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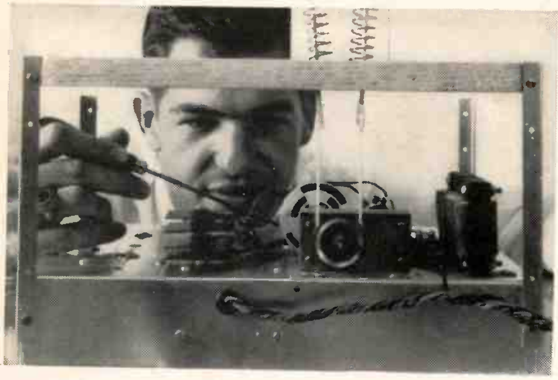

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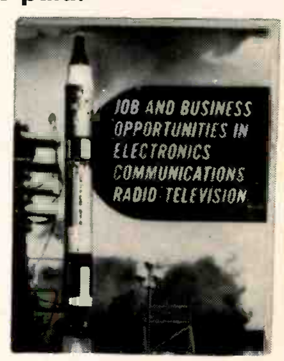

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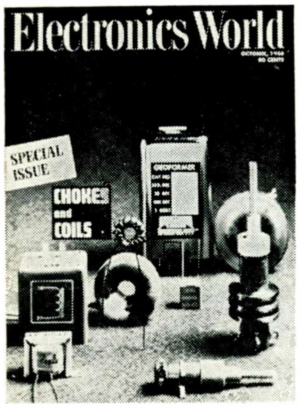

THIS MONTH'S COVER illustrates some of the chokes and coils discussed in detail in our special section in this issue. The two coils at the lower right-hand corner of the photo are Miller adjustable r.f. inductors; the one with the triple-pi winding has an inductance of about 68 mH, while the horizontal coil below it is around 2.2 μH. The rest of the coils are all Triad products. The open-frame coil at the lower left corner is a 50-H audio coupling reactor. Directly above this is an aircraft audio filter choke; the unit at the very top is a 500-H filter choke for instrumentation use, while the small, red, cube-shaped unit is an aircraft audio inductor. In addition, there are three toroidal coils shown, one of which has an open winding while the other two have covered and encapsulated windings. . . . . Photo: Bruce Pendleton.

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CONTENTS

MONTHLY FEATURES

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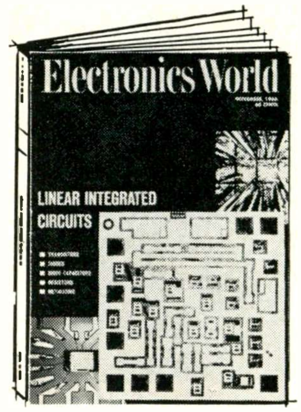
COMING NEXT MONTH



Special Feature Articles on:

LINEAR INTEGRATED CIRCUITS

Since these components are making a strong bid for acceptance in a wide range of consumer products, our November issue will take a hard look at IC's and their applications, availability, cost, reliability, and criteria for selecting linear IC's.

Linear Integrated Circuits by B. V. Vonderschmitt and R. L. Sanquini of RCA Electronic Components & Devices discusses the new design philosophy involving linear integrated circuits and the changing role of the circuit engineer.

Linear Integrated Circuits: What's Available? by Donald E. Lancaster surveys the current market, the manufacturers, and their products by circuit application and discusses where IC's can be used, their specs, what they cost, and how they are designed into various electronic circuits.

DIRECTORY OF VIDEO TAPE RECORDERS

This is an up-to-the-minute report on various video tape recorders now on the market for home and non-broadcast applications. Complete technical specs are listed for machines from ten companies offering their products in the U.S. at the present time.

POWER INDUCTORS

Robert E. Coy of Triad tells how to select the proper iron-core choke for power-supply filtering, as a charging inductor for pulse networks, for interference reduction, and for saturable reactor controls and explains why each choice is made.

THE TAPE CARTRIDGE COMES OF AGE

The emergence of the magnetic tape cartridge may be the most important innovation in musical entertainment for the car and home since the LP record. Dozens of equipment makers are offering players and record companies are busily duplicating their libraries in cartridges. This article will bring you up to date on current trends and possible future developments.

All these and many more interesting and informative articles will be yours in the November issue of ELECTRONICS WORLD *. . . on sale October 20th.*

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University surveys indicate:

STARTING SALARIES OF ENGINEERS ARE DECEPTIVELY HIGH

By James M. Jenks

TWO SEPARATE STUDIES of the salaries made by college graduates appear to contradict the commonly held belief that engineers today make out better financially than their classmates who major in non-technical subjects.

Both surveys were conducted by large universities. The first polled graduate engineers; the second, company executives. And both resulted in identical findings! That is, the average engineer today – despite a deceptively high starting salary–climbs fast but not far.

The need for technically trained men in recent years has exceeded the supply to such an extent that companies have been forced to bid for their services–to actually set-up "recruiting" offices on college campuses all over the country. Thus, starting salaries have gone up and up. But the income ceiling for these technically-trained men is lower than that for managerial personnel.

Despite the substantial head start engineers have, the differential in money earned over a ten-year period averages out at $7,000 more for the management man.

And from the tenth year on, the administrator's salary obviously outstrips that of the engineer by a wider and wider margin.

This, of course, is not to say that engineering students would be wise to shift to the study of business administration–or that working engineers face a bleak future. Quite to the contrary, the continuing growth of technology means that men with technical backgrounds are as ideally qualified for the highest rewards industry has to offer–*if they also have a knowledge of the underlying principles of business.*

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For the record

WM. A. STOCKLIN, EDITOR

NEW YORK HI-FI SHOW PROGRAM

WHAT started out to be an interesting experiment in 1964, seems to have become an annual event. The Institute of High Fidelity has again asked me and the EW staff to plan semi-technical presentations in conjunction with the forthcoming New York Hi-Fi Show (Sept. 28—Oct. 2 at the New York Trade Show Building). This not only involves planning the subjects, but it means soliciting a group of the most authoritative panelists in the industry.

Many attempts have been made to develop interesting programs for the hi-fi enthusiast, but it wasn't until 1964 that a successful pattern evolved. The pattern has remained much the same ever since. Four different semi-technical presentations on interesting subjects connected with hi-fi are covered. In addition, four identical sessions on the subject of hi-fi and the listener, directed to the novice, are given throughout the show. Many of those who attended our first session in 1964 will remember the program on "Transistors vs Tubes." This was not only an extremely timely topic, but also was one of the most controversial, and our guest speakers—Bob Furst, chief engineer, *Harman-Kardon*; Fred Mergner, chief engineer, *Fisher*; Vic Brociner, assistant to the president, *H. H. Scott;* and Dave Hafler, president and owner, *Dynaco*—all played important roles in discussing this lively topic.

In 1965 similar programs were held and now, in our coming 1966 sessions, we have what we believe to be a most exciting program. Not only do we have many chief engineers of the hi-fi component manufacturers as guest speakers, but also some members of top management. In addition, we are pleased to welcome an overseas guest, Alan Say, chief engineer of *Garrard* in England, who has graciously accepted our invitation to participate in these seminars this year.

Wednesday, Sept. 28, 7:30-8:30 p.m., will be devoted to "Tape Recorders." Reel-to-reel types, as well as video and cartridge designs, will be covered. Our guest panelists will be Wybo Semmelink, vice-president, *Norelco*, who will cover the marketing aspects—what is available and what it costs—and Kenneth Bell, engineering manager/audio, *Ampex Corporation*, who will cover quality of performance and define in layman's terms the various technical characteristics of all the various types of tape machines.

Thursday, Sept. 29, 7-8:00 p.m., will be devoted to "Phono Cartridges, Turntables, and Changers." Alan Say, chief engineer, *Garrard*, will review what is new in the area of turntables and changers and detail the importance of various performance characteristics. He will also review anti-skating devices and such problems as wow, flutter, and rumble. James Kogen, chief engineer/R&D, *Shure Brothers*, will cover the phono cartridge and describe the differences between magnetic devices, such as moving coil, moving magnet, and reluctance types, and ceramic and crystal as well as the new strain-gauge designs. He will also review and define some of the more important performance characteristics pertaining to phono cartridges with particular emphasis on a somewhat new term—"trackability"—that is expected to be applied to phono cartridges.

On Friday, Sept. 30, 7-8:00 p.m., the subject of "Tape and Special Effects Tape Recorders" will be covered. Joe Kempler, manager, technical services department, *Audio Devices*, will bring us up-to-date on the developments in the field of raw tape and describe the best types available for various applications. He will also review the problems of print-through, temperature, humidity, etc. This will be followed by what we feel will be one of the most exciting demonstrations of all the programs—a live presentation of sound-on-sound. Mr. Ivan Berger, audio specialist, will not only explain how this can be done but will actually show how any person can add one sound track over another continually to produce a duet, quartet, or possibly even an entire orchestral effect.

On Saturday, Oct. 1, 7:30-8:30 p.m., Abe Cohen, vice-president, *University Loudspeakers*, who gave such an outstanding performance last year that we have asked him to repeat his presentation this year, will cover the subject of "Stereo and the Listener." In addition to his comments on the effects of room acoustics, placement of speak-

(Continued on page 79)

SALUTE TO DAVID SARNOFF

AN unprecedented tribute by the electronics and communications industries to Chairman David Sarnoff of the *Radio Corporation of America,* in commemoration of the 60th anniversary of the start of his career in communications, will be held in the Grand Ballroom of the Waldorf-Astoria Hotel in New York on September 30, 1966, the exact day sixty years ago when General Sarnoff started working for a telegraph company.

Three national organizations—the Electronic Industries Association, the Institute of Electrical and Electronics Engineers, and the National Association of Broadcasters, will co-sponsor the "Salute to David Sarnoff."

General Sarnoff, who earlier this year celebrated his 75th birthday, came to this country in 1900 at the age of nine. He sold newspapers and worked as a delivery and messenger boy. On September 30, 1906, he joined the *Marconi Wireless Telegraph Company of America* as an office boy and began his career in wireless. When *RCA* was formed in 1919, he became its Commercial Manager.

General Sarnoff was elected President of *RCA* in 1930, at the age of 39. In 1947, he was elected Chairman of the Board and Chief Executive Officer. In 1966 he relinquished the post of Chief Executive Officer, continuing to serve actively as Chairman of the Board of the corporation.

A memorandum he wrote to his superior officers of *Marconi* in 1916 has become famous in the annals of American industry. In it, he proposed a plan for broadcasting programs into the home by using a "radio music box." This proposal led directly to the development of the radio and radio broadcasting as it is known today.

General Sarnoff likewise was the moving force behind the development of both black-and-white and all-electronic compatible color-TV. In 1944, the Television Broadcasters Association conferred upon him the title "Father of American Television."

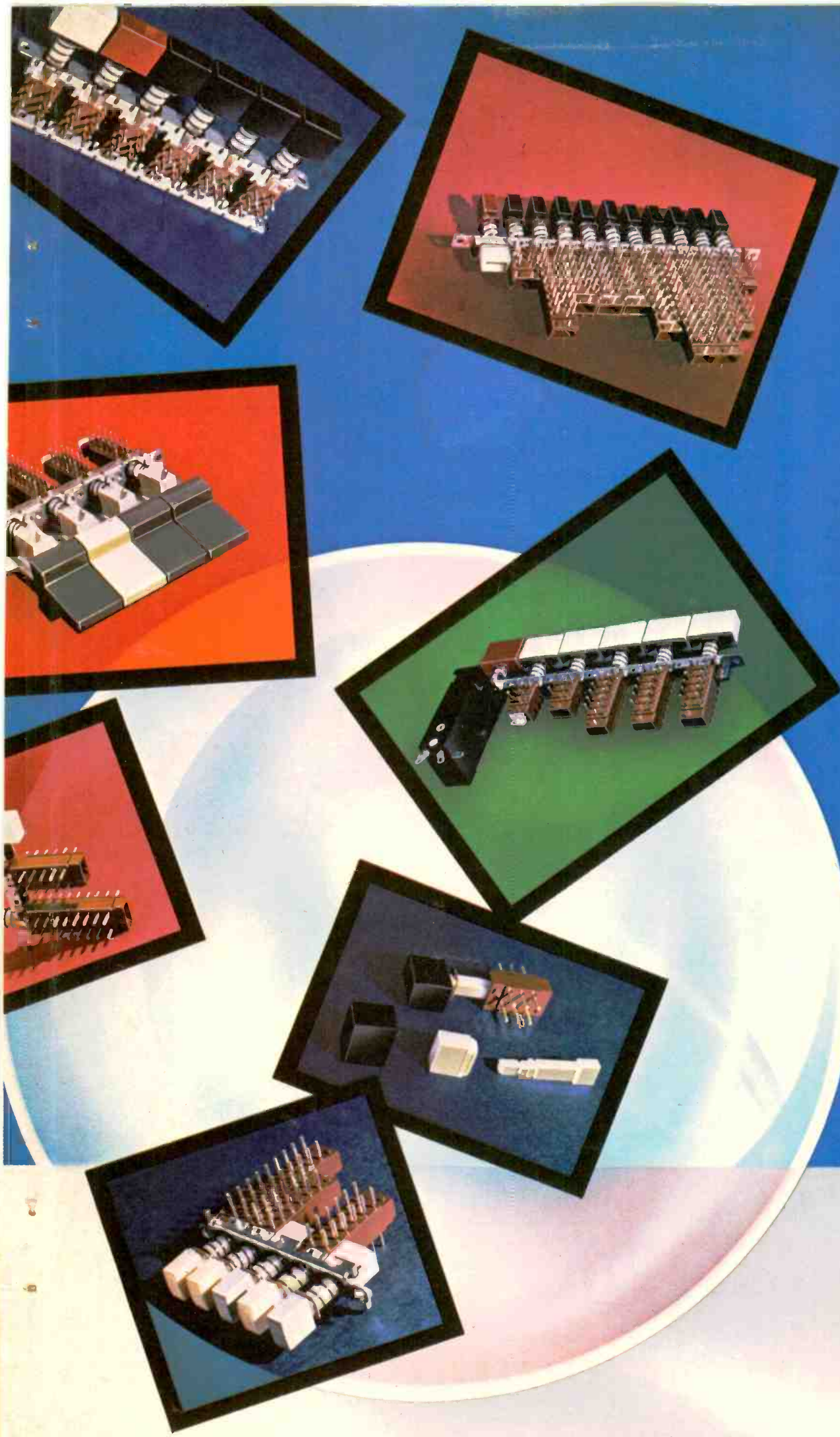
In addition to his scientific and industrial activities, General Sarnoff has achieved wide recognition for his efforts in military communications, especially during World War II. He served as Special Consultant on Communications at General of the Army Dwight D. Eisenhower's SHAEF Headquarters in Europe, and was elevated to the rank of Brigadier General on December 6, 1944.

At the Salute, Frederick R. Kappel, Chairman of the Board of the *American Telephone and Telegraph Co.,* will serve as program chairman, and Lowell Thomas, noted author, commentator, and explorer will act as toastmaster. Approximately 1700 people, including national government leaders and eminent Americans in all walks of life, are expected to attend.

The principal industry speakers for the occasion will be Dr. Jerome B. Weisner, Provost and Dean of the School of Science at MIT, former Special Assistant to the President on Science and Technology, and former Chairman of the President's Science Advisory Committee under President Kennedy, who will represent the IEEE; Robert W. Galvin, Chairman of the Board of *Motorola Inc.,* speaking for the EIA; and William S. Paley, Chairman of the Board of the *Columbia Broadcasting System,* who will represent the NAB.

In a joint statement announcing plans for the dinner, Dr. William G. Shepherd, President of the IEEE, Robert W. Galvin, President of the EIA, and Vincent T. Wasilewski, President of the NAB, said that the event was being held to commemorate General Sarnoff's "outstanding contributions to the progress and welfare of his industry, his country, and his fellow men."

The presidents of the three sponsoring organizations are serving as Honorary Chairmen of the occasion, and their respective Boards of Directors are acting as members of the Honorary Committee. This is the first time, it was pointed out, that these three associations have ever united in such a tribute. ▲



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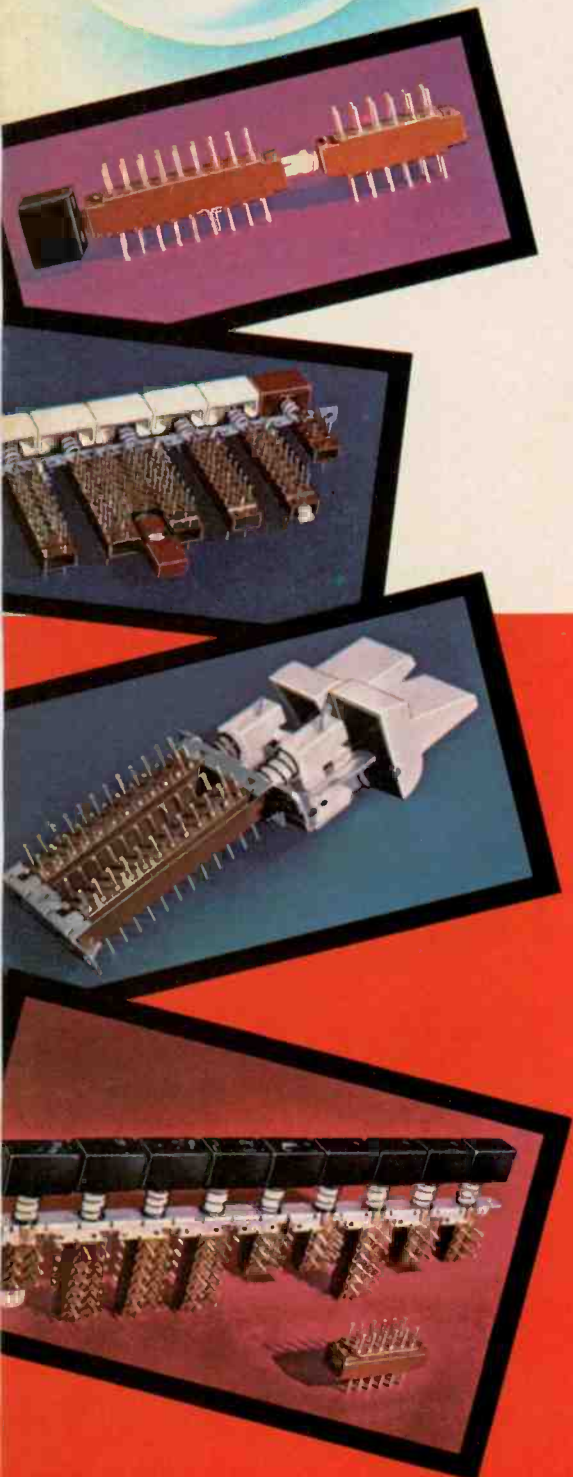

New from Centralab! A low-cost push button switch that's small, easy to wire, easy to mount and twice as versatile as any you now use!

PRICES are competitive with multiple position rotary types for many applications, much lower than other push button switches. And our new modular design facilitates same day price quotations.

SIZE of these new switches is so small that there's room to spare in printed circuit or conventionally wired chassis. Centerline spacings are 25/64″ (Model 10), 19/32″ (Model 15) and 29/32″ (Model 20).

VERSATILITY is exceptional. Switch action may be momentary, independent, push-push, row latching or even a combination of these anywhere in the same row! A zero block which releases the other blocks from the latching assembly is also available. Each switch can have two, four, six or eight double throw functions and a ganging arrangement permits up to 14 pole double throw action when required. Up to 19 switches may be ganged side-by-side on the same mounting bracket! A rear coupling is available for any switch. A line switch can be included in the assembly.

WIRING is particularly easy. Use standard dip or wave soldering methods with printed circuits. You can also make connections to the OTHER side of the switch with a pc board! In wired chassis, the design permits easy hand wiring and is ideal for automatic wire wrapping.

MOUNTING is simplified because Centralab provides a complete family of integrated hardware. Typical is a low-labor-content tab lock front mounting bracket.

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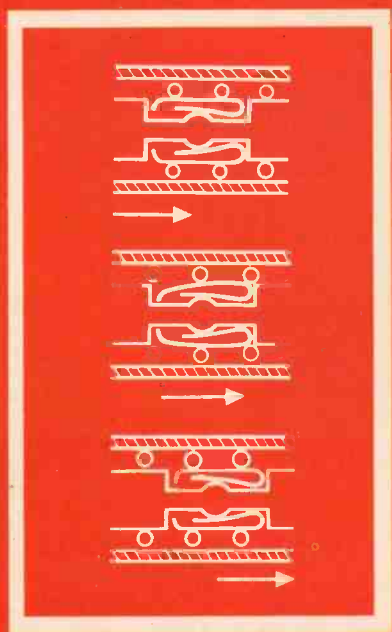

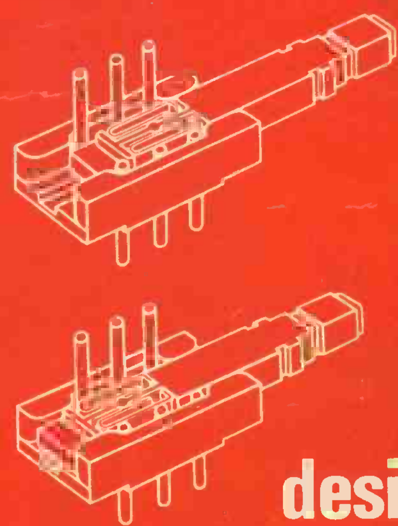

design principles

Centralab's new push button switches are completely machine-made of injection molded plastic. Even the contacts are inserted automatically for machine-sure quality control.

The unusual contacts provide excellent wiping action for electrically reliable performance. Their mechanical configuration assures even pressure on both fixed contacts, eliminates local high stress points in the contact for long failure-free life. The sketches show the simplicity and self-aligning characteristics.

Smooth switch action is assured by the low friction plastic slider which holds the moving contacts. The switch body completely encloses the switch contacts for protection from solder and dust.

P-6615

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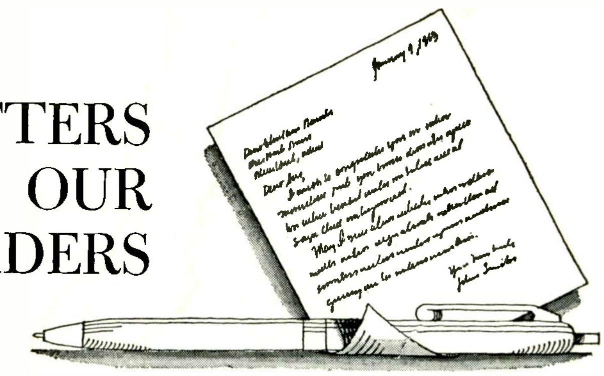
LETTERS FROM OUR READERS



SUBSTITUTING FET'S FOR TUBES

To the Editors:

I was very interested in Mr. Rheinfelder's article "Substituting FET's for Tubes in Hi-Fi Amplifiers" in your March issue. I do feel, however, that he has overstated the case for substituting FET's and silicon rectifiers for tubes in existing equipment.

The EZ81 (6CA4) rectifier has a slow warm-up to prevent d.c. from being applied to the other tubes until they have warmed up. To substitute silicon rectifiers without a thermal delay relay or other time delay switch in the circuit causes extra demands to be placed on the filter capacitors and might possibly strip the cathode coating and eventually destroy the output tubes. Also, care should be taken to add enough resistance to the transformer resistance to act as a surge-current suppressor to protect the rectifiers. Vacuum tubes and FET's cannot be used as split-load inverters to drive a class-B output stage as implied by the author.

I have built an 80-watt power amplifier using silicon rectifiers (with proper time delay) and an FET tape-head preamplifier. I must agree that there is a great future for these products, but care must be taken in substituting them for tubes in existing equipment.

JOHN R. JAMIESON, JR.
Cambridge, Mass.

* * *

TRANSISTOR FAILURE PREDICTION

To the Editors:

I read and reread the article on page 27 of the June issue regarding transistor failure prediction after storage at elevated temperatures. Somebody *has* to be kidding. Did it really take three years to determine that storing transistors in boiling water is harmful? If you can cite one reasonable example of where it is more convenient to store transistors at 100°C (212°F) than at a more moderate temperature, I'll eat the June issue!

GEORGE HRISCHENKO
Windsor, Ontario

Evidently, we didn't make the point very clear. The idea was not that it is desirable to store transistors in boiling water but that it is possible to predict failure rates at elevated storage temperatures. I doubt very much whether the transistors under test were to be used in equipment by the National Bureau of Standards, which conducted the tests.—Editors

* * *

EFFECTIVE USE OF V.O.M.

To the Editors:

I wish to take issue with the article "Effective Use of the V.O.M." appearing in the April, 1966 issue of ELECTRONICS WORLD. Rather than pointing out how inaccurate some of our v.o.m. or v.t.v.m. readings could be, the article was useful only in demonstrating what absurd conclusions can be reached when one treats specifications as literal as Ohm's Law and carries them far enough.

While it is true that a meter specified as accurate within 3% of full scale cannot be correctly assumed to be within 3% of all other points on the scale, the technician who assumes that it is, will be far more correct than one who assumes the readings might be as erroneous as stated in the article.

Full-scale readings are most accurate simply because meters are properly calibrated against a known standard at this point. A fact completely overlooked in the article is that the meter is calibrated with equal accuracy at the opposite end of the scale when the zero setting is adjusted. If the article were taken seriously, however, one would believe that the closer a reading is to zero the more unreliable it is.

HAROLD HASSE
Heath, Ohio

* * *

HERTZ FOR CPS

To the Editors:

What happened to cps, kilocycles, and megacycles in designating frequency? Also, who is Hertz, and if he is so important, why don't you capitalize his name when you write about the "60-hertz" power-line frequency?

DAVID L. MANHEIM
Pittsburgh, Pa.

