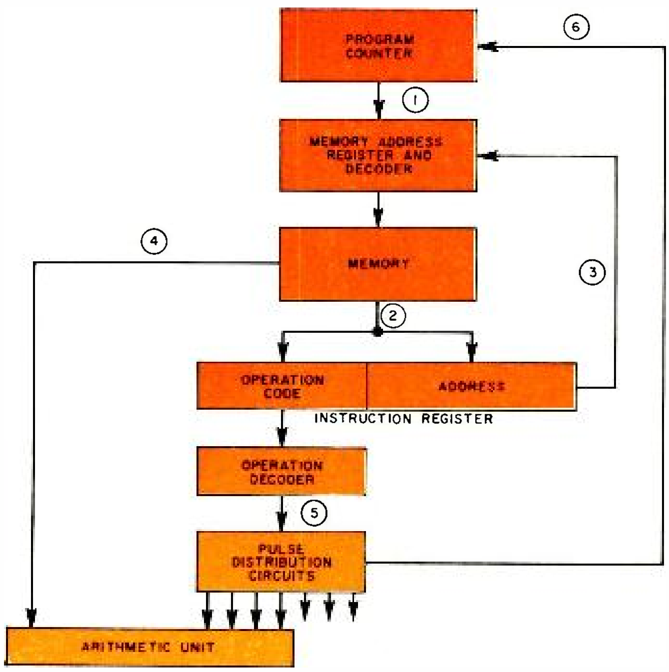


Fig. 3. Instruction register holds instruction word during the time that the called-for operation is performed.

transferred into this register, the operation and address parts of the instruction are dealt with separately. According to which operation code is in the instruction register, the operation decoder produces output at one of its output terminals. This output then controls the pulse distribution circuits to activate those circuits needed for the called-for operation. If the operation code specifies *addition*, for example, the pulse distribution circuits will activate the adder in the arithmetic unit of the computer. The pulse distribution circuits also cause the address part of (*Continued on page 59*)

Fig. 4. Generalized diagram showing the flow of data in computer.



DSB AND THE CITIZENS BANDER

By BRUCE E. PACKHAM

Although double sideband operation has advantages, the author questions its usefulness in materially improving coverage of most inexpensive CB rigs.

A NUMBER of double sideband (DSB) Citizens Band transceivers are currently on the market. Since they are "new" and give the manufacturer a chance to use higher power figures in his advertising, probably more will appear. However, there are some things about DSB which should be clearly understood to avoid possible disappointment.

There are several ideas which the author plans to discuss in this article, namely:

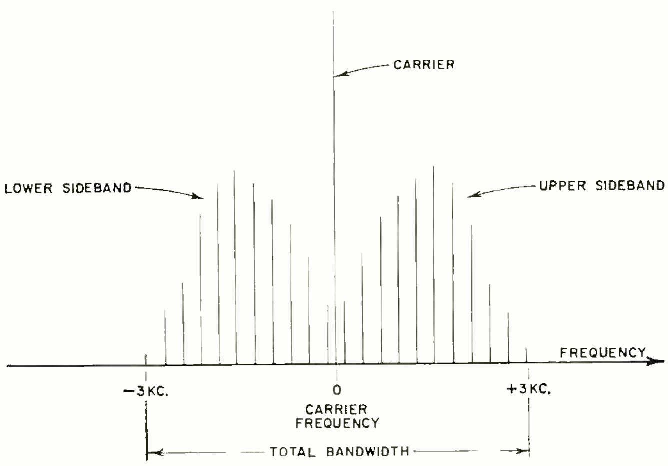
1. Pure DSB is not compatible with existing transceivers except for the very few units with narrow bandwidth and provisions for carrier re-insertion.
2. The DSB transceivers with which the author is familiar *do not materially* increase communications range over conventional AM units.
3. For a given set of conditions, the ability to communicate may actually be decreased by using DSB.
4. Properly utilized, DSB can be a most efficient and effective method of communication if you exclude cost and complexity of the receiver.

Let us develop these ideas by comparing DSB with AM as it applies to voice communications on the Citizens Band and only from the standpoint of maximum communications effectiveness. We must do this within the confines of five watts average power input to the final r.f. amplifier in the transmitter. (FCC regulations, you know.) Let us further assume that the modulating signal is a sine wave which lies in the useful range of voice frequencies up to approximately 3 kc.

An AM transmitter signal consists of a carrier with a group of frequencies on each side. See Fig. 1. These upper and lower sidebands contain the intelligence which the receiver must extract from the transmitted signal so that you may hear the message.

The upper and lower sidebands are symmetrical about the carrier frequency. The carrier has no intelligence on it at all. It serves merely as a reference signal which the detector at the receiver must have in order to do its detecting job.

Fig. 1. An AM signal consists of a carrier along with a pair of symmetrical sidebands in which intelligence resides.



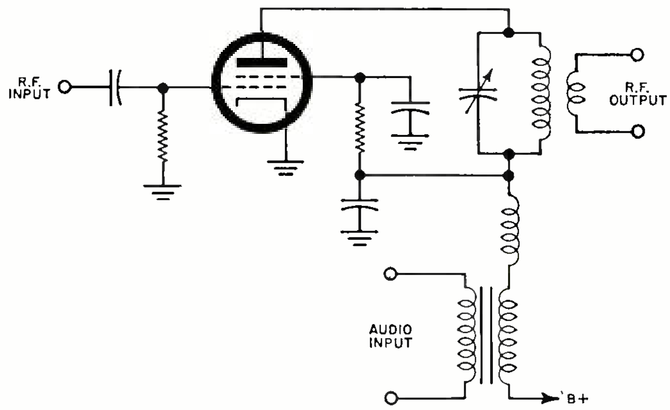


Fig. 2. Conventional plate-modulated r.f. amplifier stage.

What is DSB? An oversimplication would be to say that DSB is AM with the carrier removed. However, there are two main degrees of DSB, namely, *suppressed carrier* and *reduced carrier*.

Suppressed carrier is the pure form of DSB and, in technical circles, is what is generally understood by the term DSB. In this form, the carrier is eliminated as thoroughly as the state of the art and economics will allow. Thus, the resulting signal consists only of two sidebands containing the intelligence.

Reduced carrier consists, as the name implies, of the two sidebands and a carrier whose amplitude is reduced from that of the conventional AM signal. We will discuss why this is done when we talk about the reception of these signals.

AM is generated by (*a*) applying power to a device which generates or amplifies an r.f. signal and then (*b*) introducing additional power to this circuit at an audio rate. This process is known as modulation. The resulting r.f. signal thus varies in amplitude as a function of the impressed audio signal.

Consider the circuit in Fig. 2. With no audio power applied to the transformer, let us assume the d.c. power to the tube (a transistor would do as well) to be 5 watts (250 volts at 20 ma.). Now if we apply 2.5 watts of audio power to the transformer in order to obtain 100% modulation, the "B+" will increase and decrease at an audio rate. This causes the tube to amplify more or less than the static condition. As a matter of fact, the voltage to the tube will vary from 0 to 500 volts. The d.c. power to the tube is responsible for the carrier power and the modulator power is responsible for the sideband power in the output signal. The modulator power, however, is split between the two sidebands.

If we observe an oscilloscope pattern of the carrier, we see something like Fig. 3. This shows an unmodulated carrier followed by the carrier modulated. The instantaneous voltage peaks of the modulated wave are twice those of the unmodulated wave. This means that across the load for the tube (assumed to be a pure resistive load), the peak modulated voltage is twice the unmodulated voltage. Since, *Power* = E^2/R where R is the resistance of the load, the peak power from the tube is 4 times the power of the unmodulated carrier.

The peak envelope power is 20 watts (20 watts p.e.p.). If the r.f. amplifier cannot deliver this power on peaks, distortion results in the transmitted signal. Therefore, in order to generate 2.5 watts of useful sideband power, it is necessary to have a transmitter capable of 20 watts p.e.p.

We can also say that with 5 watts d.c. power to the amplifier and 2.5 watts of audio, the *total average* power input to the amplifier is 7.5 watts. At an efficiency of 75%, the average sideband *output* power will be 1.875 watts.

Double sideband (suppressed carrier) can be generated by several methods, but one of the most efficient and economical is the so-called high-level balanced modulator as shown in Fig. 4. The grids of the tubes are fed r.f. in phase and since the r.f. outputs are exactly out of phase, the r.f. carrier cancels out. But now apply audio power to the transformer. The audio voltage in the transformer will alternately turn on first one tube and then the other. The result will be a signal which looks like Fig. 5 on a scope and consists of two sidebands and no carrier. Both the plate voltage and current will vary at the audio rate. If peak-reading meters are used, the measured power would be 20 watts p.e.p. just as in the AM case.

Another type of high-level balanced modulator is shown in Fig. 6. In this type, audio voltage is applied to the screens. Audio voltage supplied to the transformer serves to turn on first one tube and then the other, just as in the previous example, producing sidebands. If we supply voltage equal to the peak under AM conditions, and the peak current is that under AM conditions, then the p.e.p. would be 20 watts. As in the case of all true DSB envelopes, all the energy is in the sidebands (10 watts each).

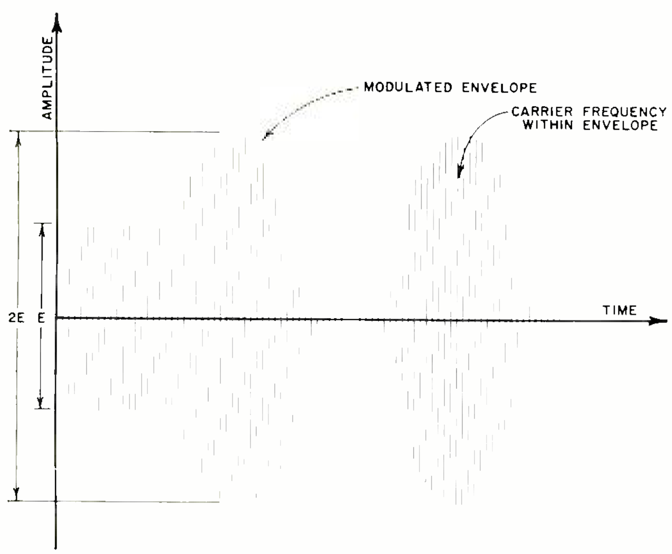


Fig. 3. Scope pattern of a 100-percent modulated wave.

The p.e.p. is a function of the circuit we choose and the degree of liberty we take with the 5 watts average power rule of the FCC.

Using *average* power, let us hold the average power of an output stage to 7.5 watts and start with AM. If we decrease the d.c. power-supply input to the tube and at the same time increase the modulator power, eventually we will have a total of 7.5 watts of average sideband power.

The DSB amplifier can be operated with about the same efficiency as the AM amplifier we started with, hence at 75% efficiency, the total average sideband *output* will be 5.625 watts.

DSB with reduced carrier has sideband power which lies somewhere between that of the AM case (1.875 watts) and that of the pure DSB suppressed carrier example just cited.

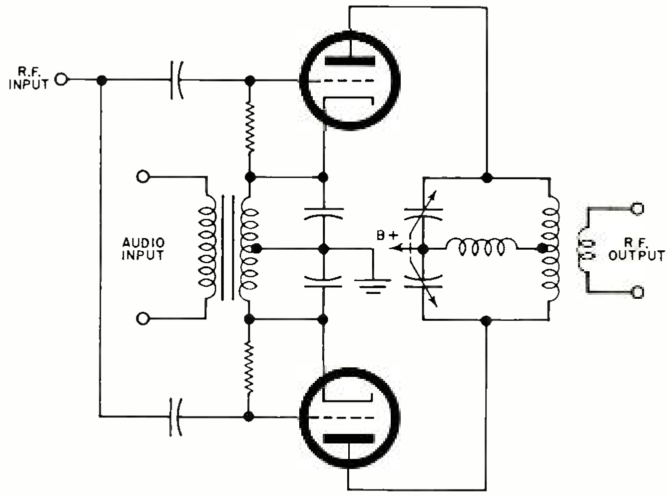


Fig. 4. High-level balanced modulator produces zero radio-frequency output when there is no audio modulation applied.

With DSB we have apparently materially increased our sideband power (which the intelligence is) and we have not violated the FCC regulations. Our talk power should be increased. To see if it is and by how much, read on.

At the Receiver

The apparently useless carrier is of the proper amplitude and, more importantly, of the proper phase with respect to the sidebands. This allows the envelope detectors in common use to do their job of demodulation. The carrier also does a splendid job of holding up the needle on the "S" meter, but we can do that by other methods as well.

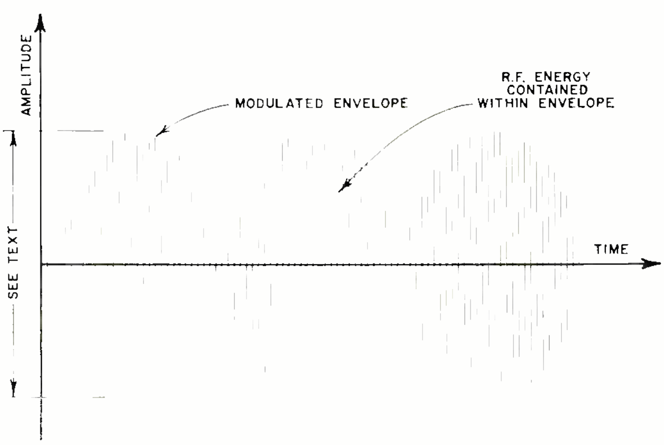
If the bandwidth (selectivity) of the receiver is 6 kc. (most of the transceivers are this wide and more), then with AM, the detector sees the full 1.875 watts of average sideband power.

Because the carrier is of proper phase, the two sidebands add together to form the audio output of the detector which will be, say, 1 output unit of audio power.

With DSB, we are apparently doomed to failure since there is no carrier for the detector to work with. Let us generate a carrier at the receiver and artificially re-insert it. We are still in trouble because the re-inserted carrier is probably of the wrong phase and frequency, and all we are able to hear is garble.

Several commercially available DSB units reduce the bandwidth from 6 kc. to 3 kc. This is done to eliminate one of the sidebands so that proper detection can be accomplished. But with so much power in sideband energy, why throw half of it away? Because now we can easily detect it. We have, like

Fig. 5. A double sideband r.f. envelope as seen on scope.



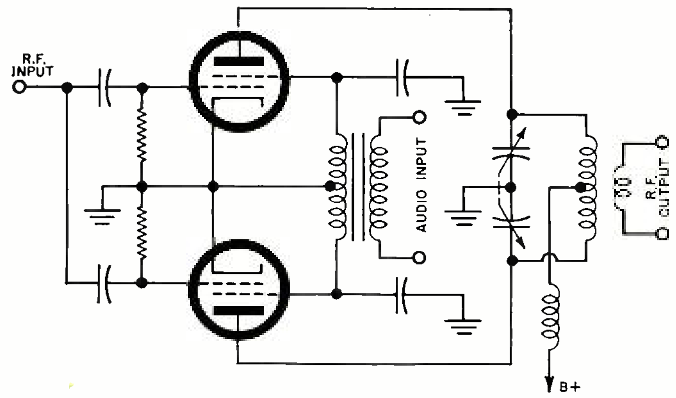


Fig. 6. Balanced modulator with audio applied to screens.

the ostrich, stuck our head in the sand and, by refusing the admittance of both of the sidebands, eliminated our problem —and half of our power.

Another way by which we can ease the problem is to *reduce* the carrier instead of eliminating it. In this way it can be used to synchronize a re-inserted carrier at the receiver or be used directly by the detector. Although the sideband power does not match that of pure DSB, at least we get some increase in sideband power.

Using the case of pure DSB (suppressed carrier) as an example, we must remember that we had 5.625 watts of sideband output. Now having thrown half of it away, we are left with 2.812 watts in sideband power. This will produce an output of 1.5 units of audio output power from the detector (compared to 1 unit for 1.875 watts of average sideband power with AM). This is a 1.8 db increase in signal strength over AM or about 3/10th of an "S" unit (assuming 6 db/"S" unit). It seems we have worked so hard for so little.

If, as some commercial units have done, we decrease bandwidth and at the same time transmit reduced rather than suppressed carrier, we have just about returned full circle to the effectiveness of AM.

Synchronous Detector

What we need is a detection system which receives both sidebands of DSB and adds them just as in the case of AM. Then we would have a 5-db gain in signal strength and audio output power. This is practically a full "S" unit increase and well worth trying for. There is a detector which will do this particular job for us, and it is known as a *synchronous detector.*

Such a detector is shown in block diagram form in Fig. 7. The operation is as follows: The signal input of DSB energy is fed to the I channel (In phase) and Q channel (Quadrature phase) detectors. Following the I channel for a moment, we see that the detector feeds an audio amplifier and the amplifier, in turn, feeds an audio phase detector and provides audio output. The Q channel signal has the same circuit flow minus the audio output.

The output of the audio phase detector is a function of the phase difference between the I and Q channels. But notice that the re-inserted carrier for the Q channel is displaced by 90° from that of the I channel. The signal input can be described as a mathematical function, one of whose product terms contains the trigonometric cosine function of θ. Since θ, the angle between the sidebands and the carrier, equals 90° and $\cos 90° = 0$, the entire term describing the signal equals zero. This is a mathematical way of saying that since the artificial carrier for the Q channel is displaced by 90° from where it should be for proper detection, the output of the Q channel detector is zero. If the phase shift is *not* 90°, the Q channel yields an output which feeds a signal to the audio phase detector. This audio phase detector gives an output which controls the phase of the artificial carrier generator in such a manner as to restore the 90° relationship. What all this means to the I channel is that its carrier is constantly of the proper phase for detection.

Such a detector employs about 5 tubes and would probably retail for about 70 to 90 dollars. No such adapter is commercially available at present, to the author's knowledge.

Over-all Effectiveness

The over-all effectiveness of a communications system is what really counts. If we consider power output of the two communications modes, then DSB wins hands down until you try to detect it. If you halve the bandwidth of your receiver down to 3 to 3.5 kc., then DSB still wins, but just barely.

If we consider the two modes from the standpoint of noise and interference rejection, then DSB wins again *until you halve the bandwidth.* Although the narrower bandwidth is less susceptible to picking up noise and interference, it is also true that because it has less bits of information and less signal energy, it is also less able to deal with noise. Narrow bandwidths tend to make discrimination between noise and signal very difficult. In the Citizens Band, the most common type of disruption to communication is not noise, but interference from stations on the same channel. *No* detector will eliminate this. To say that because we have eliminated the carrier and therefore annoying heterodynes is true, but to what avail? In channelized communications we do not have stations operating on random frequencies with consequent random heterodynes and whistles, therefore, we are back to our principal difficulty in attempting to eliminate a station on *exactly the same frequency as we are.*

Wild claims for DSB such as four times the coverage, etc. are unfounded in fact. A material gain can be had, however.

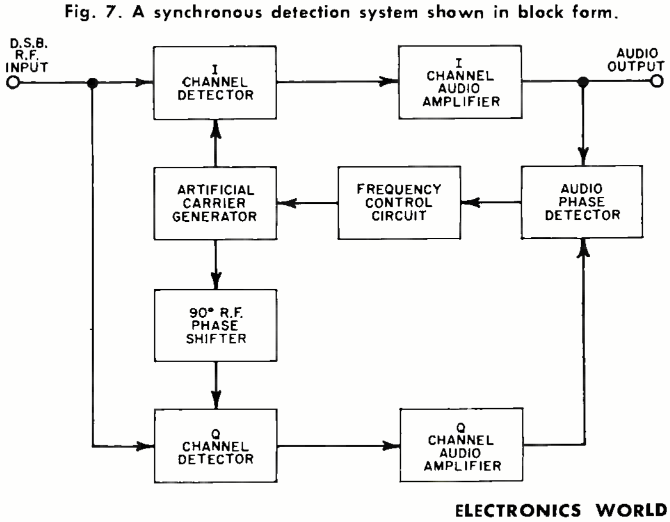
Cutting the bandwidth of a DSB signal may make it compatible with existing units, but why go to all that trouble for 3/10ths of an "S" unit increase? Using reduced carrier instead of pure DSB does give some of the advantages, but not when you slice the power in half.

The superior method of communications is pure DSB received by a 6-kc. bandwidth receiver and detected by a synchronous detector. This method is superior to AM as well as SSB. It has been shown that a 125-watt AM transmitter using clipped audio modulation can effectively jam a 1-kw. SSB transmitter.

If you wish to materially increase your communications effectiveness, you should consider using a speech clipper. A speech clipper can give 9 db or more punch to your signal. The higher voice frequencies are the ones which carry most of the intelligence. Speech compression systems usually are not fast acting enough to catch the higher frequencies of our voice and are, therefore, not as effective as clipping.

Until someone produces an inexpensive and effective DSB adapter, the author feels inclined to continue using the "old" AM rig. ▲

Fig. 7. A synchronous detection system shown in block form.



NEW APPROACH to HIGH-FREQUENCY MEASUREMENTS

By BOB FERROUS

Variation of the microwave slotted-line measurement technique permits determination of v.s.w.r., R, C, L, and "Q" at TV frequencies using ordinary equipment.

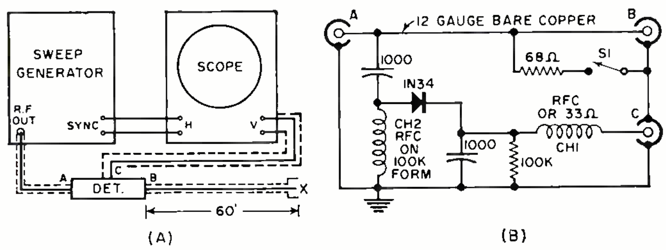


Fig. 1. (A) Test setup for making the various measurements described in the text. (B) Circuit of detector to be used.

WHEN making *R*, *C*, *L*, and "*Q*" measurements on some common electrical components, the results sometimes cause raised eyebrows. For example, a resistor having a d.c. resistance of 70 ohms may have a considerably different value at 55 mc. In one case, such a ½-watt resistor had a value of almost 270 ohms when measured at 55 mc. This particular resistor happened to be a wirewound device having an inductance of .3 μhy. and a "Q" in excess of 3. The higher value of resistance can be accounted for by recalling that the higher the frequency, the closer the current flow is pushed to the surface of the conductor. This is called "skin effect."

A second resistor, a 400-ohm, 10-watt wirewound unit, measured 400 ohms at d.c. but at 55 mc. had a resistance of 5000 ohms and a capacitance of 13 pf. In this case, the capacitance value stems from the fact that the resistor, being inductive, is operated at a frequency higher than its resonant frequency. On checking this, it was found that the resonant frequency was 25 mc.

The measurement technique to be described can be used to measure *R*, *C*, *L*, v.s.w.r., and "*Q*" and can be used on TV tuners, field-strength meters, FM receivers, antennas and their matching harnesses, attenuators, r.f. amplifiers, signal splitters, coaxial traps and stubs, and many more r.f. devices operating at high frequencies.

The technique that is used is based on the microwave system of slotted-line r.f. measurements. In this case, however, the slotted line is replaced by a coaxial cable, and instead of moving the r.f. probe along the line to locate the maximum and minimum voltages at a certain frequency, the frequency is varied and the reflected signal beats produce maximum and minimum voltages at the detector.

This measurement technique allows the technician with a sweep frequency generator and oscilloscope to measure resistance, capacitance, inductance, v.s.w.r., and "*Q*" of any device at TV frequencies, using ordinary 70- to 75-ohm coaxial cable.

The sweep generator, scope, and coaxial cable are connected as shown in Fig. 1A. If the generator does not have an internal detector, then one similar to Fig. 1B and Fig. 2 should be constructed. The coaxial cable used in this test set must not have been physically abused in any way and should be free from indentations that might change cable impedance.

Detector

The detector, shown in Fig. 1B, has an amplitude change of 1 db over the frequency range between 50 and 220 mc. and a v.s.w.r. of 1.25:1 over the same frequency range. 12 gauge copper wire, spaced ½ inch from the chassis surface, is used for the jumper between connectors *A* and *B*. This

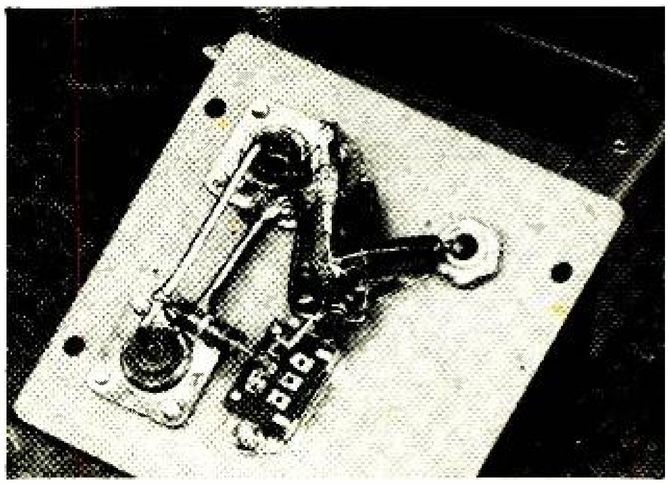
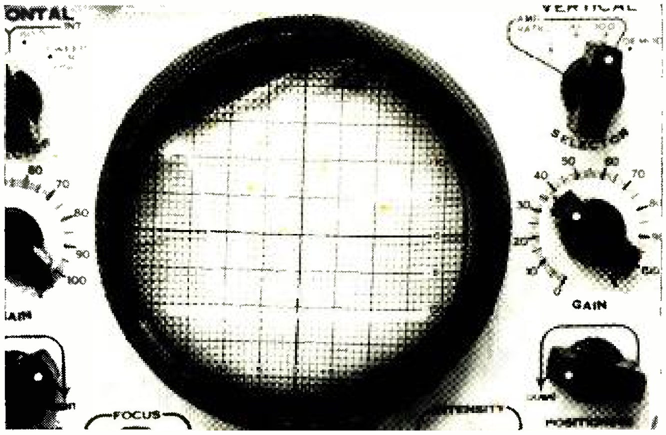


Fig. 2. The construction of the detector is clean and simple. The 12-gauge copper wire mounted between connectors A and B should be kept at least ½" above the metal panel surface.

Fig. 3. Typical scope trace showing internal blanking action.



wire and its spacing determines the v.s.w.r. of the finished detector. Switch *S1* is incorporated so that the detector can be used for alignment purposes and is not required for any of the tests described in this article. Choke *CH1* is not critical and can be replaced with a 33-ohm, ½-watt resistor if desired. Choke *CH2* is moderately critical and consists of 20 turns of #24 gauge enameled wire wound on a 100,000-ohm, ½-watt resistor body, ¼-inch in diameter. For this winding, the resistor body ends are notched with a file to allow the wire to be wound rigidly on the form. If this technique is not followed, then the wire will slip around the form as the winding progresses.

If a suitable detector circuit is incorporated in the sweep generator that is employed, it may be used in place of the detector just described.

Many technicians cringe at the thought of v.s.w.r. measurements but, in reality, this need be no more complicated than the measurement of resistance. Consider for the moment

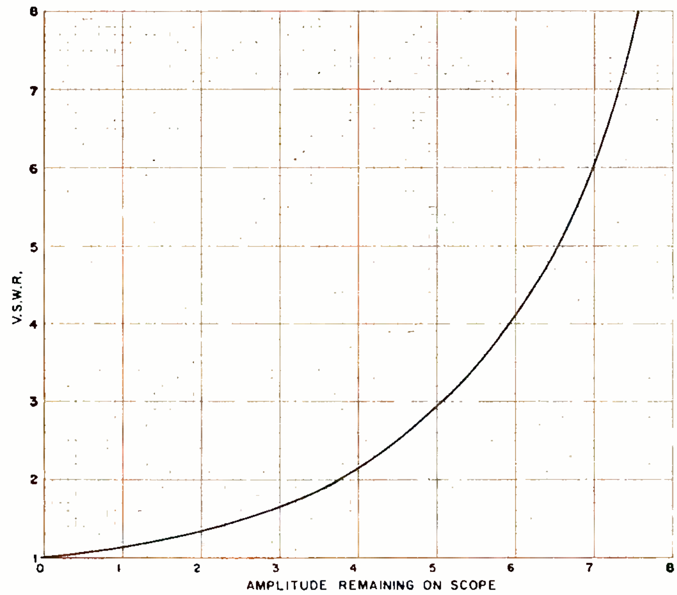


Fig. 4. By measuring the ripple amplitude remaining on the scope, the v.s.w.r. value as the ratio to 1 can be found.

the case for resistance. It is not necessary to be able to define an ohm, or to be able to design an ohmmeter, to be capable of using an ohmmeter. The same line of reasoning holds for v.s.w.r. It is not necessary to know, or to be able to use any formula, to make such measurements.

Sweep Generator

The generator must be used at a frequency where only the swept oscillator produces an output, or where a filter is used to eliminate (or at least attenuate) the undesired beats produced by the beat-frequency type of generator. This is necessary in order to be certain of the frequencies at which measurements will be made. The generator should be capable of sweeping 6 mc. or more in bandwidth with the center frequency being the frequency of interest.

Oscilloscope

The scope can be almost any type since the highest frequency it must handle will be in the order of 600 cycles. It should be provided with a graph-like calibration scale and have a sensitivity of 20 or 30 mv. per inch or better in order to obtain a large enough amplitude pattern.

Coaxial Cable

The coaxial cable is ordinary RG-59/U or other coaxial cable of 70- to 75-ohm impedance. It should be fitted with coaxial connectors at each end and long enough to present several cycles on the scope trace. When using a sweep width of 12 mc. at television frequencies, this length will be approximately 60 feet. The length is not critical, and in fact, 60 feet can generally be used for any TV channel from 2 to 13. For other frequencies, the general rule is to double the length of cable when using half the sweep width indicated above. Small-diameter cables usually have the better impedance tolerance and are preferred for this reason.

Scope Pattern

The pattern shown on the face of the scope will depend somewhat on the characteristics of the sweep generator. If the generator blanks the return trace, then the pattern will appear as shown in Fig. 3. If the return trace is not blanked, the wavy part of the pattern will appear twice and will tend to be confusing during some of the measurements. If the return trace is not blanked in the sweep generator, it may be blanked by applying the generator synchronizing signal to the scope Z-axis as well as to the horizontal terminals, or by phasing the power line and applying this to the Z-axis.

V.S.W.R. Measurement

Measurement of v.s.w.r. depends only on the amplitude of the ripple shown in Fig. 3. This ripple is produced at the detector by virtue of the reflection from the open or shorted end of the coaxial cable.

The basis for this measurement is the fact that a signal sent down a length of coaxial cable is either dissipated in the termination or reflected back to the source. The reflected wave passing the detector produces the interference pattern which is displayed on the scope as shown in Fig. 3. By leaving the end of the cable open and adjusting the generator output and scope vertical gain, the amplitude of the pattern can be adjusted to allow the pattern peak-to-peak amplitude to be set at 10 calibration scale divisions. A perfect match when applied to point *X* of Fig. 1A will produce a perfectly straight line. Any departure from perfect match will allow some ripple to remain on the screen. The amplitude of this remaining ripple can be converted into v.s.w.r. by Fig. 4. To use Fig. 4, first set the scope pattern to 10 calibration scale divisions each time a measurement is to be made. Connect the desired load to point *X* (Fig. 1A) and measure the amplitude of the ripple now showing on the scope. Locate this value

Fig. 5. Ripple amplitude determines the circuit resistance.

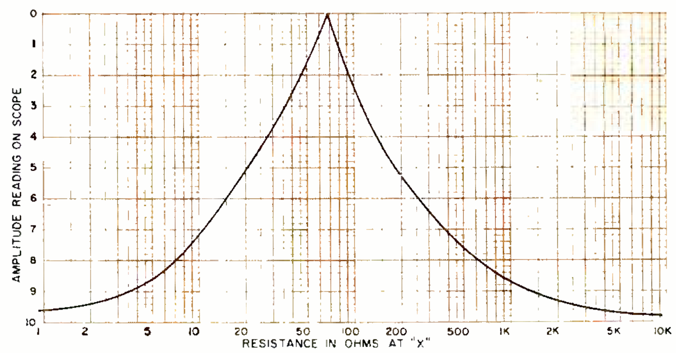
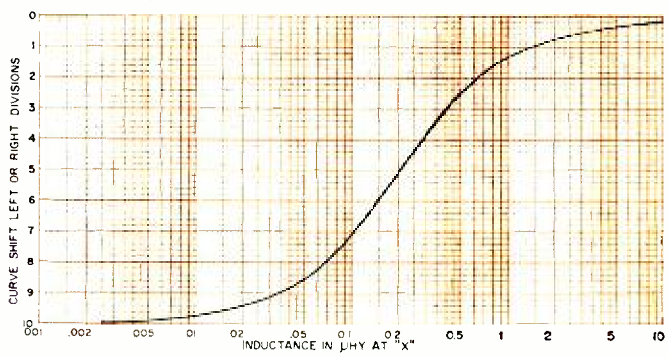


Fig. 6. Ripple curve shift is used to determine inductance.



on Fig. 4 curve. The v.s.w.r. value is the ratio to 1. Thus 1.5 represents a v.s.w.r. of 1.5:1.