In 1964, the U.S. National Bureau of Standards officially adopted the International System of Units which was defined in a resolution of the 11th General Conference on Weights and Mea-

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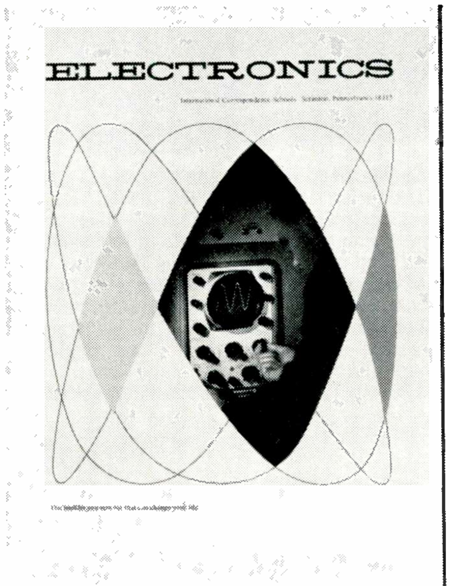

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Special rates to members of U. S. Armed Forces • Convenient payment plan • Special Training programs for industry *sures held in Paris in 1960. Standards that have been issued since 1964, such as the new IEEE standard on "Symbols for Units" and the IHF standard on "Methods of Measurement for Audio Amplifiers," have followed the new system of units. We began using the new units in our April issue.*

One of the most important of these new units, the one for frequency, has been employed in Europe for a long time. This unit is the "hertz," and it has the same meaning as cycles per second (cps). The proper abbreviation for hertz is "Hz." According to the international standard, when the unit is written out, it is not capitalized even though it is taken from the name of a person. Similar examples are ampere, farad, henry, volt, and watt. When the abbreviation is used and the unit is named for a person, then it is capitalized, as Hz (hertz), A (ampere), B (bel), F (farad), H (henry), V (volt), and W (watt).

The unit for frequency was named after Heinrich Hertz, a German physicist who studied under Helmholtz. Between the years 1885 and 1889, Hertz examined the propagation of electromagnetic waves, measured the length and velocity of these waves, and showed that they could be reflected, refracted, and polarized just like light waves.

In writing multiples and submultiples of the units, the abbreviation of the multiplier is prefixed to the abbreviation of the unit. For example, what used to be called the kilocycle is now the kilohertz, abbreviated "kHz." What was the megacycle is now the megahertz, abbreviated "MHz." The standard prefixes indicating decimal multiples or submultiples of metric-system units are:

Multiple	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

—*Editors*

* * *

INDOOR U.H.F. TV ANTENNA

To the Editors:

Here is a sketch of a simple, home-built, folded-dipole, indoor u.h.f. TV antenna I am using which outperforms my twin bow-tie with reflector and an elaborate multi-element u.h.f. array when these latter two antennas are used indoors. I live about 15 miles from the

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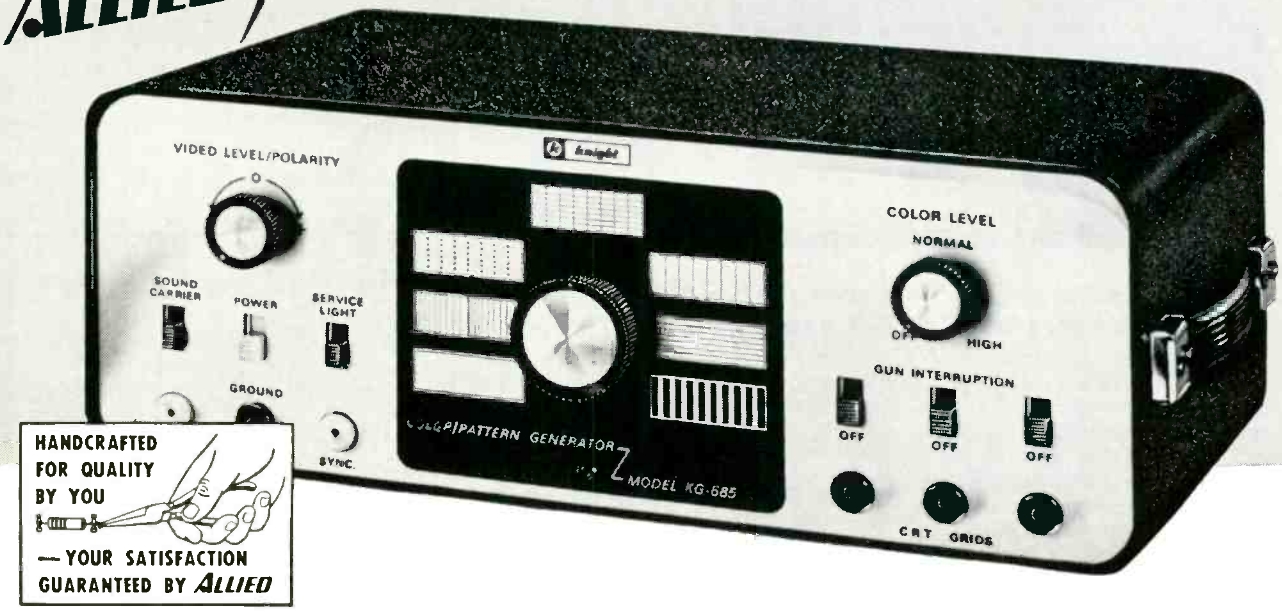

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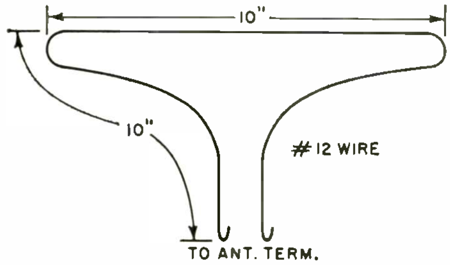
transmitting antennas of TV channels 31 and 47 in New York City so that I am in a strong-signal area. Also, my TV set is in my basement workshop and I did not want to bother installing an outdoor u.h.f. antenna with its long lead-in and resulting losses, so I have been experimenting with indoor antennas near the set's u.h.f. converter.

The antenna is made out of ordinary #12 house wire pulled from a piece of BX several feet long. The ends are shaped to connect directly to the antenna terminals of the u.h.f. converter. The horizontal straight portion is about a half-wave long at the lower u.h.f.

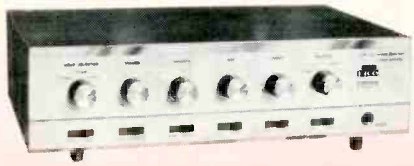


channel, while the tapered portion forms a sort of impedance-matching section. The amount of taper is adjusted for best performance. The antenna is oriented 90° away from the transmitting antenna so that it picks up a strong reflected or multipath signal. The home-built antenna definitely outperforms the other two on channel 47. On channel 31, it is not as good as the array, but the received picture is entirely satisfactory.

No doubt the little antenna is located in a particular "hot spot" for u.h.f., while the large number of reflections due to the indoor and below-ground location make it impossible for signal gain at the higher u.h.f. channel to be built up in the other two antennas. Of course, if these were installed outdoors and in the clear, their much higher gain would result in an even better picture on both u.h.f. channels.

MARC SAUL
Floral Park, N.Y.

We have also heard of successful u.h.f. reception using a metal coat hanger, especially on the lower channels. Simply cut the hook off, untwist the ends, scrape the black paint off the metal, and form the ends to fit the u.h.f. antenna terminals. Other readers have reported good indoor antenna reception with a circular or rectangular antenna. A circle of stiff wire some 8 to 10 inches in diameter or a rectangle about 10 inches by 5 inches should do the job. Many portable TV sets use such antennas for u.h.f. In all cases, experiment with the location and orientation of the antenna, and, if you are lucky and are in a strong-signal area, you should be able to get good local u.h.f. reception. —Editors ▲



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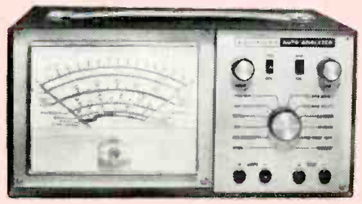

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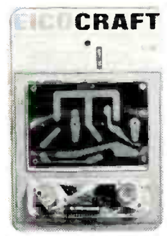

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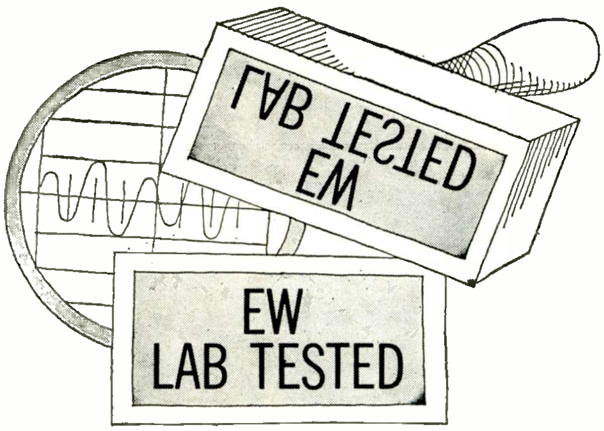


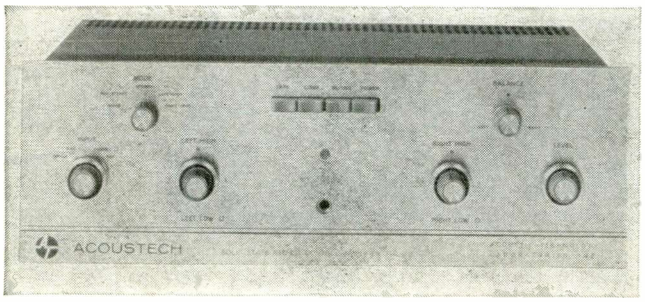
HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Acoustech XI Amplifier
Concord Model 300 Recorder

Acoustech XI Amplifier

For copy of manufacturer's brochure, circle No. 25 on Reader Service Card.



THE *Acoustech* XI "Add-A-Kit" amplifier is a rather unusual solution to the problem of building a high-fidelity system from separate components without obsolescence and with complete compatibility. The unit is a basic power amplifier, fully solid-state, and rated at a nominal 35 watts per channel. It is sold only in kit form and is compatible with any good control center/preamplifier that the hi-fi enthusiast may have available.

At any later time, the owner can convert it to an integrated amplifier, with a high-quality built-in preamplifier section, by purchasing the P/M preamp module kit. In addition to the components required for the control center section, the preamp module includes a new panel which replaces the original basic power amplifier panel. This is the only part of the Model XI which is not used in the finally converted unit. The power amplifier chassis has been prepunched in order to accommodate the preamp module parts and controls.

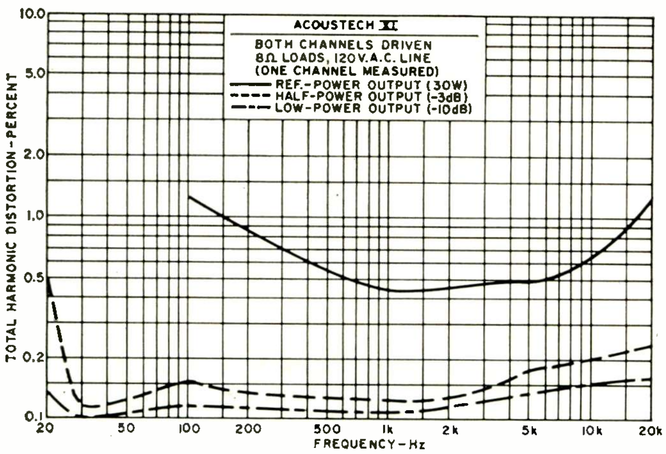
Both the *Acoustech* XI power amplifier and the preamp module are supplied with the active circuitry factory-wired and tested, on plug-in printed boards. The assembly of the basic amplifier is a relatively simple matter. The parts are packaged in bags, numbered in the sequence in which they are to be used. The bags are pinned to a "KitKloth" which protects the working surface and serves as a convenient means of keeping the parts together when the kit is put away after each wiring session.

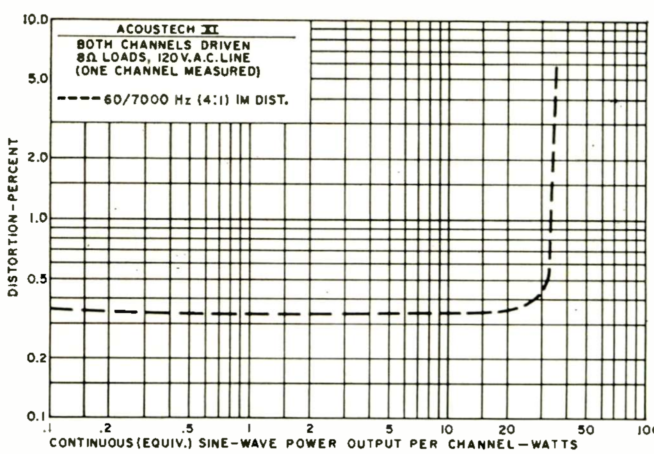
The major part of the assembly of the basic amplifier consists of mounting the mechanical components. The interconnecting wiring is open and uncomplicated. When the preamplifier module is added, there is somewhat more wiring to do, since the controls and switches must be wired into the circuit. Nevertheless, the total job seems to be well within the capabilities of a neophyte kit builder. All wiring is shown in color in both instruction books. A simple "light-bulb" check prevents damage to components in case of an undetected error that the inexperienced kit-builder may make.

The power amplifiers use silicon output transistors mounted on heat sinks. No transformers are used (other than the power transformer). The output stages are driven by complementary symmetry stages, preceded by two stages of amplification. The entire power amplifier section is direct-coupled, with blocking capacitors used only at the input to and the output from the speaker. Negative feedback is applied around the entire power amplifier module.

With the preamplifier module installed, the amplifier has concentric high- and low-frequency tone controls, separate for each channel. Markings on the panel indicate recommended settings for using the controls as rumble or scratch filters, or for loudness compensation. There are separate level and

(*Continued on page* 81)





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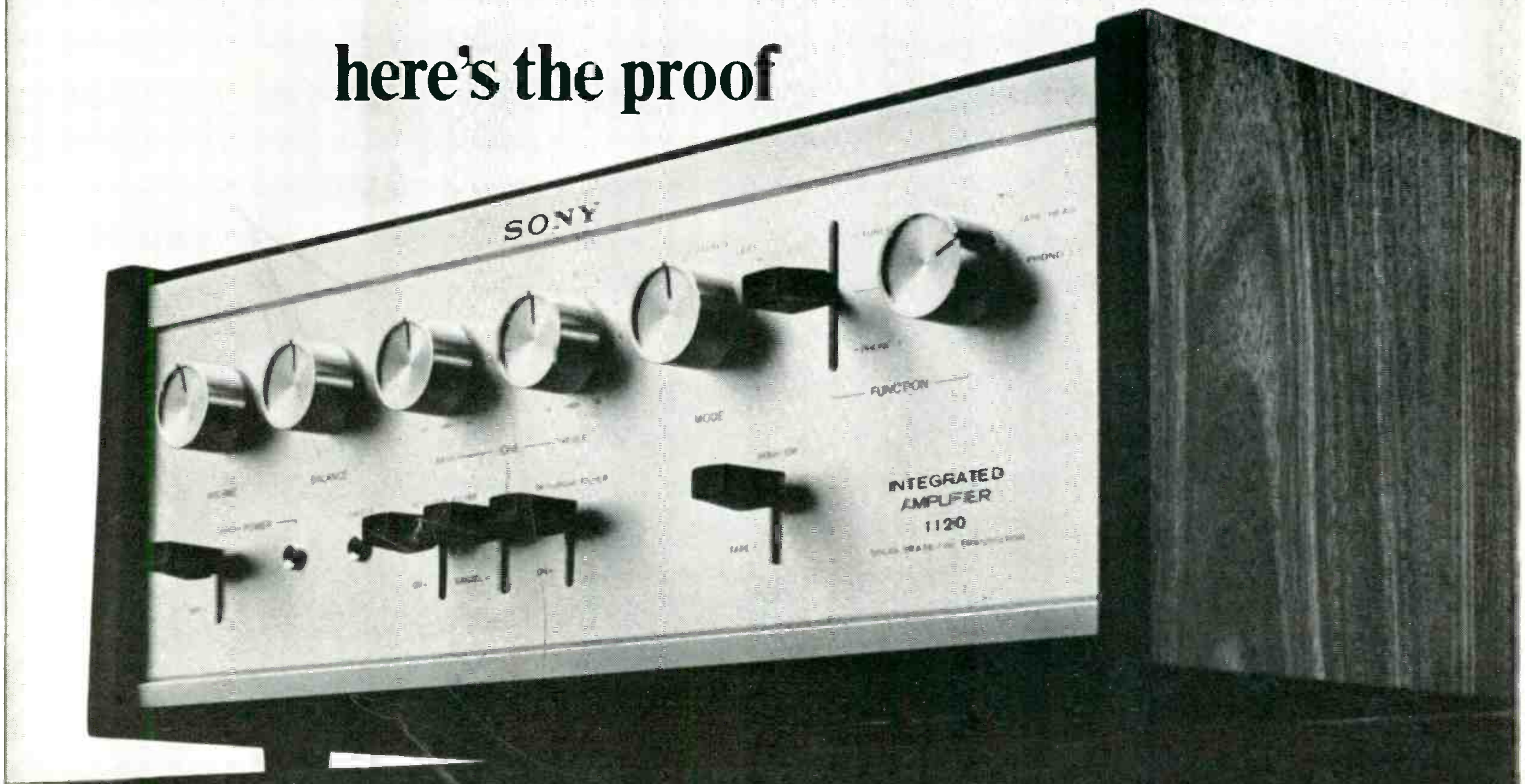

Many manufacturers have made fairly good transistor amplifiers. Until now nobody has made a great one. And everybody knows the reason: distortion. Unfortunately, most transistor amplifiers distort in a very special way. Not so much at top power, but rather more at normal listening levels where it hurts most.

The Sony TA-1120 integrated amplifier and TA-3120 power amplifier are the first high-powered transistor units to really overcome the problem of distortion. At all power levels, at all frequencies distortion is kept below that of the finest tube amplifiers. The TA-1120 and TA-3120 both provide 120 watts IHF at 8 ohms, both channels operating. Distortion, at rated output, is 0.1%. And at normal listening levels it is even less, 0.05% at ½ watt. In addition, they have achieved an extraordinarily high damping factor, better than 70 at 1000 cps to assure clean, low-frequency power response. Frequency response is practically flat from 10 to 100,000 Hz (+0 db/—1 db). For safety's sake, an SCR (silicon controlled rectifier) protects the power transistors against accidental shorts and other overloads.

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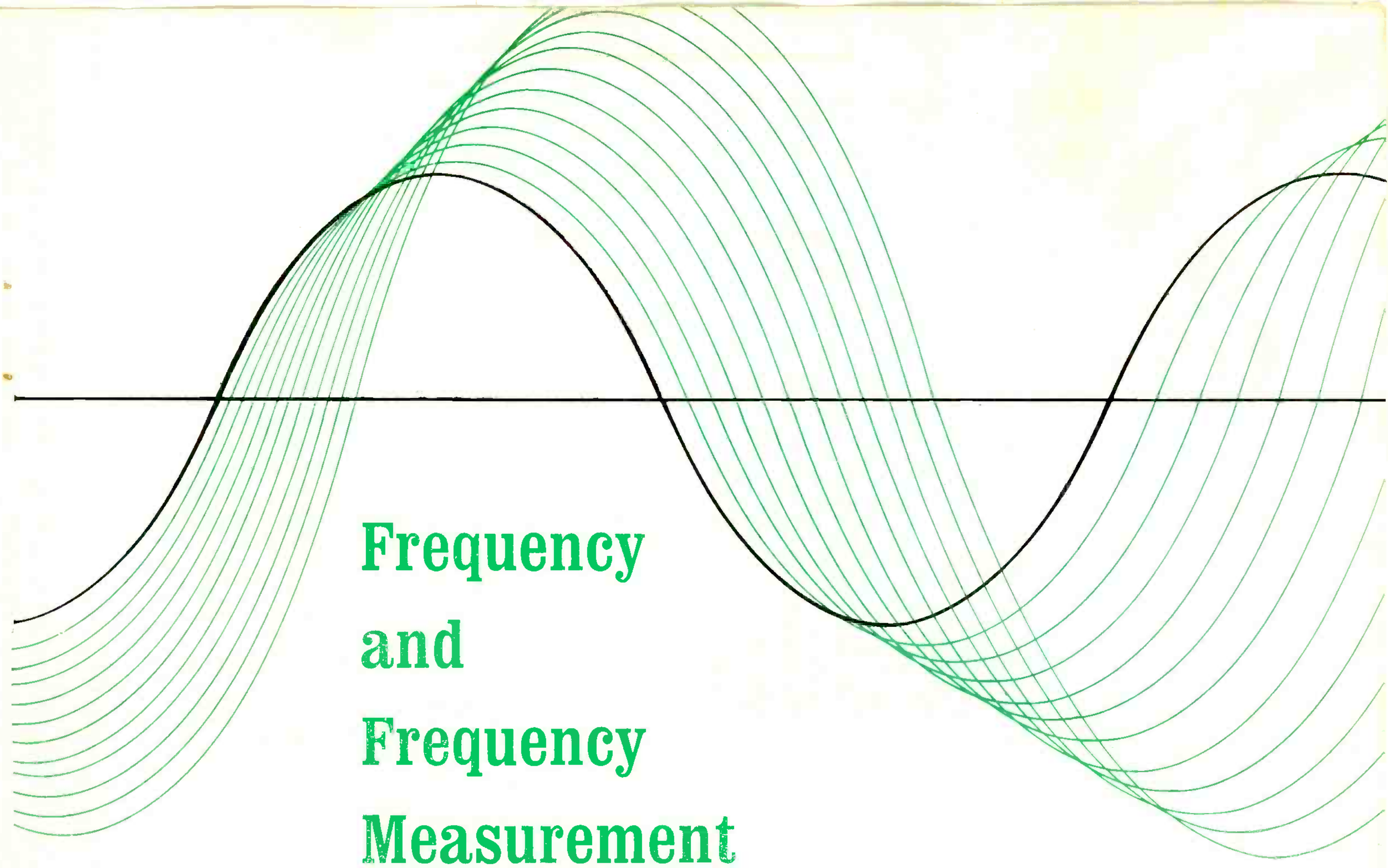


Frequency and Frequency Measurement

By MARVIN J. WILLRODT/Applications Engineer
Frequency & Time Division, Hewlett-Packard

One of the basic, yet most important, parameters in electronics is frequency. There are many methods and instruments used in its measurement, but how accurate are they? Just what errors are they subject to and how can these errors be minimized?

AT first, one might think that the nature of frequency is a very simple thing. In electronics, is it not just the number of cycles per second with which we are dealing? However, just how long a period of time is the second? Two "seconds," each different in length, are in common use in commerce and science today, and several others have been used in the past.

Problems arise, too, when the frequencies of actual signals are to be measured for such signals are usually not "pure." Real signals are always accompanied by some noise which constitutes short-term deviations in frequency. Real signals commonly drift somewhat in frequency; they may drift rapidly or slowly, and they may drift steadily in one direction, or cyclically around some center frequency. The purpose of the signal, then, must be taken into consideration before an appropriate way of measuring it can be determined.

Every frequency reading, from the simplest noting of the position of the dial on a portable radio to the most exact reading of the output of an atomic standard, is a *comparison*. We are always comparing some unknown signal with some time-based reference. The time-base may be somewhat crude, such as the resonant period of a simple capacitor and inductor combination, or it may be exceedingly accurate, as for example, the output of an atomic-controlled oscillator. Errors in measuring frequency can arise then from the nature of the signal that is to be measured, from the comparison method that is used to relate the unknown to the known, and from the degree of accuracy with which the "known" is really known.

The Two Seconds

The two internationally recognized standards for the length of the second were discussed in detail in Jane Evans' "Time and Time Measurement" in the July 1966 issue of this magazine. It is necessary, for purposes of navigation and time-keeping, to maintain a standard which relates meaningfully to the apparent path of the sun about the earth. In this way, longitude may be adequately determined by observing the position of the sun, and so the time of day which the clock calls "noon" will revolve more or less evenly around the sun's zenith, through a year. Because the length of the day is changing, due to natural events, the length of the second by which ordinary clock time is computed must change minutely each year. This is an inconvenience in precise measurement of frequency and in highly precise measurements of time interval.

What is needed for this purpose is an internationally

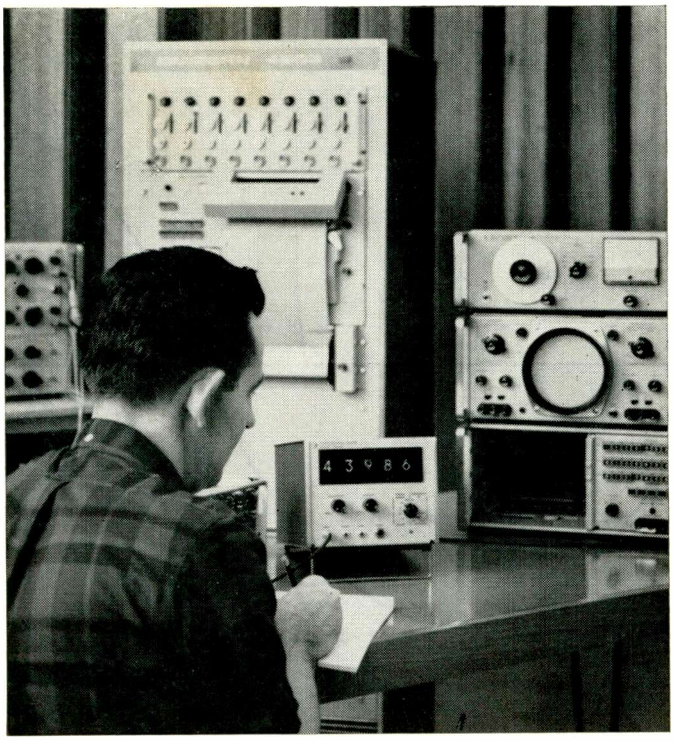


Fig. 1. A counter of medium stability with 5-digit readout is shown here. Aging rate is specified as parts in 10^6 per week. Crystal used is of high quality but is not enclosed in an oven.

agreed upon second of unvarying standard length. Such a standard exists. It is a periodic event occurring within the element cesium, to which reference can be made by electronic means easily and quickly with precision of a few parts in 10^{11} or 10^{12}. The atomic standard time scale, an invariant now used world wide for scientific purposes, is called A_1 (Atomic); the standard second of navigation and commerce is the scale called UT_2 (Universal Time). The difference between these two changes from year to year and international agreements are made on the "offset" which shall be applied. This year the offset is 300 parts in 10^{10} which is the same thing as 3 parts in 10^8. Thus, where measurements of frequency purport to be accurate to or beyond this particular level, the *kind* of second to which reference is being made must be expressed.

The Many Kinds of Drift

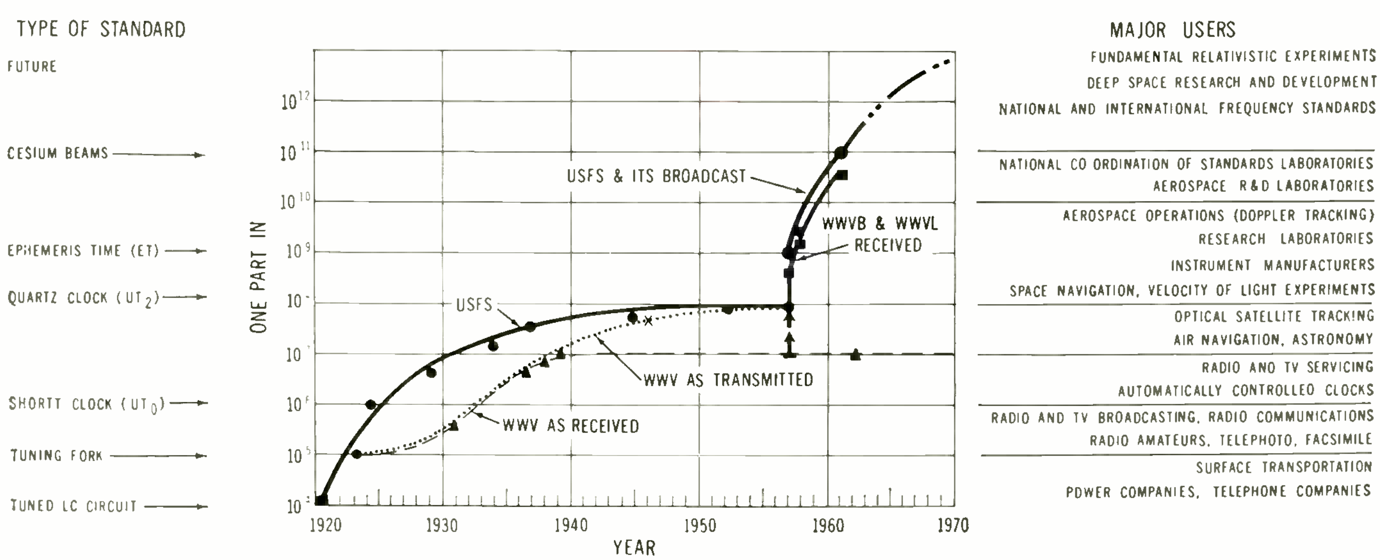
Frequency drift with time is referred to, by those who are concerned with precise measurement of frequency, as "long term" or "short term." Exactly how long is "long" and how long is "short," depends upon the context or the reference and usually, therefore, upon the purpose of the signal being measured. Short-term drift, for the designer of a local oscillator for a radio receiver, is a matter of minutes. For him long-term drift is a matter of months or years in which the dial calibration may become off by many percent. The first kind, in such a case, is largely a matter of temperature; the second is usually due to aging of the components. In any case, short-term stability refers to changes in average frequency over a time span sufficiently short that long-term effects may be neglected, and *vice versa.*

The causes of drift are much the same in other oscillators. The quartz crystal, widely used to determine the resonant frequency of filters and oscillators, drifts rapidly with changes in temperature. This is to say, short-term drift in crystal oscillators is often the result of temperature shifts. This can be minimized, as it often is, by enclosing the crystal in a temperature-controlled oven. If the oven itself warms and cools slightly in response to its thermostat, the enclosed crystal will change cyclically in frequency in a corresponding time period. This may occur somewhere in between "short" and "long" time periods. More elaborate structures are made, such as the proportional oven, which prevent temperature shifts by throttling heat input, that is, supplying heat at the same rate the oven is losing heat to the surroundings. This maintains the crystal at a very constant temperature.

Long-term change in frequency of a good crystal oscillator is due to aging. Aging may cause the frequency to move steadily downwards, or steadily upwards, over very long time periods. With modern crystals of good cut and high purity, there is no special advantage to either mode of behavior. As long as the movement of the frequency is steady and tracked, it may be predicted so that accurate corrections can be made in readings which depend upon the crystal's frequency.

Among the most important uses for a highly stable oscillator is as a reference standard for the measurement of unknown frequencies whatever their origin. At the higher levels of frequency-measuring accuracy, as in digital electronic counters, the time base is an oscillator whose frequency must be defined with considerable care. While the simplest of these instruments refers measurements to the power line, these can be taken as accurate only to perhaps 0.1% (1 part in 10^3), since this is about as precisely as power line *frequency* is ordinarily maintained.

Fig. 2. Improvements in the precision of the U.S. Frequency Standard (USFS) and its dissemination.



Curiously, synchronous clocks driven by the power line will keep *time* with very great accuracy over long periods; this is because the frequency of the line is changed deliberately from time to time so that clocks whose reading has drifted off will drift again in the direction needed to bring them back onto what is accepted as correct time. The common electric clock, then, keeps accurate *time* without being driven by a source of accurate *frequency*. When frequency is to be measured with much higher accuracy, quartz crystals are commonly used to control the oscillator time base. There are several degrees of refinement in common use here, too.

Well-cut quartz crystals, without temperature compensation, can be made to age as little as a few parts in 10^6 or 10^7 per month (Fig. 1). This is not to say that the accuracy with which their frequency is known is a part in 10^6 or 10^7, since there is no way of knowing, without constant tracking, how many days or weeks may have gone by since they were last referred to a primary standard. It is important to refer the reference crystal within the counter to another reference from time to time. Comparison by radio with the National Bureau of Standards is rapid and comparatively easy, even by high-frequency transmissions, at this level of precision. It might be noted that the Bureau's high-frequency transmissions are based on the UT_2 second, although that is of little consequence unless accuracies beyond the capabilities of these simpler, non-temperature-compensated crystals are desired. (See Figs. 2 and 3 for precision of the primary standard and broadcast schedules.)

Fine, modern high-frequency electronic counters, commonly those with 7 or 8 digits of display, usually have long-term stability specifications in the region of a few parts in 10^9 per day (Fig. 4). Once more, this is *not* to say that they may be indiscriminately regarded as *accurate* to parts in 10^9. These, too, must be referred to a primary standard from time to time if the *accuracy* of their reading is to be known. The fact that their aging is slow, known, and steady, makes it possible to predict their frequency with precision, even if some time has elapsed since calibration.

Instruments of this level of precision are most appropriately referred to the National Bureau of Standards' station WWVB on 60 kHz. This is the U.S. Frequency Standard, which itself is now referred to A_1 time. It may take several hours to accumulate records from which comparisons of a precision of parts in 10^9 or 10^{10} may be confidently derived. This is most easily accomplished by phase-tracking equipment, which automatically makes a continuous strip-chart recording of the comparison (Fig. 5).

Frequency measurements are commonly made over short periods of time, like a tenth of a second or a second. If, during this time, the frequency of the reference oscillator in an electronic counter is different from its average long-term frequency, then the reading will be off by that amount. It is important, then, to know the short-term drift characteristics of the reference oscillator. In this case, "short-term" refers to periods like a tenth of a second or a second, of course. Understanding the meaning of this term can be important where precise frequency measurements are to be undertaken.

Short-term stability, or short-term instability, is an expression of the change in average frequency over a time sufficiently short (but exceeding some minimum time) that long-term effects are of small or negligible significance. There is at present no general agreement fixing the averaging time so one must be specified for each statement of short-term stability.

A typical statement for an ultra-precise quartz oscillator might be, "fractional frequency deviation is less than 2 parts in 10^{11} r.m.s. for an 0.1-second averaging time." What this says is that the mean output of the oscillator during any 1/10-second interval will not differ from that

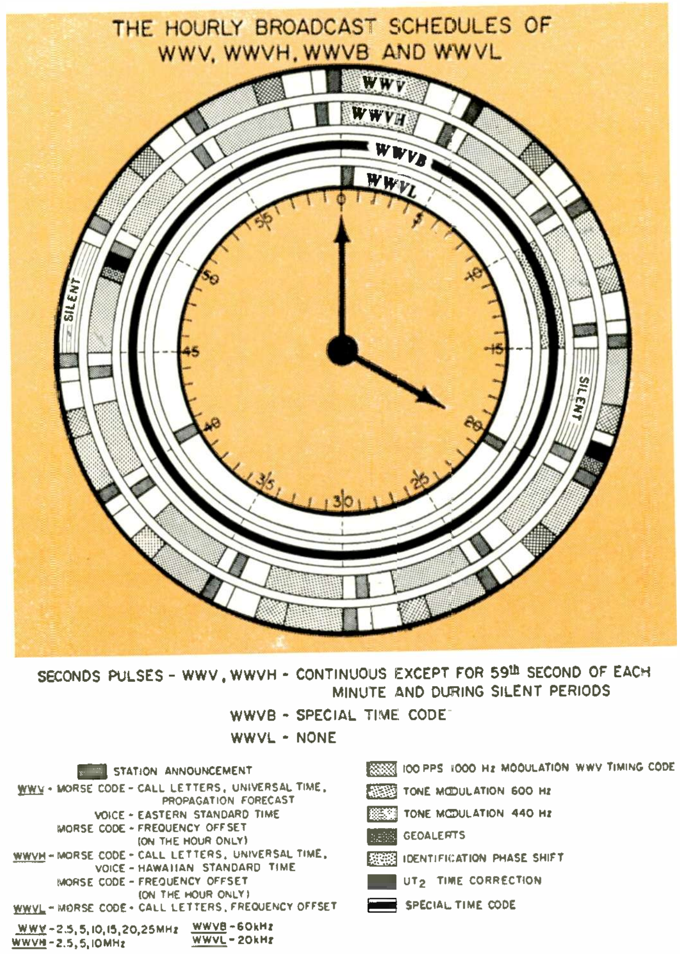
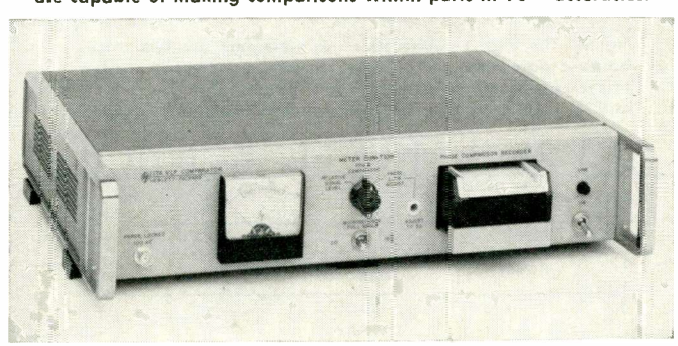


Fig. 3. The broadcast schedules of NBS radio stations. WWV is located in Greenbelt, Md., but will soon be relocated at Ft. Collins, Colo., along with WWVB and WWVL. WWVH is in Hawaii.

Fig. 4. A highly accurate electronic counter with an 8-digit display and time-base stability better than 3 parts in 10^9 per day.

Fig. 5. Automatic phase-tracking 60-kHz receiver makes continuous strip-chart recording which compares reception of NBS station WWVB with a local oscillator. Comparisons are easily reliable beyond parts in 10^9 at almost any reception point throughout the U.S. Tracking, if carried on daily and averaged over several days, are capable of making comparisons within parts in 10^{11} accuracies.



during the preceding 1/10-second interval by more than 2 parts in 10^{11}. These minute variations will be found to run along the path of long-term aging which might be 5 parts in 10^{11} per day or less. Short-term stability by these exacting specification standards *excludes* long-term aging.

As the interval over which a precise frequency measurement is taken grows very short, stability will be found to deteriorate. This is because no signal is entirely free of noise and noise constitutes a random series of frequency deviations. The purity of the signal will then influence the accuracy with which its frequency may be measured, and the purity of a reference source will determine the precision by which a comparison of an unknown frequency may be made with it if the measuring interval is very short.

Spectral Purity

The effects of noise and the natural "jitter" in the frequency of any oscillator may be taken as indistinguishable. Expressions of spectral purity, then, may be regarded as extremely short-term drift. However, they are more conveniently expressed in terms of the width of the spectrum of the signal, in hertz (cycles per second) deviation from the average, and in proportion to the total spurious sideband signals to the total signal.

Even rather crude oscillators have tolerably good spectra at the frequency of oscillation. The spectrum is degraded, however, if frequency is multiplied as is done so often. Indeed the ratio of total power in the sidebands to carrier power goes up as the square of the multiplication factor. This means, for example, that if we take a very clean signal with only 0.01% of its power in its sidebands and multiply it by 100, the resultant multiplied signal will have 10% of its power in spurious sidebands. Thus if a signal is to be multiplied, it must start out as a very pure signal indeed.

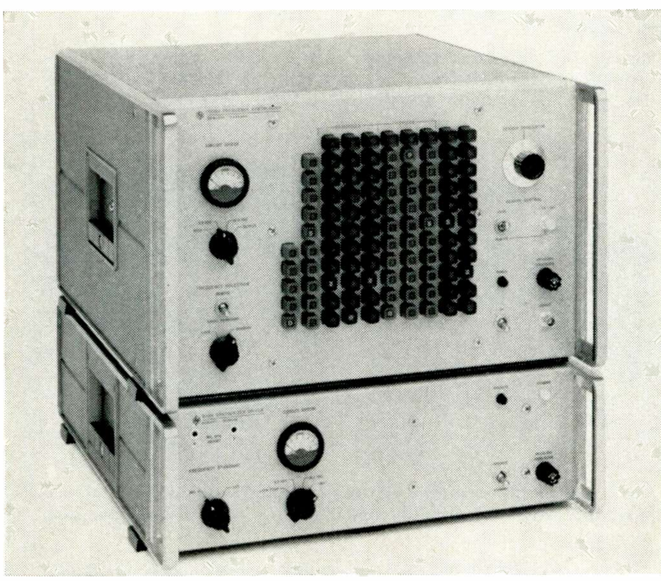
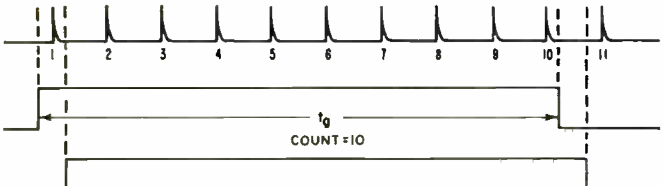


Fig. 6. Frequency synthesizer and its driver generates any of 5 billion different discrete frequencies from a single, ultra-pure and stable oscillator. Operation of this $12,500 combination is entirely by means of electronic arithmetic.

Fig. 7. The "± 1 count error" in electronic counters arises because gate-open period may straddle a different number of cycles on successive counts. Error may be 0 and + 1, or 0 and — 1. It may not, however, exceed the entire 1 count.



It might be thought that a simple way to improve the situation would be to put the signal through a narrow-bandpass filter before or after multiplication. This, however, is not very practical in the case of variable-frequency oscillators although tracking filters are used in some high-quality signal generators.

It is interesting to note that clean signals are degraded by hum and other discrete-frequency leakage in exactly the same way as by "jitter" or noise. The only difference is that the sidebands around the central desired frequency of oscillation are multiples of the added signal rather than randomly added components.

There is an elegant solution to the problem of generating a large number of very clean signals all of precisely known frequency. It is not inexpensive but when the need must be met, as in rapidly programmed changes in carrier frequency for some space communications purpose for example, it can be done. Frequency synthesizers are used to do the trick.

Among the most interesting of these (see Fig. 6) is one which generates a *single* ultra-pure frequency, determined by a well-designed crystal oscillator running at low power in a proportional-controlled oven. This signal is then multiplied, divided, added, or subtracted to generate the desired output frequency by performing only arithmetic operations, using electronic circuits, on the original crystal frequency. Refiltering of the signals after multiplication, and before further operations, preserves signal purity. The output frequency may be determined either by pushing buttons on the front panel or by remote electrical signals which set up the required arithmetic operations.

The instrument illustrated will produce any of *five billion* discrete frequencies, each differing from the next by as little as 0.1 hertz. All are of extraordinary purity, the total of non-harmonically related spurious signals being down more than 90 dB from the desired signal. That is to say, these spurious signals comprise less than 0.003% of the desired output voltage.

Measuring Frequency with Counters

While there are many common instruments for measuring frequency, the most precise in general use is the digital electronic counter. Often when an engineer picks up an electronic counter he expects that if he plugs the instrument in and connects a signal to it he will get "digital accuracy," *i.e.*, 100%, immediately. Indeed, he may expect accuracy to the last digit on the instrument, which in the higher priced types is often eight. There are good reasons why unless the situation is understood and precautions taken he may not get it.

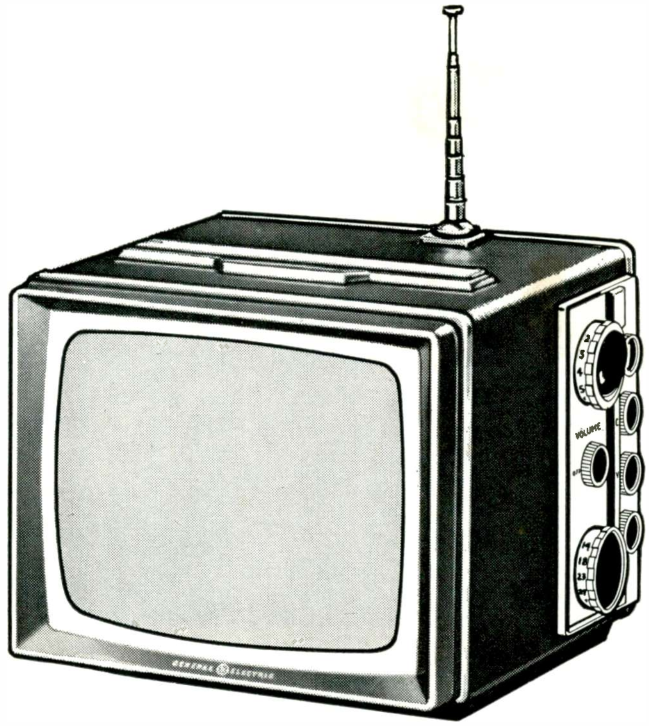
Fig. 7 demonstrates the first of several kinds of error which should be anticipated. "± 1 count error" arises because there is no reason why, on successive measurements, the time during which the measuring-gate of the counter is open (t_g) should happen to straddle exactly the same number of pulses (one of which is produced for each cycle of the input signal). This is true since the input signal is normally not synchronized with the time-base oscillator of the counter. This error can be no greater than one digit, *i.e.*, the error may be +1 and zero or it may be —1 and zero; it will not be within a range from +1 to —1 when measuring a stable frequency.

The second factor to consider in measuring frequency with an electronic counter is time-base error. As we have already discussed, it is important that the real aging rate of the oscillator which serves as time base should be known as well as the period of time since its last calibration with a primary standard. With these two factors, a correction can be calculated quickly so the actual frequency can be known. The error should never be (*Continued on page* 60)

Line-Operated Transistor TV Sets: G-E

By WALTER H. BUCHSBAUM

A new approach to vertical and horizontal outputs and a novel method of generating high-voltage for the CRT are discussed.



WITH a complement of 24 transistors and 18 diodes, the *G-E* Model TA 9-inch TV set differs from most other transistor TV receivers in that the majority of the transistors are silicon *n-p-n* types. The Model TB uses two more transistors but generally has the same type of circuits and the same over-all appearance and size.

The 9-inch picture tube determines the size of the receiver cabinet, with the tuners and all controls mounted on one side. A monopole antenna, telescoping and self-contained, is provided for v.h.f., and a detachable loop is supplied for u.h.f. The loudspeaker is mounted on the left side panel, and the bulk of the components are fastened to a single 6″ x 8″ printed-circuit board which is accessible from the rear of the receiver when the cabinet is removed. To reach the other side of the printed-circuit board, two screws must be removed and then the board hinges out from its retaining chassis.

The v.h.f. tuner of Model TA uses three silicon *n-p-n* transistors as r.f. amplifier, mixer, and oscillator, while the u.h.f. tuner has the conventional preselector, oscillator, and mixer. On u.h.f. channels, the v.h.f. tuner acts as an additional i.f. amplifier. In Model TB, the v.h.f. r.f. amplifier is a *p-n-p* stage, and this means that the a.g.c. to the tuner must be of opposite polarity in Model TB as compared with Model TA.

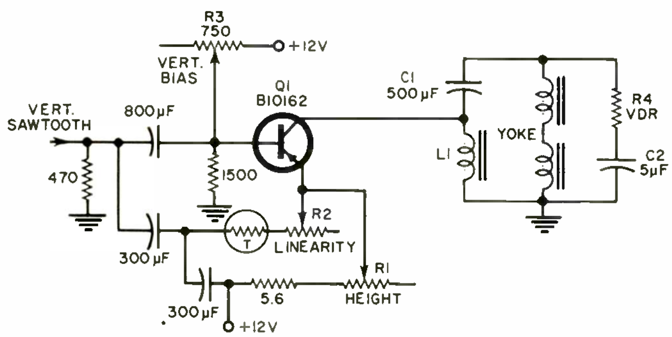
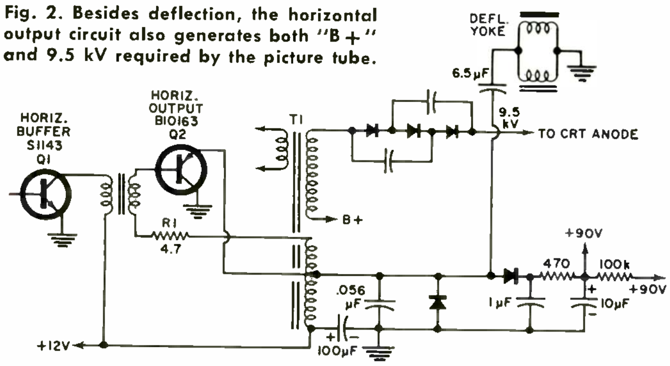


Fig. 1. Vertical output circuit uses a voltage-dependent resistor to maintain constant height with any output variation.

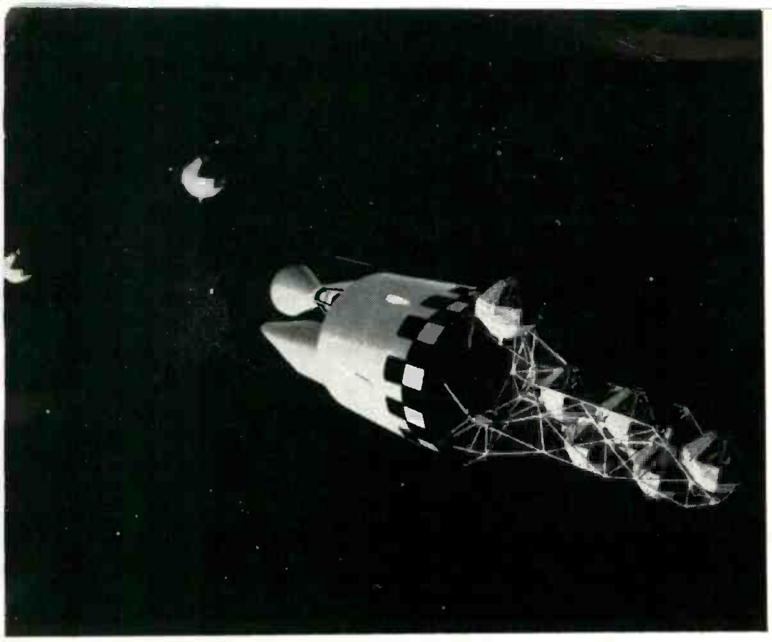
Fig. 2. Besides deflection, the horizontal output circuit also generates both "B+" and 9.5 kV required by the picture tube.