V.S.W.R. of 300-ohm Devices

The v.s.w.r. of 75-ohm devices is found as just described. To find v.s.w.r. of 300-ohm balanced devices such as TV tuners, an impedance-converting device must be used. This may take the form of a coaxial balun for the frequency required, or possibly a 75- to 300-ohm transformer. The balun method is the surest way of the two, but requires one for each channel at which measurements are to be made. Other impedances may be used, but they also require impedance-matching sections. The matching sections are connected at point X of Fig 1A, and the load to be measured is connected to the other end of the impedance-transforming section.

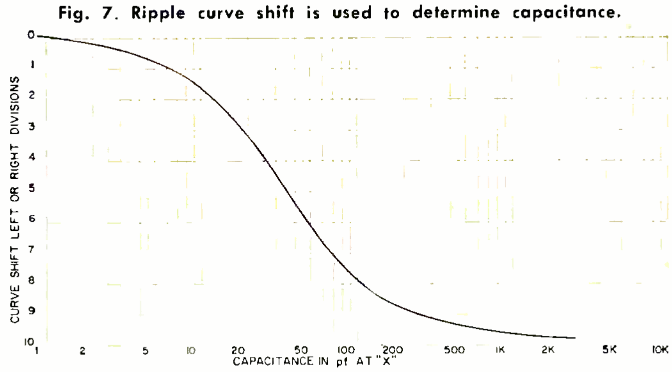
Resistance Measurement

Measurement of resistance is accomplished in the same manner as v.s.w.r. except that the curve of Fig. 5 is used. Note that for each value of scope ripple, there are two values of resistance that satisfy the problem. This ambiguity can be removed by paralleling the load at point X with a second value of resistance that is known to be well up on the high side of the curve. For example, assume an unknown load producing 3 divisions of ripple amplitude. This means a resistance of either 38 ohms or 110 ohms. By paralleling the load with a 200-ohm resistor, the resulting combination would reduce the ripple amplitude if the value of load were 110 ohms, but would produce a slightly larger amplitude for the load value of 38 ohms. This is because the parallel resistance is 32 ohms in one case and 71 ohms in the second case. Referring these values to the curve of Fig. 5 will show that the amplitude of the ripple does change as described.

Inductance Measurements

This measurement depends on the changing of the interfering pattern at the detector with the phase of the wave being reflected from the open end of the coaxial at point X of Fig. 1A. Note the pattern on the scope with the end of the coaxial cable open-circuited, then with the end of the coaxial cable shorted. Note that where there was a crest on the open-circuited condition, there is a valley in the shorted condition. In other words, the pattern on the scope has changed through 180 degrees. In the open-circuited condition, there is no load on the end of the cable. If an inductance is assumed to be connected, it must have infinite reactance. In the shorted condition, the load consists only of the inductance of the short length of wire used to short the cable. This inductance must be very small and must have zero, or nearly zero, reactance. By taking a value of inductance that has a reactance equal to the cable impedance, the scope curve shifts halfway between the two extremes of shorted and open lines. To make use of this in measurements, the open-circuited condition is used to put the peak of one of the ripples of the curve on the vertical center line of the scope calibration scale. The line is then shorted and the adjacent peak is brought to the plus 10 mark on the scope calibration scale. This is done by

Fig. 7. Ripple curve shift is used to determine capacitance.



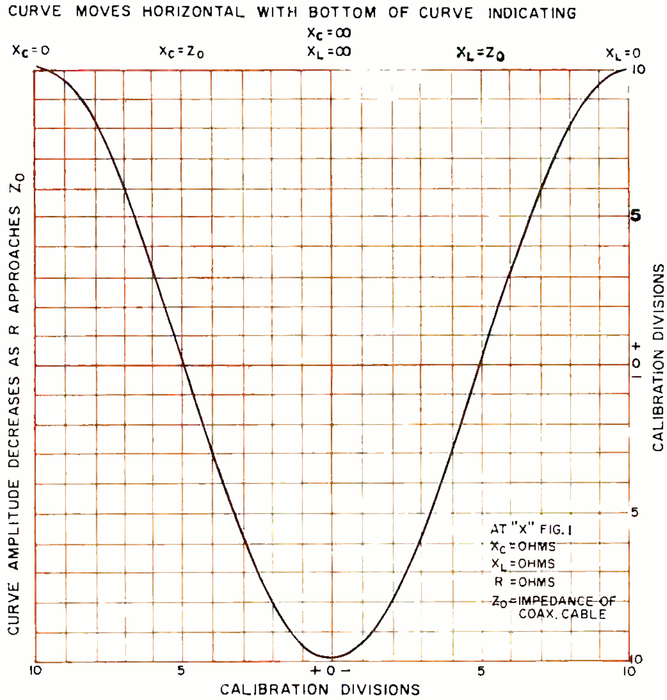


Fig. 8. Scope trace ripple will move horizontally either way depending on the type of reactance in circuit being tested.

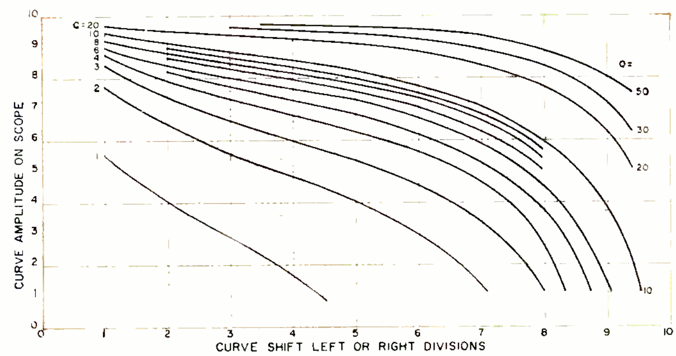


Fig. 9. Ripple curve shifts right or left, and change in amplitude is used to determine "Q" of circuit tested.

juggling both the horizontal gain control and the horizontal positioning control. The direction the scope curve moves can be easily found by connecting a two- or three-turn loop to the end of the cable and inserting a brass plug into the coil, thus reducing the inductance and hence the reactance across the cable.

By noting the direction the curve moves, and counting the curve displacement in this direction, we can chart a curve for inductance, as shown in Fig. 6.

Capacitance Measurement

This is similar to the method used to measure inductance. The theory behind this is developed the same way, except that a capacitor is attached to the cable in the open and shorted condition. Another viewpoint consists of considering the results of adding capacitance and inductance to the ends of the coaxial cable. The capacitance has the effect of lengthening the measurement cable, while inductance has the effect of shortening the cable. To make capacitance measurements, put one of the ripple peaks on the scope calibration scale center line and the adjacent peak on the minus 10 scope calibration scale mark. Juggle the horizontal gain and horizontal positioning controls to obtain this condition. By connecting a small-value capacitor to the end of the cable, thus increasing capacitance and lowering reactance, the pattern will move in the opposite direction from the curve of smaller inductance. Thus, by counting the divisions the curve is displaced, and referring (*Continued on page* 56)

HIGH-STABILITY CRYSTAL FREQUENCY STANDARDS

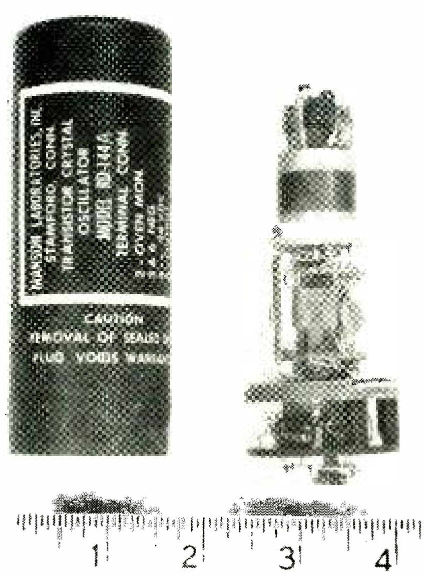
By IRWIN MATH / Electrical Engineer, Manson Labs Inc.

Crystal oscillators can be designed to have frequency stabilities approaching those of atomic standards. One such crystal oscillator can drive a clock so that time variation would be less than five seconds in 300 years.

ADVANCEMENTS in the fields of satellite tracking, terrestrial and extra-terrestrial communications systems, and new sophisticated types of navigation equipment for use both on and off the earth, have created a need for extremely accurate frequency and time standards. Just how accurate can be realized by a simple example. In an attempt to rendezvous two manned satellites or spacecraft a few hundred miles above the earth, an error of only .001 second (one millisecond) in the tracking system can cause a 30-foot error in the trajectory of the satellites. This type of error, or the long term drift of a timing source, could easily be fatal to all personnel taking part in such a maneuver.

Similarly, on the Atlantic Missile Range, exact synchronization of the various range stations is essential for accurate determination of the performance of missiles during flight. In this application, measurement of time to accuracies of one part in ten billion (or 1 part in 10^{10}), over periods as long as 24 hours or more, is essential. Because frequency is dependent on time by definition, highly stable radio-frequency oscillators can be used to drive various types of indicators for both long and short term measurements.

Fig. 1. Commercial crystal oven provides 1 mc. with over-all advertised stability of one part in a hundred million (10^8) within the temperature range 0 to 50°C.



The most familiar and widely used frequency standard is the crystal-controlled oscillator. For accuracies of parts in 10^4 (general communications and amateur radio type crystals) and higher, the quartz crystal is practically the universal frequency determining element. Schematically, a quartz crystal appears as a resonant circuit having series inductance, capacitance, and resistance paralleled by the capacitance formed by the holder, case, and electrical contacts made to the crystal. When used in an oscillator, these parameters, together with the temperature of the quartz itself, determine the final resonant frequency of the crystal. In a high-stability oscillator, it is necessary to keep these parameters as nearly constant as possible.

Variations in the ambient temperature of a crystal is one of the major causes of changes in these parameters; therefore in a highly stable oscillator, the temperature of the crystal must be maintained as constant as possible. Where stabilities of a part in 10^8 or less are required, a thermoswitched oven is usually employed.

Fig. 1 is a photograph of a *Manson Laboratories* RD-144A transistorized oscillator with a thermoswitched oven. This unit provides a 1-mc. signal with an over-all advertised stability of 1 part in 10^8 (.01 cycle at 1 mc.) or better over the range of 0 to 50°C. A cutaway view of this oscillator (Fig. 2) shows the location of the oven (heater), mercury thermoswitch, and crystal. This entire oscillator is enclosed in a small vacuum bottle, called a Dewar flask, to prevent loss of heat.

The mercury switch deserves a little more explanation. Fig. 3 shows an enlarged, detailed drawing of a typical mercury thermoswitch. It consists of a small thermometer to which two electrical contacts have been added. The bulb of the thermometer is attached to a threaded cap which fits into the oven shell. As the temperature of the oven rises, the mercury in the thermoswitch expands and, at the preset temperature, electrically connects the two contacts. This causes a transistorized switch to effectively disconnect the oven, stopping the heat flow, thus allowing the oven to cool. The mercury column contracts until the contacts open. At that point, the oven goes on, and the cycle repeats. Crystal oscillators such as these are used in various applications ranging from digital counters and test equipment, to standards for certain types of communications systems, as well as general laboratory reference oscillators.

For extremely high stability work, the thermoswitched oven cannot maintain a constant enough temperature, especially over widely varying outside ambient environments. For this type of temperature control (.01°C or better), a proportionally controlled oven must be used. In this system, heat is supplied to the crystal oven at the same rate at which it leaks out or is lost. There is no switching action, but instead a smooth, continuous control is used. A commercial oscillator that uses this type of control provides output frequencies of 1 mc. and 100 kc. with an advertised stability of 1 to 2 parts in 10^{10}. This is equivalent to a stability of .0001 cycle at 1 mc., and .00001 cycle at 100 kc. A unit such as this is usually employed as a master oscillator in frequency control systems, as a time standard, or as a precision time or frequency marker generator. To achieve this order of stability, a proportional oven system, similar in principle to the one shown in Fig. 4, is used. Two thermistors (or other temperature-sensitive devices) are mounted adjacent to the crystal. These thermistors, together with the two precision resistors, form a Wheatstone bridge. The bridge is connected across the output of an oscillator. The resistors are chosen so that under normal operation, the bridge is unbalanced and a signal is applied to the high-gain power amplifier. The signal is amplified to a level sufficient to cause the oven to heat and consequently raise the temperature of the crystal. As the temperature rises, the resistance of the thermistors begins to get closer to the values of the fixed resistors. This brings the bridge closer and closer to balance which, in turn, lowers the signal applied to the power amplifier and thus the heat supplied to the crystal. By proper choice of components, such a system can easily be adjusted to supply the exact amount of heat that is being lost with the result that the crystal is kept at an extremely constant temperature.

Although temperature is of major importance, there are other factors which must be considered in ultra-stable oscillator design. Voltages, for instance, applied to both the crystal and its associated circuitry must be very well regulated. Supplies with regulation on the order of ±.005 volt, and ripple of ±.001 volt or less are frequently employed. Automatic-gain-controlled amplifiers, similar in operation to the automatic-volume-control amplifiers of a superheterodyne receiver, are almost always used to insure that the crystal current is kept at some constant value.

Various components for these oscillators are carefully chosen for minimum variation in value over long periods of time, and extreme changes in environment. In many cases, new types of circuit components have to be designed in order to meet these stringent requirements. In addition, all high-stability oscillators are kept in continuous operation to minimize crystal "aging." This "aging" is a characteristic of the quartz crystal itself, and shows up as a slow drift in frequency over an extended period of time. In most cases, careful design of an oscillator system can reduce this drift to parts in 10^9.

By the choice of proper operating temperatures, voltages, and currents, long-term stabilities of 5 to 6 parts in 10^8, over intervals of 100 days or more can be achieved with ease. At this rate, a clock driven by such an oscillator will lose (or gain) only 5 seconds in 300 years! In many cases, short-term stabilities (a few minutes) can be brought well into the 10^{11} region.

While a part in 10^{10} may seem like a fantastic amount of stability, many of the applications mentioned in this article are already demanding even more precise standards. At the time this is written, a part in 10^{11} has been achieved with a quartz crystal oscillator in the laboratory, and parts in 10^{12} seem quite possible. Another approach is the atomic standard developed in the past few years. Two parts in 10^{12} are being obtained today consistently with a cesium beam resonator, and ±2 parts in 10^{11} can be obtained with a rubidium standard. An atomic hydrogen maser, working between nuclear hyperfine levels, may also permit the building of extremely accurate clocks.

The advantage of an atomic device is that there is no drift due to "aging." The output frequency is always within the stated limits for minutes, days, and even years. Just what the final outcome will be is unknown, but as the requirements become more and more exact, it is a certainty that new approaches to frequency standards will be developed. ▲

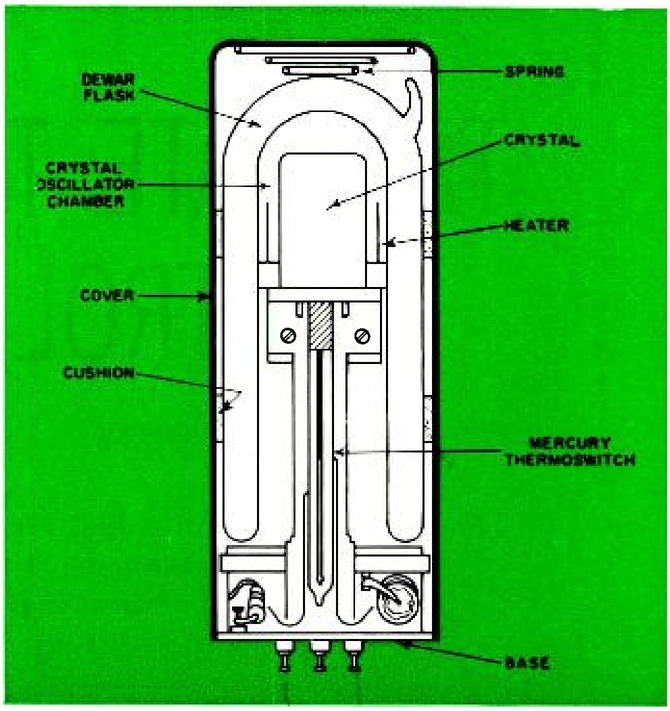


Fig. 2. Cutaway view of a commercial crystal oven shows how the crystal is mounted in a Dewar flask and has its operating temperature controlled by mercury thermoswitch and heater.

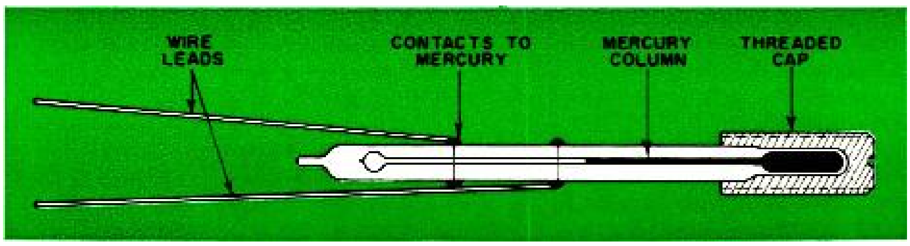
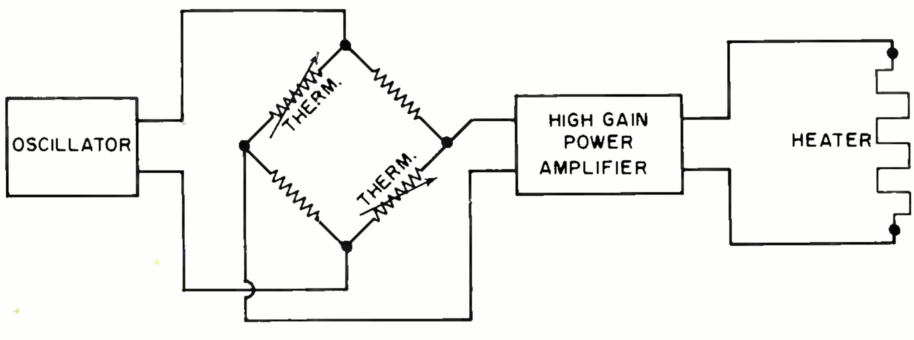


Fig. 3. When the temperature goes up, the mercury column expands to close the electrical contacts. This action turns off the power supplying the oven heater.

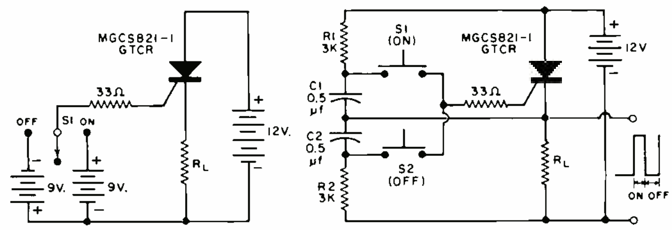
Fig. 4. The oscillator output is amplified to drive the crystal oven heater. The thermistors are mounted adjacent to the crystal so that the amount of power being supplied to the crystal oven is a function of how fast the oven loses heat.



THE GATE TURNOFF CONTROLLED RECTIFIER

By DAVID L. PIPPEN / Guidance and Control Labs, White Sands Missile Range

The gate turnoff controlled rectifier (GTCR) is more versatile than its SCR cousin because a negative pulse will turn it off. Some experimental circuits are shown.



R_L CHOSEN AS REQUIRED. MUST BE LARGE ENOUGH TO LIMIT CURRENT TO WITHIN GTCR RATINGS

(A) (B)

Fig. 1. (A) This circuit demonstrates the basic operation of the Motorola GTCR. (B) Modified circuit uses the charge on two capacitors to simulate the turn-on and turn-off batteries.

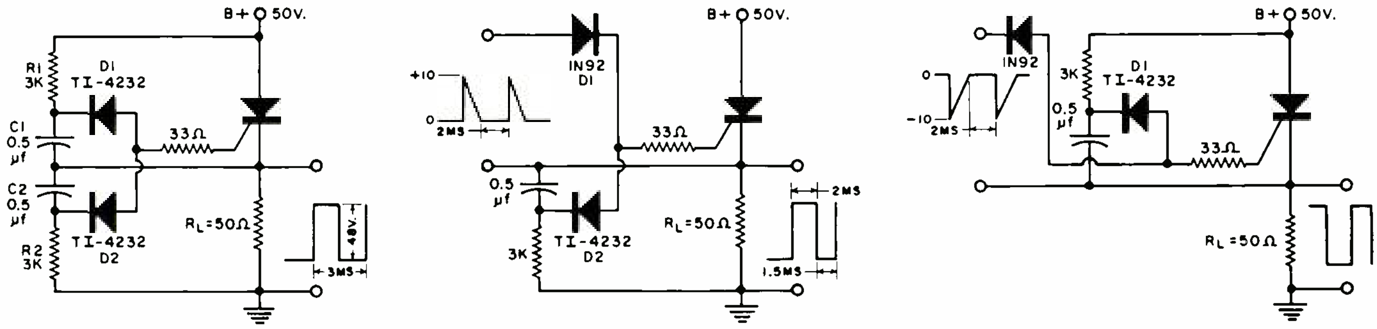
DEVELOPMENT of the conventional silicon controlled rectifier (SCR) has enabled the design of many new electronic devices that were previously impractical. The SCR is frequently employed in commercial, industrial, and military equipment and, in many applications, the SCR has replaced thyratrons, fuses, power transistors, vacuum tubes, and a host of other devices. The SCR, like the thyratron tube, does have a major limitation. This limitation is that once the device is fired by applying a positive gate voltage, the gate loses control and cannot be used to turn the SCR off.

A newly developed device, the gate turnoff controlled rectifier (GTCR), operates much as the SCR but overcomes the basic limitation of the SCR in that a negative gate voltage will turn the device off.

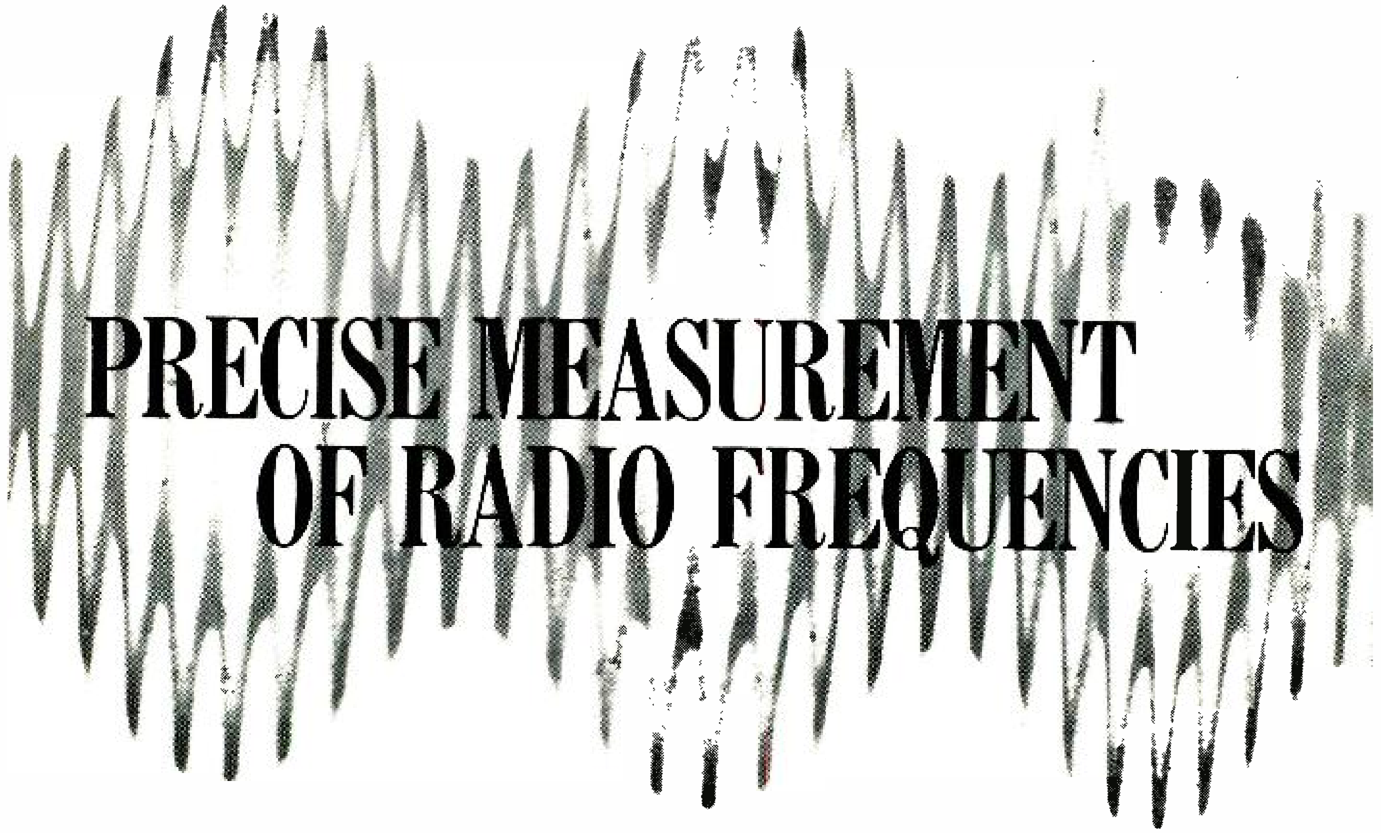
The circuit of Fig. 1A demonstrates the basic operation of the GTCR. S1 is a spring-return switch that will momentarily place either the positive or negative 9-volt battery into the circuit. When the 12-volt supply is applied and S1 is in the center position, no current will flow through the load R_L. Should S1 be momentarily placed in the "on" position, the +9-volt battery is applied to the gate of the GTCR and the device fires. Current then flows through the load, limited by the value of load resistance plus the very small resistance of the GTCR. When S1 is momentarily placed in the "off" position, the minus 9 volts cuts the GTCR off and the current through the load ceases.

Since it is not usually desired to have two batteries to turn the GTCR on and off, the circuit of Fig. 1B was devised. Switches S1 and S2 are of the quick-return type. These switches, in conjunction with capacitors C1 and C2, perform the same function as the two nine-volt batteries of Fig. 1A. When the 12-volt supply is applied, no current flows through the load. Capacitor C1 charges through R_L and R1 to a value that is positive with respect to the GTCR cathode. When "on" switch S1 is depressed, the charge on C1 is applied across the gate-to-cathode circuit to fire the GTCR. Since the GTCR has a very low "on" resistance, very little voltage is dropped across the device and essentially all the supply voltage is applied across the load. The voltage across the load is also applied across the series combination of C2 and R2. C2 then begins to charge to a value that is negative with respect to the GTCR cathode. Operation of S2 ("off" switch) applies the charge of C2 across the gate-to-cathode circuit of the GTCR to turn the device off. Note that the discharge path of C2 is opposite that of C1. *(Continued on page 74)*

Fig. 2. Three variations of a high-power GTCR switch. (A) Free-running type uses trigger diodes to initiate switching action. (B) Normally off monostable version is triggered on by application of positive-going pulses. (C) Normally on version requires a negative-going signal applied to the gate electrode to turn the GTCR off. The GTCR is a Motorola MGCS 821-2.



(A) (B) (C)



PRECISE MEASUREMENT OF RADIO FREQUENCIES

By J. RICHARD JOHNSON

Technique of using secondary standard, checked against WWV, to measure transmitter or r.f. generator frequency. Simple equipment can be employed to obtain accuracies far beyond that needed for FCC frequency requirements.

WHATEVER portion of the broad field of electronics holds your interest, frequency and frequency measurement are undoubtedly important to you. They are important not only to the performance of your equipment, but often, as in the case of transmitters, are factors which must be considered to avoid violations of the law.

Almost anyone with a basic knowledge of electronics, a modest amount of equipment, and the requisite care and patience can utilize the standard frequency broadcasts from National Bureau of Standards stations like WWV. Under such conditions, measurements accurate to within 1 part per million, or equivalent to an error of only one second in almost two weeks, are not unusual.

This article covers the use of a secondary frequency standard, checked against WWV, to make frequency measurements in the range between 1 mc. and at least 30 mc.

A complete frequency-measuring system of this type is illustrated in block diagram form in Fig. 1.

One of the advantages of this type of frequency measurement is that a high degree of precision can be realized from relatively low-cost equipment. All you need is a reasonably good communications receiver, a 1000/100 kc. frequency standard (often a TV marker generator will do), and a calibrated audio oscillator. With these and a little care, you can achieve accuracy far beyond that needed for even the most rigorous of FCC frequency requirements.

Direct Frequency Determination

If the frequency is very low, the most obvious method of measuring it is to count the cycles as they occur and then to determine how many cycles there are during a second, an hour, a day, or during any other specified period of time.

A simple example is the rotation of the earth. By definition, the rotational frequency is 1 cycle (revolution) per day. Using the sun or some star as a reference, we can "count days" as the earth spins on its axis. Since a day is defined as 24 hours, we can express the earth's rotational frequency in different units: 1 cycle per day; $1/24 = 0.0417$ cycle per hour; $0.0417/60 = 0.000695$ cycle per minute: and 365 cycles per year. This example is more than just a random one, because the "mean solar day" is an international standard for the unit of time.

As the frequency increases, the human counting method not only becomes less accurate, but also fails completely when the cycles come so fast that the operator can no longer distinguish individual cycles. This usually happens at about 5 to 10 cps.

Cycle-counting can be done electronically at moderately high frequencies, but the human direct-counting method can be used only in very special applications in which the frequency is very low and human errors in timing can be tolerated, or in which the measured signal is recorded with a time base.

In all practical frequency-measuring techniques, signals of unknown frequency are compared with other signals whose frequencies are accurately known. This comparison is made practicable by the use of *heterodyning*.

Principles of Heterodyning

When two alternating currents of different frequencies $f1$ and $f2$ flow together in a non-linear mixer circuit, they generate a series of additional signals whose frequencies are equal to $f1 + f2$, $f1 - f2$, $f1 + 2f2$, $f1 - 2f2$, $f1 + 3f2$, $f1 - 3f2$, etc. The first-order signals, at $f1 + f2$ and $f1 - f2$, are of primary interest here. These are often referred to as the *sum and difference heterodynes*. These heterodynes are not generated unless the mixer circuit has a non-linear impedance. This non-linear impedance can be supplied by a vacuum tube, transistor, or solid-state diode, providing it operates over the non-linear portion of its characteristics. Thus one cannot hear a heterodyne signal from two r.f. signals applied to a pair of linear-impedance headphones even though the frequencies of the two signals differ only by an audio frequency. The two signals must be applied to a diode or other mixing device.

Fortunately, there is such a mixing circuit in any superheterodyne receiver (and therefore in almost any receiver now in general use), *i.e.*, the second detector circuit. Therefore, when we want to heterodyne r.f. signals to accomplish frequency measurements, we often need only apply them to the antenna terminals of the receiver and the low-frequency heterodyne signals can be heard at the receiver's output. This is the kind of process that takes place when a c.w. signal is received on a communications receiver. The beat oscillator associated with the receiver's detector circuit heterodynes with the received signal (after conversion to intermediate frequency) and the heterodyne is the tone by which it is "copied."

Suppose two signals of frequencies $f1$ and $f2$ respectively are heterodyned to produce a difference beat (heterodyne) in the audio-frequency range. Suppose further that $f1$ is to be measured and $f2$ is accurately known. Frequency $f1$ can then be determined by careful measurement of $f1 - f2$ and addition of this frequency to $f2$. Because a difference heterodyne is often easier to measure precisely than the unknown frequency, the difference-heterodyne method is the one most often used in high-precision measurements. In such measurements, $f2$ in the above example is a frequency standard that has been either provided directly by the National Bureau of Standards standard-frequency broadcasts or by standards that have been checked against them.

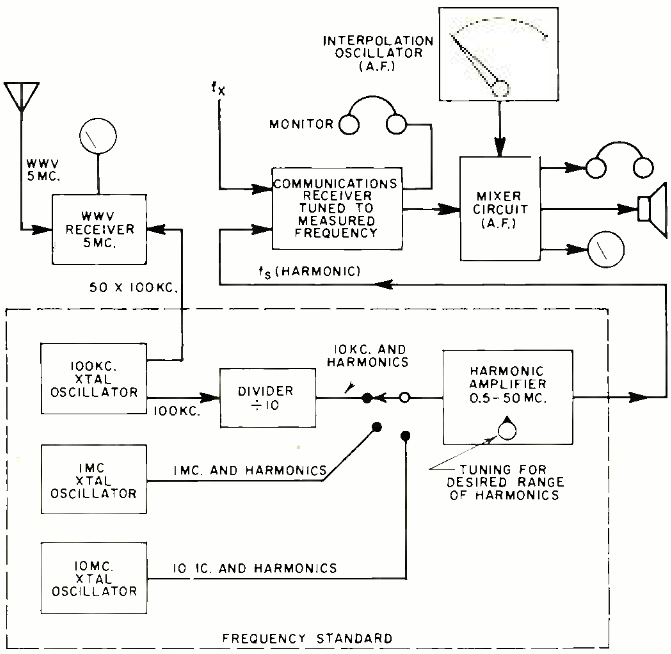
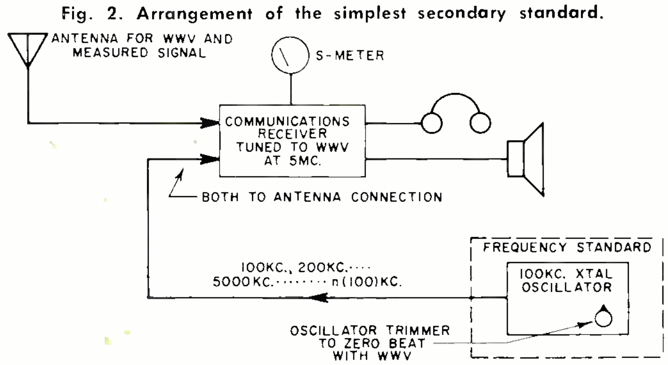


Fig. 1. Complete, accurate frequency-measuring system.