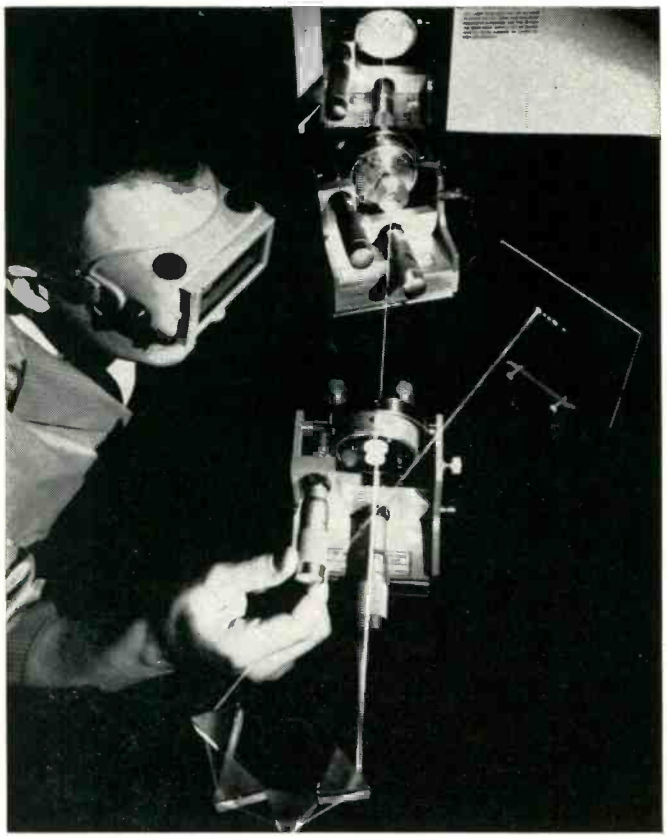
In the *Zenith* transistorized receiver (April, 1966 issue), a keyed a.g.c. controlled the first two i.f. stages through a reverse-bias arrangement, and delayed a.g.c. was applied to the tuner. In both *G-E* models, keyed a.g.c. is again used for the first and second i.f.'s. The main difference between the *G-E* and *Zenith* circuits is that in the *G-E* models both i.f. stages receive the same a.g.c. voltage on their bases, without the reverse-bias arrangement used in the *Zenith* model. The delayed a.g.c. to the tuner in *G-E* Model TA is derived from the collector of the second i.f. stage through an adjustable potentiometer. In Model TB, because the r.f. amplifier is a *p-n-p* transistor, the delayed a.g.c. transistor is changed from *p-n-p* to *n-p-n* and the bias is taken off the emitter of the second i.f. stage. The three-stage i.f. section, detector, and video amplifier are the same for both TA and TB models. Both use two video stages with the first connected as an emitter-follower driving the second stage. The contrast control is a potentiometer in the emitter of the video output amplifier, and a special vertical blanking pulse is also applied at that point. The video output amplifier uses +90 volts on the collector and couples the video signals capacitively to the picture-tube grid.

Two stages of 4.5-MHz audio amplification are used in both models, with a diode limiter in the collector circuit of the first stage to remove amplitude modulation from the audio carrier. In Model TA, three audio stages are used, with the second connected as an emitter-follower to drive the single-ended output amplifier. In Model TB, the output circuit uses a *p-n-p*/*n-p-n* emitter-follower arrangement which operates in class B and does not require an audio output transformer.

The sync separator and vertical oscillator are relatively conventional in both models. In TA, the vertical oscillator is a blocking oscillator; in TB, a multivibrator circuit combining the oscillator with the output stage is used. Both models employ a vertical output circuit which is sufficiently different from that of previously described transistor sets to warrant discussion. As shown in Fig. 1, output transistor $Q1$ receives the vertical sweep pulses on its base and has the linearity and height control in the emitter circuit. Height control $R1$ determines the voltage at the emitter. Linearity control $R2$, together with the ther- (*Continued on page* 70)



RECENT DEVELOPMENTS IN ELECTRONICS



Military Communications Satellites. (Above) Artist's rendering shows military communications satellites being placed into equatorial orbit at near-synchronous altitude by means of a unique dispenser. The dispenser permits placing eight satellites into random orbit with a single launch of the Titan III-C booster. The satellite system is being developed for the Air Force by Philco Western Development Laboratories. By using the multiple-launch technique, the number of high-cost booster rockets required to establish a communications system can be substantially reduced. The system will provide continuous communications around the globe. Any one satellite will be able to link two ground points about 9000 nautical miles apart. The satellites are protected—like peas in a pod—by a shroud during initial stages of flight. The shroud falls away in space and the satellites are ejected by springs, one at a time, and spun up to 150 rpm by a cold-gas, blow-down system. Spin stabilization eliminates need for attitude control.

Laser Color Selector. (Center) A color selector, operating at electronic speeds, determines which of several colors a multi-color laser will generate and emit. The selector may lead to the development of computer memories in which a hundred million bits of information could be stored on one square inch of photographic film. Here a green light beam has been selected. It travels through the selector (center), through prisms (lower center), and to a screen (right center). The prisms shown are not part of the selector but serve in this multiple exposure to separate the dots on the screen. These dots represent the other colors which can be selected. The setup shown is an experimental one at IBM Development Lab.

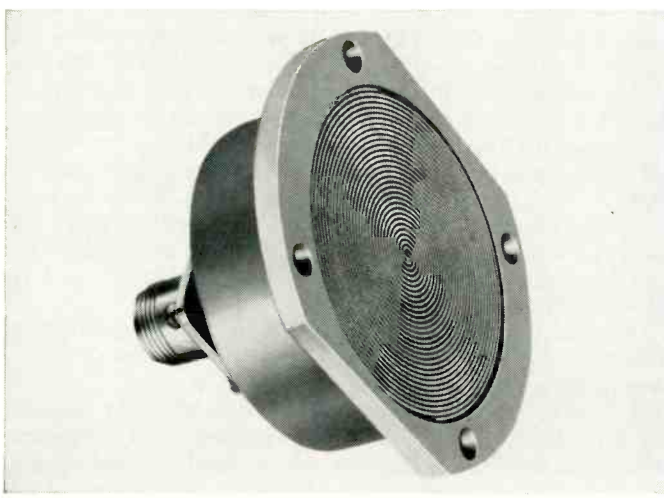
Highway Communications System. (Left) In response to public and political pressures the car manufacturers are beginning to promote and emphasize safety as well as performance. Here is a new highway communications system, developed at General Motors Research Laboratories, that promises increased safety and driver enjoyment. The experimental system would remind the motorist of speed and traffic signs, enable him to summon help in an emergency, and provide automatic routing for trips. The visual sign minder (display panel shown in inset) would be triggered by roadway signals from magnets or low-frequency radio transmitters. A route minder (unit with telephone dial) will guide the driver to his destination without use of maps. The equipment includes a programmed in-car route selector and route direction indicator activated by coded roadway signals. Voice communications will be provided on Citizen Band channels.

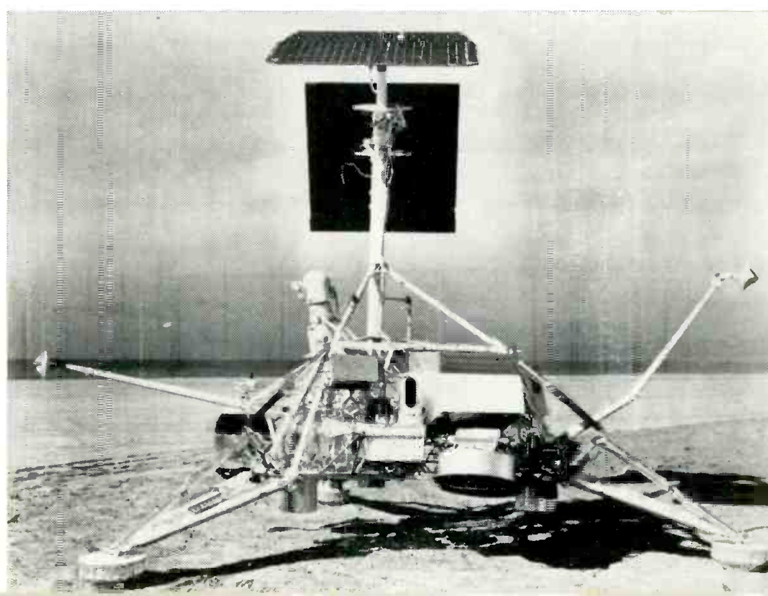
Battlefield Satellite Communications. (Right) A mobile ground terminal that can be wheeled into front line battlefield position for communications via satellite is shown here. The 4000-pound terminal, lightest ever built, was tested recently by the Air Force as part of an experimental program to improve world-wide military communications. The Sylvania unit demonstrated, by transmitting and receiving messages via Syncom III in synchronous orbit over the Pacific Ocean, that it can be employed successfully to communicate with very distant points.

Color Video Tape Recorder. (Center) A color-TV program, just taped from the set on the left, is played back over the same set in a demonstration of IIT Research Institute's recently developed color video tape recorder. The relatively low-cost unit was designed to be manufactured and profitably marketed for less than $500. So far three firms have been licensed to produce commercial versions of the system. Direct, longitudinal recording is used along with a single fixed recording head assembly for both recording and playback. Four separate channels of programming can be placed on a quarter-inch tape in four passes. The machine uses a 7-in reel of tape and operates at 120 ips. Program time varies from 15 to 30 minutes depending on reel size and type of tape used. The entire record and playback amplifiers employ twelve transistors.

Double-Spiral Antenna. (Below left) A cavity-backed double Archimedes spiral antenna that maintains essentially constant impedance and pattern performance over the frequency range from 2000 to 11,000 MHz is shown. The antenna has been developed for flush mounting in high-performance aircraft, missiles, and satellites. Adaptable to the high skin temperatures of these flight vehicles, the antenna can operate at temperatures up to 350 deg F. It measures about 3 by 2½ by 2 inches. The broadband antenna has a gain of 7 to 8 dB and produces a circularly polarized wave at a 75-deg beamwidth. The unit, made by American Electronics Labs, has applications in the fields of surveillance, telemetry, direction finding, control.

Successful Surveyor. (Below right) The fantastically successful Surveyor spacecraft, which recently soft-landed on the moon and sent back to earth a large number of pictures of that planet's surface is shown here. The small white turret at the left of the mast houses a television camera used to photograph the moon's surface. Crushable honeycomb aluminum footpads in sand (right, left, and rear) help soften landing. Protruding left and right are omnidirectional antennas. Top flap on mast contains solar cells that are employed to supply the power for the Hughes-built spacecraft.





An Integrated Circuit for Consumer Products

By LARRY BLASER
Fairchild Semiconductor

These circuits are used as self-limiting i.f. amplifiers for FM and TV receivers and as chroma oscillators for color-TV.

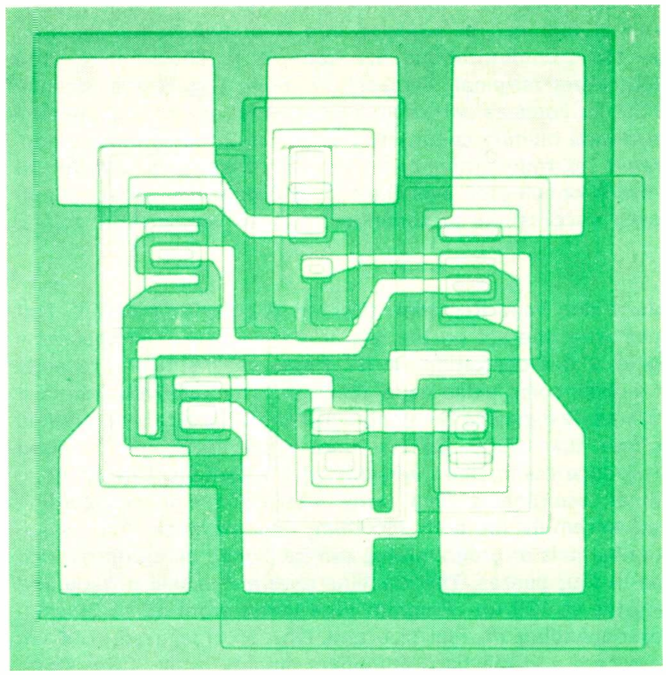


Fig. 2. Photomicrograph of 5-transistor, 2-resistor circuit.

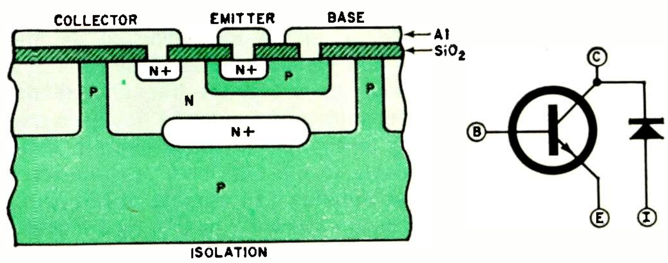
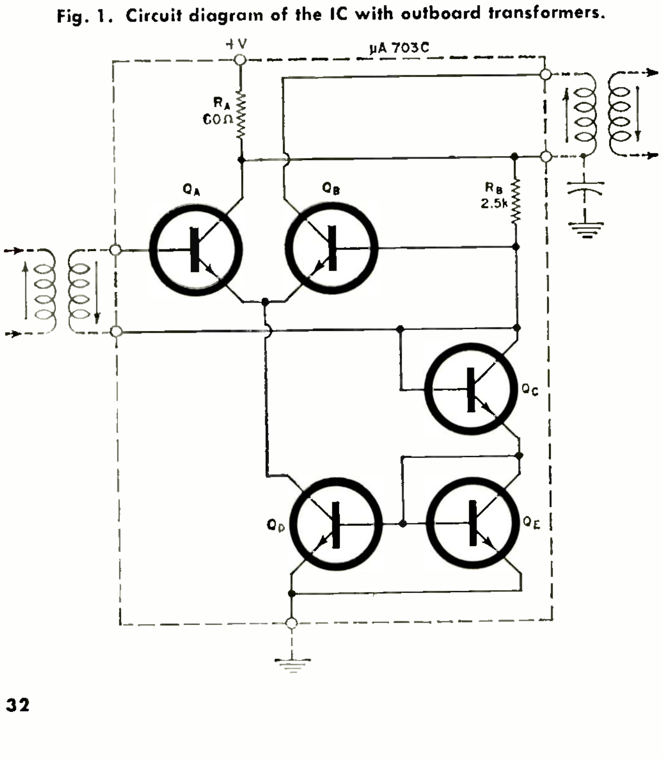


Fig. 3. Cross-section of silicon planar integrated transistor.

THE realization that integrated circuits can offer equal or improved performance at the same or lower cost in many linear-circuit applications has created a tremendous interest in their use by the consumer products entertainment industry. The consumer industry proved its adaptability to new technologies in making the recent switch from vacuum tubes to transistors in many television and radio circuits. There is reason to believe that the industry is eager and ready to incorporate integrated circuits into many of its future products.

Fairchild Semiconductor has been actively engaged in developing new integrated circuits for television, radio, and other consumer products. The initial result of these efforts has been the μA703C—a relatively simple integrated circuit designed primarily as an FM i.f. amplifier but which also has excellent properties as an oscillator. Representative applications which have been investigated for this device include: (1) 10.7-MHz self-limiting i.f. amplifiers for FM broadcast receivers; (2) crystal-stabilized, 3.58-MHz chroma reference oscillators for color television; and (3) 4.5-MHz inter-carrier sound i.f. amplifiers for both color and black-and-white television.

Fig. 1. Circuit diagram of the IC with outboard transformers.



(Editor's Note: The price of the μA703C in 1-24 quantities is $4.50, in 25-99 quantities is $3.60, and in 100-999 quantities is $3.00. In still larger quantities, the unit price is less. The μA703C and a more expensive military version, the μA703A, are available from Fairchild *distributors. For addresses, write Marketing Dept.,* Fairchild Semiconductor, *313 Fairchild Dr., Mountain View, Cal., 94040.)*

μA703C Integrated Circuit

The μA703C integrated circuit amplifier-oscillator is shown schematically in Fig. 1. Operated as an amplifier, the signals are transformer-coupled into and out of the device. The emitter-coupled (common-collector feeding common-base) amplifying transistors, Q_A and Q_B, provide high isolation between the input and the output of the integrated circuit. The bases of Q_A and Q_B are biased above ground by the voltage drop in the two diode-connected transistors, Q_C and Q_E. These transistors also form a low-impedance a.c. bypass for the base of Q_B. The amplifying transistors also share equal bias current from the current-source transistor, Q_D. The current from this source is equal to the current which flows in R_B inasmuch as (1) the current in R_B flows mainly in the collector of Q_E; (2) the bases of Q_D and Q_E are connected; and (3) Q_D and Q_E have matched V_{BE} and h_{FE} characteristics.

The collector of Q_A is decoupled to ground by an external capacitor. The supply voltage is fed through the internal decoupling resistor, R_A.

As a small-signal amplifier, the common-collector transistor, Q_A, drives the common-base transistor, Q_B. Under large-signal conditions, Q_A operates as a switch which chops the current from Q_D to the emitter of Q_B at the signal-frequency rate. Depending on the load presented to the output, the μA703C can be operated in either a saturating or non-saturating mode under large-signal conditions.

A photomicrograph of the complete integrated-circuit chip is shown in Fig. 2. The components on this monolithic chip of silicon have been fabricated using the planar process. Isolation junctions are used to electrically separate the components. Necessary component connections are made with a selectively deposited aluminum film.

A cross-section of an integrated transistor, shown in Fig. 3, illustrates how devices are fabricated with the planar process. Note that a parasitic isolation diode results at the collector of the transistor. Because the anode of the diode is the substrate, the substrate is connected to the most negative potential of the circuit in order that the isolation diode will always be reverse-biased.

The electrical properties of the μA703C are characterized by measured Y (admittance) parameters. From these parameters, a "figure-of-merit" quantity, Gain Maximum Stable (GMS), can be put on the device to tell how stable it would be as an amplifier. GMS is the ratio of forward to reverse transadmittance expressed in dB and is the gain which can be approached in a practical circuit without danger of instability. The values of GMS at 10.7-MHz (46.5 dB) and 100 MHz (31 dB) are both considerably above the actual gain which could be achieved as an amplifier at these frequencies. These figures show that stability is very high and that it need not be a prime consideration in an amplifier design using the IC.

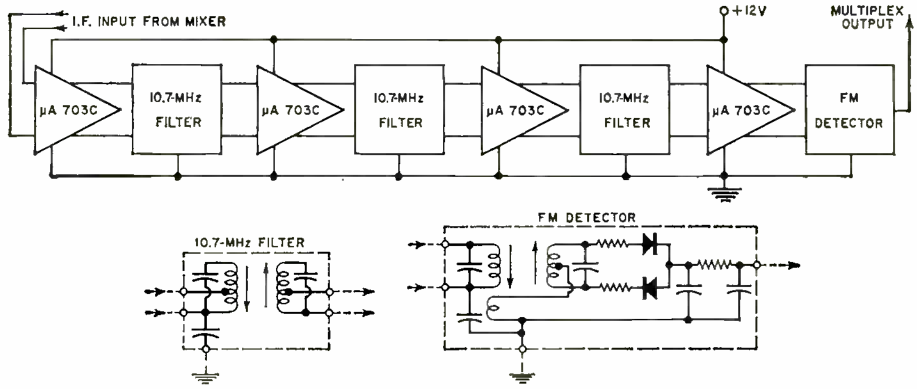


Fig. 4. FM intermediate-frequency amplifier and modified ratio detector.

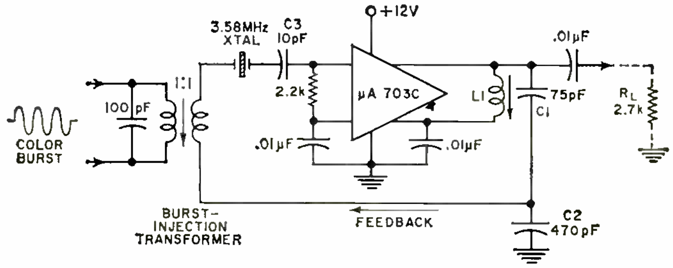


Fig. 5. Color-TV injection-locked reference oscillator.

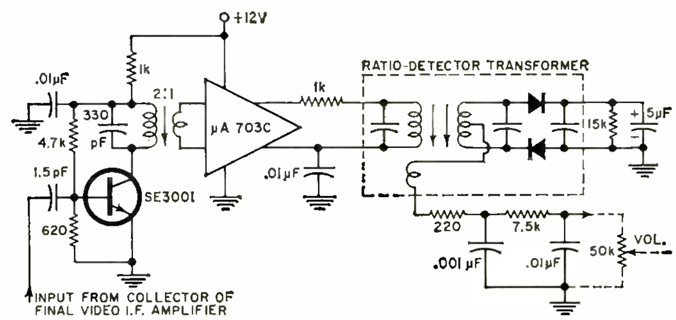


Fig. 6. Sound i.f. system for color television receiver.

FM I.F. Amplifier

The FM i.f. amplifier strip shown in Fig. 4 uses four identical μA703C integrated-circuit amplifiers, each of which is self-limiting. Selectivity is obtained with conventional double-tuned interstage filters. The only other components in the i.f. amplifier are decoupling capacitors in the supply voltage to each stage.

The interstage filters, which are all identical, have been designed to have i.f. amplifier bandpass, selectivity, and phase characteristics that represent good compromises for stereo multiplex reception. To maintain selectivity, high rejection to AM, low distortion, and a good capture ratio in an FM tuner, the bandpass characteristics of the i.f. must not be degraded under large-signal conditions. To satisfy this requirement in these self-limiting stages, the loading changes on the filters by the integrated amplifiers are minimized by selecting a sufficiently low load to achieve current limiting in Q_B (the collector does not saturate) and by mismatching from the filter to the base of Q_A.

The i.f. amplifier stage gain is about 28 dB and is relatively independent of normal spreads in the characteristics of the elements within the integrated circuit.

The FM detector is a modification of the conventional ratio detector. The important difference is the absence of the *RC* network associated with the detector diodes. In this simplified detector configuration, made possible by the excellent limiting properties of the integrated circuit, the forward voltage drop of the two silicon detector diodes is utilized to replace the voltage offset normally developed across a large electrolytic capacitor in the *RC* network of the conventional ratio detector. One inherent disadvantage of this simple FM detector is its low output which, in this design, is about a fourth that of a typical ratio detector.

The performance of the i.f. amplifier strip compares favorably with i.f. amplifier strips now found in component FM tuners. Capture ratio and AM rejection are especially good due, to a large extent, to the unique limiting characteristics of the integrated circuit.

Color-TV Chroma Oscillator

Three methods are presently used for re-establishing the 3.58-MHz subcarrier in a color-television receiver: (1) the voltage-controlled, crystal-stabilized oscillator driven from an a.p.c. detector; (2) the injection-locked, crystal-stabilized oscillator; and (3) the narrow-bandpass, crystal ringing circuit.

Fig. 5 shows the μA703C integrated circuit and associated components for an injection-locked crystal oscillator. The positive feedback voltage to start and sustain oscillations is taken from a capacitive tap in the tuned circuit at the collector of transistor Q_B. This voltage is fed back through a narrow-bandpass crystal filter network to the base of transistor Q_A. The common-collector transistor, Q_A, drives the common-base transistor, Q_B, to complete the regenerative feedback path required for oscillation.

The inductor *L1* in combination with the series capacitors *C1* and *C2* make up the reactive components of the temperature-compensated, 3.58-MHz output tank circuit. The output signal amplitude is determined by the load resistance R_L. A relatively large feedback signal (one volt peak-to-peak) is fed into the input of the integrated circuit to take advantage of its self-limiting properties.

L1 provides the initial frequency setup without affecting the output voltage significantly. The crystal in the feedback loop is the primary frequency-determining element. It operates in an inductive mode and resonates with capacitor *C3*. The burst transformer (*Continued on page* 80)

PART 2. CIRCUIT CONFIGURATIONS

Designing Silicon-Transistor Hi-Fi Amplifiers

A number of basic circuit configurations for readily available silicon power transistors, along with their comparative operating characteristics, are covered.

By R.D. GOLD and J.C. SONDERMEYER
RCA Electronic Components & Devices

LAST month we covered the performance objectives in designing hi-fi power amplifiers using silicon transistors. In this installment we will go into the circuit configurations that are used in such amplifier designs.

The type of circuit configuration selected will be dictated by the requirements of the given application. The output power to be supplied, the required sensitivity and frequency response, and the maximum distortion limits, together with the capabilities and limitations of available devices, are the main critera used to determine the circuit that will provide the desired performance most efficently and economically.

Class-A Transformer-Coupled Amplifiers

Low-cost, low-power audio systems, in which high operating efficiency is not an important consideration, usually employ a single-ended, class-A, transformer-coupled output stage, such as that shown in Fig. 1. One or more driver stages, negative feedback from the output stage to the input stage, and other features may also be necessary to obtain the desired circuit sensitivity, input impedance, and distortion characteristics.

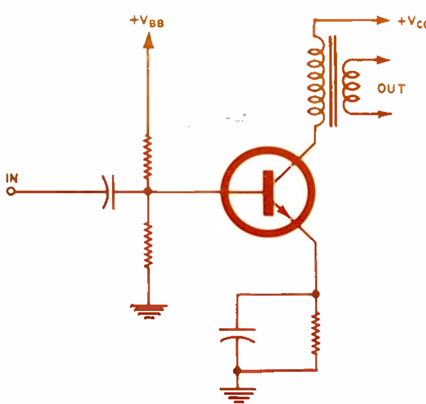


Fig. 1. Class-A transformer-coupled stage.

Fig. 2 shows a three-stage, class-A, transformer-coupled audio amplifier which uses d.c. feedback (coupled by *R*1, *R*2, *R*3, *R*4, and *C*1) from the emitter of the output transistor to the base of the input transistor to obtain a stable operating point. An output capability of 5 watts, with 3 percent of total harmonic distortion, is typical for this type of circuit. This output level, in general, is the upper limit for class-A amplifiers because the power dissipated by the output transistor in such circuits is more than twice the output power. For this reason, it is economically impractical to use a class-A audio amplifier to develop higher levels of output.

Class-AB Push-Pull Amplifiers

At output-power levels above 5 watts, the operating efficiency of the circuit becomes an important factor in the design of audio power amplifiers. The circuit designer may then consider a class-AB push-pull amplifier for use as the audio output stage. In such amplifiers, the operating efficiency is high (up to 78 percent), the power dissipated by the transistors under quiescent conditions is low, and, with the transistor operated class-AB (rather than class-B), crossover distortion is essentially eliminated.

Fig. 3 shows a class-AB, push-pull transformer-coupled audio output stage. Resistors *R*1, *R*2, and *R*3 form a voltage divider to provide the small amount of transistor forward bias required for class-AB operation. The transformer type of output coupling used in the circuit is advantageous in that a suitable output transformer can be selected to match the audio system to any desired load impedance, which assures a maximum transfer of the audio output power to the load circuit. This feature is especially important in sound distribution systems which use high-impedance transmission lines to reduce losses. Transformer output coupling has a major disadvantage in that it tends to limit the amplifier frequency response, particularly at the low-

Fig. 2. Three-stage, transformer-coupled, class-A amplifier.

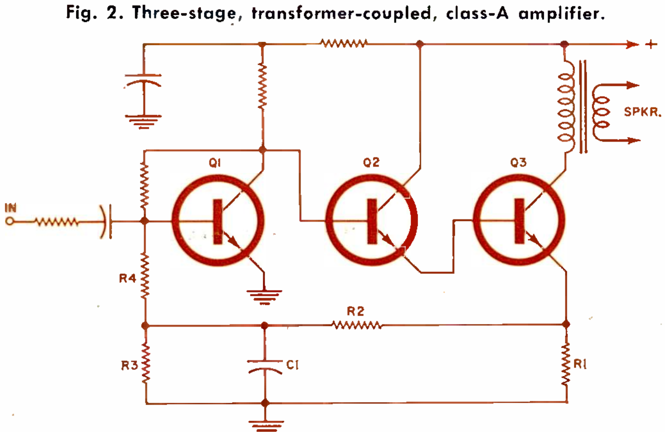
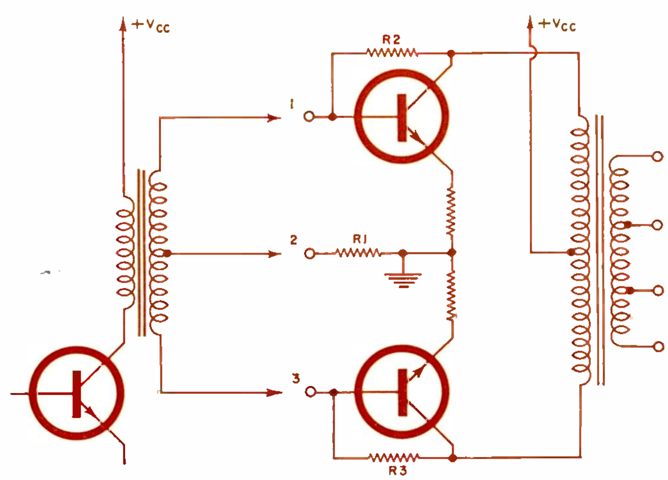


Fig. 3. Class-AB, push-pull, transformer-coupled output stage.



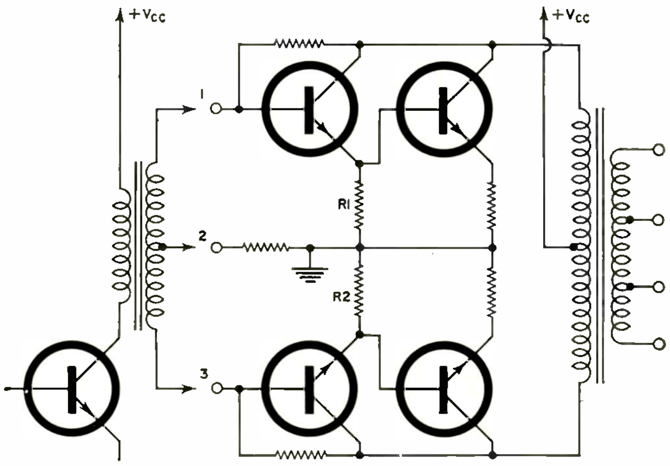


Fig. 4. Same as Fig. 3 except that Darlington pairs are employed to reduce drive requirements of output transistors.

frequency end. Variations in transformer impedance with frequency may produce significant phase shifts in the signal at both frequency extremes of the amplifier response. Such phase shifts are potential causes of amplifier instability if they occur within a feedback loop. Because of the high cost of audio-output transformers having a broad, flat frequency response, high-quality wideband transformer-coupled amplifiers cannot usually be realized economically.

Push-pull output stages, which use identical output transistors, require some form of phase inversion in the driver stage. In the circuit shown in Fig 3, a center-tapped driver transformer is used for this purpose. The requirements of this transformer depend upon the power levels involved, the bandwidth required, and the distortion that can be tolerated. This transformer also introduces phase-shift problems which tend to cause instabilities in the circuit when high levels of feedback are employed. These problems are substantially reduced when the output stage is designed to operate at low drive levels.

Fig. 4 shows a Darlington-pair output circuit used to reduce the drive requirements. Resistors $R1$ and $R2$ provide a leakage path for the driver and also permit the output transistors to turn off more rapidly. Impedance levels between the class-A driver and the output stage can be easily matched by the use of an appropriate transformer turns ratio, regardless of whether a Darlington-type of circuit is used. However, care must be taken to insure that hum pickup by the transformer is not excessive, especially when the Darlington circuit is used, because of its high gain.

An alternative method of phase inversion is to use a transistor in a phase-splitter circuit, as shown in Fig. 5A. Unlike the center-tapped transformer method, impedance matching may be a problem, because the collector of the driver, which has a relatively high impedance, operates into the low impedance of the driver stage. One solution is to reduce the output impedance of the driver stage by using smaller resistors. The resultant increase in collector current, however, also increases the dissipation. Moreover, very large coupling capacitors would be necessary to obtain good low-frequency performance. An alternate solution is to use a Darlington pair to increase the input impedance of the output stage.

Class-AB Series-Output Amplifiers

For applications in which low distortion and wide frequency response are major requirements, a transformerless approach is usually employed in the design of audio power amplifiers. With this approach, the most common type of circuit configuration used is the class-AB series-output amplifier in which two transistors are connected in series with the supply voltage and the load is connected to a common circuit point between these transistors. The series-output circuit may be operated from a single d.c. supply, in which case, the output is coupled to the load through a capacitor, as shown in Fig. 5B. Alternatively, the circuit may be operated from symmetrical dual (positive and negative) supplies, as shown in Fig. 5C. An advantage of the dual-supply arrangement is that there is no output coupling capacitor to limit the low-frequency response. More important, the low-frequency phase shift usually associated with such capacitors is eliminated. The requirement for two separate supplies does not necessarily increase the over-all cost of the system depending upon the choice of time constants of the power-supply filters. But additional problems may arise.

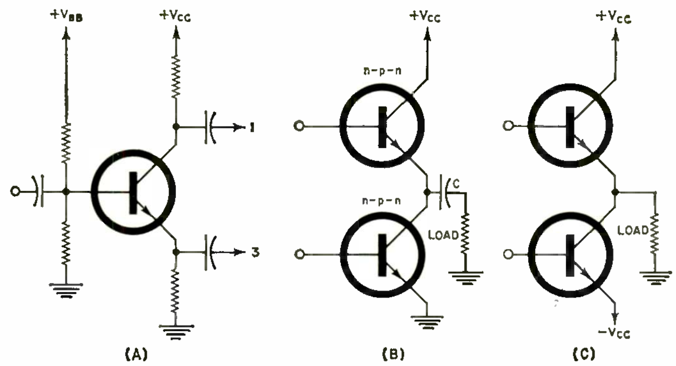


Fig. 5. (A) Transistor phase-splitter circuit. (B) Series-output circuit operated from single d.c. power supply. (C) Series-output circuit operated from opposite-polarity supply.

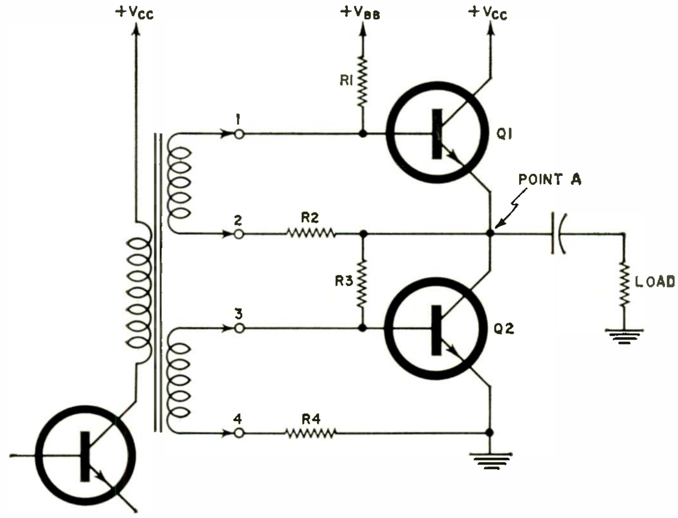


Fig. 6. Push-pull series-output amplifier with split-secondary transformer used to provide the drive-signal phase inversion.

Push-Pull Driven Circuits: The class-AB-operated *n-p-n* transistors used in the series-output circuits of Figs. 5B and 5C require some form of phase inversion of the drive signal for push-pull operation. A common approach is to use a driver transformer having split secondary windings, as shown in Fig. 6. The split (separate) secondary windings are required because of the mode in which each of the series output transistors operate. If ground were used as the drive reference for both secondary windings, transistor $Q1$ would operate as an emitter-follower and would provide somewhat less than unity gain. Transistor $Q2$, however, is connected in a common-emitter configuration which can provide substantial voltage gain. In order to obtain equal output-voltage swings in both directions, the drive input to transistor $Q1$ is applied directly across the base and emitter terminals. Transistor $Q1$ is then effectively operated in a common-emitter configuration (although there is no phase reversal from input to output) and has a voltage gain that is equivalent to that of transistor $Q2$.

The disadvantages of a driver transformer pointed out previously also apply to the circuit shown in Fig. 6. In addition, coupling through inter-winding capacitances can adversely affect the performance of the circuit. Such coupling is particularly serious because at both ends of the upper secondary (*i.e.*, terminals 1 and 2) the a.c. voltage with respect to ground is approximately equal to the output voltage. During signal conditions when output transistor *Q*1 is turned on, this coupling will provide an unwanted drive to *Q*2. The forward transistor bias required to maintain class-AB operation of the circuit is provided by the resistive voltage divider *R*1, *R*2, *R*3, and *R*4. These resistors also assure that the output point between the two transistors (point A) is maintained at one-half the d.c. supply voltage, V_{cc}.

As in the case of the transformer-coupled output, phase inversion can be accomplished using an additional transistor. Fig. 7 shows such a circuit, in which a Darlington output stage is used to minimize loading on the phase inverter. Notice that capacitor *C* provides a drive reference back to the emitter of the upper output transistor. In effect, this duplicates the drive conditions of the split winding transformer approach. A disadvantage of this circuit is the high quiescent dissipation of the phase inverter (*Q*1) which is necessary to obtain adequate drive at full power output. An unbypassed emitter resistor (*R*) is necessary because a signal is derived from this point to drive the lower output transistor. When transistor *Q*1 is driven into saturation, the minimum collector-to-ground voltage that can be obtained is limited primarily by the peak emitter voltage under these conditions. In order to obtain the necessary voltage swing at this collector (which is also approximately equal to the output voltage swing), the quiescent collector-to-emitter voltage must be higher than that required in a stage that uses a bypassed emitter resistor.

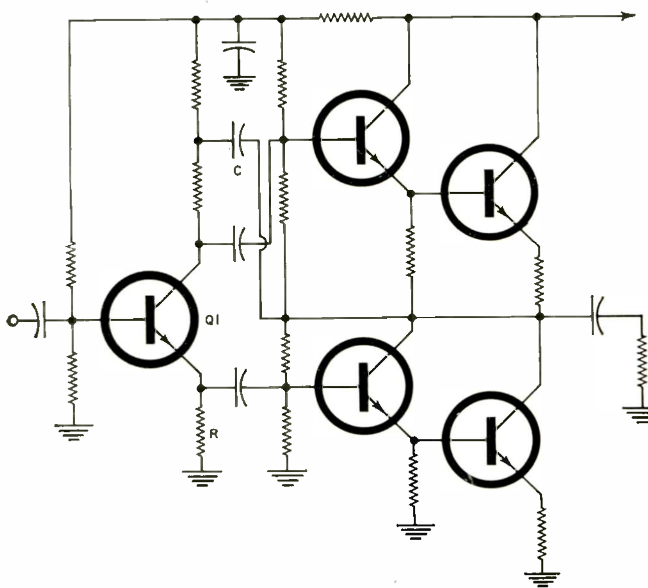


Fig. 7. Push-pull series-output amplifier in which driver and output transistors are connected as Darlington pairs and drive-signal phase inversion is provided by phase-splitter stage Q1.

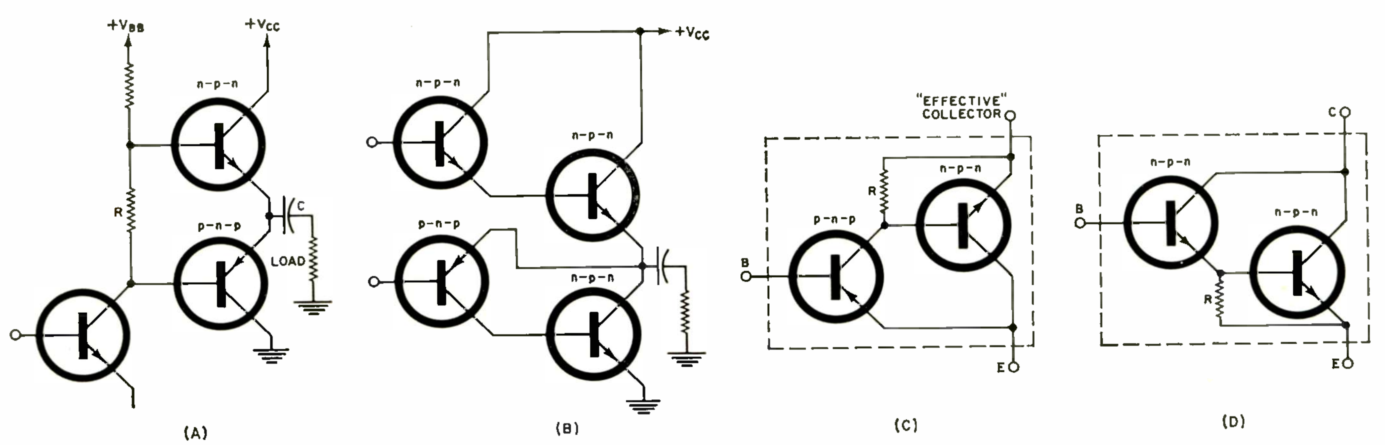
Complementary Amplifiers: With a complementary pair (*n-p-n* and *p-n-p*) of output transistors, it is possible to design a series-output type of audio power amplifier which does not require a push-pull drive. Because phase inversion is unnecessary with this type of configuration, the drive circuit for the amplifier is considerably simplified. Fig. 8A shows a basic complementary type of series-output circuit together with the simple drive arrangement that may be used. The voltage drop across resistor *R* provides the small amount of forward bias required for class-AB operation of the complementary pair of output transistors.

Rather than the use of complementary high-power output transistors, a more common approach is the quasi-complementary circuit shown in Fig. 8B. In this circuit, the driver stage employs a complementary pair of *n-p-n* and *p-n-p* transistors. This technique has become very popular with the availability of both *n-p-n* and *p-n-p* silicon driver transistors having similar electrical characteristics.

In the quasi-complementary amplifier, the driver transistors provide the necessary phase inversion. A simple but descriptive way to analyze the operation of a quasi-complementary amplifier is to consider the result of connecting a *p-n-p* transistor to a high-power *n-p-n* output transistor as shown in Fig. 8C. The collector current of the *p-n-p* transistor becomes the base current of the *n-p-n* transistor. The *n-p-n* transistor, which is operated effectively as an emitter-follower, provides additional current gain without inversion. If the emitter of the *n-p-n* transistor is considered as the "effective" collector of the composite circuit, it becomes apparent that the circuit is equivalent to a high-gain, high-power *p-n-p* transistor. The output characteristics of the *p-n-p* circuit of Fig. 8C and of a high-gain, high-power *n-p-n* circuit formed by the connection of the same type of *n-p-n* output transistor and an *n-p-n* driver transistor in a Darlington configuration, as shown in Fig. 8D, are compared in Fig. 9.

The saturation characteristics of the over-all circuit in both cases is the combination of the base-to-emitter voltage, V_{be}, of the output transistor plus the collector saturation voltage of the driver transistor. Moreover, in both cases, the current gain is the product of the individual *betas* of the transistors used. A quasi-complementary amplifier is, therefore, effectively the same as a simple complementary output circuit such as that shown in Fig. 8A, and is formed by the use of high-gain, high-power *n-p-n* and *p-n-p* equivalent transistors. In both cases, resistor *R* between the emitter and base of the output tran- (*Continued on page* 94)

Fig. 8. (A) Basic complementary type of series-output amplifier. (B) Quasi-complementary amplifier. (C) The "p-n-p" driver and "n-p-n" output transistor form the equivalent of a "p-n-p" power transistor. (D) An "n-p-n" driver and "n-p-n" transistor pair.



SPECIAL SECTION: CHOKES and COILS

The Inductor Industry

By SAM ZWASS / Chief Engineer, Triad Transformer Corp. Div. of Litton Industries

IN a broad sense, the use of inductors and the inductance principle is as varied as the electronics industry itself. From a doorbell to the atom-smashing cyclotron, from a toy train to a color-television receiver, and from an automobile ignition system to a space-traveling rocket ship—all are dependent on the inductance principle and the availability of sophisticated and highly reliable inductors. The inductor industry has stimulated the use of inductors by developing new technologies and processes to cover an ever widening spectrum of applications. Inductors are now used at d.c. and at frequencies up to the gigahertz range and from cryogenic temperatures to temperatures far above +200° C.

During the past ten years, the inductor industry has expanded at the unprecedented annual rate of 6 to 8%. In the last two years, with the boom in color television, this inductor growth has climbed to a 10 to 15% annual rate, and this year promises to top even that.

Although national figures for factory shipments of inductors alone are not available, the U.S. Department of Commerce in its Business and Defense Services Administration (BDSA) reports indicate total dollar-value of shipments of transformers and inductors. It is reasonable to assume that the inductor industry, being a sizable portion of the transformer industry, would have the same percentage of defense and non-defense business as the transformer-reactor industry figures reported. However, these figures do not show a breakdown of electric wave filter production, although filters account for more than half of the dollar value of inductors. In 1964, the BDSA reported that out of a total shipment of approximately $215,000,000, only about $50,000,000 worth of these products was for defense (about 24%). Of the total shipment, 15% was of toroidal types with the bulk of the shipment units of open-type construction (50%) in the weight range of 2 ounces to 30 pounds (72%).

These figures are even more impressive if one considers that the actual unit prices (especially for the less complicated types) are being reduced and, by the use of automated production facilities, the quantity, uniformity, and reliability of these products are increased.

(Editor's Note: Although the figures quoted above on the size of the market have been referred to by many in our industry, note that they are now almost two years old, and there are some who feel that they are far too conservative for today's booming consumer-electronics market. For example, according to Charles Liebman, President of Coilcraft, Inc., *the dollar value of all types of coils and transformers supplied to TV and radio manufacturers alone represents about $250 million. This is not surprising when we consider that about 14 million black-and-white and color-TV sets have been predicted for 1966, and each color set uses about $20 worth and each black-and-white set uses about $10 worth of inductive components. To this must be added the value of coils and transformers used in the large number of AM, FM, and communications radios.*

Even if we assume that inductive devices do not share in the industrial and military markets in the same ratio as semiconductors or other passive components, certainly the industrial and military inductance market would equal another $250 million. This indicates a total market this year of at least $500 million. And this figure is probably still conservative, since many large industrials build inductive devices but do not report their volume.)

The inductor industry can look forward to continual growth, with a larger percentage of the products going to the non-defense and consumer-goods market.

Although the development of integrated circuits tends to reduce the number of individual components, inductors in the millihenry range and the larger values used at lower frequencies are impractical to integrate and are still being used as separate components.

Advances are being made in deposited thin-film technology whereby small inductance values can be deposited or "printed in". We can anticipate a still further improvement in this method when thin-film magnetic materials and processes are upgraded. ▲

INDUCTANCE AND RELATED PARAMETERS

THE magnetic properties of lodestone have been known since early antiquity. However, it wasn't until 1819 when Oersted discovered the link between electricity and magnetism that a serious study of this phenomenon was undertaken.

Oersted demonstrated that it was possible to produce a magnetic effect with moving electric charges. Joseph Henry and Michael Faraday studied the spark phenomenon produced when the electric current in a coil circuit was interrupted and proved that the spark was due to a self-induced electromotive force. They also demonstrated that currents could be produced by moving magnets—the principle of ferromagnetic induction. Thus was the age of electronics ushered in.

Electronics engineers and technicians often use inductors in their work. Although the actual design of such coils can best be left to the specialist, a clear understanding of their basic operating principles is essential if one is to obtain optimum results from their use.

When the flow of electric current through a coil is varied, the resulting change in the magnetic field surrounding the coil causes a voltage to be induced in the coil which opposes the supply voltage. This results in the coil having "self inductance" or simply "inductance". Inductance can be defined as that property of an electric circuit which opposes any changes in the current flowing in the circuit.

Inductance (L) represents a factor by which the rate of change of current is multiplied to obtain the induced e.m.f.: $e = -L\,(di/dt)$. The constant, L, is called the coefficient of self-induction and is measured in henrys (H). One henry equals an induced e.m.f. of 1 volt for one ampere per second rate of change of current. The minus sign indicates that the self-induced voltage is of opposite polarity from the supply voltage.

The amount of inductance is determined by the amount of flux linking a given coil, and this depends on the number, size, and arrangement of the turns forming the coil and the presence (or absence) of magnetic substances in the core of the coil.

Flux linkages represent energy stored in the form of magnetic flux. The amount of that energy depends on the inductance and current value: $W = \frac{1}{2}LI^2$. Thus an inductor can be also considered an energy storing device.

The flux (φ)—the total number of lines of force—is measured in lines or maxwells (Mx). Flux density (B), *(Continued on page 43)*

Toroidal Inductors

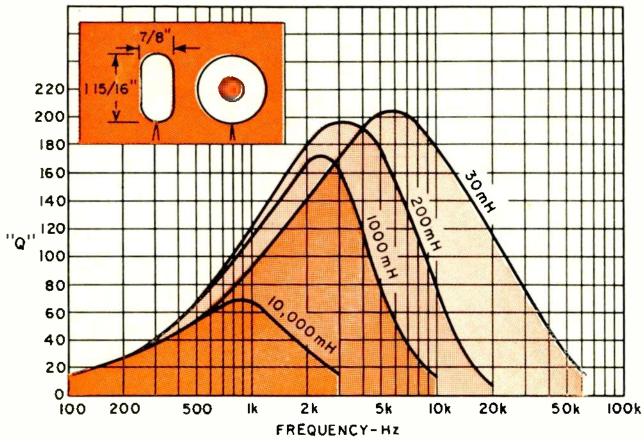
By SAM ZWASS/Chief Engineer, Triad Transformer Corp., Div. of Litton Industries

Chokes and coils made with toroidal cores are widely employed in spite of their higher cost because they have higher inductance in smaller sizes, are self-shielding, and are highly stable. Factors to consider in selecting the proper coil for a.f. and r.f. use.

A TOROIDAL coil represents a nearly ideal inductor. Within a toroidal winding, the magnetic field is almost wholly confined to the space enclosed by the winding so that most of its flux lines are contained within the toroidal core form. The flux density of a toroid is essentially uniform over its entire magnetic path. Furthermore, for a given set of conditions, the permeability within the toroid can be considered constant. Also, stray magnetic fields from external sources have a minimum effect on a reactor of toroidal construction.

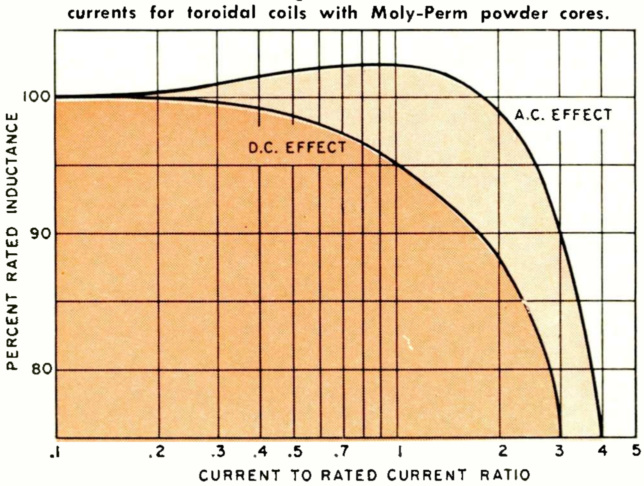
Where, a precise or close-tolerance inductance value is required, a toroid has a distinct advantage in that the turns on the windings can be trimmed right at the bridge to provide the required inductance. Toroidal inductors can be easily stacked in banks because they are physically adaptable to common shaft mounting. In addition, shielding between the individual coils will not, in most instances, be required.

Cores which produce extremely stable inductors over a wide temperature range are, at present, available only in toroidal form. These cores are made of special materials which can cause either a linear positive temperature coefficient of inductance, or, alternately, an inductance change which is limited to an extremely small value over a wide temperature range.



Representative "Q" values of a number of toroidal coils.

Percent inductance change with a.c. and d.c. excitation currents for toroidal coils with Moly-Perm powder cores.



The major disadvantage of the toroidal inductor is its higher cost. Besides the higher cost of certain materials used in toroidal cores, the cost of winding a toroid is considerably higher than for other coil shapes. Toroidal coils are not adaptable to multiple winding, that is, simultaneous winding of several coils. It is much more difficult to provide high-voltage insulation on a toroid, and, furthermore, grounding of a toroidal core is impractical. For inductances requiring a gap adjustment, a toroid would be impractical.

One important restriction on the fabrication of toroids is the wire-size-handling limitation of the winding machines. With other coil shapes, like bobbins, handling of fine wire sizes even in the range of AWG #56 is not too difficult; a wire size of AWG #48 on a toroid is very difficult to handle, and the use of such fine wires in reliable units should be avoided.