Fig. 2. Arrangement of the simplest secondary standard.



Secondary Frequency Standards

Because of the complicated equipment required, astronomically checked primary standards are maintained at only a few locations. (Refer to the article "Frequency and Time Standards" in this issue.) However, this is not a serious handicap, thanks to the standard time and frequency broadcasts made available by NBS in this country and by government agencies in some other countries.

Our own NBS broadcasts provide a wide variety of standard time and frequency signals of extreme accuracy. The most important in the applications we are now considering are the reference standards provided by the carrier frequencies of these stations. These frequencies, as transmitted by WWV, are kept accurate to better than 1 part in a hundred billion or one ten-thousandth of a cycle per second at 10 mc. (outside of a fixed frequency offset of -150 parts in 10^{10}). Accuracy at the receiver is on the order of 1 cps at 10 mc. (0.00001%) due to ionosophere instability. With the lower frequency stations, WWVB and WWVL, accuracy at the receiver is much better. The frequencies and types of transmission from NBS stations are given in Table 1.

Frequency measurements of great accuracy can be made at any location within range of the standard broadcasts by employing a *secondary frequency standard* which is itself quite stable and whose accuracy can be optimized by alignment with the transmissions from the NBS broadcasts.

The simplest type of secondary frequency standard is illustrated in block form in Fig. 2. It is a stable crystal-controlled 100-kc. oscillator. The oscillator is equipped with a trimmer capacitor connected across the crystal, or with some other arrangement to allow very small adjustments (up to several hundred cycles per second) of the frequency of the generated signal. This allows compensation for variations in the oscillator frequency due to such things as temperature and voltage variations. A typical 100-kc. crystal oscillator circuit suitable for use as a secondary frequency standard is shown in Fig. 3.

The oscillator output contains not only the 100-kc. fundamental signal, but also harmonics at integral multiples of 100 kc. throughout the useful frequency range. One of these harmonics (say the 50th, at 5 mc.) is tuned in on a receiver that is also receiving a standard broadcast from WWV on that frequency. The two signals beat or heterodyne, producing a third signal having a frequency equal to the *difference* between the frequencies of the local standard and the standard broadcast. Calibration checks of the secondary standard are made by adjusting the trimmer on the oscillator until there is zero beat between the oscillator harmonic and the WWV signal. When the oscillator frequency is very close to that of WWV, a slow pulsing (beating), indicating a difference heterodyne on the order of 1 or 2 cycles per second, can be heard in the earphones or loudspeaker or seen as fluctuations of the pointer on the receiver's "S" meter.

Much of the time WWV transmits tone modulation at either 440 cps or 600 cps (as well as pulse-type second markers). It is preferable *not* to make secondary standard zero-beat adjustments while the tone is on. The audio frequency beat between the signal from the frequency standard and WWV's carrier, in turn, beats against the tone modulation signal, giving a false zero-beat indication. For example, suppose WWV is sending a 600-cps tone. If the harmonic of the signal from the standard is 0.6 kc. higher or lower in frequency than 5 mc., a 600-cps beat tone is produced and beats against the 600-cps tone modulation, causing an effect very much like that when the r.f. signals themselves are zero-beat.

Fortunately, it isn't necessary to make the adjustment while the tone is on. Starting at 3 minutes after the beginning of each 5-minute interval, there is a period of almost 2 minutes when the tone and all other modulation except the second markers are off and thus the difficulties just mentioned are avoided. The details of the typical WWV modulation during each 5-minute period are shown in Fig. 4. The one exception is the 5-minute period starting at 45 minutes after the hour, when WWV goes off the air entirely for a period of 4 minutes.

Although a 1-cps or lower beat can normally be obtained, even with modest equipment, between the secondary standard and WWV, let us be conservative and assume maintenance of the oscillator frequency only to within 5 cps of that of WWV, so that the frequency error is limited to 5 cps in 5,000,000 cps or 0.0001%. Since the harmonics of the 100-kc. oscillator are all exact multiples of the fundamental oscillator frequency, they are all accurate to within the same *percentage*. Thus, any harmonics, in any part of the frequency spectrum, can be used as frequency markers for reference in making measurements.

Often a communications receiver is equipped with a crystal-controlled "marker" oscillator, whose harmonics are used to check the receiver's dial calibration. Such an oscillator is excellent for moderately accurate checks at 100-kc. intervals and can, like the frequency standard, be synchronized to WWV if equipped with a trimmer.

For example, if a measurement were to be made of some

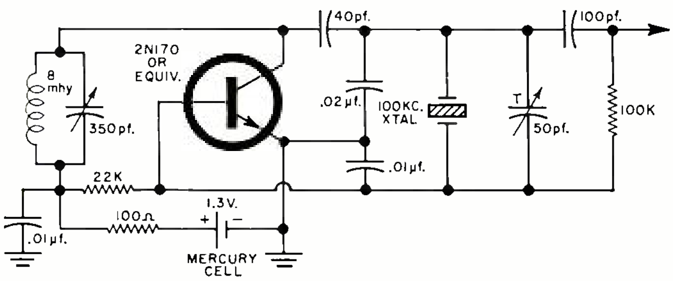
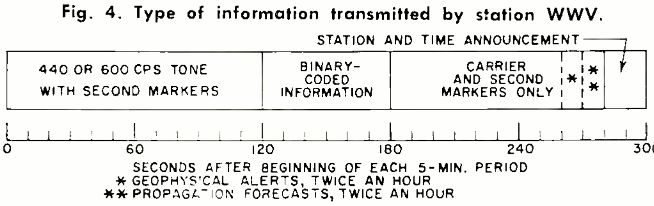


Fig. 3. Typical circuit of oscillator useful as a standard.

frequency near 20 mc., there would be frequency markers at 19.8, 19.9, 20.0, 20.1, 20.2, etc., mc. If the receiver has an accurately calibrated dial, these markers can be used as checks of receiver calibration so that rough readings of frequencies between can be made right from the receiver's dial. For a heterodyne frequency meter whose output is also fed into the receiver, the 100-kc. harmonics can provide accurate calibration references.

If the frequency to be measured falls close to one of the harmonics of the 100-kc. standard, it can be measured with great accuracy by measuring the audio frequency heterodyne between it and the harmonic. This is the process of interpolation and will be described in detail later. But if the frequency to be measured is spaced relatively far from either of the two adjacent harmonics, such precise measurement cannot be made. To provide the same accuracy at all frequencies, a *frequency divider* is added to the secondary frequency standard.

Fig. 4. Type of information transmitted by station WWV.



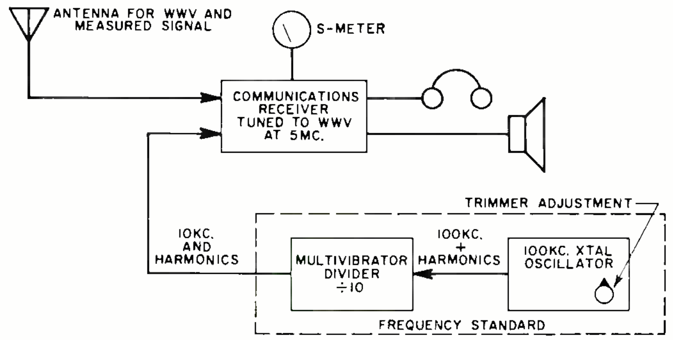


Fig. 5. System that employs frequency standard with divider.

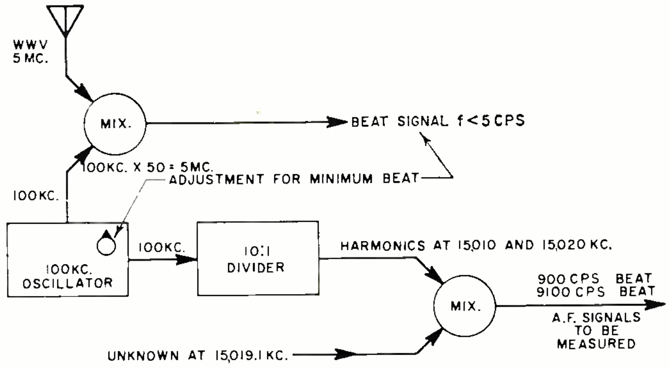


Fig. 6. Illustration of how signal at 15,019.1 is measured.

Frequency Divider

A properly designed multivibrator circuit can take an input signal with frequency f and put out a signal with a frequency which is some *submultiple* of f. In frequency standards, a multivibrator which divides by 10 is the most common. Fig. 5 shows how it is used to divide the 100-kc. frequency down to 10 kc. The 10-kc. signal, plus its harmonics, provides signals at 10-kc. intervals throughout the radio-frequency spectrum (usually as high as to 100 mc.). Because the multivibrator divider is locked to the 100-kc. oscillator frequency, the frequencies of all these harmonics are equally accurate.

Consider the example of Fig. 6. As in the previous discussion, the 100-kc. oscillator of the standard is adjusted to within 5 cps of WWV on 5 mc., or within $(5 \div 5 \times 10^6)\,100 = 0.0001\%$ or 1 part per million. A measurement is then to be made near 15 mc. (say, on a frequency of 15,019.1 kc.). Since 15 mc. is three times 5 mc., the adjustment tolerance, reflected in the 15-mc. signal is three times 5 cps, or 15 cps, which is still 0.0001% of the new 15-mc. frequency. This accuracy now applies to all the 10-kc. harmonics, including those in the vicinity of 15 mc.

A typical multivibrator divider circuit for dividing from 100 kc. to 10 kc. is shown in Fig. 7. Frequency dividing is also sometimes done by means of digital logic circuits, such as adders. These are used primarily where other associated circuits are of the digital type, but are usually not as practical as multivibrators in the majority of installations.

Interpolation

With a harmonic of precisely known frequency every 10 kc. through the spectrum, we have only 10 kc. between any pair to be covered. Thus *no unknown frequency to be measured can ever be more than 5 kc. away from one of these harmonics.* By heterodyning the measured signal against either the next higher or next lower 10-kc. harmonic, one can always come up with a beat signal in the audio frequency range. Assuming that we can identify the 10-kc. harmonic we are using, we can simply add or subtract the frequency of the beat signal, depending on whether the unknown is above or below the nearest 10-kc. harmonic.

Consider the case mentioned earlier, in which the frequency to be measured is 15,019.1 kc. Before measurement, of course, this frequency is not known. However, the measured signal is found with the receiver dial between the 10-kc. harmonics at 15,010 and 15,020 respectively. By tuning from the unknown signal toward the 15,020-kc. harmonic we hear a beat note of lower pitch than in the other direction, so we know that the unknown frequency is closer to 15,020 kc. than it is to 15,010. The receiver is then tuned to give the strongest and clearest output of this lower beat signal.

Next, the beat signal is in turn measured by comparing it with a calibrated source of audio-frequency signal until the two audio-frequency signals are themselves at zero beat. If the beat signal is measured as 900 cps, it means that the unknown is 900 cps, or 0.9 kc. below 15,020 kc. and this places it at 15,019.1 kc. If the a.f. source is even moderately accurate, at least one more decimal place can be obtained. For example, if the beat signal is measured as 955 cps, the radio frequency is 15,020 minus 0.955, or 15,019.045 kc. If we should tune the receiver toward the 15,010-kc. harmonic, we would hear a beat signal of 10 kc. minus 0.955 kc., or 9045 cps, which, being so much higher than the 955-cps beat, is not as easy to measure accurately.

The above process of determining the exact location of the unknown frequency in the spectrum space between known frequency-standard harmonics is called *interpolation*. The audio-frequency signal generator used to determine the beat frequency is referred to as an *interpolation oscillator*.

Interpolation Oscillators

An interpolation oscillator, in its simplest form, is a stable and accurately calibrated audio-frequency signal generator. Any a.f. signal generator is suitable providing its calibration is accurate and stable enough. When using the interpolation oscillator, the accuracy of the over-all radio-frequency measurement depends on the accuracy of the a.f. calibration and on how high a radio frequency is being measured. For example, if the measured radio frequency is 50 mc., an a.f. beat signal accuracy of 100 cps is only 0.0002% of the radio frequency. A relatively inexpensive a.f. oscillator can read frequencies to within 100 cps, especially if below 2000 cps. On

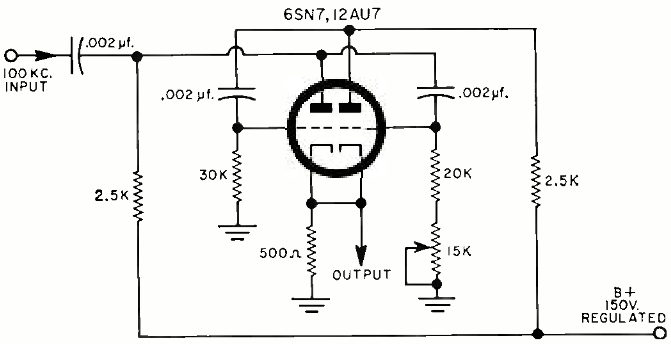
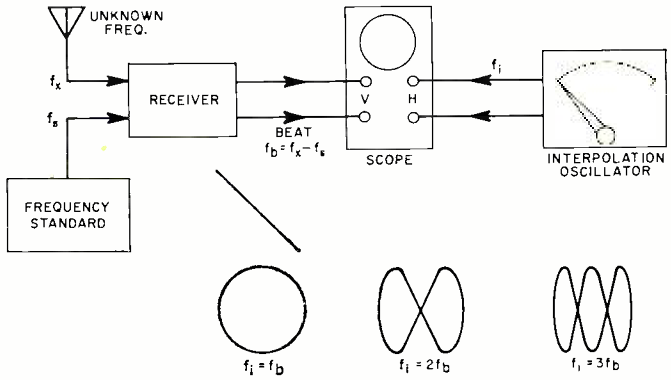


Fig. 7. Typical multivibrator for dividing from 100 kc. to 10 kc.

Fig. 8. Use of scope and Lissajous figures during interpolation.



NBS STANDARD TIME AND FREQUENCY BROADCASTS

Call Letters	Location	Carrier Freq.	Tone Mod.	Other Modulation
WWV	Beltsville, Md.	2.5, 5, 10, 15, 20 & 25 mc.	600 cps 440 cps	Second markers; Voice and code time announcements every 5 minutes; propagation forecasts; time-of-year binary codes
WWVH	Maui, Hawaii	5, 10, 15 mc.	600 cps 440 cps	Same as WWV
WWVB	Ft. Collins, Colo.	60 kc.	None	None
WWVL	Ft. Collins, Colo.	20 kc.	None	None

Table 1. Information about standard broadcasts by NBS stations.

the other hand, at a measured frequency near 1 mc., the interpolation oscillator must read accurately to 2 cps for the same relative r.f. accuracy.

Elaborate commercial interpolation oscillators are used in sophisticated frequency-measurement equipment. Accuracies are normally ±2 cps or better. The mixing circuit is usually self-contained. This is a circuit in which the a.f. beat between the unknown signal and the harmonic from the frequency standard can be mixed with the interpolation oscillator signal. As in the calibration of the r.f. standard against WWV, the beat signal is heard in earphones or loudspeaker or by indication on an output meter.

Another popular method of comparing the interpolation oscillator frequency with that of the a.f. beat from the measured signal is through use of an oscilloscope and Lissajous figures. This method is illustrated in Fig. 8. One advantage is that the interpolation oscillator does not need to be at zero beat, but can be set at some integral multiple or submultiple of the frequency that is being measured.

Use of 1-Mc. & Higher Markers

The procedure just outlined works well with just a 100-kc. reference oscillator and 10:1 divider at frequencies of approximately 5 mc. and below. But as the measured frequency gets higher, it gets more and more difficult to identify harmonics. The 100-kc. harmonics can be distinguished from the 10-kc. harmonics by use of a switch that allows the divider circuit in the standard to be shut off, leaving just the 100-kc. signals. However, at relatively high frequencies, the 100-kc. harmonics themselves bunch together so closely that, on most receiver dials, it is almost impossible to determine which one is which.

This problem is solved by adding to the frequency standard a 1-mc. crystal oscillator to help the operator, in effect, "get his bearings." With the 100-kc. oscillator turned off and the 1-mc. oscillator turned on, harmonics are found every 1 mc. throughout the frequency spectrum. The 1-mc. harmonic nearest to the measured frequency can be tuned in, then the 100-kc. oscillator turned on and the 100-kc. harmonics counted as the receiver is tuned away from the identified 1-mc. point. When the 100-kc. harmonic of interest has been identified, operation of the 10-kc. divider can be restored and 10-kc. harmonics counted, starting at the 100-kc. harmonic.

At frequencies above 20 mc., even the 1-mc. harmonics may not be sufficient to allow easy identification and some frequency standards also contain 5-mc. and/or 10-mc. oscillators. These oscillators do not have to be referenced exactly to WWV, because the final measurement is with reference to the 100-kc. oscillator and its divided 10-kc. harmonics.

All the components of a complete frequency standard and interpolation setup are included in the block diagram of Fig. 1. With reasonable care and skill on the part of the operator, such equipment will permit measurement to within 5 cps on frequencies between 1 mc. and 5 mc. All of the components required are of the type whose nature and use has been discussed in this article. ▲

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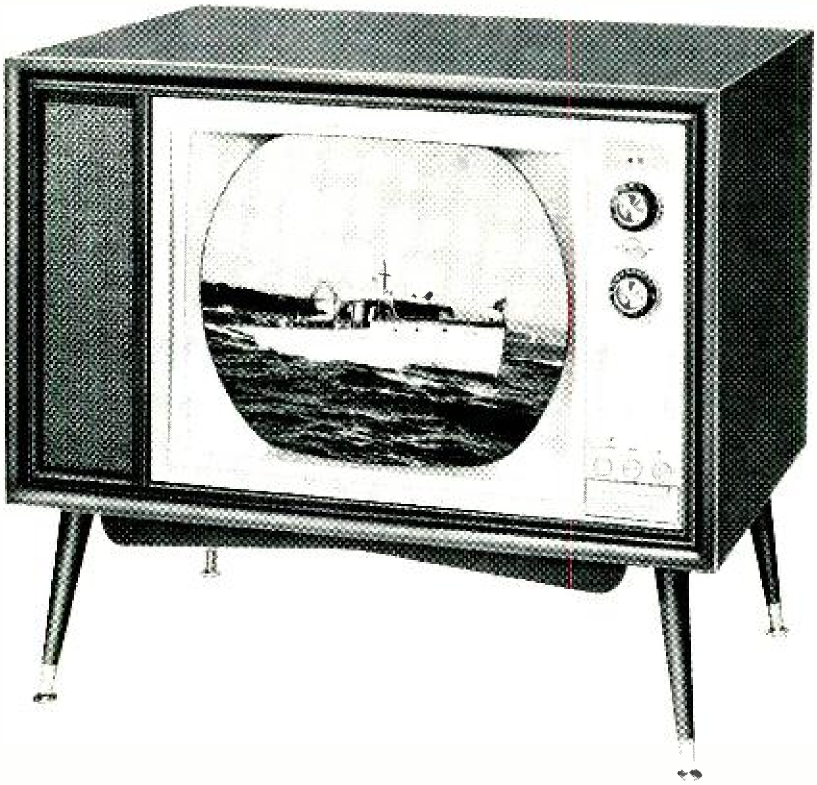

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Radio-TV Experimenter, June issue: "The repair cost savings during the Heath Color TV set's life compared to commercial units may be more than $200."

Popular Mechanics, February issue: "Mounted, prealigned critical circuits enable beginners to assemble. Picture quality is top-notch."

Science & Mechanics, April issue: "Built-in servicing circuits such as a dot generator are valuable aids in getting the set operating for the first time & eliminating expensive service calls & bills when realignment or part replacement is needed later on."

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CIRCLE NO. 115 ON READER SERVICE PAGE

JOHN FRYE

Noise suppression in mobile installations has become an urgent problem—what with FM, CB, and v.h.f. receivers.

IGNITION NOISE PROBLEMS

"YOU know, Mac," Barney said to his employer, "automobile noise suppression jobs are getting more numerous and tougher every day. I'm not talking about broadcast-band car radios. I'm talking about the FM receivers, the CB receivers, and the commercial v.h.f. receivers so common in cars today. Believe you me: there's a whale of a difference between 'de-noising' an ordinary car radio and keeping the noise out of one of these high-frequency jobs."

"I reckon we both know why," Mac answered. "Ignition noise usually peaks somewhere between 25 and 100 megacycles. On top of that, a broadcast receiver is ordinarily tuned to a nearby station radiating hundreds or thousands of watts from an antenna several hundred feet high. The CB receiver is trying to pull in a signal from a transmitter running a measly three watts into an antenna mounted, at best, on a rooftop.

"Incidentally, I dislike that term 'noise suppression.' It sounds as though all you need do is prevent popping sounds issuing from the speaker. Squelch or a.n.l. circuits will do that, especially if you're content to receive only strong stations. In fact, in an FM receiver with good limiters and a properly operating FM detector, you won't *hear* quite heavy ignition interference; yet that interference will be seriously degrading your reception by loading up the a.g.c circuit and reducing the receiver sensitivity. A good way to check on the presence of such interference is to use the diode probe of a signal tracer to pick off the signal at the grid of the first limiter.

"It's very important to keep basic concepts clearly in mind and to proceed in a methodical fashion in clearing interference. Remember any electrical spark is a miniature broadband interference transmitter. The higher the voltage producing the spark, the stronger is the interfering signal. Since ignition voltage is several hundred times greater than other voltages present in the car, that's why ignition interference should be suppressed first.

"Wires leading to sparking electrodes serve both as radiating antennas and linear tuned circuits peaking the interference. Resistance in these wires lowers the 'Q' of the tuned circuits they represent and damps out r.f. oscillations in them. The r.f. oscillations can be short-circuited to ground through a bypass capacitor of sufficiently low impedance at the interfering frequency where this does not interfere with the ignition spark. Lumped resistance inserted in the wire or bypass capacitors will be most effective when placed as near as possible to the interference-generating spark, for this effectively shortens the radiating portion of the lead."

"You mentioned interfering with the ignition spark. Some guys insist any kind of resistance noise suppression degrades engine performance. What do you think?"

"What I think doesn't matter, but tests conducted by automobile manufacturers have proved that where the ignition system is in good shape, the addition of approved resistor-type spark plugs, ignition cable, or suppressors does not affect engine performance. Of course, if the system performance is already marginal because of a weak coil, leaky capacitor, worn-out plugs, or some similar condition, the addition of suppression resistance may cause the engine to miss. In that case the answer is to correct the ignition defect, not take off the suppressors."

"Am I right in thinking the fundamental steps in preventing ignition interference are: (1) attenuate the pulses of interference greatly through the use of resistor suppression and bypassing; (2) bottle up the remaining interference inside the engine compartment by judicious bonding, shielding, and bypassing of all routes by which it can leak or be conducted outside; and (3) make sure the only way any signal—including ignition interference—can reach the receiver is by way of the antenna itself?"

"You've got the big picture! The first thing to do when starting on a job is determine how many of these measures have already been taken. Is the engine equipped with resistor-type spark plugs? *Champion* precedes the plug number with an 'X.' *Autolite* and *A.C.* resistor plugs have an 'R' in the plug number. Is resistance ignition cable used? If so, what kind? *General Motors* resistance cable is plainly marked '*GM* Radio TVRS.' It has a resistance of about 4000 ohms per foot. Other kinds will be marked 'HTLR' (3000 to 7000 ohms per foot) and 'HTHR' (6000 to 12,000 ohms per foot). This cable will not stand rough handling and should never be cut to install a screw-on suppressor or to attach a new end terminal. When resistance value exceeds 18,000 ohms per foot, the cable should be replaced."

"How about combining resistor plugs, resistance cable, and lumped-resistance suppressors? If one is good, three ought to be dandy."

"That's like taking a whole bottle of aspirin to cure a headache! Actually, resistor plugs are often used in conjunction with resistance cable *or* suppressors in two-way radio installations. The Law of Diminishing Returns prevents the improvement of adding external resistance to resistance plugs from being breath-taking, but it is usually noticeable. Increasing resistance, though, makes it tougher for the ignition system to produce the proper spark.

"A good ignition system in top shape may put out as much as 30,000 volts across an open circuit. In operation, this voltage is lowered to the amount actually needed to jump a spark across the plug electrodes. This required voltage goes up under heavy acceleration, and it also goes up if the plug is dirty or too widely gapped. With a single type of suppression installed, there is enough reserve to take care of ordinary variations, but adding resistance to the high-tension system cuts down on this reserve. The kind of driving also determines how much suppression an ignition system can stand. Stop-start, long-idle driving will sometimes foul plugs in an overly suppressed installation. If you're worried about the car's performance, it's a good idea to have the car checked with an electronic ignition analyzer, such as the *Heath* job or the *Champion* 'Plug-Scope,' after the suppression is in place."

"To avoid over-suppressing, a guy has to be on guard against hidden built-in suppressors," Barney offered. "Some older cars and trucks have 15,000-ohm suppressors built into the distributor rotor arm or concealed in the cap.

"Right, and in concentrating on the high-tension circuits, you must not overlook the importance of proper bypassing of the coil primary. Ignition pulses from the secondary can 'kick back' through the primary and spread out over the whole low-voltage system. A .1-μf. coaxial bypass capacitor should have its center lead inserted in the lead coming from the BAT connection of the coil as close to that connection as possible. An ordinary capacitor here will not work at v.h.f. and u.h.f. frequencies. It has too much inductance. Only a coaxial capacitor presents sufficiently low impedance to the high-frequency r.f. to do an adequate job of bypassing. Both the capacitor case and the coil case should have an excellent, paint-free electrical connection to the firewall or block."

"How about bonding?"

"That's what confines the residual ignition interference to the motor compartment. Heavy duty *Belden* 8662 bonding braid should be used to bond all four corners of the motor, the steering column, the firewall, the exhaust pipe, and the tail pipe to the frame. Lighter *Belden* 8668 can be used to bond metallic tubes and rods to the firewall at the point where they pass through this wall. Tooth-type washers that will bite through the paint should be used to secure the ends of the bonding braid. In some cases, it may be found necessary to bond both sides of the hood and the trunk lid."

"How can we be sure any signal reaching the receiver comes only by way of the antenna. I don't quite dig that."

"It's mostly a matter of proper installation. The case of the receiver must make a good connection to the car frame or body. The antenna lead shield must have good ground connections at both the receiver end and the antenna end. A body- or fender-mounted antenna can be mechanically solid and yet have a few ohms of resistance between the grounding lug and the body because of paint or undercoating. In the case of a bumper-mounted antenna, the bumper itself may have to be bonded to the frame. A shielded lead should bring power directly from the battery to the receiver—ideally by way of a feedthrough coaxial capacitor through the firewall. It's a good idea to install a .5-μf. capacitor between the hot battery connection and ground at the receiver if one is not already present. When the receiver is not picking up any signal through the battery lead or through a poorly grounded case or antenna lead, disconnecting the antenna will reduce the ignition noise to zero."

"That about takes care of the three main steps I mentioned. What if you still have some ignition noise?"

"You probably will be able to hear a little, especially after you have cleaned up voltage-regulator, generator, instrument, and other kinds of masking noise and when you are not tuned to a station. But it will disappear when even a weak station is tuned in. If you want to get the ultimate in noise suppression and are willing to pay for it, you must go to complete shielding of the ignition system as the aircraft and military people do. That means completely shielding the coil, the distributor, all high-tension wiring, and the spark plugs themselves. The shielding must be as complete and free of r.f. leaks as that used in keeping a transmitter from causing TVI."

"Can't you buy this sort of shielding and install it yourself?"

"Yes, the *Hallett Mfg. Co.* in Los Angeles manufactures two lines of shielding. The 'Signal-Saver' line provides complete customized shielding for practically any motor. In ordering, you give the make, model, and year of the car, plus the displacement of the engine: and the shielding sent you is tailored to fit your particular motor.

"The same company manufactures the 'Eliminoise' universal noise suppression kit which is marketed through the *E. F. Johnson Company*. With this kit, which sells for considerably less than the customized line, you have to do more fitting and trying; but step-by-step instructions are sent to help you."

"You've been reeling off facts and figures pretty recklessly," Barney observed shrewdly. "I somehow get the feeling you didn't learn all this on your own."

"Never said I did," Mac defended himself. "I learned long ago to supplement my own experience and observation with expert help whenever possible; so I've written spark-plug companies, capacitor manufacturers, automobile makers, ignition-component manufacturers, and shielding manufacturers for any facts they had turned up in their research. All were most helpful. *Champion Spark Plug* puts out a free booklet entitled 'Giving Two-way Radio Its Voice' that is full of helpful tips. Both *Cornell-Dubilier* and *Sprague* have special catalogue sheets describing their capacitors specifically designed for noise suppression. *Delco-Radio* has good material on the subject, and *Hallett Mfg. Co.* has promotional material and installation manuals that show you just how their shielding is installed. Well, we better get to work, but what say we continue the discussion by talking about stopping noise from non-ignition sources in the near future?"

"Fine with me," Barney said; "but before we leave ignition noise, I've got a question: do you think transistorized ignition systems are going to give more noise trouble than conventional systems?"

"While I could get no auto manufacturer to stick his neck out on this subject, I got the impression they are anticipating no special problems with the transistorized systems they expect to use." ▲

Hi-Fi Measurements

(Continued from page 35)

we think it pleasant or unpleasant. We only consider whether it is similar to the original. The basic technique, instead of an *A-B* technique, is an *A-B-C* technique, where *C* is the live sound.

The standard *A-B* technique is like like comparing the reproduction of a painting to another reproduction instead of to the painting itself. It is better than nothing, particularly if you know the original painting, but an *A-B* choice lacks the control which will pin the matter down to that of reproducing accuracy.

Let us assume that we make a design variation in a speaker. We will designate the standard speaker as *A*, *B* the speaker with the design variation, and *C* the live reference. Then we switch *C-A*, *C-B*. It's surprising how little listening time is required before we know whether the standard speaker *A* sounds more like the live *C*, in which case the design variation has failed, or the new design *B* sounds more like *C*, in which case we know that we're going in the right direction.

The very subjectivity of the test reading eliminates those elements which are not significant to aural perception. The test is conducted in a normally reverberant room, so we respond to the complete frequency response of the speaker. We use the technique both as a direct design and testing tool and as a validation technique. When the primary purpose of testing is to rank a group of reproducing devices in their order of excellence, the live *vs* recorded display is useful for direct evaluation. When information about a single device is to be communicated, or where diagnostic information is required, the live *vs* recorded display serves as a validation of other test techniques rather than a test technique itself. After making these tests with both random noise and music, we find that the noise is an accurate stand-in for musical sound.

It should now be clear that the choice sometimes presented in methods of equipment evaluation—listening *vs* objective testing—is a false one. Objective measuring techniques are useless unless they have been validated by subjective means, that is, by listening. Such listening must ultimately make a comparison with the original live sound, and a live *vs* recorded display provides the basic validating technique. Any meaningful listening to recorded material, of course, at least makes reference to a memory of the live sound, but this memory is necessarily imperfect.

Once a test has been validated as an index of performance, it can reveal information that might take many hours or even days of uncontrolled listening to discover. ▲

Electrical Measure

(*Continued from page* 32)

triangle with its apex (the region of best accuracy) in the intermediate range of values (Fig. 6).

Accuracy of Measurement

For resistance and voltage measurements, where a national reference standard is maintained, the apex of the "accuracy triangle" coincides with the value at which the standard is maintained. That this must be so is apparent when one considers that at this value one-to-one comparison or substitution methods are available for measurement, with only small differences involved. As one departs from the reference value, measurement techniques grow more involved and complicated; and the additional sources of error are present. For example, the accuracy with which a ratio can be established may need to be considered as part of the problem. Thus, whereas 1-ohm standards can be compared to 1-2 parts in 10^7, when we reach 10^{-3} ohm on one side of our accuracy triangle and 10^6 ohms on the other side, state-of-art accuracy has fallen off to perhaps 4-5 ppm, somewhat more than a factor of 10.

Using potentiometers and appropriate voltage-divider techniques, direct voltages can be measured within 10 ppm between 10^{-2} and 10^3 volts, and standard cells (at the 1-volt level) can be compared within 1-2 parts in 10^7. Direct currents can be established at the 1-ampere level within a few parts in 10^7, and within 10 ppm for lower values down to perhaps 10^{-1} ampere. In the higher current range (above 1 ampere) where measurement is complicated by the heating effect of power that must be dissipated in the measuring equipment, measurement accuracy is somewhat less --perhaps a few parts in 10^5 up to 10^3 amperes.

In transferring from direct to alternating voltage, an additional uncertainty is involved, amounting to perhaps 10 ppm in state-of-art voltage transfers up to 20 kc. between 1 to 500 volts. In current transfer over the same frequency span, the state-of-art transfer uncertainty is about the same, 10 ppm, in the 5-10 milliampere range where no shunts are required. The use of shunts or other circuit elements designed to carry currents of higher magnitude, involve further uncertainties because of their inductance. The total transfer uncertainty, up to about 20 amperes, need not amount to more than 0.01%.