Toroids can cover the full spectrum from d.c. to the ultra-high radio frequencies, but practical considerations limit their application at frequency extremes. From a cost standpoint, large inductance values in the toroidal shape have no particular advantage at frequencies below 100 Hz. Similarly, at higher radio frequencies, a toroid has no advantage over inductors wound on powdered-iron slugs, where parameters, such as coil capacitance, can be controlled more easily.

The widest application of toroidal inductors is in the range of audio and low radio frequencies from about 100 Hz to above 1 MHz. They are employed extensively in building precision high-"*Q*" inductors for use in electric wave filters. Toroidal inductors are also used as filter chokes for smoothing out the ripple in d.c. power supplies or as a.c. blocking chokes for passing the d.c. signal to a load and blocking the a.c. signal. In conjunction with other elements such as resistors, toroidal inductors find application in phase-shifting or phase-adjusting devices. Toroidal inductors are often used as complex loading devices to adjust the power factor of a load and as transient suppressing chokes to protect voltage-sensitive elements from damaging voltage surges and voltage spikes.

Core Materials

Among the various types of cores used in inductors, there are basically two types: (1) solid magnetic steels and (2) powder and ceramic cores.

Toroidal steel cores are available in the form of a continuous tape which is wound into a toroidal shape or as thin, stamped, washer-like ring wafers stacked to the desired height of the toroid. Available thicknesses of such magnetic tapes and rings vary from a fraction of a mil to 14 mils. Toroidal cores made of silicon steel are generally impregnated or coated with epoxy before the winding is applied. Most other magnetic-steel alloys, especially those containing nickel (or other materials creating an alloy with very high permeability), are extremely pressure-sensitive and must be protected from a distortion of their magnetic properties due to handling, winding pressure, or bending. For that reason, most of these cores are placed in a rigid aluminum or plastic box filled with a silicone compound for core cushioning.

Powder cores include (1) molybdenum Permalloy, (2) ferrite cores, and (3) powdered iron.

Molybdenum Permalloy (Moly-Perm) powder cores are made by reducing the magnetic alloy material, containing 81% nickel, 17% iron, and 2% molybdenum, to a very fine powder or flake. The powder is then hydrogen-annealed and several coats of insulation are applied. Then, by the use of extremely high pressures, the powder is pressed into a toroidal form, annealed, and an outside insulation coating is applied. The size of the powder and its grain insulation thickness determines the final core permeability and core losses. By adding other powder mixtures with various Curie points, a core with an extremely stable temperature characteristic is obtained. (Curie point is the temperature at which the magnetic properties of the material disappear due to thermal agitation.) Basically, powder cores have an evenly distributed air gap, which results in a relatively constant effective permeability. The core loss and permeability of Moly-Perm powder cores are extremely stable with time, and permeability is constant over a wide range of frequencies, flux levels, magnetic d.c. drives, and temperatures.

Ferrites are a combination of various metallic oxides such as zinc, manganese, nickel, iron, and others. They are formed into a cubic polycrystalline structure by solid-state reaction. The ferrites are then pressed and sintered into toroidal and other shapes. Due to their non-metallic structure, ferrites exhibit extremely high electrical resistivity, maintaining low eddy current losses even at very high frequencies. In toroidal form, ferrites find application in filter coils, delay lines, saturable reactors, loading coils, coils for computer storage, and in various types of transformers

The application of powdered-iron cores goes back to the turn of the century when it was demonstrated that, by inserting inductance coils at specific intervals in series with a telephone cable, transmission could be improved. The first cores for such loading coils were made of iron filings imbedded in wax and 4-mil iron wires formed into toroids. Later, a method was developed for producing cores from powdered iron. The present method employs a finely divided iron powder which is then insulated and, together with a thermosetting binder, pressed into shape and baked to set the binder. The use of powdered-iron cores spans the frequency range from audio to the microwave region. Powdered iron cores are generally of low permeability (from about 80 down to about 3). They yield inductors which are very stable over a wide range of flux levels and frequencies and have high-"Q" values even at frequencies in the megahertz range. Above 100 kHz, powdered-iron cores are superior to Moly-Perm cores and are considerably cheaper than both Moly-Perm and ferrite cores.

Wire and Winding

The most important element in an inductor is its winding. High-frequency toroidal inductors have been wound on "air cores" (that is, non-magnetic cores) which were machined out of wood or plastic merely to serve as a support for the toroidal winding.

The winding consists mainly of round copper insulated wire, although copper or aluminum sheet strips and square wires may be used. For toroidal winding, however, these are highly impractical and seldom employed. Copper or nickel-alloy foil strips may be wound on toroids for electrostatic and magnetic shielding.

Due to the high abrasion experienced by the wire during winding, toroids are generally wound with a double (or multiple) insulated wire. Used extensively are heavy Nyleze and heavy Polythermaleze type insulated wire. Nyleze is a wire coating with a very high abrasion resistance and is rated for class "S" operating temperatures (up to 130°C). Nyleze-coated wire is solderable and has an advantage in production in that it can be soldered directly at the termination. (The insulation coating melts away under the heat of the soldering iron.) Thermaleze is a high-temperature wire rated for up to 200°C operating temperature and it also has a high abrasion resistance. However, it cannot be soldered directly; the insulation has to be stripped off either chemically or mechanically. Among other wire types frequently used for toroids are: Formvar-insulated wire (with 125°C operating temperature, non-solderable); Teflon-insulated wire, used where low winding capacitance is imperative (200°C, non-solderable), and for fine wire sizes (AWG #44 through #48) Isonel wires (class "T" insulation 170°C, non-solderable). Depending upon the core size, the wire sizes that can be machine-wound on toroids range from about AWG #20 to #48. Heavier sizes are frequently hand-wound, but sizes finer than #48 are, for reliability and production-yield reasons, not recommended.

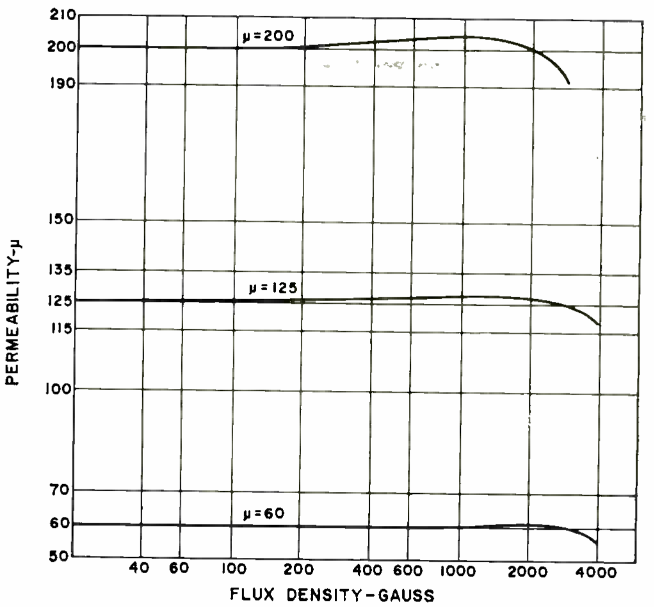
Several types of winding methods are employed. For instance, for inductors used at low frequencies, "continuous" winding is used. This winding puts the most wire on the core and results in the highest L/R ratio. The turns are applied parallel, transversing a multiple of 360° on the core in one direction.

For medium- and high-frequency applications, the effect of distributed capacitance in the coil must be taken into consideration; consequently, a winding type must be selected that will minimize coil capacitance. The "bank" and "progressive" methods of winding are then used. They result in somewhat higher winding resistance, as often one size finer wire has to be used (compared with a continuous winding) in order to accommodate the turns required for the inductance. A "bank" winding consists of several distinct winding sections or segments. "Progressive" winding is a bank winding with a large (continuous) number of banks; that is, the entire winding is applied in one 360° sweep.

In addition, at frequencies above 100 kHz, Litz wire is often employed. In the megahertz region, the core is usually wound with only a single layer of solid wire without any crossovers, often covering less than 360° of the core.

The capacitance of the coil is affected not only by the wire insulation and type of winding but also by the coil impregnating and potting compounds. Generally, distributed capacitance is increased by the impregnant, as most of the impregnants have a dielectric constant which is greater than unity. For low distributed capacitance in a coil, dry air is the best "dielectric." Coils operating at high frequencies are often embedded in tiny glass-sealed air bubbles or just sealed in a dry nitrogen atmosphere. Potting compounds used vary from waxes and tars to a wide variety of epoxies. The coils are often coated with silicone rubber which cushions the coil from pressures exerted by the potting compound.

Permeability vs flux density for various Moly-Perm cores.



Packaging

The final packaging of a coil is governed not only by its shielding requirements but also by its environmental requirements. Toroidal inductors fall into three packaging categories: (1) open coils, (2) molded coils, and (3) metal-encased coils.

Open coils have the least environmental protection. They consist mainly of a winding wound on a core and terminated with plastic insulated leads. Toroidal open coils are frequently coated on the outside with plastic which serves not so much for environmental protection as for mechanical protection against scraping or breakage of the winding wires during handling. Open coils, even with plastic coating, still absorb moisture and should be dried (baked at 125°C for a minimum of eight hours) before using. Some protection is afforded an open coil when it is impregnated.

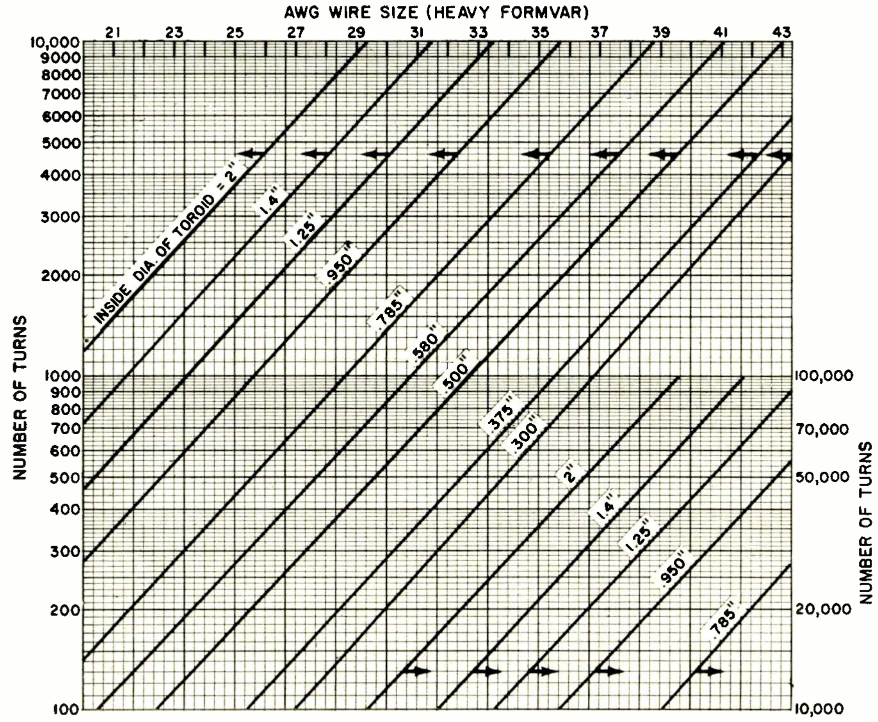
For complete environmental protection, coils must either be molded (encapsulated) or hermetically sealed and metal-encased. Encapsulated units meet stringent requirements of Grade 5 of MIL-T-27B and are generally smaller in size and less expensive than comparable metal-encased coils. Termination of the winding is also simpler and is provided by a variety of solder terminals, printed-circuit pins, or flexible insulated leads. In hermetically sealed coils, termination must be made through a sealed insulated terminal which is soldered to the case.

Generally, no mounting provision is made for open coils except for the center opening of the toroid and the winding leads. Molded units, in addition to a rigid center opening and solidly embedded terminal pins, can be provided with a variety of mounting hardware, such as threaded metal inserts and/or studs, thus offering inductors that can withstand shocks of several hundred G's and vibration of several thousand cycles. Of course, metal-encased units can be supplied with the same mounting provisions and will withstand the most severe environmental stresses. Also, additional magnetic and static shielding can easily be provided for metal-encased units.

IRON POWDER CORE MATERIALS	60-2000 Hz	AUDIO FREQ. - 50kHz	50kHz - 250kHz	250kHz - 500kHz	500kHz - 2000kHz	2MHz - 10MHz	10MHz - 40MHz	40MHz - 150MHz	150MHz - 250MHz	ABOVE 250MHz
FLAKE	65-85µ									
HA		55-65µ								
MP-34			35-45µ							
CARBONYL L				30-40µ						
MR				30-40µ						
HP				20-30µ						
C				20-30µ						
MP-38					20-30µ					
GS-6					15-20µ					
E, ME					8-12µ					
MAGNETITE				6-10µ						
TH							6-10µ			
SF								6-10µ		
J									6-10µ	
IRN-8								3-5µ		
IRN-9									3-5µ	

Suggested frequency ranges for various iron powder cores.

Numbers of turns of heavy Formvar for various i.d. toroids.



Military Specs

The principal document governing coil construction for military applications is MIL-T-27B. This document standardizes several types of construction and environmental conditions which the units must be able to withstand. *(Refer to the article on "Power Inductors" scheduled for next month for further details.—Editors)*

Although MIL-T-27B is the main military document applied to inductors, additional military specifications are frequently referred to. Among them are MIL-W-583 concerning magnetic wire for coil winding; MIL-W-16878 for electrical insulated lead wire; MIL-STD-202 on test methods; and many other military specs for insulating tapes, potting materials, etc. In some instances, the Defense Electronics Supply Center, in coordination with Military Standards, will generate a specification that completely describes all requirements of an inductor and assign to it an MS identification number.

Selecting and Specifying

In choosing between a toroid and other configurations, many factors must be considered, such as available space, type of mounting and termination, environmental conditions including shielding requirements, and cost. Except for precision high-"*Q*" coils in the audio-frequency range, because of the higher cost of toroids, other inductor types should be used. Where space and weight are at a premium, however, a toroid will usually result in minimum weight and volume.

In most cases, it will be advantageous to select a toroid for audio-frequency inductors used in electric wave filters or for inductors which require a large inductance and high-"*Q*" stability.

In specifying inductance value and tolerance, one should indicate how the inductance is to be measured. Most techniques measure apparent inductance, which may vary considerably from true inductance, especially when the self-resonant frequency of the coil is approached. In addition to frequency, voltage level and d.c. currents, if any, should also be specified, as they can markedly affect the inductance reading.

In establishing tolerances for an inductor, one must first consider the circuit in which it will be used and what inductor tolerances the circuit can bear. Tight tolerances can increase unit cost considerably.

Coil d.c. resistance tolerances vary greatly with the wire size used for winding, and on fine wire coils, it is impractical to maintain tight d.c. resistance tolerances. In specifying "Q" and d.c. resistance of the inductor, make sure the figures are compatible or omit d.c. resistance specification altogether.

All conditions for "Q" measurement must be specified: voltage, frequency, d.c. current, and method of measurement. Tolerances on "Q" values must be more liberal than d.c. resistance and inductance tolerances combined. Coil capacitance and self-resonant frequency, if they have an effect on the circuit, should also be specified (capacitance as a maximum and frequency as a minimum).

One important parameter often overlooked in high-current-carrying inductors is the temperature rise of the unit. This is directly related to winding resistance, core losses, and type and size of coil enclosure. Ambient operating temperature (which should always be specified) plus the temperature rise determine the life expectancy and reliability of the inductor. For good reliability, the physical size of the unit should not be restricted; thus, fine wire sizes can be avoided. Materials and processes, if specified, must be able to withstand the expected electrical and mechanical stresses with a sufficient margin of reserve.

In summary, here are the points that must be considered when ordering an inductor for a new circuit design:

1. Inductance value: ___ H ± ___%, measured at ___ V, at a frequency of ___ Hz, and ___ A d.c.
2. D.c. resistance: ___ ohms ± ___%
3. "Q": ___ (min. or ± ___%), measured at ___ V, ___ Hz, and ___ A d.c.
4. Coil self-resonance: ——— Hz min.
5. Permissible changes in coil parameters over the (a) frequency range, (b) voltage and current ranges, and (c) temperature range
6. Dielectric strength and insulation resistance requirements
7. Static and magnetic shielding requirements
8. Description of inductor application and the associated circuitry
9. Environmental conditions: (a) shock and vibration and (b) maximum altitude
10. Permissible size and shape of inductor package: (a) type of enclosure (metal case, molded unit), (b) type of termination, (c) mounting method, (d) outside coating (paint) and marking, and (e) the total amount of permissible weight.

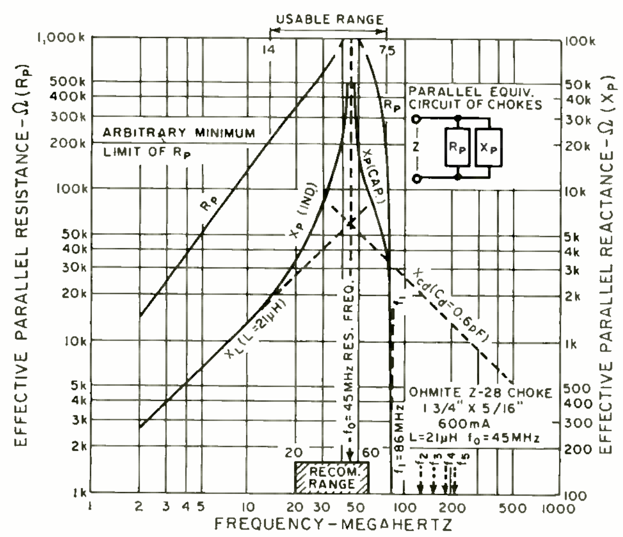
In the future, we expect to see much smaller coils using finer wire and more permeable cores. New plastics and epoxies will also be employed. Also, advances in thin-film technology promise an increased development and use of deposited and "printed-on" inductors in the integrated-circuit field. ▲

RADIO-FREQUENCY PLATE CHOKES

SINGLE-layer-wound r.f. plate chokes are available to cover the frequency range from 3 to over 500 MHz. Such chokes are wound on low-power-factor plastic cores for the higher frequencies and on steatite tubes for the lower frequencies. The single-layer winding is designed to avoid adverse harmonic effects within the recommended operating range and to prevent breakdown from high r.f. potentials. Inductance values for these chokes are fairly low, ranging from 84 μH for a choke suitable for use from 3 to 20 MHz down to 0.20 μH for a choke suitable for use from 320 to 520 MHz. Current rating for these chokes is from 600 to 1000 mA.

The true inductance of a choke, as measured at a sufficiently low frequency, differs appreciably from and is considerably lower than the **effective** parallel inductance at frequencies within the recommended operating range, but below the natural resonant frequency (f_0 in the figure). At frequencies above f_0 but within the operating range, the effective reactance of the choke is actually capacitive. This, of course, is in accordance with the inherent properties of parallel-resonant circuits, the general characteristics of which are exhibited by the choke over its operating range of frequencies.

The figure shows the frequency characteristics of an **Ohmite** Z-28 plate choke over a broad range of frequencies. This graph is typical and shows the basis used to determine limits of recommended operating frequency ranges.



The inherent frequency characteristics of these chokes, as well as those of all single-layer chokes, are such that they exhibit optimum performance when used at or near their natural resonant frequency. However, since the effective parallel resistance of these chokes remains sufficiently high over a broad range of frequencies both below and above the natural resonant frequency, f_0, the chokes have good efficiency up to the limits of the frequency ranges that are recommended.

Within the frequency limits shown on the graph, the apparent parallel resistance of the chokes, designated as $\mathbf{R}_p$, is appreciably in excess of 200,000 ohms. This arbitrary figure is the criterion for the lower limit of operating frequency for the lower frequency chokes, while a minimum figure of 100,000 ohms is used for the higher frequency chokes.

Referring to the figure, note how the value of $\mathbf{R}_p$ drops rapidly to a very low value at the first overtone frequency. This frequency, designated as f_1 occurs near the second harmonic frequency of the plate chokes.

At this critical frequency, the chokes behave in a manner similar to that of a series-resonant circuit as contrasted to their parallel resonance at f_0. Consequently, at the frequency f_1 the choke presents a low-impedance path to ground for the r.f. currents. Therefore, the chokes should never be used at or near the frequency f_1. Any single-layer choke used at this critical frequency will not only render the circuit in which it is used extremely inefficient if not inoperative, but may destroy itself from heat as a result of the very high energy absorption.

Since the **LC** product determines the values of f_0 and f_1, it is evident that neither the inductance nor distributed capacitance for a choke is, in itself, an adequate indication of performance. The true indices of performance are the critical frequencies f_0 and f_1 and their proximity to the desired operating frequency of the choke. Both inductance and distributed capacitance, as well as any small capacitance existing between the choke and ground as a result of mounting and wiring, will affect the frequency response of the choke. In general, with the chokes mounted close to a grounded plane or chassis, the critical frequencies as well as the recommended operating frequency range are shifted downward, perhaps by as much as 20 percent, depending on the actual proximity to ground. For this reason, it is generally advisable to select a radio-frequency plate choke whose resonant frequency, f_0, is slightly higher than the operating frequency that is desired. ▲

Ferrite Beads

By LESLIE SOLOMON/Associate Editor

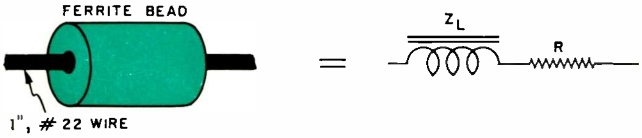
Electrically equivalent to an r.f. choke, these tiny ring-like devices offer a convenient, simple, and inexpensive way to obtain effective r.f. decoupling, shielding, and parasitic suppression.

FERRITES are best known for their wide usage in portable radio antennas, i.f. transformer cores, transistor power converter and inverter transformers, in the horizontal output transformers and deflection yokes of TV sets, and in most tape-recorder heads.

However, there is another ferrite component that is not so well known and should be given serious consideration by circuit designers and constructors. These ferrite components are commonly called "beads" by most, although the names "noise suppressors", "anti-parasitic beads", and "inductance multipliers" have been used. As will be shown, they offer a convenient, simple, and inexpensive way to obtain effective r.f. decoupling, shielding, and parasitic suppression without an attendant sacrifice in d.c. or low-frequency (below r.f.) power.

The amount of current flowing through a conductor depends upon the impedance that the conductor offers at the frequency of the flowing current. In the case of the short length of ordinary copper wire commonly used as an interstage conductor, very little impedance is offered to almost any reasonable frequency. D.c. to r.f. can pass with almost no reduction in strength except that produced by the low copper losses.

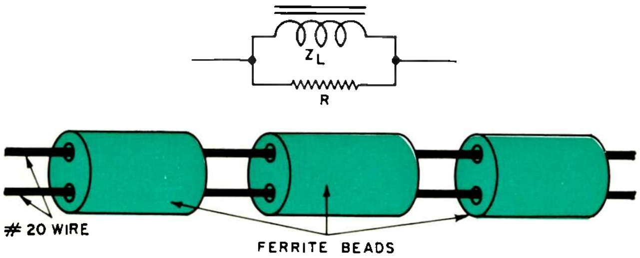
Whenever any inductance is placed in the current path, the impedance to the frequency of current flow will vary at $2\pi fL$, the classic inductive reactance equation. This is



FREQ. (MHz)	R (Ω)	Z_L (Ω)
50	53	+j45
100	95	+j55
200	230	+j80
250	350	+j120

Fig. 1. The equivalent series impedance of single Ferroxcube K5-001-00/3B ferrite bead on a one-inch length of #22 wire.

Fig. 2. Equivalent impedances of three Ferroxcube 56-390-31/4B ferrite beads strung on a pair of #20 filament power leads.



FREQ. (MHz)	R (Ω)	Z_L (Ω)
30	240	+j180
50	252	+j270
98	286	+j400
146	310	+j500
220	340	+j700

the purpose of an RFC. However, as RFC's are wound with great lengths of wire on a form, they can have a relatively large physical size, have some unwanted d.c. copper resistance, be restrictive as to the amount of current flow they can tolerate without burning, and, as typical inductors, they can be accidentally tuned by stray capacitance to offer an impedance that varies with frequency. What is needed, then, is a circuit component that offers no impedance to current flow at d.c. or audio frequencies yet has a high impedance to r.f., can pass currents restricted only by the conductor itself, and cannot be detuned accidentally. This is the purpose of the ferrite bead.

As the unwanted current flows through a conductor (passing through a ferrite bead), it creates a magnetic field. As the field passes into the ferrite bead, the higher (than air) permeability of the bead at r.f. causes the local impedance to rise rapidly and create the effect of an RFC in that immediate area. Therefore, at low frequencies, where the permeability of the ferrite bead is low, there is almost no impedance to the flow of current, except for copper wire resistance. When the frequency of the current flow goes up, the impedance goes up, stopping the unwanted flow. Because the ferrite bead operates as a bulk device, it cannot be detuned by stray capacitance.

Ferrite beads come in a variety of physical sizes, are usually dowel-shaped, and range from about 1/8 inch in diameter to about 1/2 inch or more long, although these are not the extreme limits in physical size. They come with either a single hole or multiple holes throughout their length and are made of ferrite materials having various electrical and magnetic properties. It is not necessary to ground ferrite beads in use.

Supply leads and circuit conductors adjacent to a chassis or other components frequently offer a very convenient path for the transfer of unwanted r.f. energy from one circuit to another. The distributed capacitance and inductance of these leads and conductors can also generate spurious oscillations within the circuitry, particularly at the higher r.f. ranges.

The use of capacitive decoupling and/or series inductance to minimize these effects is seldom completely successful. In some cases, this may contribute to the problem either electrically by possibly changing the frequency response of the system, or mechanically in finding a place to mount the extra components. The use of ferrite beads avoids these problems without introducing either electrical or mechanical complexities into the system. As an example, when a one-inch length of ordinary #20 or #22 hookup wire is threaded through a single ferrite bead, the wire will then appear as if it were greater than 50 ohms resistive in series with greater than 50 ohms reactive over the entire v.h.f. range, with negligible transmission losses at either d.c. or audio frequencies. Fig. 1 illustrates the impedance changes with frequency for a single ferrite bead made by one company.

By simply stringing one or more ferrite beads on power-supply leads or desired circuit conductors, excellent high-frequency isolation between stages is readily obtained. As a typical example, take the case where r.f. is being rectified by a high-impedance input of an audio amplifier. The usual remedy is to place an *RC* circuit in series with the input to bypass the r.f. However, the insertion of a series resistor and parallel capacitor may, in some cases, seriously hamper stage gain and frequency response. In the case of some transistor equipment, there simply may not be

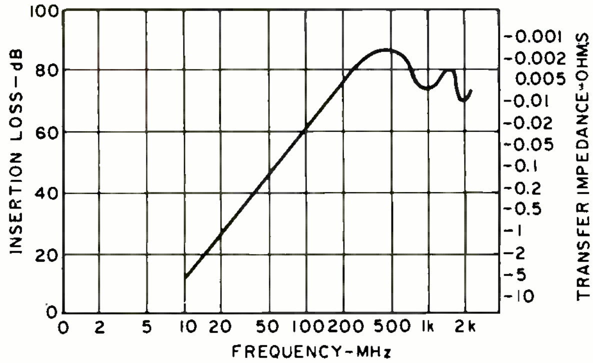


Fig. 3. Typical attenuation characteristics of an Erie "Filtercon," made as a commercially available L-decoupling network.

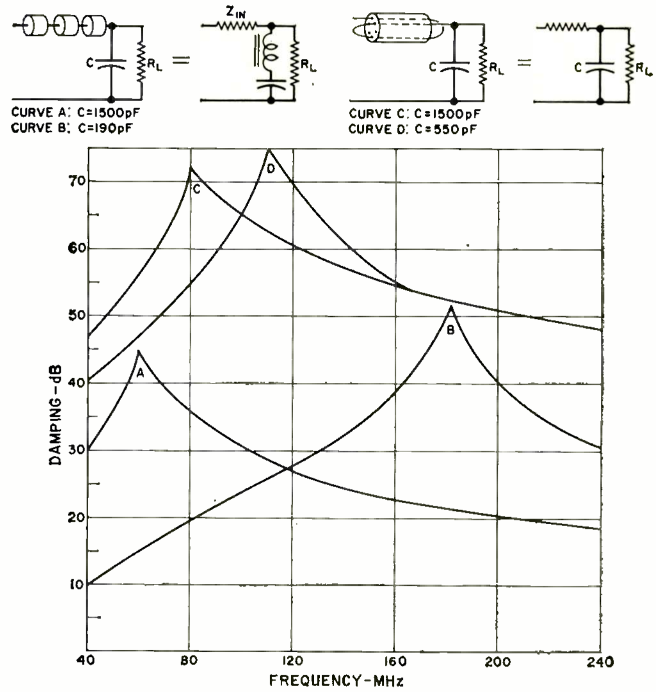


Fig. 4. Typical damping curves of ferrite beads with an additional bypass capacitor. Both single and multiple holes shown.

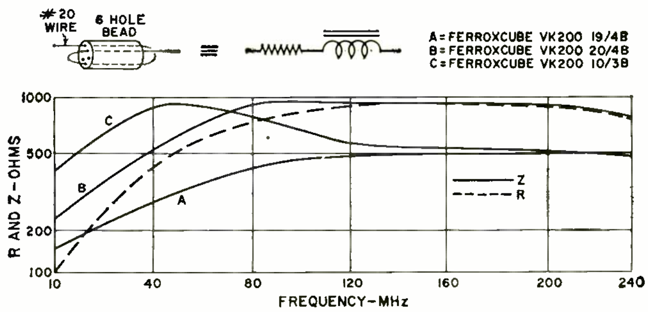


Fig. 5. Impedance of ferrite choke over a broad r.f. spectrum.

the necessary room to mount the extra components. The easy way out is to open the grid (or base) lead, slip the lead through a ferrite bead, and reconnect the lead to the grid (or base). The bead should be as close to the grid (or base) terminal as possible. The lead now has an appreciable series impedance to the r.f., effectively suppressing it without altering the circuit impedance to d.c. or audio frequencies. The bead does not have to be grounded. Many manufacturers are now using ferrite beads to decouple "B+" leads in radios and audio amplifiers.

In the case of filament power leads providing accidental paths for unwanted r.f., Fig. 2 shows the reactance of a pair of ordinary filament leads that have been passed through three ferrite beads. Although the filament leads now have a high impedance to r.f., they present only the ordinary wire resistance to either d.c. or power frequencies.

Some manufacturers have combined the use of a ferrite bead with an associated bypass capacitor to create a compact and efficient "L" decoupling network with the characteristics shown in Fig. 3. This particular unit is an *Erie* "Filtercon."

Typical curves showing impedance variation with frequency of a wire conductor passed through ferrite beads and terminated with a small value of bypass capacitor are shown in Fig. 4. The curves marked *C* and *D* are those of one complete turn of the conductor passed back through a multi-hole ferrite bead.

Ferrite Chokes

The characteristics of a multi-hole ferrite bead as a wide-band r.f. choke are shown in Fig. 5. Above about 60 MHz, the impedance is substantially resistive and constant. These chokes may be used in conjunction with small-valued ceramic capacitors in "damping" circuits to provide additional rejection at the self-resonant frequency of the capacitor, as shown in the curves marked *C* and *D* in Fig. 4. Compared with conventional air-core r.f. suppressor chokes, a ferrite choke offers an extremely wide operating bandwidth, avoiding the sharp fall-off in impedance with slight detuning and vulnerabililty to detuning by variation in stray circuit capacitance inherent in the wire-wound choke. The need for a parallel resistor to damp out spurious resonances is also avoided, thus saving the price and space of another component. ▲

INDUCTANCE AND RELATED PARAMETERS

(Continued from page 37) the number of lines per unit area, is measured in gauss and represents the number of maxwells per square centimeter. The flux density is proportional to the magnetizing force (H), the proportionality factor being the permeability (μ) of the medium. Thus, $B = \mu H$.

The magnetizing force (H) is a measure of the work required to move a unit pole 1 cm against the field and is measured in oersteds (Oe). The work required to move the unit pole around the total magnetic path is defined as the magnetomotive force and is expressed in gilberts (Gb). The magnetomotive force is proportional to the product of amperes and turns and does not require that the turns be distributed evenly over the entire magnetic path.

In order to have an inductance, a core of magnetic material is not essential. It is often omitted at high frequencies. At medium and low frequencies, however, a magnetic core is essential for all but the lowest values of inductance.

The ratio of the number of lines in a given medium to the number of lines which the same magnetizing force would produce in air is termed the "permeability" of the medium. In an iron core, the flux density (B) is not a linear function of the magnetic intensity (H). Therefore, the permeability (μ), representing the slope of the B-H curve, is not a constant. Furthermore, the permeability also depends on the "past history" of the iron core—a phenomenon known as core "hysteresis".

Permeability can be further complicated by direct current flowing in the coil. In this case, of prime importance in establishing the inductance is the incremental permeability: the permeability of magnetic material to alternating currents superimposed on direct current. This is defined as the permeability of the material to small increments of alternating magnetomotive force. Permeability in the concept of flux density and field intensity is analogous to permittivity of dielectric substances in electric fields. While permittivity of dielectrics is usually independent of the magnitude of the electric field intensity, permeabilities of ferromagnetic substances are critically dependent on magnetic field conditions.

An inductor usually has ohmic losses which can be represented as a resistance (R) in series with the inductance (L). When a voltage (V) is applied across that inductor, the current rises gradually to its steady value (V/R), following the logarithmic curve:

$$I_r = [(V/R)\ (1 - \varepsilon^{-tR/L})]$$

The term $L/R = T$, called the time constant, represents the time in seconds required for the current to reach 63.2% of its final value.

The decay of current in an inductor will also follow a logarithmic curve given by the formula:

$$I_d = [(V/R)\ (\varepsilon^{-t/T})]$$

The MIL-C-39010 Specification

By W. DIETER HAUSER / Manager, Electronic Technical Services, Jeffers Electronics Div., Speer Carbon Co., Div. of Air Reduction Co., Inc.

MIL-Spec requirements for fixed r.f. molded coils along with the parameters that are to be measured.

MIL-C-39010, a Tri-Service Military Specification entitled "Coils, Fixed, Radio Frequency, Molded, Established Reliability, General Specifications for", supplements MIL-C-15305 which has long covered the *general* requirements for molded radio-frequency inductors, as well as other coil and transformer types.

MIL-C-39010 covers general requirements for fixed r.f. molded coils only. This document, with its supplemental MS Sheets, is intended to be utilized as a specification for qualification, as a design guide, and for procurement. As with MIL-C-15305, it defines parameters to be measured, equipment and procedures to be used, and the statistical sampling plans involved. Most important, however, it is an *established reliability* specification which factually defines methods, procedures, and equipment for establishing proven failure rate figures based on a precisely defined life test. The true intent of this specification, then, is to provide a specified reliability for coils for use in equipment where reliability, long life, and continuity of operation are needed.

Most of the Military Standard Detail Documents (MS Sheets) covering individual inductors have already been prepared by the military—some are now in preparation. These MS Sheets are similar in layout and intent to the slash sheets which form part of the resistor specifications MIL-R-11 and MIL-R-39008.

Among users there is general agreement that specifications attempting to establish a judgment of a component's reliability are desirable. This places a considerable burden on the manufacturer who has to assume expensive responsibilities for time, equipment, and personnel. These costs have been accepted, to some degree, by the molded r.f. inductor industry.

Strict familiarity with a 32-page Military Specification is gained only by constant exposure to it through necessity. A comparison between MIL-C-39010 and MIL-C-15305 is difficult because 39010 is for a particular type (molded inductors) and 15305 is for all types of coils and transformers. For the purposes of this discussion, it will be assumed that a copy of MIL-C-15305C is available and is, to some degree, understood by the reader.

The format of MIL-C-39010 closely follows that of MIL-C-15305. Additional provisions of MIL-C-39010 are four initial electrical characteristics, three environmental tests, and temperature storage. MIL-C-39010 omits temperature rise and high-temperature tests that are specified in MIL-C-15305.

Coils qualified to MIL-C-39010 are marked with part numbers, JAN prefix brand, and require no color bands. Where space permits, a date code and manufacturer's identification are required. For example, a coiled marked JLTR02A1R2KM would be classified as follows: "J" is the JAN certification brand indicating control by U.S. Military; "LTR" identifies the coil as established reliability, fixed r.f. and molded; "02" identifies the particular applicable MS Sheet; "A" denotes maximum operating temperature of 105° C (two other classes are "B" 125° C and "F" 150° C); "1R2" is 1.2 μH; "K" is ± 10% tolerance (two other tolerances listed are "J" ± 5% and "L" ± 20%); "M" is 1% per 1000 hours failure rate level.

Failure rates listed are 1%, 0.1%, 0.01%, and 0.001% at a 60% confidence level. These are respectively symbolized in part numbers as "M", "P", "R", and "S". For initial qualification to the "M" failure rate level, 172 production samples of each style are subjected to a temperature cycling test, and are then divided into groups for the different environmental and mechanical tests such as dielectric, moisture, RTC, solder change, solderability, shock, terminal strength, etc.

Fifty-one coils of highest inductance and fifty-one of lowest inductance are put on life test for 2000 hours, with one defective allowed in 204,000 unit test hours. The test consists of exposure to maximum operating temperatures for 2000 hours interrupted at specified intervals for electrical tests.

Failure rate extensions are gained by accumulations of acceptance tests, extension of qualification test, and specified extended life tests. A minimum of 110 units is selected from each inspection lot for acceptance life test of 250 hours' duration. A minimum of ten units is selected from each inspection lot and set aside for the extended life test. This number may be increased to develop the necessary unit test hours for maintaining failure rate figures, or extension of qualification.

Maintenance of failure rates is accomplished by periodic submission of all test data with records of continuing life test data to support these rates. Certification of all reports by a company official and government inspector is required.

The following tests on inductors, as previously noted, are new with the first issue of MIL-C-39010.

Initial Electrical Characteristics

Coupling Coefficient: This is simply a measure of the relative degree of external field attenuation by the shields on shielded inductors.

Incremental Current Inductance Reduction: This test determines the sensitivity of inductance to direct current. A maximum inductance change is permitted with a specified d.c. applied.

Effective Parallel Resistance: This is important to some users in high-frequency applications. A method is outlined using a *Boonton* "Q" meter to determine the a.c. resistance which is the parallel resistance of the coil at a particular frequency.

Resistance Temperature Coefficient: Temperatures and their sequences are listed to determine resistance change with temperature.

Environmental Tests

Life: Inductors are stored at a specified ambient temperature and measured at specified intervals.

Low-Temperature Storage (—65° C): Inductors are placed in a cold chamber for 96 hours, then examined for cracks or other mechanical damage.

Solderability: This is simply a measure of the ability of the leads to be wetted by a new coat of solder. It is used to verify that the treatment during manufacturing processes will not hinder soldering.

Other important tests, equipment, and fixtures are as in MIL-C-15305C.

The foregoing provides information useful to describe the established reliability inductor MIL-Spec to anyone completely unfamiliar with it, but who has some knowledge of MIL-C-15305. ▲

Coil Construction and Packaging

By ROBERT L. KOCHER

Lack of complete standardization and overspecifying still plague the industry. A proper choice from the extremely wide variety of coil types and configurations is difficult, but it must be made.

CHOKES and coils used in today's more sophisticated electronic circuits display a disturbing lack of standardization. And no wonder. The variations which influence the design of an inductor are almost unlimited. Such factors as the length of the coil form, the number of windings, turns of wire per winding, the wire gauge, and the configuration of the windings all serve to frustrate efforts to standardize coil design, construction, and packaging.

As a result, possibly 90% of the small coils built during 1966 will be custom devices which meet the special requirements laid down by the project engineer designing a circuit.

These custom coils range from fairly simple fixed inductors for television sets to complicated designs for military communications. They may be rather plain little devices coated with Durez (thermosetting plastic molding compound) or handsome, color-coordinated encapsulated ones.

The specification of inductors is further complicated by the fact that inductors, unlike semiconductors, resistors, and capacitors, cannot be labeled as producing a particular electrical characteristic when plugged into a circuit. This is because the frequency at which a coil is tested affects its inductance as well as its "Q". Also, a coil has a great many independently variable characteristics—distributed capacitance, resistance, bandwidth, resonant frequency, impedance, and so on.

The engineer, when designing a circuit, may begin with components which are standard—vacuum tubes, semiconductors, resistors, and capacitors. As he reaches the end of the circuit design, he finds he needs certain characteristics of inductance and so specifies a choke or coil to produce precisely the characteristics required.

This lack of standardization necessarily frustrates efforts to keep costs down, since each new coil design costs money for tooling and production engineering. Even more perplexing, this tendency of some engineers to conjure up exotic coil configurations has been known to create inductors with electrical requirements that were so critical that no one could build them.

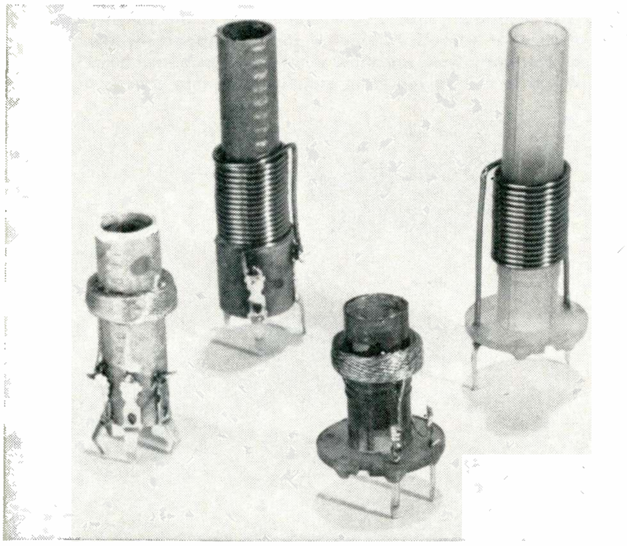
Factors Influencing Cost

In evaluating coil construction and packaging, the engineer frequently can save himself mental anguish as well as save his company money by considering these suggestions:

1. When evaluating a coil from the standpoint of its construction, disregard the cosmetic factor. Theoretically, a "neat"-looking coil won't perform any better than a drab-looking coil. Evaluate an inductor on the basis of its performance on a "Q" meter and its environmental requirements, not on the basis of its physical appearance.

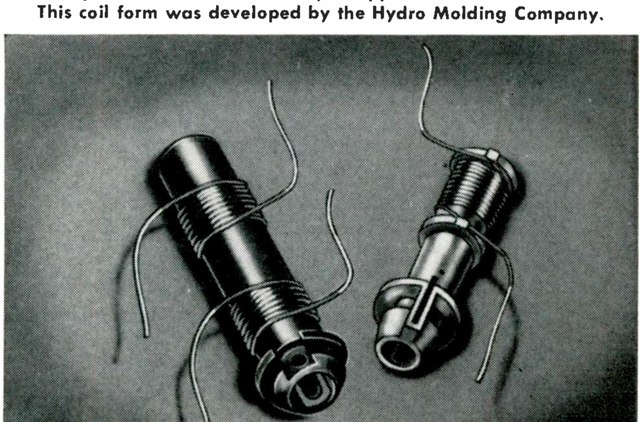
2. In designing a choke or coil, look to a manufacturer of these devices for advice and engineering assistance. Manufacturers can frequently offer valuable suggestions so that the final design of a coil is practical, economical, and does the job for which it is intended—and no more. Coils frequently are over-engineered by a project engineer, whose specifications may be based on data not related to the real needs of the circuit in question. When seeking a supplier, make certain that he has had experience in engineering and building the desired configuration.

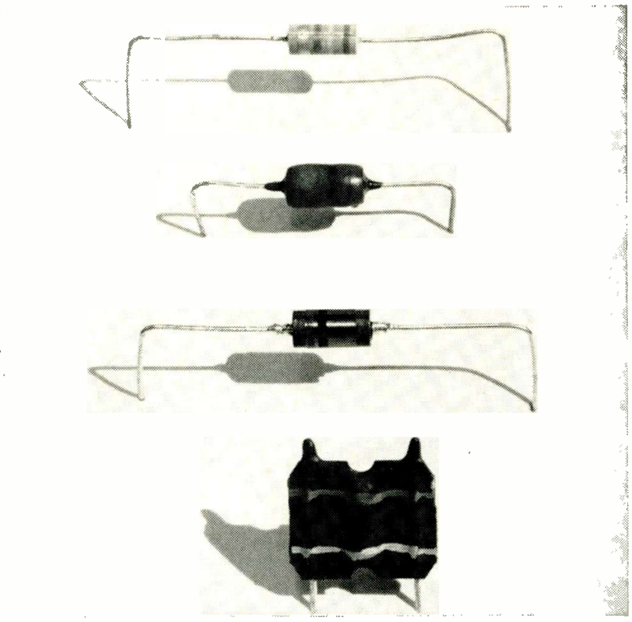
3. In considering a package for a coil, consult with the manufacturer to determine the true cost of one type of



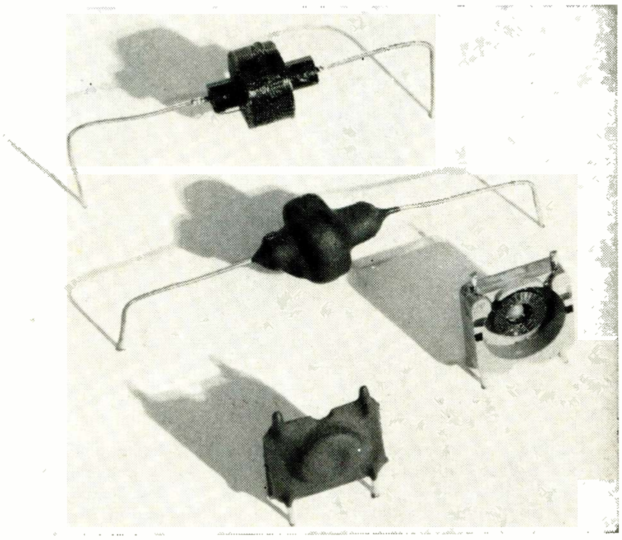
Examples of construction of variable coils used in a TV set. Two coils at left are conventional types using paper forms, glued collars, and staple-on terminals. At right are inductors using plastic coil forms. Note how winding at far right has leads, which are extensions of the coil itself, held in the flange of the one-piece plastic form, thus eliminating lugs. When fine-gauge wire is used, lugs are embedded in the flange (second from right). Technique patented by Coilcraft.

Coil forms shown here have a molded nose-cone construction that permits them to be easily snapped into a chassis hole. This coil form was developed by the Hydro Molding Company.





Four ways to package a simple choke, positioned from top to bottom in order of decreasing cost. The molded choke, at top, is the most costly, with the Durez-coated choke next, followed by the lacquered choke. Least expensive is the Durez-coated configuration using a fiberboard form to support the winding. Tips protruding from top show where lead terminals have been soldered to coil—away from ends inserted into chassis board.



Methods of packaging chokes using universal windings. Two chokes at top with axial leads are lacquered and Durez-coated respectively. Parallel-lead versions of this coil, intended for printed-circuit use are shown below. Choke at left uses fiberboard mount, one at right premolded plastic cup.

packaging over another. What may appear to be a cheaper type of package may really be the more costly.

4. When designing the basic configuration, keep it as simple as possible. If a tunable inductor is specified, make certain that it really has to be tuned. It is a costly case of over-engineering if a tunable inductor is specified but is never tuned in the chassis. A fixed inductor could perhaps do the job and for less money.

5. Think twice about specifying a shield for a coil. It may seem perfectly logical—even thrifty—to have a coil and its shield built as a complete assembly ready for insertion in the chassis. By making a shield part of the coil package, however, the engineer may unknowingly specify an assembly which is more costly than simply ordering the shield and the coil separately.

With printed circuits, the coil can be inserted in the chassis and an inexpensive metal shield snapped over the coil prior to soldering. When coil and shield are built as a single unit, insertion in the circuit can frequently be somewhat complicated due to the presence of the shield.

Over the years, the trend in the inductor industry has been to simplify as much as possible the connection of coil components to the circuit. Prior to the development of the printed circuit, a coil bolted or snapped into a metal chassis. The leads had to be free so that they could be hand-soldered to the circuit. Yet the coil gained no structural stability from being soldered in place.

Printed-circuit boards make it possible to simplify coil construction by connecting the leads to metal lugs, which in turn fit into a pin circle in the board. This also gives the coil added strength, since it is now an integral part of the circuit.

But this design—using a paper coil form, glued paper collar, and staple-on terminals—has its drawbacks, not the least being the glued construction. Conventional paper coils are also costly to manufacture compared with some of the newer, more sophisticated designs.

For example, plastic coil forms eliminate not only paper tubes and glued collars but also, in many instances, the staple-on terminals. When heavy (20 to 22 gauge) copper wire is used for the windings, the plastic coil form supports the ends of the windings so that they act as their own leads without the use of staple-on terminals.

In its simplest form, a variable inductor may use only three parts—the plastic coil form, the winding, and the metal tuning core. Where finer gauge wire is specified, the plastic form is still used but with metal lugs embedded in the plastic flange. After soldering the winding ends to these lugs, they are bent up, providing the important "slack in the leads" feature.

While paper coil forms are still very popular, the natural shift toward other coil-form designs would seem to be gradually assigning paper forms to a secondary role.

Unlike many facets of the electronics industry, project engineers seem unconcerned about taking approaches to choke and coil design that are 30 or more years old. Indeed, instead of demanding more sophisticated concepts of inductor design, some engineers often express a definite opposition to change. This is an interesting condition in an industry where "obsolescence" is such a common problem in dealing with the finished product.

Fixed Inductors

In older, hand-soldered circuits, fixed inductors and chokes had to be structurally rugged since they usually ended up in the circuit hanging by their leads. Printed circuits made it possible to provide two cut-out holes in the circuit board into which the coil leads could be inserted.

Conventional chokes require bending and cutting of their leads prior to assembly of the chassis. Also, the coil is still relatively unprotected after installation and soldering.

By taking a completely new approach to the design of chokes, packages have been perfected which are structurally rugged and yet markedly more economical to build than the conventional choke.

One technique has been to use a small square of fiberboard as the coil form. The lead wires are pressed into slits on either side of the fiberboard form and the winding riveted in the center. In the older design of chokes, the user flexes the same lead to which the coil winding is attached. This can cause later failure of the choke. The design using the fiberboard form places the connections between the leads and the coil winding at the top of the form—away from the wires being flexed during installation in the chassis.

A wax-impregnated Durez coating is added to protect the coil and leads from damage during insertion in the circuit board. By standardizing construction of many fixed inductors—tinned ¼-inch leads on ½-inch centers is common—lead trimming and other secondary operations have been completely eliminated.

Avoid Over-Designing

Project engineers, when designing an inductor, usually prepare either (1) "make prints" or (2) "buy prints." The make print contains all details on the inductor, including a bill of materials, the coil's physical and electrical characteristics, and so on. The buy print pinpoints only the functional requirements of the coil, and there may not even be a drawing.

Not infrequently, the engineer submitting a make print has over-designed the coil. Tolerances may be too broad or too critical. But given his orders, the manufacturer builds the coil, even though it may cost the customer twice what it should considering the job for which it is intended.

Many engineers inadvertently put the coil supplier into a straitjacket by including too much information with the make print. They may even compound the problem by not discussing with the coil supplier exactly what they need in the way of inductance characteristics.

On the other hand, some project engineers take the attitude that it matters little what a choke or coil looks like as long as it produces the desired electrical results. These engineers supply a buy print which includes only the stated inductance problem and nothing more. Given this much information, however, most coil manufacturers can, with considerable savings to the customer, produce an inductor which possesses the needed electrical parameters and yet is economically priced.