In this article, we have described and examined our National Standards of electrical measure. We have covered their derivation and maintenance, as well as assessed the present state of the art regarding measurement accuracy. ▲

H.F. Measurements

(*Continued from page 43*)

to Fig. 7, capacitance may be measured.

The curve of Fig. 8 may help clarify the explanation. Using the center peak at 0 and the peaks as shown to plus 10 or minus 10 (depending on what you are going to measure), when the load is connected to point X of Fig. 1A, count the number of divisions that the scope trace, or center peak has moved. The directions shown in Fig 8 are those for the author's scope and generator. For other scopes and generators, the reverse directions may be the ones to use. This can be determined by noting the direction for the coil and brass plug as described under inductance measurements.

"Q" Measurement

Since resistance, capacitance, and inductance can be measured, "Q" can also be measured. There are, however, several problems encountered when this is attempted. By connecting a small capacitor at point X of the test setup, the curve on the scope screen shifts left or right. Paralleling this capacitor with several resistors will cause the curve amplitude to change. However, as 70 ohms is approached, the ripple reduces and disappears. The second problem occurs when we continue to lower the resistance value placed across the capacitor. In this case, the amplitude of the ripple increases in value. Thus, for each ripple shift and amplitude measured, there are two possible values of "Q." The first problem cannot be skirted and must therefore be lived with. The second problem disappears when the "Q" values represented by these measurements are found. The highest "Q" that any measurement here could represent is a "Q" of 2, and the lowest "Q" is about 0.03. This refers of course to those "Q" values represented by the parallel resistors below 70 ohms.

These values are so low that you may encounter some confusion if you are measuring coils made with resistance wire or coils wound on low-value resistors, but such low values should not present any difficulty in normal measurements. Similarly, low values of "Q" for a capacitor would occur only if high-value resistors are in series with, or low values in parallel with, the capacitor. The ordinary coil or capacitor that may be encountered does not fall into this range. For this reason, the "Q" chart shown in Fig. 9 appears adequate considering the measurement range available. One check that can be made is to parallel any unknown "Q" at point X with a short-lead composition resistor of about 200 ohms. If the ripple size decreases, you can be sure that Fig. 9 applies to the unknown; if the ripple size increases in amplitude, the unknown has a "Q" of some value less than 2.

For v.s.w.r., resistance, and "Q," the charts are correct for any applied frequency, while for capacitance and inductance, the charts are for 55 mc. or TV channel 2 only. Other capacitance and inductance ranges could be used by converting these to their reactance at 55 mc. and charting the amplitude obtained. This new chart would then show reactance *versus* amplitude and could be used at any frequency. The drawback to this method is that a reactance frequency chart would then be required to convert these values back to capacitance or inductance values.

Variations of this method of using conventional TV test equipment to determine the characteristics of circuits and components at v.h.f. (TV) frequencies are used by many companies producing TV equipment as well as by many service companies that are responsible for the proper operation of community antenna systems. ▲

Floating Trackers

(*Continued from page 19*)

measuring position accurately with reference to surveyed sonar beacons.

2. The communications system will receive post-burnout signals from Cape Kennedy.

3. The computer will integrate the equations of motion of the missile faster than real time to determine an acquisition point prior to the missile's arrival. Using measured values of latitude and longitude from SINS, a continually corrected stable acquisition point, relative to the ship, is acquired.

4. SINS will supply heading, pitch, and roll through the Central Data Conversion and Control Equipment (CDCE) to the computer, which combines these with the acquisition point. The result is a digital acquisition orders.

5. CDCE converts these orders to synchro voltages for aiming the antennas to the proper position.

6. The tracker which first acquires the missile is designated the master.

7. The other antennas are slaved through CDCE with corrections for ship's flexures.

8. When the C-band radar acquires the missile, CDCE converts the trajectory and signal strength to digital form and records on magnetic tape.

9. The missile path is plotted from the acquisition point to impact.

10. After impact, recorded data is transmitted to waiting aircraft *via* telemetry and balloon snatch.

The prime mission of ARIS is accurate tracking and data gathering of re-entry vehicles. However, these ships also will participate in future projects like Dyna-Soar, Gemini, Apollo, and other space ships to follow. ▲

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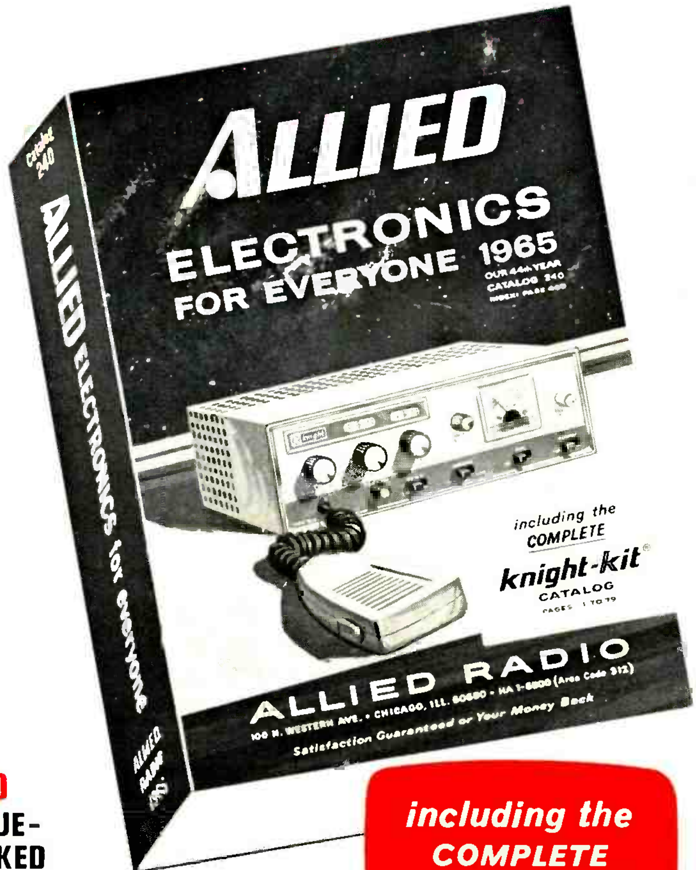

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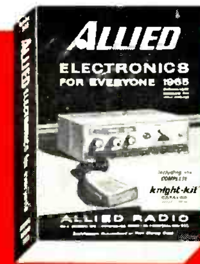

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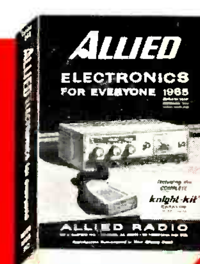

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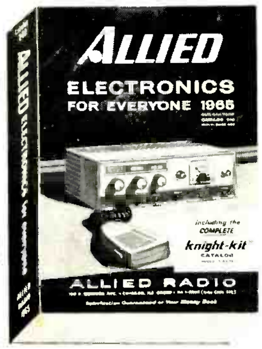

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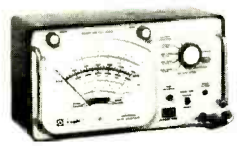

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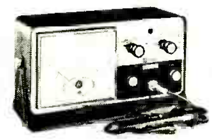

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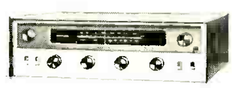

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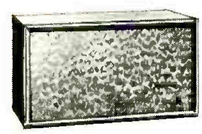

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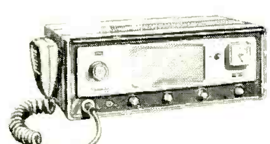

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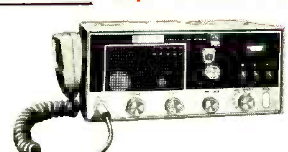

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Data Flow in Computers

(*Continued from page 37*)

the instruction word to transfer into the memory address register. The data word at this address will therefore transfer into the adder.

Data Flow

Fig. 4 shows a generalized block diagram illustrating data flow in a computer. Assuming that the address of the first instruction word has previously been placed in the *program counter*, the following events occur.

1. The address in the program counter transfers into the memory address register.
2. The instruction word at this address transfers from memory into the instruction register.
3. The address part of the instruction word transfers from the instruction register to the memory address register.
4. The data word from this address transfers to the arithmetic unit (or other destination according to the operation code).
5. The operation decoder, responding to the operation part of the instruction word, controls the pulse distribution circuits so that the called-for operation will be performed.
6. The pulse distribution circuits supply an input to the program counter, increasing its count by one. Since the instruction words are in sequential addresses in memory, the program counter now contains the address of the next instruction to be executed. The above steps are repeated over and over until all of the instructions have been performed.

Not only can the computer perform a series of instructions in sequence, it can be programmed to modify this sequence. One type of instruction that causes the computer to abandon the normal sequence is the *branch* or *jump* instruction. This causes the computer to skip to a specified instruction instead of taking the next instruction in the normal sequence. Jump instructions are often made conditional, that is, the jump occurs only if a certain condition exists. A typical instruction of this type causes the computer to "jump" if the number in the arithmetic unit is negative.

Another technique commonly employed by programmers is to include an instruction which directs the computer to return to a previous instruction. This puts the machine into a *loop* of instructions which it repeats over and over. A counter circuit keeps track of the number of times the loop has been repeated and allows the machine to escape from the loop after a predetermined number of repetitions. Such loops can considerably reduce the total number of instructions employed in the program. ▲

NEW LOOK IN MICROWAVES

By LEO G. SANDS

There have been many changes in microwave communication systems the past few years. Besides moving to all solid-state devices, heterodyne techniques are coming to the fore.

MICROWAVE communications equipment is taking on a new look. Conventional vacuum tubes are now being replaced by transistors, klystrons are on the verge of being superseded by solid-state microwave power sources, storage batteries are replacing engine-driven standby power plants, channel capacity has risen to 600 (up from 24 a decade ago), and the trend is away from passive reflectors to directly fed antennas, and to higher operating frequencies. In the past, microwave systems were purchased principally for oral communications purposes. Today, the need for data, TV, and high-speed facsimile transmission is the prime justification for investing in a microwave system.

The cost of installing a microwave system has not gone down, but has in fact gone up, because users are demanding more sophisticated equipment. However, some manufacturers are considering production of lower-cost equipment for short-haul, lower-density systems.

While there is vigorous competition among microwave equipment manufacturers, they are now jointly competing even more vigorously with the telephone and telegraph companies. The telephone companies now offer Telpak service which, in some cases, costs less to use than to own and operate a private microwave system.

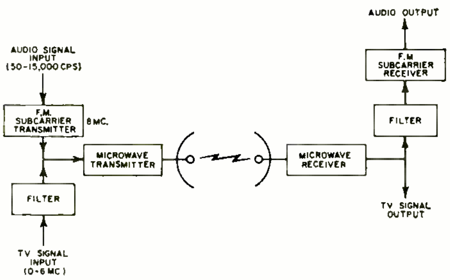


Fig. 1. TV microwave link has audio signal on a subcarrier located above video signal.

Under Telpak rates, a 12-voice channel facility can be leased for $15 per mile per month, 24 channels for $20, 60 channels for $25, and 240 channels for $45 per month. But, the customer must also pay $5 per month for terminating each end of a channel, whether used for voice, Teletype or slow-speed data, except for the first channel of a group for which the charge is $15 per end. In all cases, the taxes involved and the installation costs are additional.

It is rates like these that have made some prospective microwave users hesitate, and cause equipment manufacturers to offer systems of higher capacity and greater reliability which also cost less to operate than former systems.

Solid-State Equipment

Transistorized microwave equipment, now on the market, uses no tubes. In some so-called hybrid equipment, operable in the 6000-mc. band, a klystron is required and, in most cases, a klystron is still used as the receiver local oscillator. However, the local oscillator klystron is being replaced by a solid-state signal source consisting of a crystal-controlled transistor oscillator and varactor diodes for multiplying the frequency to the 6-gc. region.

Fully solid-state microwave equipment is available at the present time. Claimed power output of these systems is 100 milliwatts in the 6-gc. band. Transmitters for the same band, using klystrons, have been available for several years in 100-milliwatt and 1-watt output types.

Solid-state klystrons are coming out of the laboratory and recently *Fairchild* introduced its version. But they are not yet used in any commercial microwave communications equipment.

Power Sources

Until recently, nearly all microwave equipment was designed for operation from a.c. power lines. Today, most manufacturers offer equipment which is operable from storage batteries floated across a battery charger. When batteries are used, there is less need for permanently installed, engine-driven, standby power generators. Since the batteries are usually capable of several hours' operation after power line failure, there is usually sufficient time to bring in a portable generator to take over the battery replenishing job.

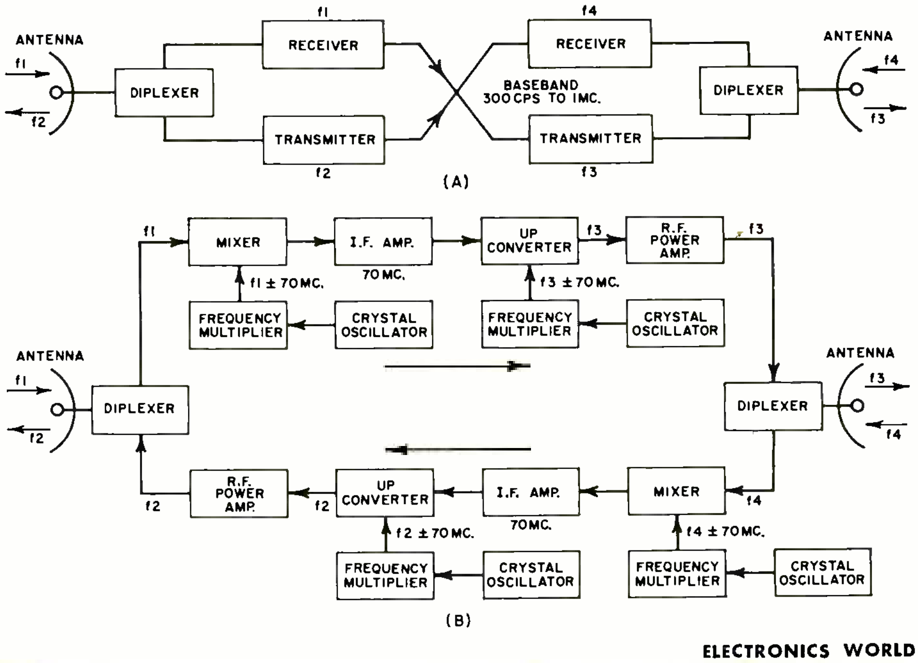
Increased Capacity

When the microwave era began a dozen years ago, 24 voice channels was deemed adequate for private systems. Channel capacity was later upped to 60, then 120, doubled to 240, and now stands at 600. While most users do not envision ever requiring 600 voice channels, they do expect to need reserve bandspace both for high-speed facsimile which requires 250 kc. of the available 3-mc. baseband of a 600-channel system, or 1-mc. baseband of a 240 channel system, or for high-speed data service.

The latest multiplex equipment is capable of expansion to 600 voice channels in increments of 3, 12, and 60 channels. Several manufacturers offer this type of equipment using solid-state, plug-in circuitry resulting in less heat generation and smaller space requirements.

Telegraphy, slow-speed data, tele-

Fig. 2. The old look (A) used back-to-back repeaters where the signal was demodulated and remodulated. (B) The new look uses a heterodyne technique where the FM signal is passed through a system similar to a double-conversion superhet.



metering and control signals are transmitted as pulsed tones and as many as 18 tone channels, each operating at an audio frequency below 3400 cps, can be transmitted over a single voice channel. Each tone channel is usually rated as being capable of handling 75 bits per second. A tone channel consists of an FSK (frequency-shift keyed) or AM ("on-off" keyed) audio oscillator, and a companion receiver at the far end of the circuit.

Microwave equipment now on the market can be used for transmitting TV or up to 600 voice channels, or a combination of audio, video, and data. One of the newer types can accommodate modulating signals from d.c. to 10 mc.

When TV is transmitted, audio program channels or voice carrier channels are operated at frequencies above 6 mc. so that the video signal occupies the lower portion of the baseband. Such a system is illustrated in Fig. 1.

Other Improvements

Some repeater stations, such as shown in Fig. 2A, consist of two transmitter-receiver terminals connected back-to-back. In this system, the FM signal is demodulated upon reception, and used to modulate the companion FM transmitter.

Lately, there has been a growing demand for the heterodyne-type of repeater, where the FM signal is not demodulated at each repeater. As shown in Fig. 2B, the incoming frequency $f1$ is passed to a mixer where it is combined with a crystal-controlled local oscillator to form a 70 mc. i.f. This signal is passed to another mixer where it is combined with another crystal-controlled local oscillator. In this case, the higher beat frequency is chosen ($f3$), amplified and transmitted as the relayed signal. The other channel works the same way. Diplexers in each antenna system keep each of the different r.f. frequencies from entering the wrong channel.

The heterodyne principle is also being used in microwave terminals as shown in Fig. 3. Here, the input signal is amplified and used to modulate a 70-mc. FM transmitter. The output from the transmitter is then mixed with a crystal-controlled local oscillator and the 6-gc. beat is picked out (up-conversion), amplified, and used as the output signal (6825 mc.). Incoming signals pass through a conventional high-quality superheterodyne receiver having a broad bandwidth.

Another improvement in microwave system receivers is the use of phase-lock detectors, parametric amplifiers and tunnel diodes to improve effective signal-to-noise ratio.

Most prospective users of low-cost microwave systems, those who are eligible for licenses only in the Business Radio Service, must operate at frequencies above 10,000 mc. Equipment is now available for the 12,000-mc. Business Radio band that costs about the same as 6000-mc. band equipment.

It is expected that low-cost 12,000-mc. band equipment will be available that will make short-haul private microwave systems more competitive with leased-circuit facilities. This new equipment will probably use vacuum tubes to keep cost within reason.

Antennas and Radiation

Most 6000-mc.-band microwave stations use passive reflectors at the top of a tower to reflect the signal from vertically oriented antennas at the base of the tower. This use of reflectors eliminates the need for long waveguide runs. However, when antennas are aimed skyward, it is possible that in the future, interference to, or from, space communications systems might result. Antenna systems for the 6000-mc. band, using special coaxial cable and permitting top-of-tower mounting of antennas, have been introduced. Microwave systems operating in the 960- and 2000-mc. bands ordinarily use top-of-tower mounted antennas fed through conventional coaxial cable.

Longer distances can be spanned by *scatter* systems (see Fig. 4) but their use within the United States is not permitted because of their capability of interfering with other stations over a wide area. However, there are no restrictions against the use of *trans-horizon* transmission as long as all pertinent FCC requirements are otherwise met.

To get microwave signals over mountain tops without installation of hard-to-get-at repeater stations, large passive *billboard* reflectors are sometimes used. A pair of parabolic antennas, connected back-to-back, can also be used as a passive repeater.

Propagation tests conducted in California revealed that *trans-horizon* transmission is superior to the use of a back-to-back parabolic repeater in an over-mountain test link about 50 miles long. As a result of these tests, more *trans-horizon* links are expected to be installed for the longer hops.

While telephone and telegraph companies can employ *frequency diversity* to ensure more reliable communications, other private microwave system users cannot. They are permitted to use *space diversity* which requires installation of a second antenna system above the primary antenna. To add 50 feet of height to a tower, it must be done at the bottom end to obtain the required strength—and this costs money.

When a hop is relatively long or crosses water, and the use of diversity would ensure greater reliability, there is a new wrinkle. Frequency-diversity operation, achieved by operating a 6000-mc.-band and a 12,000-mc.-band system in parallel, is permitted, according to an FCC official. New antennas have been developed which can be uti-

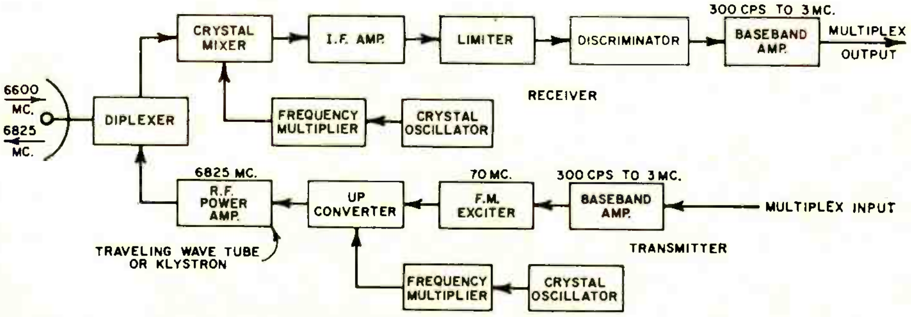
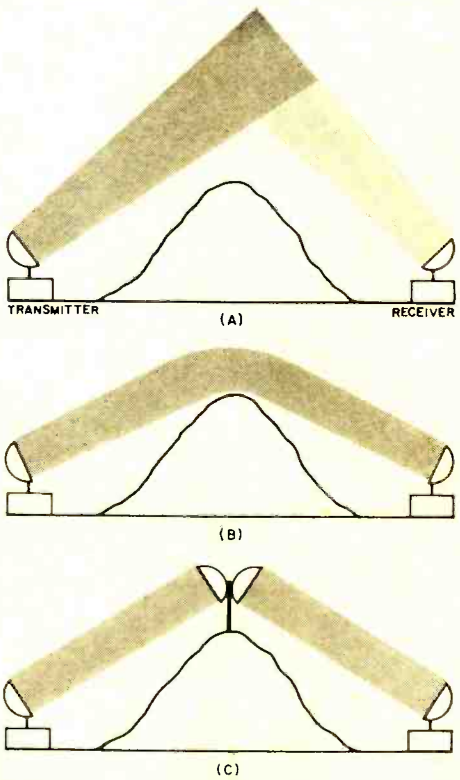


Fig. 3. In a microwave terminal setup, the input signal modulates an FM transmitter whose signal beats with a local oscillator in the up converter. The 6-gc. beat is amplified as the output. The receiver is a high-quality, broadband type.

Fig. 4. Three techniques for transmitting over mountains. (A) Shows the scatter method, (B) the trans-horizon (knife-edge) system, and (C) a line-of-sight system that uses a pair of parabolic reflectors.



lized on both the bands simultaneously.

In a frequency-diversity system, the transmitters and receivers operate simultaneously. The receivers are linked to a diversity combiner that selects the output of the receiver producing the highest usable signal level.

ETV and Other Markets

One of the big new markets for microwave is in ETV (educational television). A recent survey indicates that about 82% of colleges responding to queries expect to have a requirement for transmission of closed-circuit TV between on-campus buildings and off-campus points, some at considerable distances.

Under recently proposed FCC rule changes, educational television (ETV) microwave systems not only can be operated at frequencies above 10,000 mc., but also in portions of the 2000-mc. microwave band.

Another new market for microwave equipment is in the remote control and data gathering field. The FCC recently permitted use of omni-directional transmission on specified frequencies in the 952-960 mc. band. It is now possible to use an omnidirectional base station for one-way or two-way transmission of coded signals to street corner traffic signal controllers. Another application for omnidirectional microwave is transmission of burglar alarm signals to a central point.

Citizens Band

The FCC is considering opening up new microwave bands for Citizens Radio type operation at frequencies above 16,000 mc. While most citizens will not be able to afford a microwave system, there will be a growing need for frequency space for short-haul microwave systems. Since present microwave bands are already congested, the only direction in which expansion is possible is higher in frequency. ▲

"My wife's away and I found I couldn't stand the silence."

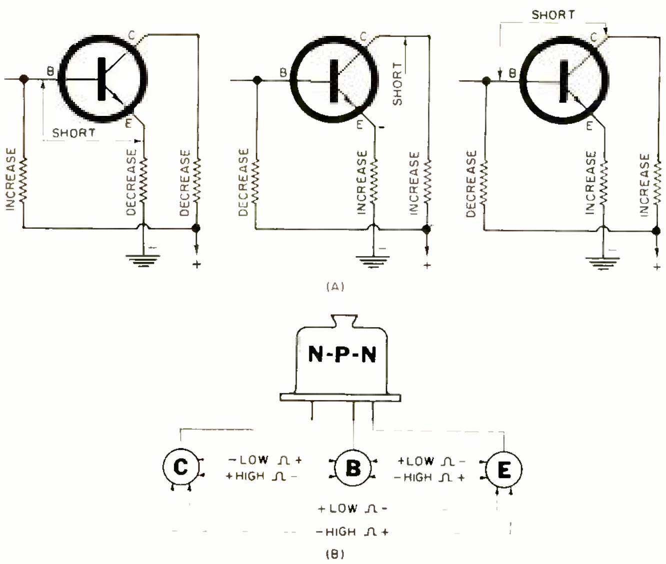


Fig. 1. (A) shows how voltage at transistor terminals varies with different elements shorted. (B) shows approximate values of resistance measured between various transistor elements.

SIMPLE TRANSISTOR TESTS

By GLEN McKINNEY

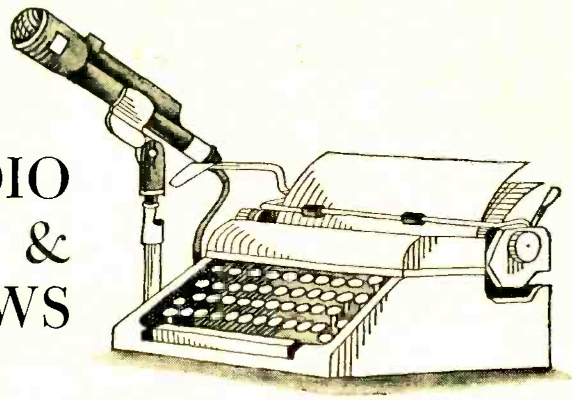
SINCE operation of a transistor depends largely on the current flowing through its associated resistors, they can be used as convenient test points for determining the transistor's condition.

Fig. 1A shows the probable change in voltage across these resistors when the transistor shorts in any of the three possible ways. This information is useful in locating a shorted transistor as the circuit resistors will indicate either an increase or decrease in voltage drop depending on which two electrodes of the transistor have become shorted. When there is an abnormal drop, either high or low, across these resistors (and the resistors test good), chances are that the transistor is defective. A little experience in this voltage measuring technique will yield fruitful results in pin-pointing "leaky" or shorted units.

Fig. 1B is helpful for checking and comparing transistors that are out of the circuit. This shows the approximate resistance to expect when measuring between the different electrodes, for both forward and reverse directions.

There should be a large difference between the resistance measured as the ohmmeter leads are reversed if the transistor is good. In one direction, the resistance will be very low. In the other direction, it should read fairly high (200,000 ohms or so). The exact resistance measured will vary for different types of transistors, but there will always be a high-to-low resistance ratio when the ohmmeter leads are reversed. This method of checking works with either *n-p-n* or *p-n-p* transistors, however, the polarities shown will be reversed for the high-low readings with the *p-n-p* type. A word of caution is in order here as to the ohmmeter range to use when making these resistance measurements. The lower scales of some ohmmeters can supply damaging currents to the transistor under test, while the higher scales can supply damaging potentials. As a precautionary measure, it is best to start out on the highest, safe range (depending on the ohmmeter) then change to the scale that gives an adequate reading. ▲

RADIO & TV NEWS



WE normally think of a color TV transmission as a conventional monochrome signal with the chromatic portion interwoven within it. There are many ways to transmit color. In this country we use the NTSC system, but there is also the German PAL, the French SECAM, and the Mexican SBS systems. All of these systems have one thing in common—they are analog methods in that the transmitted signal continuously varies in amplitude or phase to the desired levels within the modulation capabilities of the transmitter being used.

A new approach to color TV transmission was recently unveiled by *RCA* in their secure color TV system that uses digital signals, similar to those used in computer techniques. This *RCA* system first converts the analog color TV signal to digital form through the use of sampling analog-to-digital converters. The digital signals can then be coded or "scrambled" if desired to insure security of the transmitted image. At the receiver, the signals are decoded and passed through a digital-to-analog conversion system where they are reconverted to analog form to produce the original color image. This is viewed on a conventional color monitor. One of the byproducts of this method of color transmission is the lack of amplitude or phase distortion that can contribute heavily to degradation of a color image.

While on the subject of color TV, recently there was a meeting of more than 100 delegates from 20 European countries in London, England who spent considerable time discussing the relative merits of the three available color systems. (These are NTSC, PAL, and SECAM.)

They were trying to establish a color system for use throughout Europe including Britain. No decision was reached and another meeting was scheduled for next year in Vienna.

The delegates at this meeting represented the sub-group on color TV of the International Radio Consultive Committee (CCIR), a part of the International Telecommunications Union, an agency of the United Nations.

Meanwhile, back in England, the view is that since it is difficult for the Europeans to agree on a color standard, the British Government should unilaterally adopt the American NTSC system.

This view was discounted by the BBC although a BBC spokesman stated that by using NTSC, they (Britain) could start limited color programs on 625-line u.h.f. in 1965. Adoption of any other color system would mean a later start for color TV in England.

Flying TV

NASA engineers over at Langley Research Center are experimenting with the use of a closed-circuit TV camera mounted on the wing of an aircraft with the monitor in front of the pilot as a new approach to aircraft landing techniques.

Looking forward to the day when very high performance aircraft may have restricted forward vision, the closed-circuit TV approach has already made 45 successful landings with the pilot entirely dependent on the TV for vision.

The wing-mounted camera not only provided adequate forward view during landing but also enabled pilots to take-off without any trouble.

Automatic Degaussing

Some of the 1964 *RCA* color TV sets include a built-in degaussing coil permanently mounted near the CRT shadow mask and connected to the power supply.

When the set is first turned on, the rush of a.c. current flowing through the coil demagnetizes the shadow mask. As the set warms up, the current flow diminishes, thus reducing the magnetic field around the coil. This produces the same effect as keeping the coil energized and moving it away from the CRT before turning off the current.

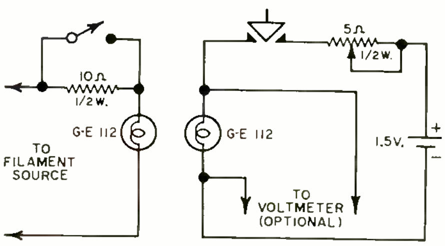
This automatic degaussing action every time the set is turned on will reduce degradation of the color (or contamination of the monochrome image) due to accidental application of a magnetic field, such as that produced by an appliance being turned off near the set, or by a magnet such as that found in many toys being brought near the set, or by slight re-positioning of the color set such as may occur during normal household cleaning. ▲

MEASURING FILAMENT VOLTAGE

ONE of the major problems associated with certain types of high-voltage rectifiers is that sometimes it is difficult to tell when the filament is lit, and if it is, then we have to guess at the filament voltage.

A recent issue of *G-E* "Techni-Talk" shows a simple way to measure this voltage using the circuit shown. It consists of matching the brilliancy of a bulb deriving its filament voltage from the high-voltage rectifier socket, with the brilliancy of a bulb drawing power from a dry cell. When the brilliancy of the two bulbs is matched, the amount of battery voltage should be about the same as the voltage from the socket. Accuracies of ± .1 volt have been attained.

Insulated high-voltage leads are used to interconnect the filament test bulb with the high-voltage rectifier socket. Place the anode high-voltage lead in a safe place. The 10-ohm resistor in parallel with the s.p.s.t. switch is used to measure a wide range of filament voltages. With this resistor shorted, up to 1.5 v. can be measured. With the resistor in the circuit, up to 3.6 v. can be measured.



The No. 112 lamp is an ordinary 1.2-volt, 0.22 amp. flashlight-type bulb.

The *G-E* 112 lamp filament resistance closely approximates a rectifier filament resistance.

When the push-button switch is depressed, the second bulb filament current, hence its brightness, is controlled by the 5-ohm linear potentiometer. When this bulb filament brightness is adjusted to equal the test bulb filament brightness, the voltmeter will indicate the approximate filament voltage.

With the left-hand switch in the low position (10-ohm resistor shorted), the voltmeter requires no correction factor. However, in the high position, 2.1 volts must be added to the meter reading to compensate for loss incurred in the 10-ohm dropping resistor.

It should be pointed out that this device does not actually measure the filament source voltage, but indicates how much d.c. voltage is required to make the power input of one lamp equal that of another, matched, lamp. ▲

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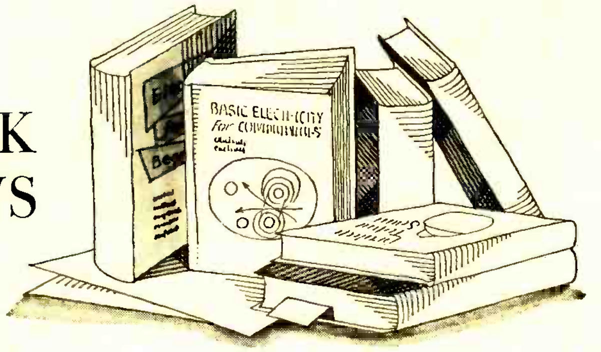
BOOK REVIEWS



"THE STORY OF THE LASER" by John M. Carroll. Published by *E. P. Dutton & Co., Inc.* 176 pages. Price $3.95.

This interesting high-school level book is intended as a semi-technical introduction to the laser (and maser) from the original concepts that led to the discovery of this remarkable device through its latest outer-space applications.

The author has assembled considerable laser information which he has successfully reduced from its engineering aspects to a readable handbook for the intelligent layman.

Starting with the relatively simple ruby laser, the author covers the operation of other types such as the gas and injection laser, explains how various colors are achieved, what power outputs can be obtained, what can be done with a laser, and what cannot be done. Besides the military thinking in the area of "death rays," the book also covers the many commercial and medical applications of the laser. He concludes with a somewhat tongue-in-cheek discussion on how to make a laser.

° ° °

"TEST EQUIPMENT MAINTENANCE HANDBOOK" by Robert G. Middleton. Published by *Howard W. Sams & Co., Inc.* 160 pages. Price $2.95. Soft bound.

This is an easy and quick reference volume for the service technician to enable him to keep his vital test equipment in good operating condition. Included is information on the calibration, troubleshooting, repair, and modification of a variety of test instruments—v.o.m.'s; v.t.v.m.'s, audio oscillators; square-wave generators; r.f. generators; color generators; oscilloscopes; and tube, transistor, and CRT testers.

The material is presented in practical down-to-earth style and enough schematics, scope patterns, partial schematics, and block diagrams have been included to cover a typical and representative selection of such instruments.

° ° °

"SEMICONDUCTOR ELECTRONICS" by Tugomir Surina & Clyde Herrick. Published by *Holt, Rinehart and Winston, Inc.* 414 pages. Price $8.00.

This is an interesting collaboration by the director of the Institute for Electronics and Automation in Yugoslavia and an instructor of electronics at San Jose City College. With the authors' pedagogic background, it is not at all surprising that this material is in textbook format. The book covers the field of semiconductors from basic physics and construction of the devices to the theory of their operation in practical circuits.

Prerequisite are a background in algebra, vector algebra, basic trig as well as a good foundation in a.c. and d.c. fundamentals and basic circuit theory.

Each chapter carries as series of questions plus a "multiple choice" test for self-testing or classroom assignment. Two appendices which include much of the basic reference material and information on semiconductors, plus a Greek alphabet, and a listing of pictorial symbols used in the diagrams accompanying the text make this volume more-or-less "self-contained."

° ° °

"GRAMMAR REVIEW FOR TECHNICAL WRITERS" by Rufus P. Turner. Published by *Holt, Rinehart and Winston, Inc.* 112 pages. Price $2.25. Soft cover.

Since the author is both an Assistant Professor of English and a Registered Professional Engineer, he is in an enviable position to act as mentor for the many engineers and technical men who have been pushed into "technical writing" for professional reasons as well as technical writers who have more or less forgotten their English grammar courses.

The early chapters of the book deal with parts of speech and their uses while later chapters are devoted to composition and the language of science and technology.

Almost all of the examples given to illustrate various points of usage and structure are technical in nature so that the student can find direct equivalents for the material he is preparing. There is also a list of frequently used (and often misspelled) words along with current "preferred" spellings.

° ° °

"CB RADIO SERVICING GUIDE" by Leo G. Sands. Published by *Howard W. Sams & Co., Inc.* 158 pages. Price $2.95.

This one is for technicians who handle the servicing of CB equipment—base station, mobile, or portable. The bulk of the book is devoted to troubleshooting procedures and the tracking down of operational difficulties in single and multichannel receivers and transmitters. Also covered are the alignment and measurement of receiver sensitivity, circuit analysis, determining the cause of low sensitivity, poor selectivity, distortion, and intermittent operation. A step-by-step analysis of transmitter circuitry includes sections on crystal oscillators, modulators, power amplifiers, antenna tuning, and coupling networks.

Information on CB regulations and laws is included along with chapters on how to set up a CB shop, field servicing, and the business aspects of CB work.

° ° °

"TV HOME-CALL SERVICE GUIDE" by Sams Staff. Published by *Howard W. Sams & Co., Inc.* 192 pages. Price $3.95. Soft bound.

Since often what seems to be a simple service call involving tube replacements or a new fuse develops into a full-fledged job of troubleshooting, the authors suggest that this compact and condensed manual of pertinent information on a great number of popular receiver models might accompany technicians on all home calls

The guide is intended to provide the information necessary for making TV repairs and adjustments in the field as quickly and easily as possible. It includes such helpful aids as the type of controls employed and their location on the chassis, the location of fuses or circuit breakers, a tube placement chart for locating and identifying the various tubes and their functions, and a tube failure chart listing possible suspects which might produce specific symptoms.

Also included are instructions for horizontal sweep-circuit alignment and detailed disassembly instructions to be used in cases where the chassis must be removed. The sets covered are listed alphabetically and then by model numbers in the master index at the front of the guide.

° ° °

"FUNDAMENTALS OF ELECTRIC AND ELECTRONIC CIRCUITS" by Matthew Mandl. Published by *Prentice-Hall, Inc.* 376 pages. Price $13.25.

This is a medium-level text designed for those in the early semesters of technical schools and junior colleges. Because of this, the prerequisites include only a basic grounding in algebra and trig, with familiarity with slide-rule operation desirable but not essential. The appendix carries tables of trigonometric ratios, logarithms, exponential functions, and other data needed to work with this text.

Since many fields today, notably computers, automation, control systems, and guided missiles, radar, communications, satellite instrumentation and allied circuitry, involve both electricity and electronics, this text is set up to provide an explanation of the dual applications of these principles.

The text is divided into seventeen chapters covering systems of units, atoms and electrons, basic electrical units, simple series and parallel circuits, complex series-parallel circuits, principles of magnetism, d.c. measurements, inductance, capacitance, a.c. circuits, *RLC* circuits, a.c. measurements, resonance, transformers and coupling, polyphase a.c., and pulse-shaping circuits.

Since this volume is designed especially for classroom use, there are numerous problems to be worked out by the student. Answers for the odd-numbered problems are included.

° ° °

"MAGNETIC TAPE RECORDING" by H.G.M. Spratt. Published by *D. Van Nostrand Company, Inc.* 361 pages. Price $10.50.

This is a second edition of a book that first appeared in 1958, and represents an up-dating of the original material as well as the addition of new information on circuits and techniques which have made their appearance in the ensuing six years.

The text covers the principles of magnetism, sound reproduction and electro-acoustics, magnetic recording, tape manufacturing materials, tape manufacture, tape testing, tape recording machines, testing of machines, applications of magnetic recording, and trends and new developments.

This volume is addressed to recording engineers and, as a result, the treatment is mathematical and technical. Would-be readers are advised that this is *not* a handbook for the owner of the home-type tape recorder who wants to know how to operate his machine or make simple modifications for doing trick recording.

Since this volume is written by a Britain and published in England, the coverage is basically English as far as techniques and equipment is concerned. ▲

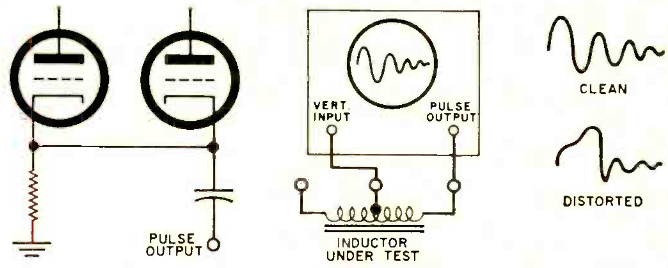
SIMPLE TESTS FOR INDUCTORS

LOCATING a shorted turn in a multi-turn inductor is almost next to impossible. Usually it is very difficult to tell if there is a shorted turn unless the inductor has been carrying a large amount of current, in which case the coil may have some discoloration.

In the short-turn checker suggested by *Sylvania*, the inductor is shock-excited by a pulse and the resultant damped oscillation can then be displayed on an ordinary oscilloscope.

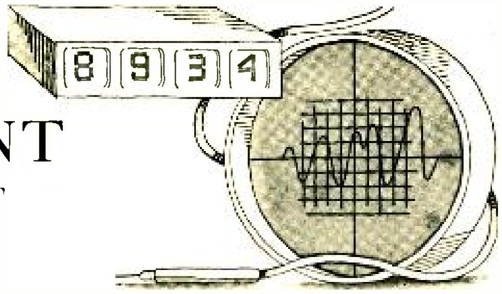
The required test pulse can be taken from the common cathode connection of the scope sweep generator (A). External connections for the test circuit are shown at (B) in the diagram below. The value of the pulse output coupling capacitor is not critical.

When the inductor is shock-excited by the pulse, it will ring and produce a damped sine wave at that frequency. If there is a shorted turn, the displayed waveform will be distorted as shown in (C). To check several inductors of the same type, first try a known good one, then wrap several turns of insulated wire around the coil and short the ends. Note the distorted waveform that results. This can be used as a comparison for testing the others. ▲



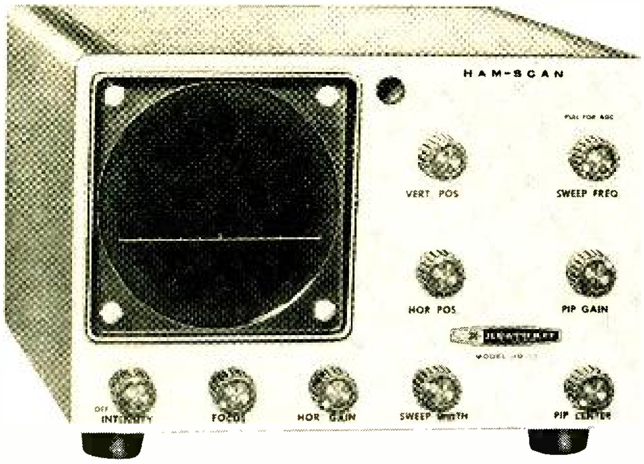
TEST EQUIPMENT

PRODUCT REPORT



Heathkit HO-13 Spectrum Monitor

For copy of manufacturer's brochure, circle No. 54 on coupon (page 9).

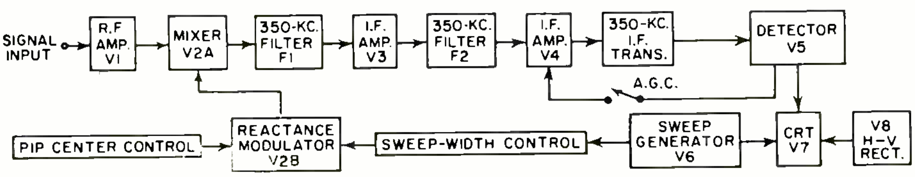


SIGNAL quality and operating habits are the topics of much discussion these days on the ham bands. The new *Heathkit* Model HO-13 "Ham-scan" Spectrum Monitor should be able to answer many of the questions about the signals with its panoramic display of the received r.f. spectrum.

The "Ham-scan" is essentially a superheterodyne receiver combined with an oscilloscope. The receiver is continuously tuned over a given frequency range and the output is visual rather than audio. Each signal received is displayed as a sharp vertical deflection of a cathode-ray tube trace ("pip") and the horizontal position of the "pip" is proportional to frequency. Thus, the operator can observe all signals appearing either side of the received signal. As the companion receiver is tuned, the "pip" display moves horizontally across the CRT face, with the received frequency always appearing in the center of the screen.

Referring to the block diagram, the signal input is obtained from the plate of the mixer stage which produces the receiver i.f. signal. The response of the companion receiver is broad at this point and enables the spectrum monitor to view as much as 50 kc. on each side of the received signal with a fairly constant response. This receiver i.f. signal is amplified by the r.f. amplifier (*V1*) and fed to the mixer (*V2A*) where it is combined with the local oscillator signal from *V2B*, which is electronically tuned by the horizontal sweep signal. The i.f. frequency is fixed at 350 kc. by the ceramic filters *F1* and *F2* which also provide the narrow selectivity required for good "pip" resolution. The i.f. signal is amplified by *V3*, detected by *V5*, then fed to an amplifier which provides vertical deflection of the CRT (*V7*). The detector also supplies a.g.c. voltage for controlling the gain of the i.f. amplifier, if desired. The sweep generator (*V6*) supplies both horizontal deflection to cathode-ray tube as well as the signal which electronically tunes the reactance modulator (*V2B*).

One of the outstanding features of the Model HO-13 is its inherent capability for accommodating a wide range of companion receiver i.f. frequencies. Optional components and instructions are provided for wiring the r.f. amplifier and reactance modulator circuits so that the "Ham-scan" can be assembled to operate with receiver i.f.'s of 455, 1600, 1650, 1681, 2075, 2215, 2445, 3000, 3055 or 3395 kilocycles.



The ceramic i.f. filters fix the i.f. frequency at 350 kc. and make alignment a simple matter of tuning the i.f. transformer for maximum output. In addition, the excellent selectivity obtained with the ceramic filters results in narrow "pips" which can be easily discerned even though they are within a few kilocycles of one another. Circuitry is also simplified by means of a semiconductor diode which functions as a voltage variable capacitor to tune the reactance modulator. The use of a.g.c. in the i.f. circuit permits extremely strong signals to be accommodated without producing off-screen deflection while having little effect on weak-signal reception.

Many characteristics of received signals can be determined by careful observation of the CRT display. The monitor is just as usable with general-coverage receivers as it is with ham-band receivers since it permits monitoring any 100-kc. segment of the spectrum within the tuning range of the receiver. Operators of CB equipment will find the unit an ideal visual channel monitor which can detect the activity on channels adjacent to the one being audibly monitored.

The monitor provides approximately 1 inch of vertical deflection with a 100-microvolt input signal. A control is also provided for placing the received signal "pip" at the exact center of the screen and a horizontal gain control is provided for adjusting the horizontal size of the display. Sweep width can be varied from approximately 30 kc. to 100 kc.

The kit price of $79 will prompt many hams to add sight to sound in their shacks. ▲

Budelman 17A4 CB Frequency Meter

For copy of manufacturer's brochure, circle No. 55 on coupon (page 9).

THE *Budelman* 17A4 frequency meter is a battery-operated, portable instrument which can be used for measuring up to 12 Citizens Band frequencies when equipped with only four frequency-reference crystals. The instrument was originally designed as a frequency-deviation meter to test FM transmitters. But, since it indicates frequency error directly on a meter scale, it can be employed to check off-frequency operation of CB transmitters. When equipped with a crystal for CB channel 14, for example, it can be used to measure CB channels 13, 14, and 15. If also equipped with a crystal for channel 2, it will cover channels 1, 2, 3, and so on.

The instrument consists of a switch-selectable four-channel crystal-controlled frequency reference oscillator, harmonic generator/mixer, beat-frequency amplifier, amplitude limiter, and

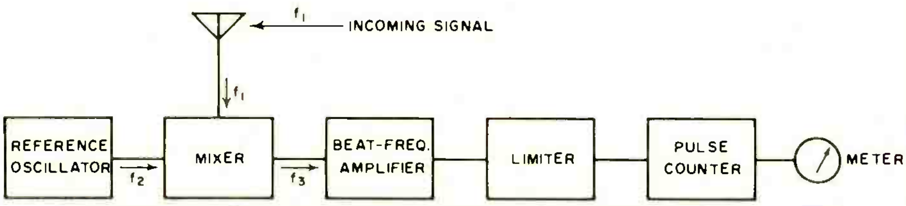
direct-reading counter, as shown below. By means of a short wire antenna, the CB transmitter signal ($f1$) is picked up and fed to the mixer. The reference signal ($f2$) is also fed to the mixer. The beat signal ($f3$), whose frequency is equal to their difference, is amplified, limited in amplitude, and displayed by a meter.

The reference oscillator consists of a Pierce crystal oscillator circuit and an electron-coupled amplifier, utilizing a single pentode tube. The crystal is set to the correct frequency at the factory. The plate circuit is tuned to the second harmonic of the crystal frequency. If the crystal operates at 6781.25 kc., for example, the oscillator output is 13,562.5 kc. This second harmonic is fed to the crystal mixer which generates harmonics. The second harmonic generated by the diode (fourth harmonic of the crystal frequency) is at 27.125 mc. in the Citizens Band.

If the CB set being checked operates at 27.126 mc. (1 kc. off frequency), for example, its signal will mix with the 27.125 mc. reference signal and produce a 1-kc. beat. This beat signal passes into the beat-frequency amplifier, is amplified about 55 db, and is then fed to a full-wave amplitude limiter, which changes the signal into a train of positive and negative square-wave pulses. The pulses pass through a coupling capacitor to a full-wave rectifier. Only the positive pulses pass through to the 0-150 d.c. microammeter, whose reading is in direct proportion to the frequency error. In this case, the 15-kc. deviation scale (0-150) would be read as a value of 10, indicating a 1-kc. error.

While it has been assumed here that the CB set is operating 1 kc. too high, the instrument would give the same indication if the CB set were 1 kc. below the correct channel frequency. This can be determined by momentarily closing a switch which lowers the frequency of the reference oscillator. If the meter reading increases when the switch is closed, the CB set is operating at a frequency higher than the correct channel frequency since there is now a greater difference between the reference and measured signals. If closing the switch causes the meter reading to fall, the CB set is low in frequency.

The frequency meter has three frequency-deviation ranges: 0-1.5 kc., 0-5 kc., and 0-15 kc. The accuracy of the reference oscillator is .001% at room temperature. The price of the unit is from $310 to $385, depending on the number of crystals installed. ▲



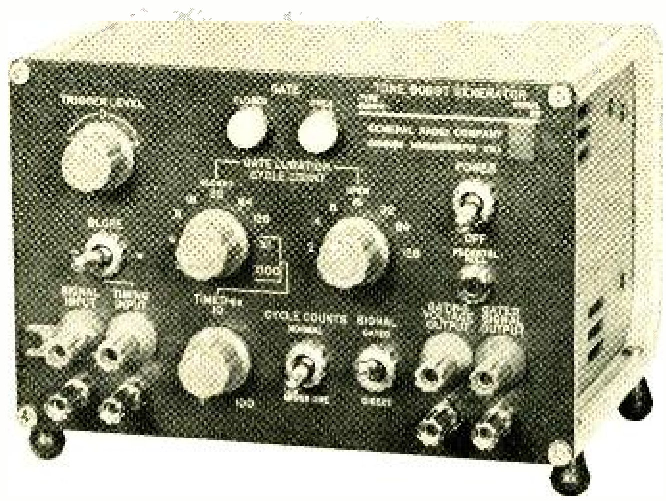
General Radio Type 1396-A Tone-Burst Generator

For copy of manufacturer's brochure, circle No. 56 on coupon (page 9).

THE *General Radio* Type 1396-A Tone-Burst Generator is a unique instrument which, when used in conjunction with an audio oscillator, generates short, precisely controlled bursts of an a.c. signal. Such tone bursts are useful in a wide variety of time-response tests on a.c. circuits and for simulating pulsed a.c. signals commonly used in sonar and other audio-ultrasonic systems.

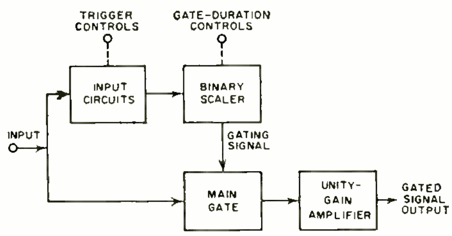
The tone-burst generator operates as a coherent gate, that is, the starting and ending points of each tone burst are exactly in phase with one another. (This is often required for oscilloscope display, since a steady trace is possible only with a coherent burst.) The operation of the instrument's electronic gate produces alternate periods of no output when the gate is closed and a reproduction of the input signal when the gate is open. The gate-open and gate-closed durations are set by front-panel controls. The gate-open duration may be 1, 2, 3, 4, 7, 8, 15, 16, 31, 32, 63, 64, 127, or 128 cycles. The gate-closed duration may be any of these or may be timed from 1 millisecond to 10 seconds.

While the above summarizes the basic principles of the tone-burst generator, a full complement of controls adds many capabilities. For instance, there are two



sets of input connectors, and one signal may be used to time the bursts of a second signal. Also provided on the front panel are trigger level and slope controls, which function as on an electronic counter. The user can thus control the phase of the input signal at which the main gate opens. For use with oscilloscopes, a gating output signal of +10 volts during gate-open and −10 volts during gate-closed is supplied.

A simple block diagram is shown here. When the gate is opened, the binary scaler advances one count per input



cycle. When the number of cycles set by the "Gate Open" control has been counted, the gate closes and the scaler resets to zero. The scaler then counts the number of cycles selected by the "Gate Closed" control, after which the gate reopens, the scaler resets to zero, and the cycle repeats. The unity-gain amplifier has a bandwidth of about 1 mc. The maximum input frequency is 500 kc. Nonsinusoidal signals with repetition rates up to 500 kc. can be gated provided the significant harmonics are within the amplifier's bandwidth capability.

Applications for the tone-burst generator are many. The short, precisely controlled bursts can be fed to sonar amplifiers to measure rise and fall times, pulse-envelope distortion, and frequency response. Also, many measurements (impedance, response, power) may be made on sonar transducers. The tone-burst generator may be used as a source of pulsed a.c. for bridge measurements, and as a source of transients in the measurements on loudspeakers. In fact, useful measurements may be made on virtually any audio-ultrasonic device (filters, detectors, recorders, etc.) by means of calibrated transients from the generator.

Specifications are as follows:

Input signal, d.c.-coupled ±7.5 volts maximum, from d.c. to 500 kc., with a typical input impedance of 12 kilohms.

Timing signal, d.c.-coupled, ±10 volts maximum, 1 volt peak-to-peak minimum, from d.c. to 500 kc., with a typical input impedance of 7 kilohms.

Gated output signal: Total distortion products are less than −60 db with reference to maximum output (15 volts peak-to-peak sine wave) at 1 and 10 kc. During closed-gate condition, feedthrough of input to output is less than −40 db with reference to maximum output.

Output impedance, 600 ohms.

The tone-burst generator is housed in an 8″ x 5¼″ x 6″ cabinet with optional provision for rack mounting. Price is $490. ▲

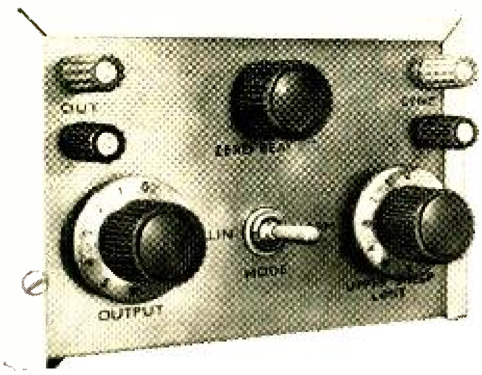
METER PROTECTION

By JAMES G. LEE

WHEN you want to check a d'Arsonval meter movement quickly to see if it is all right, simply wiggle the meter with the terminals open and note the approximate meter deflection. Then short the terminals with screwdriver or wire and then wiggle the meter again.

If the meter movement is good, the deflection will be reduced drastically and should appear sluggish. The short causes a low-impedance (high current) load to appear across the meter movement as it cuts through the magnetic lines of force. This requires a stronger turning moment than the lightweight movement can sustain. As a result, the movement becomes highly damped. If the deflection remains the same, however, it is possible that the movement is open and the meter is defective.

Using this same technique, you can protect your unused meters by simply putting a wire short across the terminals before you store them. ▲



Front-panel view of the author's compact a.f. sweep generator.

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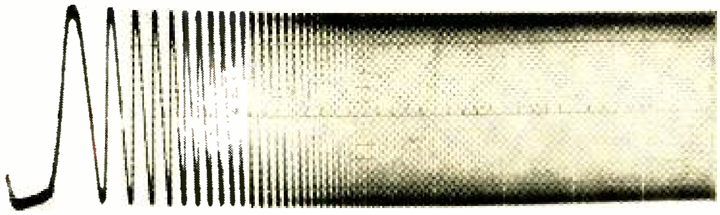


AUDIO SWEEP GENERATOR

Construction of device that will produce a scope display of frequency response of audio amplifiers, bandpass filters, and audio compensating networks.

By ROBERT H. DOUGLAS

HAVE you ever wanted to monitor the frequency response of an audio system while you were working on it? If so, here is an instrument that will indicate the frequency response of audio amplifiers, bandpass filters, compensating networks, or any other audio circuit.

Audio sweep generators produce a varying tone which covers the range from the low end of the audio band to above 20 kc. This changing frequency can be applied to a circuit under study and the output of that circuit connected to an oscilloscope. If the sweep of the scope is synchronized with the sweeping of the generator, the scope display will be a plot of gain *versus* frequency for the circuit under study.

Most audio sweep generators sweep the audio spectrum at a constant rate. This type of sweeping distorts the plot of frequency response and does not give the user a standard frequency response curve. If you look at the frequency response curves given for hi-fi equipment, you will notice that the frequency scale is not linear, that is, one inch is not equal to, say, 1 kc. at all points on the scale. Instead a logarithmic scale is used, where the scale is graduated so as to give greater space to the low frequencies than the high ones. The audio sweep generator to be described can plot frequency response on a logarithmic as well as a linear scale. (See scope-trace photos in Figs. 3, 4, and 5.)

Circuit Description

In this transistorized audio sweep generator, the audio frequency output is obtained by heterodyning two r.f. signals and utilizing the difference frequency. If one of the r.f. signals is held fixed and the other varied slightly in frequency, the audio difference will also vary. Referring to Fig. 1, the circuit block diagram, we see Q1 connected as a fixed-frequency oscillator operating at about 1500 kc. Q3 operates as a variable-frequency oscillator that sweeps in frequency from 1500 to 1520 kc. These two oscillators feed buffer amplifiers Q2 and Q4, whose outputs are mixed and the difference frequency generated in the detector. This difference signal will then sweep from zero to 20 kc.

The output of the detector is coupled to an audio amplifier, Q5 and Q6, where the r.f. signals are filtered out and the difference signal amplified. The signal used to sweep the variable-frequency oscillator is generated by Q9, a sawtooth generator. Q7 and Q8 serve to modify the slope of the sawtooth when the generator is in the normal (logarithmic) mode of sweeping.

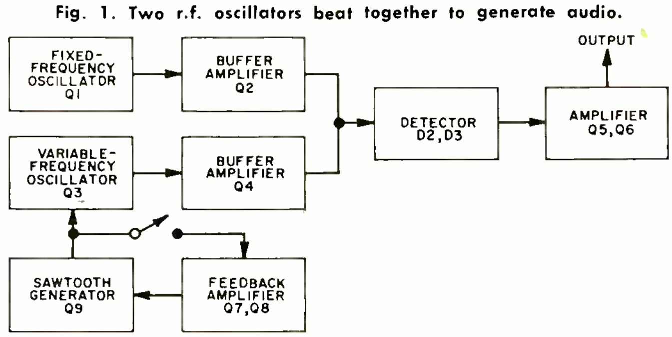
Looking at the circuit in more detail (Fig. 2), we see Q1, the fixed-frequency oscillator, connected in the grounded-base configuration. The combination of C1, C2, and T1 resonate at approximately 1500 kc. The output of the oscillator is developed across R4 and coupled through C5 to Q2. The output of Q2 is coupled through C7 to the detector.

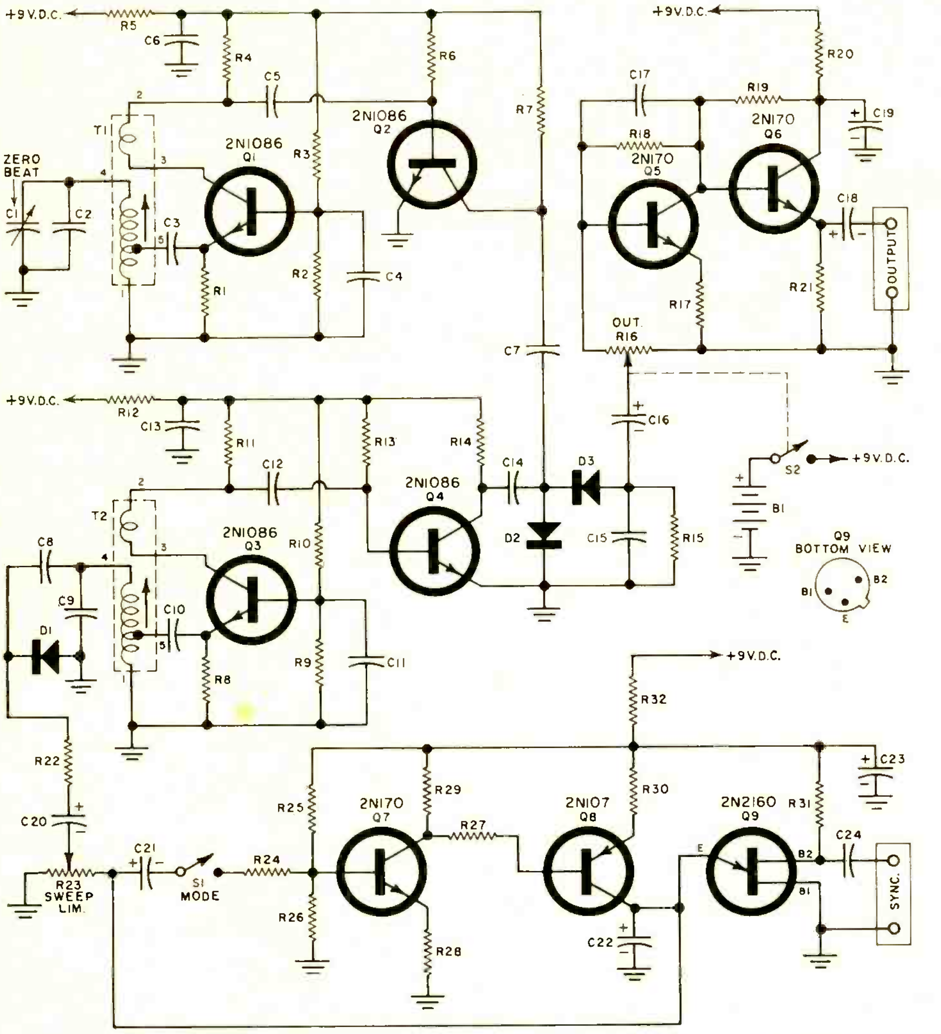
The variable-frequency oscillator and amplifier, Q3, Q4, T2, and associated circuitry, is identical to the fixed-frequency oscillator except for the addition of D1. The operation of the oscillator causes a reverse-bias to be applied across this diode. When a diode is reverse-biased, a region forms around the junction, called the depletion region, where no current carriers are available. This depletion region becomes the dielectric of a small capacitor with the *p* and *n* regions forming the plates. If the voltage across the diode increases, the depletion region becomes wider; and the capacity across the diode's terminals decreases. Since D1 is connected across T2, its capacity helps to determine the oscillator's frequency. Varying the voltage across D1 will vary the oscillator's frequency.

The outputs from the two buffer amplifiers are mixed *via* C7 and C14. At this point we have an r.f. signal whose amplitude varies at a frequency equal to the difference between the two oscillator frequencies. D2, D3, C15, and R15 make up a detector which produces an output equal to the instantaneous amplitude of the r.f. input. This difference frequency is coupled through C16 to the output control and then to Q5. C17, connected between the collector and base of Q5, serves to reduce the gain of the amplifier above 20 kc. This prevents any r.f. signals from reaching the output. Q6, an emitter follower, gives the generator a low output impedance. It will deliver a 1-volt signal into a 600-ohm load.

The sweep generator, Q7, Q8, and Q9, is a rather unusual circuit. The heart of this circuit is Q9, a unijunction transistor. Unijunction transistors are similar in operation to gas-discharge tubes. The emitter-base (B1) circuit is essentially open until the emitter is raised to a critical voltage. At this point the emitter impedance drops to a low value until the emitter current is reduced below a critical point. Then the emitter returns to the open state.

Fig. 1. Two r.f. oscillators beat together to generate audio.





PARTS LIST

R1,R4.R7.R8.R11.R14.R29—2200 ohm, ½ w. res.
R2.R9—10.000 ohm, ½ w. res.
R3.R10.R27—27,000 ohm. ½ w. res.
R5.R12.R20.R21.R31—1000 ohm, ½ w. res.
R6.R13.R22—180.000 ohm, ½ w. res.
R15.R19.R24.R26—4700 ohm, ½ w. res.
R16—10.000 ohm audio-taper pot
R17.R28.R30.R32—390 ohm, ½ w. res.
R18—100.000 ohm, ½ w. res.
R23—25.000 ohm linear-taper pot
R25—47.000 ohm, ½ w. res.
C1—2-17 pf. variable capacitor (Hammarlund APC-15B)
C2—33 pf. ceramic capacitor
C3.C10.C15—.001 μf. ceramic capacitor
C4.C6.C11.C13,C24—.05 μf., 50 v. ceramic capacitor
C5.C7.C12.C14—200 pf. ceramic capacitor
C8.C17—68 pf. ceramic capacitor
C9—22 pf. ceramic capacitor
C16,C20,C21,C22—10 μf., 15 v. elec. capacitor
C18.C19,C23—100 μf., 15 v. elec. capacitor
S1—S.p.s.t. toggle switch
S2—S.p.s.t. switch (on R16)
T1.T2—Transistor osc. transformer (J. W. Miller #2021)
B1—9 v. trans. battery (Burgess 2N6 or equiv.)
D1—1N950 diode (see text)
D2.D3—1N34A diode
Q1.Q2.Q3,Q4—2N1086 transistor
Q5,Q6.Q7—2N170 transistor
Q8—2N107 transistor
Q9—2N2160 unijunction transistor

Fig. 2. The circuit employs readily available germanium transistors and a unijunction transistor as sawtooth generator.

In this circuit, *C*22 charges through *Q*8 until the unijunction fires and rapidly discharges the capacitor. While the unijunction is discharging *C*22, a negative-going spike is developed across *R*31 and coupled through *C*24 to synchronize the oscilloscope with the generator sweep. After *C*22 is discharged, it begins to slowly charge again. This action forms a sawtooth waveform across the capacitor. This sawtooth appears across *R*23 and a portion of it is coupled through *C*20 to *D*1, causing the variable-frequency oscillator to sweep in frequency.

In the linear mode of sweeping, the sawtooth across *C*22 has constant slope due to the fact that the current through *Q*8 is constant. In the normal (logarithmic) mode of sweeping, the collector current of *Q*8 is varied to produce a sawtooth with the curved slope.

To follow the circuit action when the generator is in the normal mode of sweeping (*S*1 is closed), let us consider the circuit immediately after *Q*9 has fired and the voltage across *C*22 is at its lowest point. Due to the coupling action of *C*21 the voltage at the base of *Q*7 is also very low, hence the collector current of *Q*7 is very small. This means that the input to *Q*8 will be very small and its collector current will also be low. Note that the rate of charge of *C*22 is determined by the collector current of *Q*8. The capacitor will, therefore, charge very slowly.

However, as the capacitor charges, the input to *Q*7 increases. This increases the output current of *Q*7, the input to *Q*8 increases, and the output current of *Q*8 increases. The rate of charging of *C*22 is increased which further increases the input to *Q*7. This action is regenerative and would rapidly charge *C*22 to the supply voltage if *Q*9 did not fire, discharging *C*22 and allowing the whole cycle to be repeated. Therefore, with *S*1 closed we have a sawtooth across *C*22 whose slope increases as its amplitude increases.

Fig. 3. Output of generator displayed on an oscilloscope.

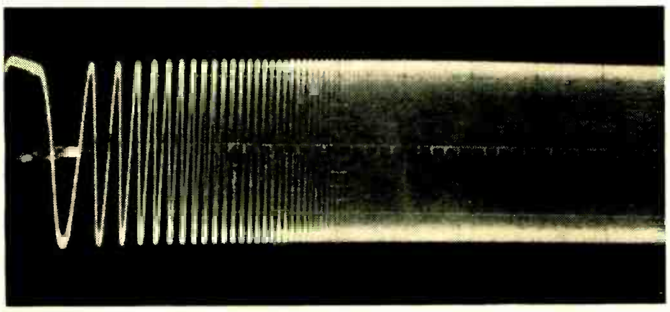
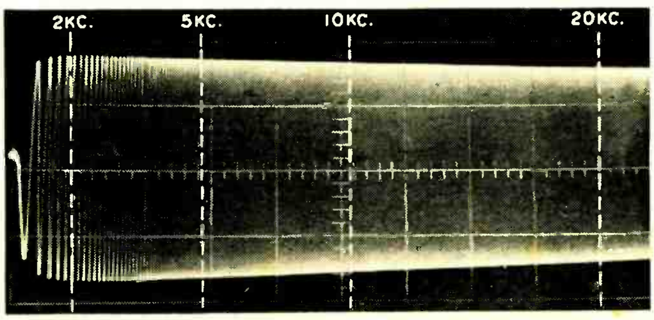


Fig. 4. Output of amplifier with generator in linear mode.



When this waveform is applied to D1, the generator produces a logarithmic sweep. With S1 open, the currents through Q7 and Q8 are constant and the slope of the sawtooth is constant. This makes the generator sweep at a constant rate.

Construction and Alignment

There are no critical parts in this circuit. All the semiconductors, with one exception, are standard, readily available units. Equivalent types for the units listed in the parts list should work satisfactorily. D1, however, may be difficult to obtain. The 1N950 is a special type made by *Hughes* for use as a voltage-sensitive capacitor. The author found that low-power zener diodes will work in this circuit. The requirements are that the diode be of the low-power type (250 to 400 mw.) and have a zener voltage of around 30 volts. The two usable types are 1N725 and 1N972. The builder may find that this modification will reduce the amount of sweep but the circuit should still sweep to 20 kc.

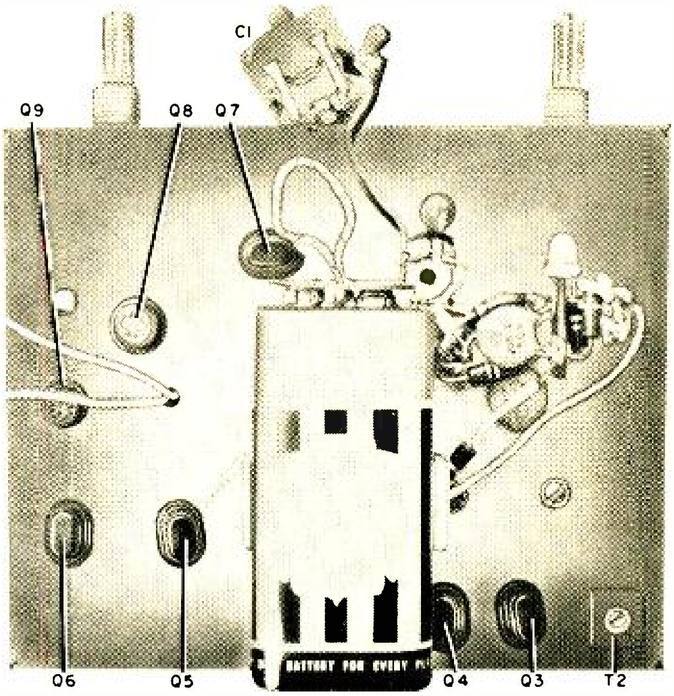
It is recommended that the builder adhere to the values of the components as specified, especially in the feedback amplifier. While none of the parts is critical, circuit performance will be affected by major changes in component values. If the constructor does not need the logarithmic mode of sweeping, this feature can be easily eliminated. Replace the entire feedback amplifier, Q7 and Q8, R24 through R30, S1, and C21 by a 2200-ohm resistor connected between C22 and the junction of C23 and R32. This modification will give the same sweep as when S1 is open. Even with no help from the builder's junk-box, the entire sweep generator can be built for under $50.00.

The author assembled the sweep generator in a 4"x5"x2" aluminum chassis which was then mounted inside a chassis box. While this particular size chassis gives a compact unit, it makes a very difficult wiring job for the average builder. Unless you are particularly adept at miniature wiring, assemble the unit on a larger chassis.

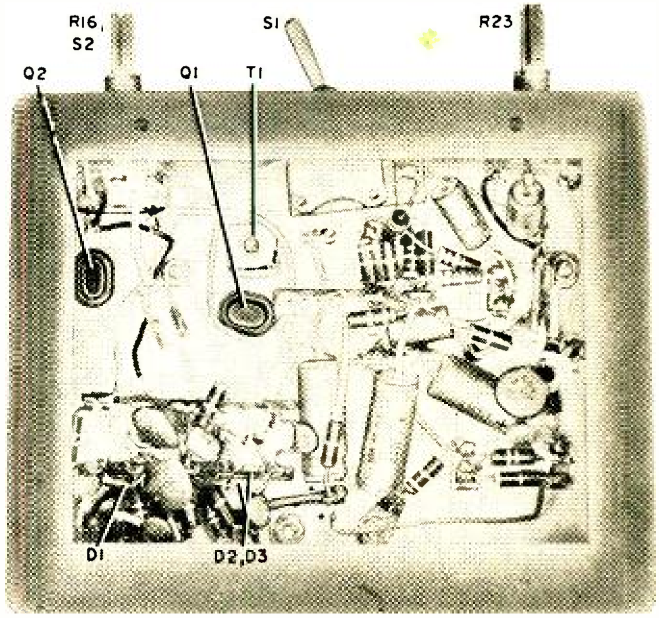
Layout of the circuit is not critical as long as the two oscillators are kept isolated from each other. To accomplish this in the author's model, the variable-frequency oscillator and the amplifier were mounted with the transistors and oscillator coil on top of the chassis and the wiring on the bottom. The fixed-frequency oscillator was mounted "upside down" with the wiring on the top and the transistor coil on the bottom. The prospective builder should make a sketch of the parts layout before the chassis is drilled. This avoids the problem of squeezing too many parts into a small space or, on the other hand, having components hanging from 1½" leads on both ends. Neither situation is desirable in any electronic circuit.

Once the sweep generator has been built and checked, the unit must be aligned. Set the output control fully up and the upper sweep limit control down. Connect an oscilloscope to the output terminals. Set the scope to observe a signal of about 1 volt. With the plates of C1 halfway meshed, take an alignment tool or insulated screwdriver and turn the slug of either T1 or T2 until a signal is observed on the scope. Adjust the slug until the signal is of maximum amplitude. (This is not a very critical adjustment; all you are doing is getting the difference signal within the bandpass of the audio amplifier.) If nothing is observed by turning one slug, put that slug in the middle of its travel and turn the other.

When the oscillators are approximately adjusted, connect a lead from the sync terminals on the generator to the external synchronization input of your oscilloscope and set the scope to external sync. Momentarily connect the scope input to the generator sync terminals. One should see a train of narrow pulses about 3 volts in amplitude. Adjust the sweep



Top view of the 4" x 5" x 2" aluminum chassis employed.



Bottom view shows fairly close wiring. A somewhat larger chassis would permit a little more spread in the wiring.

Fig. 6. Setup employed to put marker pips on the display.

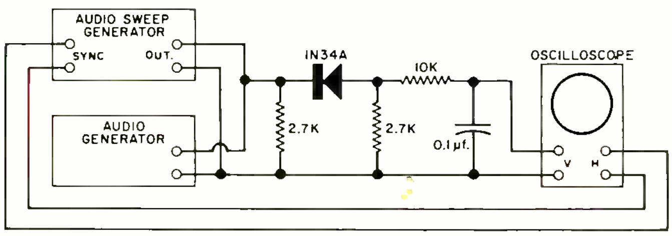
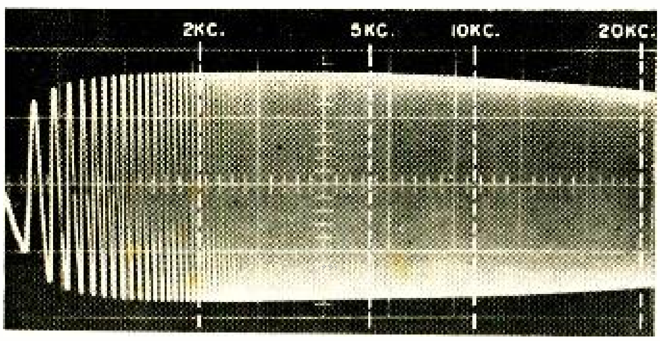


Fig. 5. Output of same amplifier, generator in log mode.



controls of the scope to display one pulse. Without touching the sweep control of the scope, reconnect the scope to the output terminals. By turning the upper sweep limit control and adjusting the zero beat control, one should see a display similar to Fig. 3.

With the generator applied to a hi-fi power amplifier, the trace shown in Fig. 4 was observed with the generator set for linear mode. When switched to the logarithmic mode, the same amplifier produced the curve shown in Fig. 5. The response at 20 kc. is about 1½ db below the mid-frequency output.

In some applications it may be desirable to know the actual frequency range that the generator is sweeping. This is easily accomplished with a calibrated audio oscillator and the circuit shown in Fig. 6. To use the circuit, adjust the audio oscillator for an output equal to that of the sweep generator. With the scope synchronized to the sweeping of the sweep generator, a pulse or marker will be observed at the point where the sweep generator's frequency is equal to that of the audio oscillator. If, for example, the audio oscillator is set for 5 kc., a marker will be observed at the point on the trace where the sweep generator is passing through 5 kc.

Besides uses in the hi-fi field, several unusual applications for this unit have been suggested. The generator can be used to analyze the rejection of filters and the narrow bandpass of systems used in tone telemetry. In these applications the generator does not necessarily have to sweep from zero to some frequency. By adjusting the controls the unit can be made to sweep from, say, 8 to 12 kc. or from any lower to any higher frequency within the bandpass of the audio amplifier. The generator can also be used to produce a fixed frequency by turning down the upper sweep limit control.

The hi-fi enthusiast soon realizes that one of the weakest links in his system is between the system's speakers and his ears. The acoustic design of the room in which the system is installed greatly affects the over-all frequency response of the system. With the audio sweep generator connected to the system and a good quality microphone connected to an oscilloscope, you can display the response of your entire audio system from preamp input to your ear. It is surprising what a different listening position, speaker placement, or even the location of furniture in the room can do for system response.

When you have built the generator, you will find it a valuable aid in checking all audio-frequency systems. Everyone from the hi-fi enthusiast to the broadcast engineer can undoubtedly find more than one use for this transistorized audio sweep generator. ▲

The GTCR

(*Continued from page* 46)

Prior to introducing other circuits utilizing the GTCR, it is necessary to introduce the "trigger" or "snap-back" diode since this device will be used in the remaining circuits that will be discussed. The trigger diode exhibits characteristics similar to the zener diode, but is constructed quite differently. Four layers of doped semiconductor material are joined in either an *n-p-n-p* or a *p-n-p-n* arrangement. As the d.c. voltage across the diode is increased, the device acts as an open circuit until the "snap-back" or "trigger" potential is exceeded. As the diode conducts, a negative-resistance region is realized that allows a very fast, regenerative switching action. This action can be used in GTCR circuits to great advantage.

It is realized that if a means were provided whereby "turn on" and "turn off" pulses could be applied to the gate in proper sequence, then a free-running switch with very-high power capability could be designed. The trigger diode provides a simple way of doing this. Fig. 2A is a circuit diagram of such a free running switch. When the "B+" voltage is applied and the GTCR is off, capacitor $C1$ charges through R_L and $R1$ until the trigger potential of $D1$ is reached. The "snap-back" action of the trigger diode provides a fast discharge path for $C1$ and this discharge fires the GTCR. The "B+" voltage is then switched across R_L and the series combination of $C2$ and $R2$. Capacitor $C2$ charges until the trigger potential of $D2$ is exceeded. This allows $C2$ to discharge into the gate to turn the GTCR off. The cycle then repeats, providing a periodic, rectangular wave output.

The circuit given in Fig. 2A has been modified in Fig. 2B to illustrate a normally off monostable switch. An externally applied positive switching pulse is applied to the gate of the GTCR through $D1$. The GTCR fires upon application of this pulse and conducts until the capacitor charges to the breakdown potential of trigger diode $D2$. The capacitor then discharges into the gate and turns the GTCR off until the next switching pulse is applied.

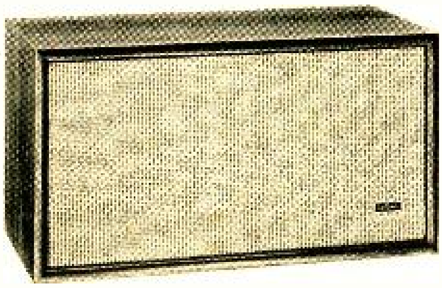
Fig. 2C illustrates a normally on monostable switch that requires a negative switching pulse to turn the GTCR off. In this circuit, when "B+" is applied, the capacitor charges to the breakdown potential of trigger diode $D1$ and the device fires. The GTCR conducts until the external switching pulse turns the GTCR off. The capacitor will begin to charge as before and when the breakdown potential of the trigger diode is reached, the GTCR again conducts and will remain in the conduction state until another off switching pulse is applied. ▲

EW Lab Tested

(Continued from page 14)

sion results in a sub-audio free-air cone resonance, which is controlled by the stiffness of the air within the fully enclosed box. The crossover frequency is 800 cps and the tweeter circuit is padded down to match the high tweeter efficiency to the lower efficiency of the woofer. A three-position slide switch on the rear panel of the cabinet controls the high-frequency response of the system. The center position is "normal" and a greater or lesser amount of treble response may be selected to suit the taste of the listener or the requirements of the acoustic environment.

The EV-2 is rated for a frequency response of 30 to 15,000 cps, with a power-handling capacity of 30 watts of program material. Due to its relatively low efficiency, it should be driven by an amplifier of at least 20 watts rated output, and it thrives on the "heavyweight" class of amplifiers capable of delivering over 40 watts. In our indoor frequency-response measurements, averaging the speaker response at seven different microphone positions, we found that the EV-2 has a relatively smooth, wide-range response, within ±5 db from 30 to 2500 cps and gently sloping off at higher frequencies. Our response meas-



urements, unlike the usual on-axis response curve, indicates the total energy output of the speaker and shows it to be an unusually smooth reproducer, particularly above 1000 cps. The plotted curve was made with the high-frequency level switch in its normal position, which also sounded best to our ears. In its "high" setting, the over-all response would probably have been quite uniform to 15,000 cps. In our listening room, this position tended to produce a rather over-bright sound.

The important characteristic of the response curve above 1000 cps is not its slope, but its smoothness. There are no peaks or dips of more than 1.5 db within this important frequency range, which implies an excellent transient response. Our tone-burst tests confirmed this, with nearly perfect response as shown by the typical scope photos taken at 800 cps and 5000 cps. At lower frequencies, there was some ringing, as shown in the 310-cps tone-burst photo.

The harmonic distortion of the woofer output, at a 1-watt driving level, was low down to 40 cps, and rose rapidly at lower frequencies. This frequency is the useful lower limit of most compact speakers, other than a few of the most expensive types, and is more than adequate for reproduction of musical program material.

In listening tests, the EV-2 sounded as good as it measured. It is relatively uncolored, with a solid but not boomy bass and crisp, well-dispersed highs. Compared side-by-side with other compact speaker systems, it held its own without difficulty against some much more expensive models. It has the natural, easy sound, unmarred by harshness or boxiness, which has made the acoustic-suspension speaker so popular.

At its price of $108, the EV-2 is a fine value. For budget-conscious individuals, it is also available in a knocked-down kit form for only $81, in oiled-walnut finish. This provides an exceptional amount of "good sound per dollar" and is matched by few, if any, speakers at this price. ▲

FILAMENT TRANSFORMER AS AUDIO SUBSTITUTE

By RUFUS P. TURNER

ALTHOUGH power-supply transformers are not found in the category of hi-fi components, a filament transformer is a good emergency substitute in many audio circuits. The author has used a small, inexpensive 6.3-volt unit in the following positions: microphone input, transistor output, low-level tube output, transistor interstage and voltage amplifier for a.c. v.t.v.m. (transformer steps up 1 millivolt to better than 1 volt for deflection of the v.t.v.m.).

Because the 6.3-volt secondary is center-tapped, two turns ratios are available—the lower one with respect to the full secondary, and the higher one with respect to one-half secondary. This transformer (a Stancor F-14X, 6.3-volt c.t. at 1.2 amp) has good frequency response and low distortion. The table lists the important audio and d.c. characteristics as measured by the author.

The technician who finds himself suddenly needing a transformer after store hours should remember his stock shelf or junk box can often provide an emergency substitute of this type. ▲

Turns Ratio:	Pri. to full sec. 18.2 : 1 Pri. to half sec. 36.4 : 1
Imp. Ratio:	Pri. to full sec. 332 : 1 Pri. to half sec. 1320 : 1
D.C. Res.:	Pri. 90 ohms Sec. 0.5 ohm
Pri. Inductance:	2.6 hy. @ 1000 cps
Freq. Res.:	20-20,000 cps ±1.4 db.
Total Harm. Dist.:	1 % @ 1000 cps

NEW PRODUCTS

Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, simply fill in the coupon appearing on page 9.

COMPONENTS • TOOLS • TEST EQUIPMENT • HI-FI • AUDIO • CB • HAM • COMMUNICATIONS

R.F. SIGNAL GENERATOR

1 **Path Products Corporation** is now importing an all-transistor wide-range r.f. signal generator made by **Nombrex Ltd.** of England. The Model 27 covers 150 kc. to 350 mc. in eight overlapping bands. The unit is battery powered and

completely self-contained. Accuracy is better than 2% and modulation is 30% from an internal 400-cps oscillator.

The instrument, which measures 6⅝"x 4⅝"x 2⅝", weighs less than 2 pounds. It can be used as a laboratory instrument, by field engineers, by TV and industrial technicians, experimenters, hams, hobbyists, and CB-ers.

TRANSISTOR CIRCUIT DEMONSTRATOR

2 **Digital Electronics, Inc.** has announced the availability of the "Digiac 60," a transistor circuit demonstrator for classroom use.

The device covers transistor fundamentals, transistor techniques in power supplies, voltage regulators, radio amplifiers, audio amplifiers, pulse circuits, computer circuits, radio transmitters, radio receivers, p.a. systems, among others.

The unit consists of eleven panels, each 15"x 20" and a steel frame on which they can be supported. The whole unit is mounted on casters. All components and panels are stored in a self-contained, locked steel storage cabinet. The unit is safe since there are no exposed high voltages. The circuit schematic is completed by inserting components. Each component is mounted on a rugged glass epoxy plug-in board. Circuit and component values may be changed by removing the plug-in components and inserting new ones.

R.F. PEAK-READING WATTMETER

3 **Bird Electronic Corporation** has designed the Model 4310 portable peak-reading wattmeter specifically for the measurement of pulsed r.f. systems such as air navigational aids, telemetry, radar, television, command and control, and p.e.p. measurement of SSB signals.

The principle of measurement consists of displaying the demodulated envelope on an oscilloscope and biasing the detector to cut off. The voltage from the variable bias supply is monitored on the meter which is calibrated in peak r.f. power.

In a train of recurrent pulses of various amplitudes, the peak power of each pulse can be read separately by adjusting the bias until only that particular pulse has disappeared. The higher the scope sensitivity, the greater the measurement accuracy.

The Model 4310 measures from 50 watts to 10 kw. peak power from 2 to 1260 mc. and from 0.1 microsecond pulse width, depending on the element selected.

DIELECTRIC STRENGTH TESTER

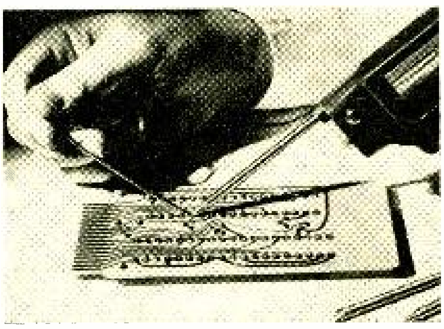
4 **Associated Research, Inc.** is now offering two new models of its "Hypot Junior" instruments for dielectric strength testing of a.c. and d.c. electronic components, harness, cables, capacitors, tools, motors, and allied electrical equipment.

These single instruments now combine the previous features of separate a.c. and d.c. units. The Model 4016 has an a.c.-d.c. working range of 0 to 2500 volts while the Model 4045 covers the range from 0 to 5000 volts. Output is continuously variable from zero to maximum on each model. Ripple is less than 2% on d.c. at full load.

Each model is housed in a steel case 6"x 9"x 8½", with a carrying handle. A compartment in the lid holds test leads and line cord for 117-volt, 50-60-cycle, a.c. input.

FINE-POINT TIP ASSEMBLY

5 **Wen Products, Inc.** has recently introduced a new fine-point tip for its Model 75 soldering pistol. The new tip is designed for fine soldering work and for soldering in hard-to-reach places. The three-inch long tip assembly steps down from



³⁄₁₆" to ⅛" diameter, tapering to a very fine point. The new design permits easy soldering and unsoldering of printed-circuit board connections. The new tip is readily interchangeable with the standard chisel-shaped tip.

ELECTRONIC SNIPS

6 **Xcelite Incorporated** has added new fine-wire and filament cutters to its line of tools for electronic assembly and service work. Known as the No. 86 electronic snips, the new tool is made of high carbon, hot drop-forged tool steel. It may also be used for removing insulating coverings and for cutting sheet metals and other light materials up to .025" thick.

Shearing action of the short, pointed blades prevents peaks on cut wires and damaging shocks to components in electronic assemblies. Over-all length of the snips is 6½ inches and maximum length of cut is 1¼ inches.

NEW 300-OHM TV LINE

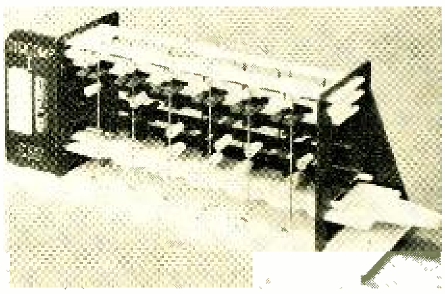
7 **Alpha Wire Corporation** has developed a competitively priced 300-ohm TV line which is being offered in three basic constructions to meet every possible environmental condition.

The 5153 twin-lead is recommended for installations where a wire with great resistance to atmospheric contamination is needed and where increased strength and resistance to wind whipping is essential. Type 5152 is designed for maximum signal strength in installations requiring a rugged, durable cable with high resistance to corrosion and abrasion. The type 5150 is for installations in average operating conditions.

All three types are available in 1000-foot spools, and 25,- 50,- and 100-foot hanks.

COMPUTER-EQUIVALENT UNIT

8 **E.S.R. Inc.** is now marketing the "Digi-Comp I," a scientific toy that simulates an electronic computer. The colorful 4½"x 12" plastic unit is easy to assemble and is capable of



demonstrating computer logic on missile countdown, satellite re-entry, automatic elevator operation, missile checkout, logic problems, and accounting processes.

The open-frame construction is designed to permit the observation of movable plastic sections operating as mechanical flip-flops and clock circuits. In addition to solving problems, the kit can be used as a teaching tool. A comprehensive step-by-step instruction book covers assembly and operation plus an explanation of the scientific concepts behind a modern digital computer.

V.T.V.M. POWER SUPPLY

9 **Lectrotech Inc.** is offering a new unit which can permanently replace the dry battery used in v.t.v.m.'s. Called "Lectrocell," the device is a miniaturized power supply of exactly the same size and shape as the battery it replaces. It can be installed in a few minutes and, once in place, furnishes the 1.5 volts of d.c. formerly supplied by the dry battery.

ANTENNA ROTOR CONTROL

10 **Cornell-Dubilier Electronics** is now offering a new antenna rotor control system, the TR-2C. Housed in an inconspicuous control box, the fin-

ger-touch control is designed for simple, effortless operation. By depressing the lever either to the left or right, the antenna is rotated and its position monitored by a series of compass lights.

NON-TOXIC SPRAY PRODUCTS

11 **Electronic Chemical Corporation** has announced that its "No-Noise" volume control and contact is now being manufactured in strict conformity with all federal, state, and municipal

laws and regulations. In addition, the new formula is guaranteed not to affect plastics.

The new line, according to the company, is unconditionally guaranteed to be non-flammable, non-toxic, safe for plastics, and to contain no carbon tet.

U.H.F. TRANSLATOR CONVERTERS

12 **Gavin Instruments, Inc.** has recently introduced two new nuvistor-powered u.h.f. converters designed especially for translator applications.

Designated Models GT-8 and GT-9, these sin-

gle- and double-stage converters cover channels 70 through 83 inclusive. Nuvistors and special low-noise diodes are employed.

The converters are housed in wood-grain front-panel enclosures with pilot-light channel selector.

SINE/SQUARE WAVE GENERATOR

13 **Waveforms, Inc.** is now marketing the Model 403C sine- and square-wave generator, a 2-in-1 instrument for servo, audio, and video measurements. Although designed primarily for laboratory and systems use, it is small enough to fit under a plane seat on troubleshooting assignments.

The instrument provides both sine and square waves in the 1 cps to 1 mc. range. Dial accuracy is ±3%. Symmetry of the square wave is maintained to within 1% at all frequencies.

Output is 10 volts into 600 ohms and 1 volt into 75 ohms. Voltages into both impedances are read directly on the front-panel controls. Attenuator control is precise down to 100 microvolts.

The instrument measures 8"x 6"x 10½" and weighs 12 pounds.

PISTOL-GRIP IRON

14 **General Electric's** Industrial Heating Department has developed an all-new pistol-grip soldering iron for light to medium production work in electronics, communications, and allied industries.

A threaded shank allows the new iron to accommodate a choice of three 60-watt integral tip and heater assemblies, or 40- or 60-watt heaters which will accommodate 20 different interchangeable ironclad or copper screw-on tips. An electrical "sliding contact" in the shank allows the working face of any tip to be turned to the desired position, eliminating the hazards of cord or wire twisting inside the handle. The unit is equipped with a three-conductor cordset and standard ground plug for added safety.

HAND RIVETER

15 **Brookfield Associates** is marketing the new "Rivet-All" riveter, a hand-operated device that will join metal to metal, plastic to wood, fabric to fabric, eliminating screws, bolts, adhesives, and soldering irons in the repair of a wide variety of products.

The riveter resembles a pair of pliers and operates on much the same principle. One squeeze of the handles sets the rivet and clinches it permanently for a vibration-proof fastening.

Offered in kit form, this tool (made by **Marson Corp.**) comes with an assortment of the most-often-needed rivets.

PRECISION FILM RESISTORS

16 **International Resistance Company** is now offering a new line of precision film resistors whose hermetic glass seals are the basis for improved stability and reliability.

The type GEM resistors, which have evaporated metal film elements, surpass characteristics C and E of MIL-R-55182. Hermetically sealed glass enclosures provide long-term stability by shielding the element from drift-producing moisture.

Three sizes are available: 1/10, 1/8, and 1/4 watts at 125 degrees C. Resistance values start at 50 ohms and range up to 100,000, 499,000, and 1 megohm in the various wattages. Standard tolerance is ±1%.

NEW POWER MODULES

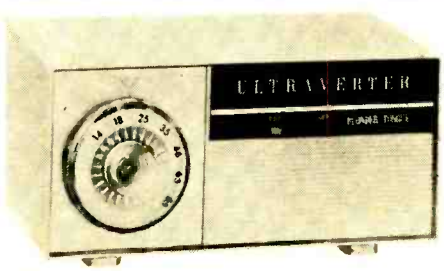
17 **Kepco, Inc.** has developed six high-power modules that incorporate the firm's "Flux-o-Tran" line-regulating transformers to provide a wide range of fixed voltages. The unit delivers a regulated square wave to a silicon rectifier and capacitive filter with maximum component utilization.

The new PRM group is being offered with outputs of 6, 12, 24, 28, 36, and 48 volts at maximum current ranging from 4 amperes at 48 volts to 25 amperes at 6 volts.

SOLID-STATE U.H.F. CONVERTERS

18 **Blonder-Tongue Laboratories, Inc.** is now offering three new versions of its u.h.f. converters based on the latest advances in solid-state circuitry and tunnel diode design.

The BTX-99 is designed for good signal areas; the BTX-11 is a converter/amplifier which yields



a three- to five-fold increase in signal; while the Model BTD-44 is a tunnel-diode unit which operates from a single flashlight battery and is cordless.

All of the units are housed in modern, inconspicuous cabinets which can fit into most home settings.

STAKED ROTARY SWITCHES

19 **Oak Manufacturing Co.** has developed a new line of staked rotary switches which are designed for a wide range of commercial applications. These multi-section, 1½-inch diameter switches reduce costs by eliminating strut screws, lockwashers, nuts, and complicated hand assembly. Three types are currently available, all with optional spring-return feature.

Type J switches are available in up to four sections, with each section ranging from six poles, two positions to s.p. 11-positions. Type K is available in up to three sections, each having the switching capabilities identical to Type J sections. Type N is available with up to four sections, each ranging from 4-pole 2-position to s.p. 11-positions. Contacts are double-wiping and self-cleaning.

LOG-PERIODIC U.H.F. ANTENNA

20 **JFD Research & Development Laboratories** is now in production on the "Zig-a-Log" antenna which is designed for u.h.f. channels 14 to 83. The antenna is a 16.5 ±½ db, horizontally polarized, back-fire surface-wave antenna. It is designed to have maximum usable gain for weak signal areas and minimal side lobes for best ghost rejection.

Input impedance is designed to match a 300-ohm transmission line by adjusting the spacing between the two lightning-shaped elements. The v.s.w.r. remains less than 1.8:1 across all u.h.f. channels.

The new antennas are currently available in single- and two-bay versions.

LARGE PHOTOSENSITIVE PANELS

21 **Metalphoto Corporation** has announced the availability of new larger sizes of its photosensitive anodized aluminum plates and sheets for use in preparing a wide variety of instrument and equipment panels.

Available sizes now include thicknesses ranging from .003 foil through 1/8-inch plate and sheet sizes from 4"x 5" through 24"x 40".

According to the manufacturer, anything that can be photographed can be reproduced on the panels. The imbedded photographic image is protected by a sapphire-hard surface which makes it impervious to corrosive atmospheres, weathering, fungi, solvents, or lubricants.

NEW A.C. RELAY DESIGN

22 **Allied Control Company, Inc.** has developed a new a.c. relay, the type T-255, a 4-pole, d.t. design. This telephone-type relay has a polycarbonate snap-on cover and plug-in base. The mounting design is completely compatible with the firm's d.c. type T-154, introduced earlier this year.

The gold-plated contacts have a rating of 2 amperes and are actuated by a very low coil current. Contact arrangements are available up to 4-pole d.t. A unique split armature contributes to a hum-free a.c. motor section. Coils are available up to 220 volts a.c.

CIRCUIT-BREAKER KIT

23 **Colman Electronic Products Inc.** has announced the availability of a compact kit of circuit breakers containing ten breakers of five different types which are said to meet over 97% of all replacement needs in television receivers.

A cross-reference replacement guide is printed inside the cover of the box. It includes 89 different part numbers that can be replaced by units from the kit.

50-WATT INVERTER

24 **Merit Coil & Transformer Corp.** has developed a transistorized 40- to 50-watt inverter which is designed to operate from any standard 12.6-volt storage battery of the type found in cars, boats, and planes.

With an input of 12.6 volts d.c., the output is 115 volts a.c. The load can be 40 watts for continuous duty and 50 watts for intermittent duty. The INV-12-40 is fully transistorized and uses two replaceable 2N234A power transistors.

The unit, which is supplied with a 3-foot cord and plug for insertion into a cigarette lighter receptacle, measures 4¾"x2⅝"x2¼" and is housed in a rugged steel case.

HI-FI—AUDIO PRODUCTS

CARTRIDGE TAPE RECORDER

25 **Channel Master Corp.** is marketing a new 32-ounce, transistorized miniature tape recorder that features a double-decker tape cartridge for instant loading.

The new cartridge design of the "Lodestar" is

intended to eliminate tape threading. Reloading takes just two seconds. The unit itself measures only 6½" x 3½" x 1⅜". All controls are at the top of the unit for easy access and simple operation. A four-purpose knob controls all four operating functions: record, rewind, stop, and playback. Another control, an indicator meter, indicates correct recording volume level and, in conjunction with the speed regulator, assures constant tape speed even when batteries age.

The instrument operates from four penlight cells and is designed primarily for the voice frequencies. Two-track recording provides 16 minutes of playing time on each side for a total of 32 minutes per cartridge.

IMPROVED STEREO PHONES

26 E. J. Sharpe Instruments, Inc. has announced a new and improved version of its HA-8 stereo headphones.

Among the improvements incorporated in the new models are an extended frequency response (20 to 15,000 cps), the use of vinyl foam-filled circumaural ear cushions; an improved dual-slide headband, and the addition of a zippered removable vinyl foam-filled headband cushion.

The maximum input power is 2 watts and impedance is 8 ohms per phone.

FM-STEREO TUNER/AMP

27 Sherwood Electronic Laboratories, Inc. has added an 80-watt FM-stereo tuner/amplifier to its line of hi-fi equipment.

The Model S-8000IV features a powered center-speaker channel, a front-panel stereo headphone jack, and front-panel speaker disabling switch. The tuner/amplifier has a 1.8 μv. (IHF) sensitivity for receiving low-power FM stations. A 2.4-db capture effect eliminates stereo broadcast background noise while special FM interchannel hush circuits suppress between-station noise when tuning.

PROFESSIONAL TAPE RECORDER

28 Midwestern Instrument, Inc. is now marketing the Model 1022 magnetic tape recorder, a professional-type unit for recording studio and radio station applications.

Differential band brakes are equipped with both high- and low-tension springs to provide gentle and smooth tape handling. Other features include solenoid operation of the tape gate, pressure roller, and brakes. A rugged belt-driven capstan, utilizing a double flywheel arrangement, driven by hysteresis synchronous motor makes for low wow and flutter.

The electronics are completely solid-state for high reliability, low heat, and low power consumption. The record amplifiers, playback amplifiers, bias/erase oscillator, and power supply are of modular construction while the amplifier and bias oscillator are on printed wiring boards.

The Model 1022 will handle reel sizes up to 8 inches and operates at 7½ and 15 ips.

SPEAKER/TABLE LAMP UNIT

29 Acoustica Associates, Inc. is now offering a high-fidelity speaker which radiates sound from the lampshade and base of a normal-looking table lamp.

Called the "Omnisonic Lamp-Speaker," the unit consists of a cylindrical electrostatic loudspeaker in the form of a translucent lampshade and a special woofer in the lamp base. The electrostatic speaker, including the fabric shade cover, is less than ¼ inch thick. Frequency range is said to be from below 40 cps to over 25,000 cps.

The lamps are offered in variety of decorator designs to fit various home decorating schemes. Although designed to be energized by the company's all-transistor FM-AM/FM-stereo receiver/amplifier, the new speaker system may be used with most quality hi-fi systems.

REPLACEMENT CARTRIDGES

30 Sonotone Corporation is now offering three new stereo ceramic cartridges designed especially for replacement applications.

The Models 21TR, 22T, and 23T provide new safety features to protect records and needles. The 21TR is designed around a retractable mounting bracket while the 22T and 23T offer snap-in mounting brackets. Replacement can be done in a matter of minutes without using tools. All of the cartridges are equipped with the company's "Sono-Flex" flexible needles and protective "bottoming" buttons. These buttons act as bumpers between the needle assembly and the record. When pressure is applied to the tonearm, the buttons ride across the record instead of the needle. These buttons will not harm the record surface.

FM ANTENNA BOOSTER

31 Winegard Company has developed a compact FM amplifier that is said to provide eight times more FM signal power for improved FM reception.

Known as the "FM Supercharger," the new unit is designed to cut down background noise and bring in more FM stations on stereo or mono units in suburban, fringe, and even deep-fringe areas.

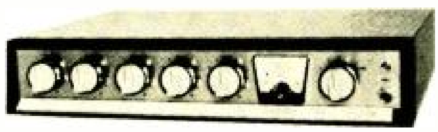
The booster uses a 2N2495 transistor to provide a minimum gain of +17 db. Bandpass is 88-108 mc. and response is flat ±½ db.; v.s.w.r. input is 1.2:1 and output 1.25:1. Both input and output impedances are 300 ohms.

The unit is a.c. operated, 117 volts at 60 cps. It draws 2.1 watts.

MIKE MIXER-AMPLIFIER

32 TRW Columbus Division has added a new four-channel all transistorized microphone mixer-amplifier to its "Bell Sound" line of p.a. equipment. Designated the BE-M4, the new unit is designed to work with any existing p.a. amplifier or booster amplifier to extend the input capability of the system.

The instrument includes individual inputs and gain controls for four low-impedance microphones and an external phono unit. A vu meter is included as well as headphone jacks so program level may be monitored both aurally and visually.



Response is 20 to 20,000 cps ±2 db. The unit requires only 5 watts a.c. for operation. It measures 3" x 10" x 15" and is styled to be compatible with other of the firm's BE-series amplifiers.

HIGH-POWER P.A. SPEAKER

33 Atlas Sound has upped the continuous power rating of its Model CJ-44 "Cobra-Jector" reproducer to 40 watts (60 watts equalized response).

An improvement in diaphragm design and magnetic circuitry has made this power increase possible. The unit is an all-purpose, wide-angle projector complete with super-power driver. The horn is of all-weather fiberglass construction. Impedance is 16 ohms and response is 115 to 12,000 cps.

The bell opening is 23"x 13" and over-all length is 19".

SENSING/EXPANDER MODULE

34 Harman-Kardon Incorporated is now offering a "sensing/expander" module for use with its "Galaxy" series of commercial-industrial amplifiers.

The Model M-8 module incorporates a special expander section which, when operating with a "sensing" microphone, automatically adjusts the sound output level of the entire sound system in proportion to a rise or fall in ambient noise.

The M-8 serves to monitor the environment and imposes its intelligence on the system, making the necessary adjustments as required. It is especially suited to installations at racetracks, airports, factories in heavy industry, and arenas.

AUTOMATIC FM-STEREO TUNER

35 Kenwood Electronics, Inc. has recently added a new automatic FM-stereo tuner, the Model KW-550, to its line of hi-fi equipment. The new unit features an exclusive FM-stereo instant indi-

cator. The front-panel design incorporates a red light which automatically changes to blue when receiving an FM-stereo broadcast.

Frequency response is 20-28,000 cps ±½ db on FM and 50-15,000 cps ±½ db on FM-stereo. Sensitivity is 1.6 μv. (IHF) for 20 db quieting. Stereo separation is 36 db.

The unit also features automatic relay switching to proper mode and automatically indicates FM-stereo or mono operation.

STEREO TONE SIGNAL UNIT

36 Lafayette Radio Electronics Corporation is now offering a low-cost stereo tone signal unit for use with FM tuners utilizing external multiplex adapters.

Known as the LT-87 "Stereo Searcher," the unit is designed to be connected between the adapter and tuner to provide an audible tone signal through the speaker system for instant identification of an FM-stereo broadcast. A single switch controls the tone function.

The unit, which is housed in a slim cabinet measuring 2 11/16" x 3" x 9½", employs one 6BE6 tube and one diode.

ACOUSTIC MATERIAL

37 Hartley Products Company is now offering its "Soundsorber" acoustic material for those who build their own speaker enclosures or wish to improve the performance of existing units.

"Soundsorber" is a combination of two acoustic materials of varying densities, interleaved in a jellyroll pattern. Sound from the rear of the speaker penetrates the more open material, which has a low absorbency factor, and is then almost completely absorbed by the other material which is highly absorbent. The two materials act together to effectively damp the rear sound wave by reducing its output 65 db.

The material is standard in all of the firm's speaker systems. A module contains approximately 35 square feet of acoustic materials which is sufficient to treat an enclosure up to 3 cubic feet in volume.

24-HOUR RECORDER

38 Concord Electronics Corporation is now marketing the Model 440 stereo tape recorder which allows up to 24 hours of recording time on a single 3600-foot reel of tape at 1⅞ ips. In addition, the recorder features full push-button operation, transistorized preamps, three speeds, sound-with-sound, separate mixing inputs, automatic pressure-roller disengagement, two dynamic mikes, cue and edit buttons, and a digital tape counter.

Two 6" speakers, one separated from the unit, are used, with added speaker output available.

CB-HAM-COMMUNICATIONS

TONE CONTROL FOR CB

39 Webster Manufacturing is now offering a "flat pack" selective-calling tone control for CB transceivers. The 545 "Trans-Pager" is especially designed to plug directly into the firm's "Band-Spanner 412" which is pre-wired to accept it. The accessory can also be connected to most two-way radio transmitters and receivers.

Employing a high-precision reed relay, the unit provides signal control to within ±0.1%. All circuitry is solid-state for low current drain and minimum size.

The unit sends out one of twelve coded tones. This tone actuates a receiver tuned to the same frequency and puts it into full operation or flashes a lamp on the panel of the unit.

The "Trans-Pager" operates from either 12-volt d.c. automotive circuits or 117-volt a.c. lines.

ACCESSORY UNIT

40 Raytheon Company is now marketing a "silent sentry" attachment for two-way radios which causes the transceiver to which it is attached to remain silent until a message for the unit is received.

The encoder-decoder generates a tone of a special frequency on transmit. On receive, another unit listens for the tone and permits only the preset frequency to pass. This signal will either flash a light or actuate the loudspeaker in the set.

The "Ray-Call" is fully transistorized and measures only 1¾"x 5⅞"x 7". It can operate from an automobile or boat 12-volt battery or from 117-volt a.c.

ALERTING/MONITOR RECEIVERS

41 Eltec Laboratories, Inc. has developed the Models TX 30 and TX 150 FM communications tone voice alerting and/or monitor receivers. These compact units, 4" high by 7" deep by 11" wide, are completely transistorized and crystal controlled. They operate from all power sources. Frequency range is 25-54 mc. or 144-174 mc. Both feature powerful audio output, modular

construction, dual conversion superhet, 15 transistors for tone alerting sensitivity and 17 transistors for monitoring for a sensitivity of less than 1 μv. for 20 db quieting.

These new units have been designed especially for fire departments, Civil Defense, or commercial applications.

23-CHANNEL CB UNIT

42 Multi-Elmac Company has added the Model SS "Citi-Fone" to its line of CB equipment.

The new unit features full 23-channel, crystal-controlled operation, delta tuning, triple-tuned

r.f., "noise immune" squelch, noise limiter, illuminated channel selector and dual-function panel meter, a.c.-d.c. power supply, and "Tone Guard" connector.

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The unit comes complete with all crystals, a.c. and d.c. power cords, mounting bracket, and microphone.

PORTABLE TWO-WAY RADIO

43 **General Electric Company** has recently introduced a new type of communications device, the "Porta-Mobil"—a two-way radio which can operate as a plug-in mobile radio in a car, as an office base station, and as an expanded-range portable of hand-carried design.

The new equipment has up to 18 watts of transmit power in the 25-50 mc. band and up to 10 watts in the 132-174 mc. band. Engineered with all-solid-state circuits, it uses silicon transistors in

all transmitter and receiver circuits. The entire design has been compressed into 365 cubic inches and measures 11"x 3⅝"x 9⅛". It weighs just 13 pounds.

SELECTIVE CALLER

44 **Lafayette Radio Electronics Corporation** is now marketing a selective caller, the Model HA-200 "Priva-Com."

The unit is a dual-tone signaling device which minimizes the possibility of hearing unwanted signals. The tone sounds and the signal light goes on. The receiver is then automatically activated. The light stays on until manually reset. The car horn or other external alarm can be actuated when the vehicle is unattended. Each of the "Priva-Coms" can transmit 10 different combinations of dual-tone frequencies for even greater privacy.

The front panel has a lever switch with standby, normal, and call positions; a volume control; speaker/horn switch; and indicating light. The unit comes complete with bracket for mounting. It measures 3⅝"x $3\frac{5}{16}$"x 5¼". It is not recommended for transceivers with carbon mikes less preamplifiers.

HEAVY-DUTY RADIOTELEPHONE

45 **Bendix Marine** has developed a heavy-duty 170-watt radiotelephone especially for commercial and fishing fleets. Designated the Model 7150, the all-vacuum-tube, 8-channel unit has a basic frequency range of 1.6 to 9 mc. In addition, it has a tunable broadcast band.

The unit features automatic noise limiting, squelch, high-low receiver sensitivity switch, and a multi-function meter. It is available for operation from 12-, 24-, 32-, or 110-volt d.c. and 117-volt a.c.

CB BASE-STATION MIKE

46 **The Turner Company** is now offering a 600-ohm base-station CB microphone especially designed for use with transistorized transceivers.

The Model 254D has a seven-foot cable and comes with a 91-MPM5L plug attached. Frequency response is 300-6000 cps. It is especially recommended for use with the **Cadre** and **E. F. Johnson** "Messenger III" units.

CB RADIOTELEPHONE

47 **Kaar Engineering** is now offering two CB radiotelephones which carry a two-year guarantee.

The D-333 is a fixed tuned unit with eight crystal-controlled channels. The D-333B provides eight crystal channels, external crystal socket, and a tunable receiver. A three-stage noise limiter provides optimum performance under extreme

noise conditions. Both models have a number of optional provisions including tone squelch, remote control paging, and transistor supply.

CB TRANSCEIVER

48 **Hallmark Instruments** has added a compact new CB transceiver to its line of transceivers and testers. The Model 1250 utilizes hand-wired construction in a modular chassis.

Sensitivity is better than 0.3 μv. for 10 db (S+N)/N ratio. Adjacent channel rejection is in excess of 30 db. A new ferrite speaker gives an audio output greater than 4 db over conventional speakers while a new silicon rectifier full-wave bridge provides the power for maximum output and modulation.

This 12-channel, crystal-controlled dual-powered unit is housed in a cabinet measuring 4"x 6¼"x 10". It operates from 117 volts a.c. or 12 volts d.c.

CERAMIC MIKE

49 **GC Electronics Company** is now marketing an all-purpose ceramic microphone, No. 30-902. The mike may be hand-held or permanently placed on desk or table top. The unit has its own built-in stand which folds flush into the back of the unit. It is equipped with a six-foot cable terminated with an **RCA**-type pin plug.

Made of durable gray plastic, the unit is specially suited for use with CB transceivers, p.a., and paging systems.

RUGGED CB MICROPHONE

50 **Robins Industries Corp.** is now offering a ruggedized microphone for CB and communications applications as the Model MK-30.

Frequency response is essentially flat from 60 to 7000 cps at −49 db. Features include a push-to-talk switch, high-impact shatter-proof housing, strong strain relief to protect internal connections of the mike, 6-foot multiple-conductor shielded coil-cable with tinned ends, and dashboard mounting bracket for easy installation in autos and boats.

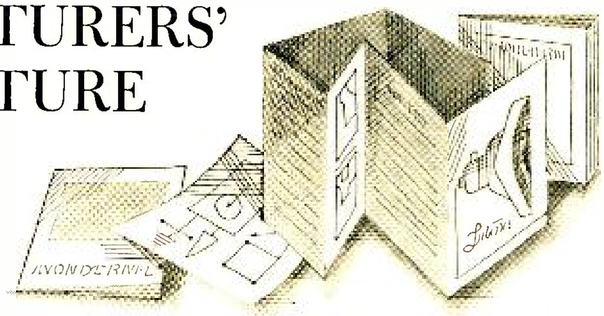
INDUSTRIAL TWO-WAY RADIO

51 **Motorola Inc.'s Communications Division** is now offering a high-power, fully transistorized mobile two-way FM radio designed for commercial and industrial applications.

Known as the "Motran" radio, the new unit operates on standard v.h.f. frequencies in the 25 to 50 mc. low band and 136 to 174 mc. high band. Thirty and 50-watt models are available for low-band operation and 25- and 30-watt units for high band.

Complete elimination of tubes and relays, new internal circuit designs, and low transmitter power requirements combine to increase reliability of communications. Since the maximum power needed to operate the transistorized transmitter is only 26 volts, a highly simplified power supply has been developed. ▲

MANUFACTURERS' LITERATURE



LOW-CURRENT SR STACKS

57 **Tung-Sol Electric Inc.** has published a 12-page catalogue covering new modular assemblies for low-current silicon rectifier stacks. Detailed specifications are given on single-phase center-tap assemblies; single-phase bridge assemblies; and three-phase bridge assemblies in the current range from 3 to 75 amperes.

The catalogue shows a photograph of a typical single-phase bridge modular assembly and includes six outline drawings giving mechanical dimensions for each type of modular assembly. A graph is included for each family of stacks which shows output current as a function of ambient temperature.

CAPACITOR MIL SPECS

58 **Cornell-Dubilier Electronics** has now published a pocket guide to military specifications for fixed capacitors. Formerly published as one of the company's series of two-color application-guide wall charts, the new format is designed for easy portability.

All current military specifications, in detail, are conveniently displayed, with MIL styles, temperature range, capacitance, and capacitance tolerance defined.

NEW PICTURE TUBE CONSTRUCTION

59 **Pittsburgh Plate Glass Company** has issued an illustrated 8-page two-color brochure describing its laminated tube system, "Telebond."

The new system features a specially developed chemically etched "Teleglas" face that is said to provide a non-glare viewing surface with greatly improved color fidelity, brightness, and picture contrast.

SHORT-FORM CATALOGUE

60 **International Rectifier Corporation** has issued a 1964 semiconductor short-form catalogue which lists nearly 4000 semiconductor devices with applicable specifications.

The listings are in numerical sequence for rapid, easy reference and include over 1000 of the company's JEDEC types. Ratings, characteristics, and descriptive data are covered in condensed, tabular form and include cross reference to device classification and page number.

CB MICROPHONE BROCHURE

61 **The Turner Microphone Company** is offering copies of its Bulletin 1021 which covers the firm's complete line of microphones for Citizens Band applications.

CONDENSED SEMICONDUCTOR DATA

62 **Amperex Electronic Corporation** has announced publication of a new condensed semiconductor catalogue, a 48-page booklet containing new material of interest to engineers as well as basic specifications on a full line of transistors, diodes, and photosensitive devices.

The catalogue is illustrated throughout with photographs and drawings.

PRODUCT GUIDE

63 **The Superior Electric Company** has issued a compact 12-page product guide which covers the firm's line of variable transformers, variable voltage controls, power supplies, synchronous motors, indexers and translators, electrical connectors, and binding posts.

The units are illustrated and specs listed in tabular form for easy selection.

INSTRUMENTATION TAPE

64 **Ampex Corporation** is now offering a 12-page bulletin on magnetic tape for instrumentation recording. Information on tape selection, tape characteristics, and accessories is included along with a brief history of the tape.

A chart lists the types of instrumentation tapes available and their applications.

TIME DOMAIN REFLECTOMETRY

65 **Hewlett-Packard Company** has published a 24-page Application Note on "Time Domain Reflectometry," a new technique which isolates and identifies the character of transmission line disturbances. Using a fast step generator and scope in a "closed-loop radar" arrangement, TDR's echo technique shows at a glance the impedance of each segment of the line, separates junctions, locates and identifies resistive, inductive, and capacitive discontinuities, and shows if they are series or shunt.

The publication has been designated "Application Note No. 62."

SILICON POWER TRANSISTORS

66 **Silicon Transistor Corporation** has issued a 12-page catalogue covering its line of silicon power transistors and SCR's.

The book lists the units by power ratings, military types, "p-n-p," and industrial "n-p-n" types. For quick reference, the table of contents lists, in numerical sequence, all transistor types made by the company with their reference page number. Case types and dimensional diagrams are also included.

H.V. SELENIUM RECTIFIERS

67 **Electronic Devices, Inc.** has issued a four-page catalogue sheet which describes its entire line of high-voltage selenium cartridges. Catalogue SE-1004 provides an easy reference for designers to select peak inverse voltage, length, and current rating. Cartridges up to 25,000-volt peak inverse rating and up to 60-ma. forward current are available in the line.

PILOT-LIGHT DATA

68 **Industrial Devices, Inc.** has released a new short-form catalogue containing illustrations and a concise description of a wide variety of neon pilot lights and electro-mechanical products.

Among the items covered are pilot lights, legend displays, clips and cords, bar knobs, rotary instrument switches, capacitor bases, test lights, and test meters. The catalogue is designated Form SFA-164.

THIN-FILM CIRCUITS

69 **Sprague Electric Co.** has issued a portfolio of data sheets covering its "Ceracircuit" linear and non-linear thin-film integrated circuits.

In addition to an 8-page technical paper on "A General-Purpose Ceramic-Base Thin-Film Microcircuit Amplifier," there are individual data sheets on wide-band amplifiers, phase splitters, audio amplifiers, limiting amplifiers, transmission-line drivers, and pulse amplifiers. Each of the circuits is illustrated and technical specifications and interconnection data provided.

CERAMIC CAPACITOR DATA

70 **Hi-Q Division of Aerovox Corporation** has published a new 40-page catalogue on ceramic capacitors for industrial and "Hi-Rel" applications.

Described with full specifications are disc, transistor, plate, tubular, feedthrough, and stand-off capacitors as well as the firm's "Hi-Q," "Cerafil," "Cerol," and "Ceralam" units. Thin plate, microelement, high-voltage cartwheel, and high-power capacitors are also covered.

SWEEP/SIGNAL GENERATORS

71 **Telonic Industries, Inc.'s** new 32-page catalogue provides detailed descriptions and specifications on an extensive line of sweep/signal generators and accessory equipment.

The catalogue also includes information on sweep measurement techniques and a general treatment of sweep generator operation. Each of the firm's 30 models is presented with complete specifications, block diagrams, and scope patterns to illustrate performance.

STEREO RECORDER DATA

72 **Freeman Electronics Corporation** has published a single-page data sheet detailing specifications and features of its Model 800 stereo tape recorder.

Features are spelled out in concise form while specifications and operational details are covered completely. Optional accessories for this particular model are also pictured and described in the data sheet.

TUBE & TUBE EQUIPMENT

73 **Litton Industries' Electron Tube Division** has issued a new 36-page, illustrated 1964 "Product Summary" which lists the majority of unclassified microwave tubes, display devices, and tube-related equipment designed and manufactured by the firm.

These include pulse and c.w. magnetrons, cross-field amplifiers, M-type backward wave oscillators, pulse and c.w. klystrons, electrostatically

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focused klystrons, millimeter wave tubes, traveling wave tubes, beam switching tubes, CRT's, fiber optic tubes, and related equipment.

WIRE/CABLE TERMINOLOGY

74 **Royal Electric Corporation** has issued a 12-page booklet containing a glossary of commonly used abbreviations for wire, cable, and portable cords. This listing of standardized terminology is offered as a service to the industry.

TRANSPORT DATA PROCESSING

75 **Honeywell Electronic Data Processing** has compiled two 8-page brochures on the use of its 200 data processing system and a PERT chart for computer installation planning in the transportation industry.

The publications outline revenue accounting and operations control applications for motor transport companies.

DECADE COUNTER BULLETIN

76 **Janus Control Corp.** has announced distribution of a new technical bulletin which describes a 2-megacycle all-silicon decade counter. The publication provides complete specifications and operational data on the Model B100-1 high-speed decade counter. It also contains three operational characteristic diagrams, a functional block diagram, and a detailed dimensional drawing.

TRANSISTORIZED POWER SUPPLY

77 **Perkin Electronics Corporation** has published a technical data sheet illustrating and describing in detail the firm's Model TVR 28-200 silicon controlled rectifier/transistor series-regulated power supply with output of 22-32 volts d.c. at 200 amperes.

The data sheet includes a description of the unit, its features, detailed specifications, dimensional information, price, and a photograph of the unit.

TUBULAR CAPACITORS

78 **Aerovox Corporation** is now supplying copies of a new technical bulletin which provides data on the film's Type DBE dipped Mylar-paper bypass tubular capacitors.

Specifications given include operating temperature, range, power factor, insulation resistance, dielectric strength, humidity characteristics, wire sizes, and standard and special tolerances. Almost 60 types are listed.

CB ANTENNAS & ACCESSORIES

79 **New-Tronics Corporation** has announced publication of Bulletins NT-100 and CE-203 which cover several models of CB mobile and base-station antennas. Also included are various accessories designed for Citizens Band use.

PRODUCT CATALOGUES

Sylvania Electric Products Inc., 1100 Main Street, Buffalo, New York 14209 has announced the availability of four new publications covering industrial/military CRT's, receiving tubes, semiconductors, and microwave devices.

All of the catalogues have been completely revised and up-dated to reflect the latest designs and products. The CRT brochure is order number ET-3914 at 14 cents a copy; the receiving tube characteristics publication is ET-1350 at 20 cents a copy; the semiconductor catalogue is designated SM-3905 at 20 cents a copy; and the microwave devices booklet is ET-3913 at 20 cents a copy.

Payment must accompany all orders which should be sent direct to the company at the above address. ▲

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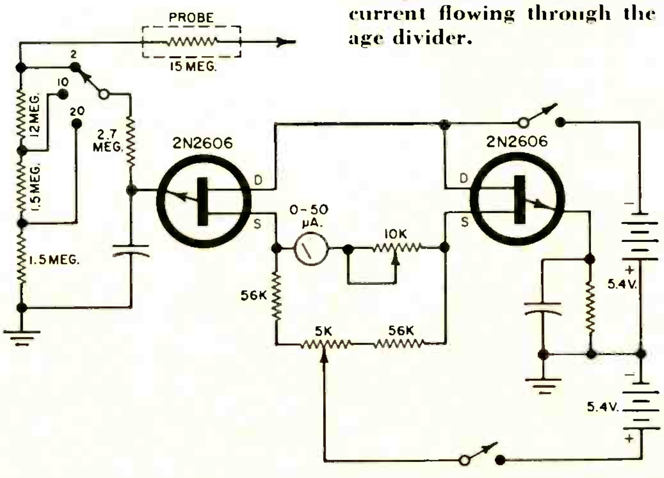
BECAUSE of increasing availability of field-effect transistors, many circuits taking advantage of the uni-polar field-effect transistor's low noise and pentode vacuum-tube-like characteristics are appearing.

To demonstrate the compactness of a field-effect transistor circuit, engineers at Siliconix built a three-range voltmeter on the rear side of a conventional Simpson 4½" rectangular meter (50 μa. d.c.). Having an input resistance of 30 megohms, the circuit has three switchable scales for 2, 10, and 20 volts.

The circuit is shown in the schematic. The number of voltage ranges and the value of input resistance were selected for a particular application. The input resistance could be increased but consideration must be given to the error voltage that will be generated by any gate current flowing through the range voltage divider. ▲



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The result: the HiFi/STEREO REVIEW Model 211 Stereo Test Record!

Stereo Checks That Can Be Made With the Model 211

- ✓ **Frequency response**—a direct check of eighteen sections of the frequency spectrum, from 20 to 20,000 cps.
- ✓ **Pickup tracking**—the most sensitive tests ever available on disc for checking cartridge, stylus, and tone arm.
- ✓ **Hum and rumble**—foolproof tests that help you evaluate the actual audible levels of rumble and hum in your system.
- ✓ **Flutter**—a test to check whether your turntable's flutter is low, moderate, or high.
- ✓ **Channel balance**—two white-noise signals that allow you to match your system's stereo channels for level and tonal characteristics.
- ✓ **Separation**—an ingenious means of checking the stereo separation at seven different parts of the musical spectrum—from mid-bass to high treble.

ALSO: ✓ Stereo Spread / Speaker Phasing / Channel Identification

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UNIQUE FEATURES OF HiFi/STEREO REVIEW'S MODEL 211 STEREO TEST RECORD

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  Warble tones used are recorded to the same level within ± 1 db from 40 to 20,000 cps, and within ± 3 db to 20 cps. For the first time you can measure the frequency response of a system without an anechoic chamber. The frequency limits of each warble are within 5% accuracy.
- White-noise signals to allow the stereo channels to be matched in level and in tonal characteristics.
- Four specially designed tests to check distortion in stereo cartridges.
- Open-air recording of moving snare drums to minimize reverberation when checking stereo spread.

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HiFi/STEREO REVIEW's Model 211 Stereo Test Record will give you immediate answers to all of the questions you have about your stereo system. It's the **most complete test record** of its kind—contains the widest range of check-points ever included on **one** test disc! And you need no expensive test equipment. **All checks can be made by ear!**

Note to professionals: The Model 211 can be used as a highly efficient design and measurement tool. Recorded levels, frequencies, etc. have been controlled to very close tolerances—affording accurate numerical evaluation when used with test instruments.

DON'T MISS OUT—ORDER NOW

The Model 211 Stereo Test Record is a disc that has set the new standard for stereo test recording. There is an overwhelming demand for this record and orders will be filled by ELECTRONICS WORLD on a first come, first served basis. At the low price of $4.98, this is a value you won't want to miss. Make sure you fill in and mail the coupon together with your check ($4.98 per record) today.

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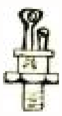

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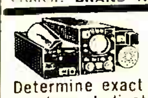

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FINE QUALITY NAVIGATIONAL EQUIPMENT

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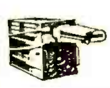

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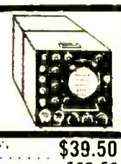
APN-12 3-INCH SCOPE



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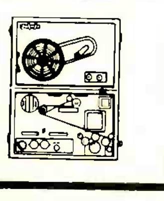

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Set of 15 Reels, Army Code Practice Lessons. BRAND NEW, original packing .... P.U.R.

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TN-16, TN-17, TN-18, TN-19 and TN-54 Tuning Units for above in stock. . P.U.R.

SCR-522 2-METER TRANSMITTER-RECEIVER

Terrific buy! VHF Transmitter-Receiver, 100-156 Mc. 4 channels. Xtal-controlled. Amplitude modulated voice. Complete with all 18 tubes, top rack and metal case. LIKE NEW!
SPECIALLY PRICED .... P.U.R.
SCR522 as above, exc. used $32.50

AN/ART-13 100-WATT XMTR

11 CHANNELS
200-1500 Kc
2 to 18.1 Mc

$79.50 EXC. USED
complete with Tubes

Famous Collins Autotune Aircraft Transmitter. AM CW, MCW. Quick change to any of ten preset channels or manual tuning. Speech amplifier/clipper uses carbon or magnetic mike. Highly stable, highly accurate VFO. Built in Xtal controlled calibrator. PP811s modulate 813 in final up to 90% class "B." A Real "HOT" Ham buy at our low price!
AN/ART-13 XMTR. as above, in LIKE NEW condition, with all tubes and crystal $89.50

0-16 Low Freq. Osc. Coil for ART-13 ...... 7.95
24V Dynamotor for ART-13 .... 11.95
We carry a complete line of spare parts for above.

SCR-274 COMMAND EQUIPMENT

ALL COMPLETE WITH TUBES

Type	Description	Used	Like NEW
BC-453	Receiver 190-550 KC	$14.95	$18.95
BC-454	Receiver 3-6 MC	15.95	19.50
BC-455	Receiver 6-9 MC	13.95	19.50

BC946 Receiver 530-1500 Kc Complete with all tubes. Brand New, in original packing $44.95
1.5 to 3 MC. Receiver Brand New $17.95

110 Volt AC Power Supply Kit for all 274-N and ARC-5 Receivers. Complete with metal case, instructions $8.95
Factory wired, tested, ready to operate . $12.50
SPLINED TUNING KNOB for 274-N and ARC-5 RECEIVERS. Fits BC-453, BC-454 and others. Only 49¢

2.1 to 3 Mc Transmitter, Brand New $12.95
BC-457 TRANSMITTER—4-5.3 Mc. complete with all tubes and crystal, BRAND NEW $9.75
Like New $7.95
BC-458 TRANSMITTER—5.3 to 7 Mc. Complete with all tubes and crystal, BRAND NEW $10.95
Like New $7.95
BC-696 TRANSMITTER 3-4 Mc Complete with All Tubes & Crystal. Like New $11.95
BC-456 Modulator .... USED 3.45 NEW 5.95
ALL ACCESSORIES AVAILABLE FOR ABOVE

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SCHEMATIC DIAGRAMS For most equipment on this page, each 65¢

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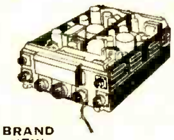
G & G RADIO SUPPLY CO.
Telephone: CO 7-4605
77 Leonard St. New York 13, N. Y.

FAMOUS BC-645 TRANSCEIVER

15 Tubes 435 to 500 MC



Can be modified for 2-way communication, voice or code, on ham band 420-450 mc. citizens radio 460-470 mc. fixed and mobile 450-460 mc. television experimental 470-500 mc. 15 tubes (tubes alone worth more than sale price!): 4—7F7, 4—7H7, 2—7E6, 2—6F6, 2—955 and 1—WE-316A. Now covers 460 to 490 mc. Brand new BC-645 with tubes, less power supply in factory carton. BRAND NEW
Shipping weight 25 lbs. SPECIAL! $19.50

PE-101C Dynamotor, 12/24V input $7.95
UHF Antenna Assembly 2.45
Complete Set of 10 Plugs 5.50
Control Box 2.25

SPECIAL "PACKAGE" OFFER:
BC-645 Transceiver, Dynamotor and all accessories above. COMPLETE, BRAND NEW. While Stocks Last $29.50

BC-344 RECEIVER. 150-1500 Kc., continuous tuning, 4-band, for 115 V 60 Cycle AC. Excellent used, perfect working order, complete with tubes. $79.50

BC-342 RECEIVER. 1.5 to 18 Mc. AC Only Like New, complete with all tubes $79.50

BC-348 SUPERHET RECEIVER 200 to 500 Kc and 1.5 to 1800 Mc. Voice Tone. CW. Self-contained dynamotor for 24 V DC. Exec. Used. Checked out $89.50
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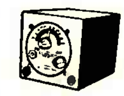
BC-683 FM RECEIVER, 27 to 38.9 Mc., Complete with all tubes, exc. used. Checked out, in working order $49.50

BC-603 FM RECEIVER, 35-50 Mc. Complete with all tubes, checked out. Like New $49.50
Original Tech. Manual for above .... $ 3.15
AC Power Supply for above, wired $12.95
12-Volt Mobile Dynamotor Power Supply, NEW .... $ 5.50

BC1206-C BEACON RECEIVER



195 to 420 Kc. made by Setchel - Carlson. Works on 24-28 volts DC. 135 Kc. IF. Complete with 5 tubes. Size 4" x 4" x 6". Wt. 4 lbs. LIKE NEW ... $9.95
USED, less tubes $4.95

234-258 MC RECEIVER AN/ARR-2

BRAND NEW 11-tube UHF Tunable Receiver with schematic. Only a few at this low price! Complete with tubes. Exc. used $5.95.... $8.88

ARB/CRV 46151 NAVY AIRCRAFT RADIO RECEIVER 190 to 9050 KC in 4 bands: 190-550, 550-1600, 3-6 Mc, 6-9.050 Mc, 6-tube super with local and remote tuning, band change. Complete with tubes and dynamotor, like new $39.50
As Above, brand new $59.50
Power Supply, 110 V AC wired .... $ 8.95

ARC-3 RECEIVER!

Complete with All tubes Exc. Used..... $21.50
Like NEW $33.50

Crystal-controlled 17-tube superhet, tunes from 100 to 156 MC., AM., on any 8 preselected channels. 28-volt DC power input. Tubes: 1-9002, 6-6AK5, 1-12SH7, 3-12SG7, 1-9001, 1-12H6, 2-12SN7, 1-12SL7, 1-12A6.
110 V A.C. Power Supply Kit for above 15.00
Factory Wired and Tested 19.95

ARC-3 TRANSMITTER

Companion unit for above tunes 100 to 156 MC on any 8 pre-selected channels. 9 tubes, crystal controlled, provides tone and voice modulation. 28V DC Power input. Complete with all Tubes: 3-6V6, 2-832A, 1-12SH7, 1-6J5, 2-6L6. Exc. Used .... Only $18.95
Like new condition $28.50
ARC-3 PUSHBUTTON CONTROL BOX $5.95

AN/ARN-7 RECEIVER

Frequency range 100 Kc to 1750 Kc in 4 bands. Aircraft navigational instrument comprising superhet receiver and additional circuits. Complete with tubes, exc. cond. $29.50
Accessories for above, available.

DYNAMOTOR VALUES:

Type	Input	Output	Excellent Used	BRAND NEW
DM-32A	28V 1.1A	250V .05A	2.45	4.45
DM-33A	28V 5A	575V .16A		
	28V 7A	540V .25A	4.45	7.50
DM-34D	12V 2A	220V .080A	4.15	5.50
DM-35	12V	625V .225A	—	19.50
DM-36	28V 1.4A	220V .080A	1.95	2.95
DM-43	28V 23A	925V .220A		
		460V .185A	—	7.95
DM-53A	28V 1.4A	220V .080A	3.75	5.45
PE-73C	28V 20A	1000V .350A	8.95	14.95
PE-86	28V 1.25A	250V .050A	2.75	3.85

DM-37 DYNAMOTOR. Input 25.5 V DC @ 9.2 A. Output 625 V DC @ 225 Ma. BRAND NEW. Each $3.25

MICROPHONES Checked Out, Perfect

Model	Description	EXC. USED	BRAND NEW
T-17	Carbon Hand Mike	$4.45	$7.95
RS-38	Navy Type Carbon Hand Mike	3.95	5.75

HEADPHONES Checked Out, Perfect

Model	Description	EXC. USED	BRAND NEW
HS-23	High Impedance	$2.79	$4.95
HS-33	Low Impedance	3.15	5.45
HS-30	Low Imp. (featherwt.)	.90	1.65
H-16/U	High Imp. (2 units)	3.75	7.95

TELEPHONICS—600 ohm Low Impedance HEADSETS. BRAND NEW. PER PAIR $3.95
CD-307A Cords, with PL55 plug and JK26 Jack .99
Earphone Cushions for above—pair .50

CIRCLE NO. 111 ON READER SERVICE PAGE

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BRAND New Tubes, World's lowest prices on Radio, TV-industrial-special purpose tubes. Write for free parts catalog. United Radio, Newark, N.J.

BEFORE you buy receiving tubes, test equipment, Hi-fi components, kits, parts, etc. . . . send for your giant free Zalytron current catalog, featuring Standard brand tubes; RCA, GE, etc.—all brand new premium quality individually boxed. One year guarantee—all at biggest discounts in America! We serve professional servicemen, hobbyists, experimenters, engineers, technicians. Why pay more? Zalytron Tube Corp., 469-W Jericho Turnpike, Mineola, N. Y.

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ELECTRONIC TUBES—Top Brands SOLD at substantial savings! (Minimum Order $15.00) Authorized GE Distributor. Send for FREE Buyers' Guide for all your Tube Requirements. TOP CASH PAID for your excess inventory (New ONLY—Commercial Quantities). Metropolitan Supply Corp., 443 Park Avenue South, New York, N.Y. 10016. 212-MU 6-2834.

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cover a full foot-and-a-half swath with one pass . . .

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Delivers as much paint per minute as a $200 industrial compressor model. HANDLES WATER SOLUBLE, RUBBER BASE, OIL BASE, FLAT, SEMI-GLOSS AND ENAMEL PAINTS. LIGHT OILS . . . INSECTICIDES . . . FLOOR WAXES, POLISHES AND OTHER LIQUIDS.

- No costly compressors
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- **FINGER-TIP CONTROL OF PAINT FLOW**—trigger lets you start and stop spraying instantly
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- For 115V AC operation
- Fully guaranteed
- **ALUMINUM DIE CAST HOUSING** for light weight and rugged durability
- **CAN'T EVER CLOG IN OPERATION** Powerful GE motor and rotary action spin the paint at a steady 17,000 RPM . . . actually makes the Sloan-Ashland Paint Gun impossible to clog in operation!
- Reduces misting and overspray to a minimum. Eliminates 90% of usual masking! No more need to cover everything in sight.

$59.95

AMAZINGLY EASY TO CLEAN OR CHANGE COLORS . . . Fill container with water or proper solvent, run gun for a minute or two. That's all there is to it! No mess, no bother!

FREE TWO QUARTS OF SPRED-SATIN PAINT

Covers 300% more width in each stroke than a 6" brush or roller . . .

Now you can do 100 Sq. ft. of surface in minutes—because you cover three times as much area on each stroke, with the Sloan-Ashland Rotary Paint Gun. You cover a full foot-and-a-half swath with perfect control. Big job or small . . . inside or outside . . . whether you're spraying paint or other fluids—nothing does the work as quickly, as easily as this amazing paint gun!

Typical Oval Pattern of Ordinary Spray Gun.

Oval spray and wide feathering around edges make precise work difficult, requires extensive masking.

"Straight Line" Pattern of Sloan-Ashland Paint Gun.

Straight line spray and minimum of feathering gives you perfect control for the most precise painting.

American Products Division, 589 Broadway, New York 12, N.Y.

Send me your new Sloan-Ashland Rotary Paint Gun. I may use it for seven days free, and return it at your expense if I am not fully satisfied.

Also—send me two free quarts of Spred Satin Paint (worth $4.30) which I may keep and use whether or not I agree to buy the Sloan-Ashland Rotary Paint Gun.

If I do agree to keep it, I will pay only $8.50 a month until I've paid the low price of just $59.95 (plus shipping and handling).

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Paper Tape: 3/8" 900 Ft Roll: 25¢—30 f/$3—60 f/$5		
Telegraph Repeater WE-61824A	New:	39.50
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TG-31 Telegraph Repeater	New:	16.95
PE-250 Telephone Ringer	Re-New:	7.95
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BD-71 Switchboard—6 line	Used:	9.95
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RS-38 Microphone Button only	New:	1.50
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TS-13 Butterfly Switch w/PL-55/PL-68—Used: $4.95	New:	6.95
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HS-33 Headset: with chamois cushions	New:	$ 7.95
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HS-23 Headset: with chamois cushions	New:	6.95
with rubber cushions	New:	5.95
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HS-30 Headset—Hearing Aid Type—Used: 75¢	New:	1.00
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CIRCLE NO. 110 ON READER SERVICE PAGE

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PICK up hidden programs on FM Broadcast band for music without commercials. Works on any FM radio. Text, schematics $3.00. Music Associated, 65 Glenwood Road, Upper Montclair, N. J.

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TAPEMATES MAKES AVAILABLE TO YOU—ALL 4-TRACK STEREO TAPES—ALL LABELS—POSTPAID TO YOUR DOOR—AT 40% COMBINED SAVINGS. FOR FREE BROCHURE WRITE TAPEMATES CLUB, 5280-E W. PICO BLVD., LOS ANGELES, CALIF. 90019.

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Reconditioned FM 2-Way Radio Savings

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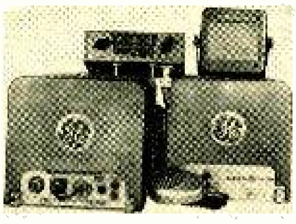

30-50mc MOBILES

GE 2-Piece Unit—6 volt or 12 volt
4ER6—4ET5 30w 30-40mc 40-50mc ...**$ 88**
4ER6—4ET6 60w 30-40mc 40-50mc ...**$108**
Complete with all accessories except antenna and crystals.
Equipment can be crystalled and tuned to any frequency in the 30-50mc band.
GE 2-Piece Unit—6 volt or 12 volt
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4ER6—4ET6 60w 30-50mc **$188**
Complete with all accessories including antenna and crystals. Fully narrow banded (Tx & Rx) and tuned to your frequency with in the 30-50mc range.

GE PROGRESS LINE LOW BAND

Vibrator power supply 6/12 volt WTA/E 13
30 watt, less accessories—20" case **$175**
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MT13 12 volt Transistor power supply 14" case **$215**
Accessories for the above including cables, microphone control head and speaker add $40.00. These units were used by Bell Telephone.

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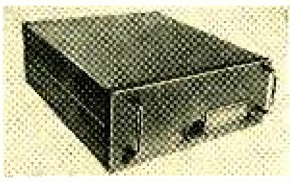
Add $40.00 for accessory group including cables, microphone control head and speaker. Crystals tuning and brand new antenna, ready to be installed, add $40.00.



148-172mc RCA CMC 60B

6/12v dual Dynamotor 60 watt
(a) Fully narrow banded complete with all accessories, less crystals & antenna **$218**
(same unit without accessories $198.00)
(b) Same unit tuned to your frequency including brand new antenna **$253**

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CIRCLE NO. 113 ON READER SERVICE PAGE

GET IT from GOODHEART!

ALL-BAND SSB RCVR BARGAIN: Hallicrafters R-45/ARR-7, 550 kc to 43 mc continuous: Voice, CW, MCW, aligned and modified now also modified to include PRODUCT DETECTOR. 2 RF, 2 IF stages. S-Meter, Xtl, w/120/230 v 50/60 cy pwr sply. Hot and SHARP & **works like a charm!** FOB Los Ang. **199.50**
Same less SSB, fob San Antonio **179.50**

TIME PAY PLAN: Any purchase totalling $160.00 or more, down payment only... **10%**

ARC-5 Q-5'er Rcvr 190-550 kc w/85 kc IF's. 3 Ant. posts: Loop DU-1 (see below) or ordinary. Electrically checked, aligned, OK grtd. w/spline knob, tech. info. 10 lbs. **14.95**

DIRECTION FINDER DU-1 has preamp, compares Loop & Sense Ant.'s, gives TRUE BEARING in 3 seconds. Use ahead of any rcvr 200-1600 kc. W/instruct. to convert to MARINE BAND. Gets B+ & htr V, from rcvr. New. 13 lbs. **29.95**

LM FREQ. METER generates AM or CW to align rcvrs or tells unknown freq. to align oscillators or xmtrs, 125 kc to 20 mc w/accuracy approx. .01%, self-calibrated w/1 mc xtl osc. w/harmonics beyond 20 mc, itself an xlnt exact-signal source. Our HONEST OPINION: Next to a multimeter, it's the most valuable tool for ANY radio hobbyist or serious lab. Exc. cond., electric. checked, OK grtd., w/matching-serialized calib. book, plug, dwgs & much tech. info. 15 lbs. **57.50**
Same exc. condition. Calibration books have dogeared edges but grtd readable.. **42.50**

GRTD CONDITION TELETYPE right off operating line, all w/SYNCH motors. No pwr splies. Clean, oiled, no rust. We will send you any repair parts you need FREE except window glass if you specify part Nos., so get the books too.
Mod. 15 send/rcve plus hi-base Typing Reperforator plus #14 Trans-Distr. all in operator's console cabinet w/paper storage, etc. Made of panels which open out on piano hinges for ready access to all machines **175.00**
Same except machine is Mod. 19 ......**195.00**
Mod. 14 Trans-Distrib. with cover **37.50**
Books (TM11): —352 on Mod. 15 **$7.50.** —2222 on #14 TD, **$8.50.** —2223 on #14 Typing Reperf. **$9.00.** —2216 on Mod. 19, **$12.50.**

ARC-3, ARC-27, ART-13 TECH. MANUALS each **10.00**

TEKTRONIX SCOPES grtd OK & gorgeous, w/books:
#514A: DC to 10 mc; sensit, 30 mv/cm; sweep calib. uv/cm; calib. deflection ... **395.00**
#514AD is same plus Video Delay Line ..**450.00**
#512: Slow sweeps. Medical & Servo use ..**425.00**
#513: HV accel. for pulses, 20 mc pass ..**495.00**
#524D: For TV Station engineers **550.00**

GERTSCH RATIOTRAN RT-10R AC Voltage Divider .001% accurate, 50-10,000 cy, 5 decades plus final interp. slidewire, rack mtg ... **175.00**
w/ST-200 xfmr & sw. to reverse polarity **200.00**

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K-2 Potentiometer (#7552) **295.00**
#4760 4-dial .1% DC Wheatstone Bridge ..**100.00**
#2310-(•) pointer galvan. for above **27.50**
WESTON #440 pointer galvanometer **37.50**
#5430A, similar above, galvo built in **125.00**
#4725 5-dial DC Wheatstone Bridge .05% **275.00**
#2430-c Lamp & Scale galvo for above ...**150.00**
RUBICON galvo very similar to above **125.00**
#5365 Power Cable Fault Bridge + Rheost.**275.00**

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CIRCLE NO. 112 ON READER SERVICE PAGE

WINDSOR Tape Club members HEAR BEFORE THEY BUY. Free "samplers" of new releases. Save on tape purchases.—All major labels. Free brochure. Windsor Tape Club, Dept. E, Windsor, Calif.

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JEEPS $64.50, boats $6.18, typewriters $4.15, airplanes, electronics equipment, thousands more, in your area, typically at up to 98% savings. Complete directory plus sample Surplus Market-letter $1.00. Surplus Service, Box 820-K, Holland, Michigan.

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FREE electronics catalog. Tremendous bargains. Electrolabs, Dept. C105E, Hewlett, N.Y. 11557.

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WANTED Aircraft Radio Sets—Collins: 51R3-51X—51Y—51V—51Z, Bendix: T-21; R21; DFA-70; RA-18C; MK-7; GSA-1, Test Sets: ARC—Boonton—Collins—Hewlett-Packard. Highest prices pa'd. J. Lee, Box 105, New Haven, Conn.

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VETERANS—WW II Combat Infantrymen and Medical Badge holders are entitled to the Bronze Star Medal. Send $1.00 for particulars. MW Enterprises, 2114 Tower Bldg., Denver, Colorado 80202.

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TV Tuners Rebuilt and Aligned per manufacturers specification. Only $9.50. Any Make UHF or VHF. We ship COD Ninety day written guarantee. Ship complete with tubes or write for free mailing kit and dealer brochure. JW Electronics, Box 51B, Bloomington, Indiana.

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RECORD greater sales by running your ad in these columns. A handy order form will be found in this section. Return it with your remittance to Martin Lincoln, 1 Park Ave., N.Y.C.

MISCELLANEOUS

SPANKEE! New Fashioned Shingle! With Old Fashion Results! $1.00 Postpaid. Spankee! Box 466, Salem, Mass.

SAVE $200 to $2,000 on European automobiles delivered at low, low factory tax-free prices by using our direct shipment plan. Delivery guaranteed, references available. Tourist and Military deliveries available in Europe. Information on all models and makes Eurauto, Postbus 333, Rotterdam, Holland.

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"RW" CLEARANCE SALE!

We must move—A new highway will occupy "RW's" present location. So we must reduce our huge inventory with a clearance sale. Our new Bulletin No. 40 is loaded with clearance items.

Send for your free copy—Now!

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2430 So. Michigan Ave. Chicago, Ill. 60616 Dept. 875 Phone CAlumet 5-1281

CORNELL TUBES

1 YR. GUARANTEED

Tubes are new or used and so marked

Mutual Conductance Lab tested, individually Boxed, Branded and Code Dated

33¢ PER TUBE

100 TUBES OR MORE: **30¢ PER TUBE**

0Z4	6AG5	6BD6	6CM7	6H6	6SC7	6SR7	12AD6	12SQ7
1B3	6AK5	6BG6	6CZ5	6J5	6SH7	6U7	12AE6	25L6
1H5	6AL5	6BH6	6D6	6J6	6SJ7	6U8	12AF6	25Z6
1J3	6AN8	6BJ6	6DA4	6K6		6V6	12AT7	35W4
1L4	6AQ5	6BL7				6W4	12AU7	35Z3
1T4	6AS5	6BN4				6W6	12AX7	35Z5
1U4	6AT6	6BN6				6X4	12BA6	50L6
1X2	6AT8	6BQ6				6X5	12BD6	24
3CB6	6AU4	6BZ6				7A7	12BE6	27
5U4	6AU5	6C4				7A8	12BF6	41
5V4	6AU6	6C6				7B6	12BH7	45
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6A6	6AW8	6CD6	6DE6	6K7	6SK7	7B8	12BY7	75
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If Not Shipped in 24 hrs. YOUR ORDER FREE!

Special! With every $10 Order **25¢** per tube (No Limit) from this list.

6AG5 6SN7
6AQ5 6J6 6V6
6AU6 6K6 6W4

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- Electronic Solder
- T.V. Courses
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TERMS: Add 3c per tube shipping. Orders under $5.00 add 3c per tube shipping plus 50c handling. Canadian orders add approximate postage. Send 25% deposit on C.O.D. orders. No C.O.D. orders under $5.00 or to Canada. No 24 hr. free offer on personal check orders. 5-DAY MONEY BACK OFFER!

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Dept. EW8 4217 University Ave., San Diego, Calif. 92105

CIRCLE NO. 105 ON READER SERVICE PAGE

"IT'S THE HOTTEST" OFFER

☐ FREE $25 WORTH OF
- Transistors
- Diodes
- Rectifiers
- Knobs
- Condensers
- Coils, etc.

Include 25¢ for handling

PLUS

$1 ☐ FREE POLY PAK OF YOUR CHOICE

BOTH FREE WITH EVERY $10 ORDER

WORLD'S MOST POPULAR $1 PARTS PAKS

- ☐ 25 SPRAGUE "YELLOW MYLAR" CONDENSERS to 1mfd. $1
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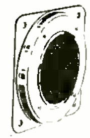
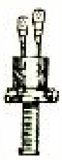
- ☐ 60 CERAMIC CONDENSERS, discs, npo's, to .05mf.... $1
- ☐ 50 1-WATT RESISTORS, popular values, asstd, 5% too. $1



HI-FI SPECIAL! 4" SQ. ELECTROSTATIC TWEETER

Made by Lorenz, ITT, for Grundig. Never before offered. A natural for hi-fi enthusiast. Buy 2 for stereo. Illustration resembles tweeter in stock. Includes hookup.

1.49 ea. 2 for 2.50



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BRAND NEW LOWEST PRICES

PRV	7 Amp	15 Amp	25 Amp
50	☐ 1.00	☐ 1.25	☐ 1.50
100	☐ 1.50	☐ 1.95	☐ 2.25
150	☐ 1.75	☐ 2.25	☐ 2.75
200	☐ 1.95	☐ 2.75	☐ 2.95
250	☐ 2.25	☐ 2.95	☐ 3.25
300	☐ 2.69	☐ 3.19	☐ 3.50
350	☐ 2.95	☐ 3.50	☐ 4.25
400	☐ 3.25	☐ 3.95	☐ 4.50

FACTORY TESTED SEMI-KON-DUCTORS

- ☐ 10 30-MC TRANSISTORS, TO5 case, with shield...... $1
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- ☐ 25 EPOXY RECTIFIERS, axial lead, 750 mil, untested. $1
- ☐ 25 GERMANIUM DIODES, 1N34, 1N48 equals......... $1
- ☐ 10 PNP SWITCHING TRANSISTORS, TO5 case......... $1
- ☐ 2 25-AMP SILICON STUD RECTIFIERS.............. $1
- ☐ 2 'MESA' 4-WATT TRANSISTORS, npn, silicon, TO5... $1
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- ☐ 4 GENERAL ELECTRIC 2N170 PNP RF TRANSISTORS... $1
- ☐ 3 CBS—20-WATT TRANSISTORS, pnp, stud, 2N1320.... $1
- ☐ 5 GENERAL ELECTRIC 2n107 PNP TRANSISTORS...... $1
- ☐ 3 20W TRANSISTORS TO5 case, 2n1038, 'n heat sink.. $1
- ☐ 2 500-MC MESA TO18 CASE TRANSISTORS, pnp...... $1
- ☐ 15 NPN TRANSISTORS, asst types and cases.......... $1
- ☐ 15 PNP TRANSISTORS, asst types and cases.......... $1
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- ☐ 10 RAYTHEON CK722 TRANSISTORS, pnp........... $1
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- ☐ 10 NPN SWITCHING TRANSISTORS, 2N440 equals..... $1
- ☐ 4 CK721 TRANSISTORS, new aluminum case, pnp.... $1
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- ☐ 3 2-WATT SIZE zener references, axial leads, 1 volt.. $1
- ☐ 2 TRANSITRON 1N429 TYPE ZENER REFERENCES, 6 volts $1
- ☐ 1 20W SILICON MESA, 2N1648, TO10 transistor....... $1
- ☐ 6 TEXAS 750 MIL 400V RECTIFIERS, epoxy, axial... $1
- ☐ 3 2N255 POWER TRANSISTORS or equal, TO3 case.... $1
- ☐ 1 TEXAS 3N35 TETRODE 150 MC SILICON transtr, TO5. $1
- ☐ 1 2N718 NPN SILICON PLANAR, 1W, TO18 case...... $1

10 WATT STUD ZENERS $1.49 ea.

☐ 5V	☐ 14V	☐ 42V	☐ 70V	☐ 100V
☐ 6V	☐ 20V	☐ 45V	☐ 80V	☐ 110V
☐ 12V	☐ 24V	☐ 60V	☐ 90V	☐ 124V

SILICON POWER DIODE STUDS

Amps	Volts	Sale	Amps	Volts	Sale	Amps	Volts	Sale
☐ 6	50	15¢	☐ 25	100	1.29	☐ 50	100	2.95
☐ 6	100	29¢	☐ 25	200	1.60	☐ 50	200	3.75
☐ 6	200	37¢	☐ 25	300	1.75	☐ 100	25	1.50
☐ 6	400	59¢	☐ 25	400	1.95	☐ 100	50	1.80
☐ 6	600	69¢	☐ 25	600	2.50	☐ 100	100	2.25
☐ 6	800	89¢	☐ 35	50	1.05	☐ 100	150	2.75
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☐ 12	100	69¢	☐ 35	200	1.75	☐ 240	100	5.90
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☐ 12	300	1.00	☐ 35	300	2.55	☐ 240	200	8.25
☐ 12	400	1.37	☐ 50	25	1.50	☐ 240	300	12.50
☐ 25	50	99¢	☐ 50	50	1.95	☐ 240	400	19.95

FREE! 225-ITEM SUMMER BARGAIN "FLYER"

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TERMS: send check, money order, include postage—avg. wt. per pak 1 lb. Rated net 30 days. COD 25%.

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"PAK-KING" of the world

CIRCLE NO. 123 ON READER SERVICE PAGE

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SELL HiFi Components—As distributors handling all major brands of HiFi components, we can now offer dealerships to aggressive people who can sell full or part time. Knox Electronic, Dept. 764, Galesburg, Ill. 61401.

EARN $2.50 hour assembling our small Lures and Flies for stores. Write: Lures. Lake Village 14, Arkansas.

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FREE Book "990 Successful. Little-Known Businesses." Work home! Plymouth-717H, Brooklyn 4, N. Y.

IMPROVE YOUR BUSINESS OPPORTUNITIES by advertising in the Electronics Market Place. Our readership of more than 200,000 electronics professionals monthly assures you of success. Use the handy order form found in this section and mail it today! If you are interested in additional information, write Martin Lincoln, Electronics World, One Park Ave., New York, N.Y. 10016.

STAMPS

U.S. STAMPS Plus Complete U.S. Catalog. All for 10¢ Four sensational offers in one: 1. Genuine centennial postage stamp, picturing first U.S.A. (issued 117 years ago!) 2. Valuable collection all-different U.S.—Ancient 19th Century, 100 stamp, etc. 3. Collection beautiful commemoratives: American Revolution, Wild West, 1893 Columbian, many others. 4. Collector's Guide; exciting stamp offers for your inspection; Big new U.S. Bargain Catalog. Send only 10¢. Act Now! H.E. Harris, Dept. 597, Boston 17, Mass.

ELECTRONICS Professionals are STAMP enthusiasts, too. Find out for yourself by running a low-cost high-producing ad in this section. Send copy and payment to: Martin Lincoln. Electronics World, 1 Park Ave., N.Y., N.Y. 10016.

ELECTRONICS WORLD AUGUST 1964

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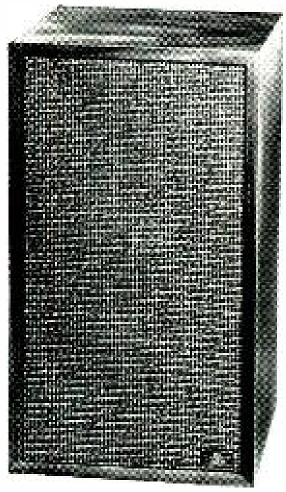
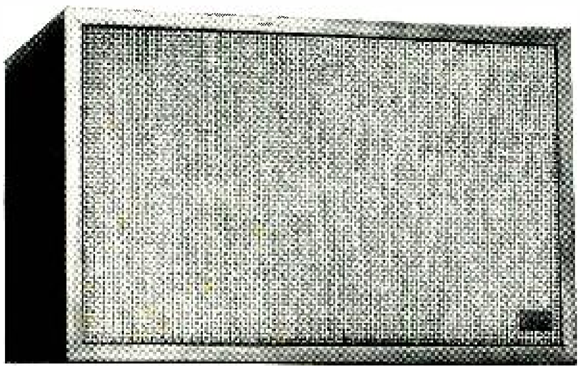
Printed in U.S.A.

New, revolutionary way to choose a speaker system:

listen

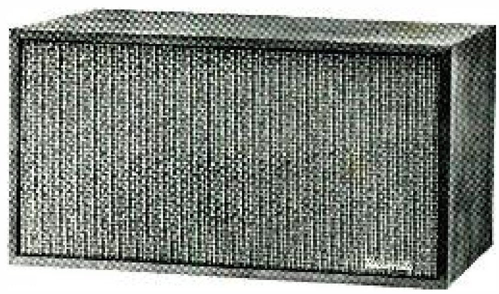


UNIVERSITY
COMPANION II
Ultra-Linear
10" woofer,
3" mid-range,
3½" tweeter.
24x13½x11½"
D. $79.50



UNIVERSITY SENIOR II
Ultra-Linear 12" woofer, 3½" mid-range, Sphericon
Super-Tweeter; 25x15⅝x12⅛" D. $99.50

UNIVERSITY MINI-FLEX
6½" woofer, 3" mid-range
3½" tweeter. 15x9 7/16
x5 3/16" D. $69.95



UNIVERSITY COMPANIONETTE
Ultra-Linear 8" woofer,
3" mid-range, 3½" tweeter.
21¾x11½x8⅝" D. $69.95

...and listen and listen. New? Revolutionary? Yes—when you consider how many people buy speakers based on the recommendation of others. Sound involves **subjective** criteria. The sound that pleases a friend, (a hi-fi editor or salesman, for that matter) will not necessarily please you. Therefore . . . hear and compare many systems. For the largest selection, **start with University.** Choose the superb University model that best meets your requirements, then compare it to all other brands of its type. For example—if it's a full-size bookshelf you want, ask your dealer to demonstrate the Senior II vs. the AR, KLH, and other bookshelf systems of similar size. You'll hear the difference. Especially in the mid-range. Especially in the Senior's complete absence of restraint, that tell-tale drawback of so many other bookshelf systems. Unlike other systems, the sound of the Senior, the Companion, or of **every** University system, large or small—is **free** and **open.** The bass is cleanly defined; the mid-range punches through for greater presence; the highs literally have wings. Want proof? (Of course you do) Visit your dealer . . . and **listen.** University sounds better. Free 1964 Guide to Component Stereo! Write: Dept. S-8.

LTV
UNIVERSITY
A DIVISION OF LING-TEMCO-VOUGHT, INC.
9500 West Reno, Oklahoma City, Oklahoma

U-45

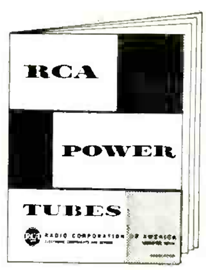
CIRCLE NO. 134 ON READER SERVICE PAGE

Power ratings for every industrial application

What do you need in an industrial rectifier? RCA offers you a choice of 27 different types. Gas-filled, vacuum or mercury-vapor half-wave types. For applications up to 22,000 volts and up to 60 amperes.

Steady, dependable DC power. RCA industrial rectifiers are engineered for maximum reliability and long life—to minimize equipment down-time, tube-replacement, and to reduce operating costs. High operating efficiency and long life are assured by an improved coated filament that prolongs peak-emission capability, by a well-shielded cathode and by low initial voltage drop in all tubes.

Other advantages include wide ambient temperature tolerance and high resistance to transients.



For specifications and applications data on all RCA rectifiers, pick up a copy of this RCA Power Tube Catalog (PG-101F) at your local RCA Industrial Tube Distributor.

RCA ELECTRONIC COMPONENTS AND DEVICES, HARRISON, N.J.

AVAILABLE THROUGH YOUR LOCAL RCA INDUSTRIAL TUBE DISTRIBUTOR

FOR NAME AND ADDRESS OF YOUR LOCAL DISTRIBUTOR WRITE OR CALL YOUR NEAREST RCA DISTRIBUTOR PRODUCTS SALES OFFICE—NEW YORK, NEW YORK: 36 W. 49th St., (212) MU 9-7200; NEEDHAM HEIGHTS 94, MASSACHUSETTS: 80 "A" St., (617) HI 4-8480; WASHINGTON 6, D. C.: 1725 "K" St., N.W., (202) FE 7-8500; ATLANTA, GA.: 134 Peachtree St., N.W., (404) JA 4-7703; CLEVELAND, OHIO: 1621 Euclid Ave., (216) CH 1-3450; CHICAGO, ILL.: Merchandise Mart, (312) 467-5900; DALLAS 7, TEXAS: 7901 Carpenter Freeway, (214) ME 1-3050; KANSAS CITY 14, MO.: 7711 State Line, (816) EM 1-6462; HOLLYWOOD, CALIFORNIA: 6363 Sunset Boulevard, (213) 461-9171; SAN FRANCISCO 2, CALIFORNIA: 420 Taylor St., (415) PR 5-5135-6-7.

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