The point is that any good supplier of coils will be able to offer a variety of design solutions—making it possible for the project engineer to select the solution best suited to his particular problem.

Toroids

Traditionally, toroid coils were usually packaged by molding them in Bakelite or encapsulating them in epoxy. Not infrequently, the cost of molding the toroid exceeded the cost of the component. The question was finally asked, "Do all toroids have to be either potted or molded?"

Experience has shown that many applications do not demand such durable packaging. In fact, the toroid winding can easily and economically be slipped onto a plastic coil form, with the fine leads soldered to metal lugs embedded in the flange of the plastic form. With tedious molding or encapsulating operations eliminated, costs for this type toroid can be dramatically reduced.

Potting versus Molding

Where environmental or structural needs dictate the use of a durable package, some engineers automatically discount potting in favor of molding in the belief that molding is the less expensive of the two processes.

While experience naturally differs with manufacturers, many coil builders have found that when the total cost is evaluated, the encapsulated coil is more economical than the molded one.

The same situation applies to other processes associated with designing and building chokes and coils. When confronted with a major decision regarding the construction or packaging of an inductor, the project engineer frequently will save time and money by calling in the coil manufacturer for consultation.

Molded Chokes versus Lacquer or Durez

The common molded choke appears to many engineers to be a rugged, attractive, economical way to package the device. Conversely, the choke coated with lacquer or Durez is not nearly as "pretty" as the molded device and hence may be thought inferior.

However, molding of a choke gives it no real structural value, and environmental requirements may not even demand a molded design.

During the molding process, the leads and winding are placed under a stress which may alter the choke's electrical characteristics. Also, as the mold closes around the winding during processing, the leads may be nicked by the mold. This nicking may later cause problems in the form of broken leads. With the lacquered and Durez-coated chokes, of course, no pressure is involved, hence the leads and windings are not affected.

Some Conclusions

Obviously, we have been able to present only a sketchy discussion of coils and chokes and some of the factors influencing their construction, packaging, and cost. Probably one of the reasons many engineers still do not take the designing of inductors seriously is that they think of chokes and coils as nickel and dime products.

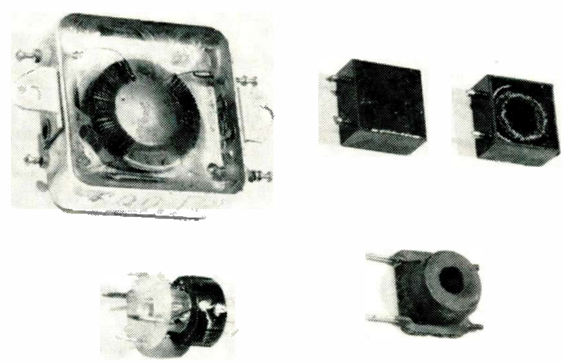
To be sure, a very fine choke may be designed for a circuit and end up costing only 10 cents each in quantity. But what if, over a period of years, the company uses one million of these 10-cent coils. That's $100,000. Had the project engineer, utilizing the experience of a reputable coil supplier, secured a coil with the same reliability and electrical characteristics for only 5 cents, the savings to his company would have been $50,000.

A startling example of over-engineering is the Ph.D. electronics expert who, rather than admit he didn't really understand inductance, designed a 35-cent coil that was so poorly conceived that it was almost impossible to build. What he did not know was that several coil manufacturers could have easily solved his inductance problem with the ultimate solution in the form of a 5-cent coil.

Probably the most important single factor in obtaining practical solutions to inductance problems is to find the right supplier. The coil-manufacturing industry is a splintered industry. What may be a difficult problem for one supplier, another supplier may be solving several hundred thousand times a day.

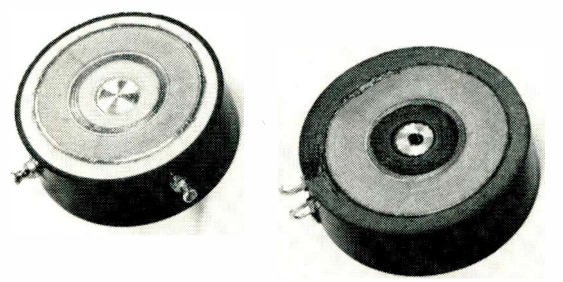
What for one coil supplier may be a challenging problem—requiring months of engineering, testing, and tooling —for another manufacturer is so simple that production quantities can be delivered in two or three days.

One brief comment on shelf-item chokes and coils *versus* custom-built chokes and coils. Many engineers believe that a shelf-item coil is always more economical than a custom-made coil. They naturally just associate "shelf item" with economy and "custom made" with expensive. Experience has shown, however, that custom-made coils, when large quantities are involved, can be produced at a cost equal to or less than the cost of shelf-item products. And, instead of the engineer having to compromise in order to use the shelf item, he receives in the custom-built product exactly the electrical parameters demanded by the circuit. ▲



At top left is a toroid winding encapsulated in a metal cup which costs more than $2 each. Below it is a smaller toroid mounted on a plastic coil form with the same electrical characteristics but costing less than $1 each. At top right is a toroidal coil in a cup before and after encapsulating. Below is an even less expensive toroid in a much simpler package.

Cutaways of encapsulated toroid (left) and molded package. Should the toroid shift during potting, there will still be at least thickness of the cup to protect encapsulated coil.



R.F. Chokes and Coils

By W. R. COURTNEY / Chief Engineer, J. W. Miller Co.

In order to get better r.f. coil performance, the circuit designer should be aware of the important characteristics and limitations of the various inductors that are available. Knowledge of these factors will permit an intelligent and more economical selection to be made.

COIL catalogues usually give only a few parameters that indicate the ranges and types of coils available to circuit designers. To obtain the best results for a specific application, it is advisable to contact a coil design engineer since the majority of coils produced today are built to meet a designer's specific performance requirements. Since the coil designer can do a better job with more complete information, the circuit engineer would do well to consider some of the important characteristics and limitations of coil performance.

Types of Coil Construction

R.f. inductors can be manufactured in a number of basic winding configurations. Each of these types has its advantages depending on its function in a circuit and the associated components.

Solenoid or single-layer winding is used in the simplest type of coil (Fig. 1A). This coil becomes a true air inductor when the winding is self-supporting. This type of winding provides the least amount of inductance in a given space. However, it produces a very low value of distributed capacitance and allows excellent heat transfer since air can move over the entire winding area. Magnetic or non-magnetic core material can be used to support the winding and to provide a means of mounting the start and finish leads. The core can also be made adjustable to vary the amount of inductance.

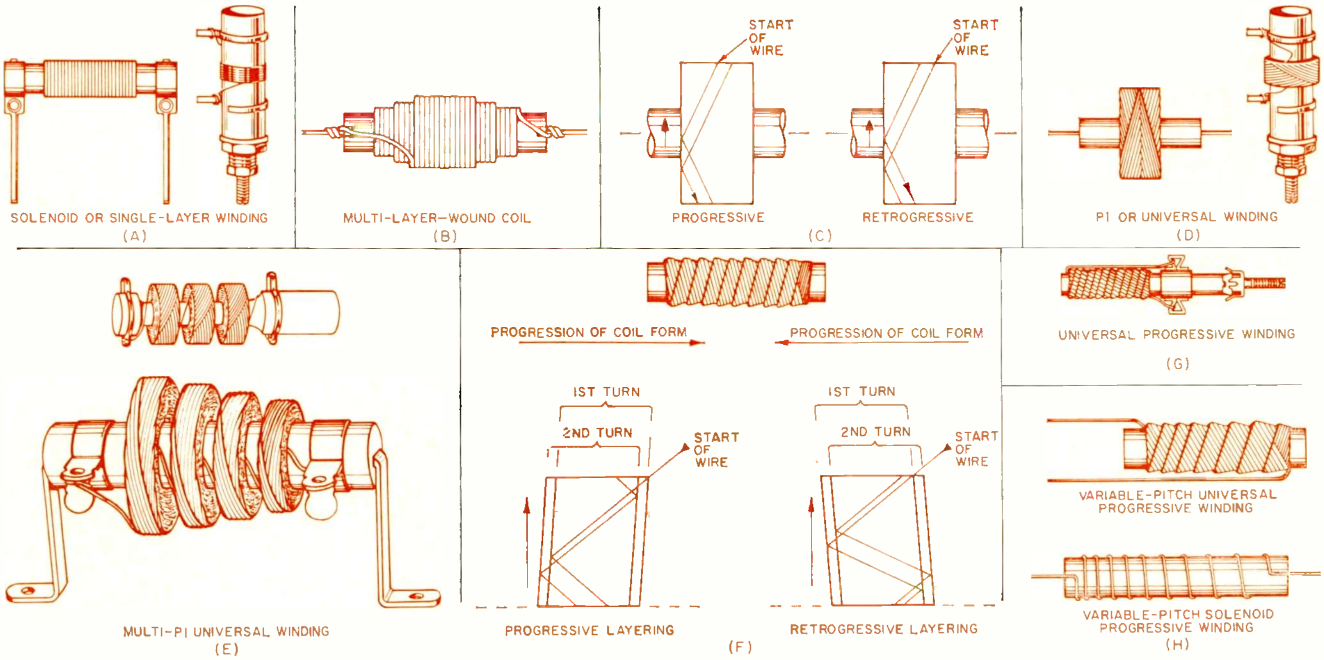
A multi-layer-wound coil (Fig. 1B) realizes an appreciable increase in the amount of inductance over that of a single-layer-wound coil. Turns are wound on top of each preceding layer to build up coil diameter by adding layer on layer. This permits the maximum amount of inductance.

Layer winding is satisfactory at low frequencies. However, even at the higher audio frequencies, the effect of the large distributed capacitance between turns can affect circuit operation significantly by limiting frequency response.

Before the development of the universal winding method, great efforts were made to divide windings into sections or pi's by means of multi-section forms. This method is still used in the production of windings for use with pot-type cores.

The pi or universal winding provides a larger value of inductance per cubic volume of space than a solenoid, but not as much as a multi-layer-wound coil. The main advantage of a universal coil over a layer-wound coil is a much lower value of distributed capacitance. If we break our coil into a number of pi's, the value of distributed capacitance is lowered still further. This gives the same

Fig. 1. Various types of winding techniques that are employed in the construction of r.f. chokes and coils.



result as adding fixed values of capacitance in series. Generally d.c. resistance of the inductor will increase because more wire is required to produce the same inductance.

Pi or self-supporting universal winding must be done on a machine while the single-layer or multi-layer winding can be done by hand without the aid of a mechanical device. Basic design parameters of wire size, form diameter, winding width, or cam throw are entered into a number of basic formulas to give ratios that determine rotation of the winding form and wire movement on the coil form. These ratios are related directly to gears in the coil-winding machine that establish an exact relationship to the wire at all points of the form rotation. Since the wire is carried from one side of the form to the other and back again as the form rotates, it is necessary that each turn either progress or retrogress in relation to the preceding turn in order to achieve a mechanically stable coil (Figs. 1C, 1D, and 1E).

The universal progressive type of winding was developed to increase the inductance of the solenoid winding and further reduce the distributed capacitance of the pi winding. This is accomplished by laying the pi winding along the form instead of allowing it to build up into a single pi (Figs. 1F and 1G). In addition to the calculations for the regular universal winding, gear ratios must be calculated for the progressive movement of the winding on the coil form that is used.

Variable-pitch universal progressive winding is a specialized variation of the universal progressive winding. Whenever a piece of equipment is designed to use permeability tuning, such as most auto receivers, this type of winding is commonly used. The winding is layered on the form to obtain frequency distribution that is either linear or close to linear as the iron core is inserted (Fig. 1H). In normal progressive winding a much greater increase in inductance is achieved during the initial movement of the core into the winding than is achieved after the core has entered the winding more fully.

Pot-core winding is a highly specialized layer winding used with a cup-shaped powdered-iron or ferrite core to produce extremely efficient inductors. This type of coil exhibits most of the advantages of toroid coils since the flux is confined almost entirely within the magnetic material (Fig. 2).

The final choice of wire size, winding pattern, and form material should be left to the coil design engineer because of the knowledge he has gained in designing coils over the years. For example, a specific wire size will carry different amounts of current depending on the winding pattern and core materials for a specific temperature rise. It is very important, however, for the circuit designer to understand what he wants to achieve with a coil, and to pass the requirements on to the coil engineer.

R.F. Chokes

The usual data on r.f. chokes specifies the value of inductance and "*Q*" measured at a nominal radio frequency. In addition, the self-resonant frequency is given as an aid in determining the range over which the choke may be operated satisfactorily. Additional data usually includes the d.c. resistance of the winding and the maximum d.c. current rating.

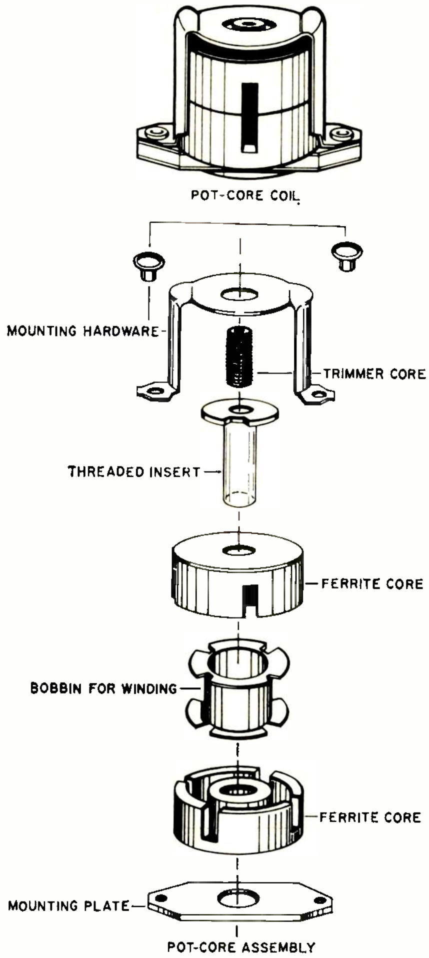


Fig. 2. Construction of pot-core coil.

This data is generally quite satisfactory for use over a limited frequency range. The designer usually selects a choke with a parallel self-resonant frequency slightly higher than the highest frequency to be encountered in the circuit. In this manner, he obtains maximum impedance with greatest voltage gain, and avoids possible burnout at series-resonant frequencies.

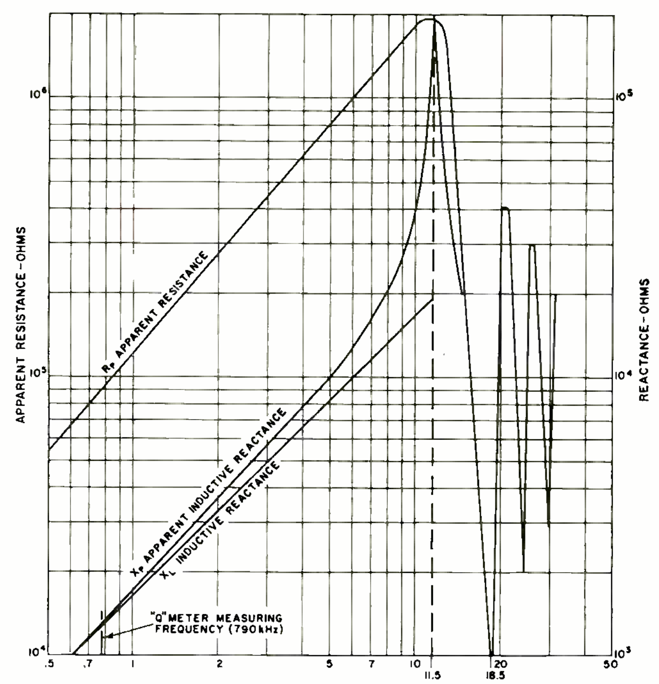
Although an r.f. choke may appear as one of the least complex inductors, its effect can become quite complex. Consider the r.f. choke characteristics plotted in Fig. 3. Catalogue data gives the inductance as 260 μH measured at 790 kHz, and the self-resonant frequency as 11.5 MHz. *(See also the boxed item on "Radio-Frequency Plate Chokes" in this section.—Editor)*

From this information it is possible to make an educated guess regarding the choke's characteristics below the self-resonant frequency. It would be possible to apply a rule-of-thumb that the first series-resonant point would be approximately twice that of the parallel-resonant frequency.

The curve of Fig. 3 was plotted from actual measurements and calculations, some of which are listed in the table. As the parallel self-resonant

Fig. 3. Characteristics of choke measuring 260 μH at 790 kHz.

f (MHz)	X_L (Ohms)	X_p (Ohms)	"Q"$_{eff}$	R_p (Ohms)
1.0	1,630	1,680	71	121,000
5.0	8,160	9,950	81.8	813,000
10.0	16,320	40,200	25.9	1,800,000
11.5	18,800	186,000	0	1,865,000



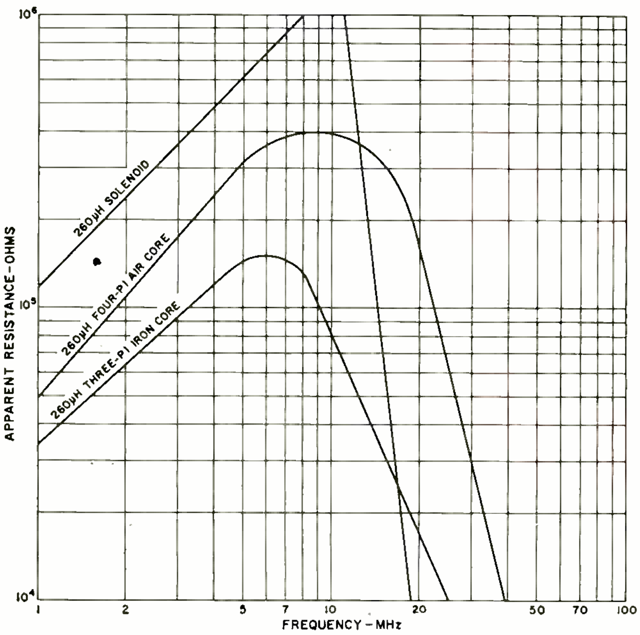


Fig. 4. Apparent resistance curves for three 260-μH r.f. chokes.

frequency is approached, apparent inductive reactance X_P becomes greater than X_L. Effective "Q" reaches a peak, then drops to zero at the self-resonant frequency. This happens because apparent resistance R_P increases more rapidly than X_P.

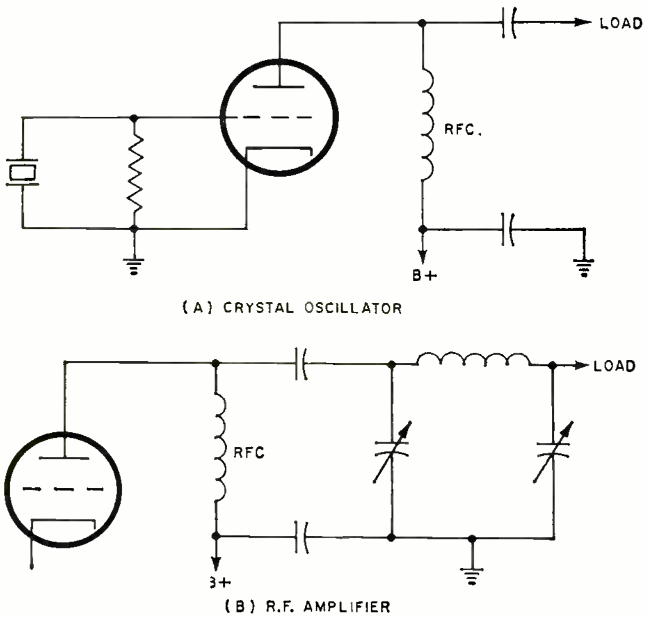
Losses increase with frequency because of skin effect and proximity effect in wire, increasing dielectric losses in coil insulation, and eddy currents in nearby objects.

As the operating frequency increases beyond the self-resonant frequency, the choke exhibits a high value of capacitive reactance. Impedance falls rapidly until the first series-resonant frequency occurs at 18.5 MHz and effective impedance is on the order of a few hundred ohms. The choke is very inefficient at this frequency and could burn up if operated in a circuit where appreciable current flows.

As the operating frequency increases further, the choke continues to show parallel- and series-resonant points similar to standing waves on a transmission line.

Other types of windings based on the same value of inductance, will exhibit markedly different characteristics

Fig. 5. Use of r.f. chokes in crystal oscillator, amplifier.



over the same frequency range. Therefore, it is important for the circuit designer to determine the effect he wants the choke to produce before he specifies a given type of winding. See comparison curves in Fig. 4.

A grid-dip oscillator can be used to determine resonant points. Parallel-resonant frequencies are those where a dip occurs when the choke terminals are open-circuited. Series-resonant frequencies are those where a dip occurs when the choke terminals are short-circuited. If an accurate frequency check must be made, mount the choke on the chassis with surrounding components in place. Ground the coil end and leave the hot end free. Then check for parallel- and series-resonant points.

Effect of Choke Characteristics

In an application where an r.f. choke acts as a load without any tuned circuit, the inductive reactance represents the actual value of load impedance (assuming the choke is operated well below self-resonance). The crystal oscillator illustrates this type of application (Fig. 5A). For the oscillator to function, it must operate into an inductive load. To insure this condition, a designer should specify an r.f. choke with a parallel self-resonant frequency twice that of the intended operating frequency.

In an application where an r.f. choke is placed in parallel with the tuned circuit of an amplifier, frequency range must be taken into account (Fig. 5B).

At frequencies lower than the self-resonant frequency, a choke produces the effect of lowering the value of the tank inductor. Capacitance must be added to compensate for this effect. The choke actually becomes part of the tank circuit, and significant losses can be introduced at frequencies where an appreciable amount of shunting effect must be resonated by the tuning capacitor.

A good rule-of-thumb is to specify a choke with an inductive reactance approximately five times greater than that of the tank coil. This will reduce the shunting effect on the tank circuit. The first series-resonant point will be quite high, and the choke will be suitable for use in an amplifier covering a rather wide range of operating frequencies.

In the design of high-power, low-frequency (100 kHz to 1MHz) amplifiers, it is possible to use a relatively low value of inductance for the r.f. choke, provided the effective "Q" is large enough to assure a low value of series resistance. Using a choke on the order of 1 millihenry in this manner, the power losses in the choke can be reduced, and a relatively large frequency range can be covered. See Fig. 6 for relationship between "Q" and R_S.

R.f. chokes that have large values of distributed capacitance will often burn out when an amplifier is detuned and there is a sharp rise in the off-resonant circulating current. This occurs frequently when a single-pi choke is used. The use of a multi-pi choke usually corrects this problem.

For operation at a single frequency, a choke with a parallel self-resonant frequency near the operating frequency offers maximum impedance to permit greatest voltage gain. (See 11.5-MHz point in Fig. 3.)

For operation over a narrow (less than 2:1) frequency range, a choke with a parallel self-resonant frequency slightly lower than the lowest frequency of the range to be covered presents a high value of capacitive reactance. This minimizes the effect of adding an inductance to a tuned circuit since it effectively adds a small capacitor in parallel with the main tuning capacitor. (See 11.5- to 15.5-MHz range in Fig. 3.)

For operation over an extended (less than 10:1) frequency range, a choke with a parallel self-resonant frequency approximately two-thirds the highest operating frequency provides a high level of impedance throughout the range. (See 1.5- to 15.5-MHz range in Fig. 3.)

When using chokes in both input and output of either tube or transistor circuits, the generation of low-frequency parasitic oscillations similar to those in tuned-plate, tuned-grid oscillators frequently occurs. To correct for this condition of too much inductive reactance, use a lower value of inductance.

If a ferrite-core choke is used in a high-power transistor circuit, saturation of the ferrite core due to high current flow can produce an effect similar to that of a blocking oscillator. Air or a powdered-iron core should be considered to correct this situation.

Military & Commercial Specifications

With the issuance of MIL-C-15305 specifications, the first steps were taken by the military and civilian suppliers in establishing ground rules that would cover design requirements for r.f. choke coils. There are a series of Military Standard (MS) drawings available that cover r.f. chokes in several physical sizes, as well as their electrical ratings. Most MS chokes are rated for a temperature rise not to exceed 35° C at 90° ambient, and an overload not to exceed 1½ times rated current.

Chokes manufactured to meet MIL-C-15305 using epoxy molding for protection are the most common. Inductance values and tolerances are color coded similar to resistors (Fig. 7).

A more recent addition to the MIL series of r.f. chokes has been the magnetically shielded series which uses a ferrite bobbin and sleeve. The winding is wound on the bobbin, the sleeve is placed over the bobbin, and the assembly molded. In this type of construction, the magnetic field is confined almost entirely within the magnetic material.

Two current ratings must be considered when designing one of these chokes into a circuit. First, the incremental current rating is that current which causes an inductance to decrease 5% from nominal. In circuits where inductance is a critical value, the designer should specify a choke that does not exceed the incremental current.

Second, the maximum current rating that is given is the least desirable operating condition because saturation can cause a wide variation in inductance value, and temperature rise may exceed specified values.

Variations of both inductance and "*Q*" should be watched very closely when using this series of chokes in changing temperature environments.

The specifications for this series of chokes gives maximum current ratings that can be greater than the incremental current. Whenever a current greater than the incremental current is used, the inductance will decrease more than 5% and the temperature rise characteristics should be taken into consideration (see Fig. 8).

Chokes in the MS series are relatively low-power devices with maximum power ratings of between 0.25 and 0.55 watt and are subject to derating above 90° C (Fig. 9).

Although the inductance tolerance for chokes in the MS series has been established at ±20% for values of 0.1 to 0.82 μH and ±10% from 1.0 μH and greater in the standard molded choke series, it is possible to wind these devices with tolerances as close as 1%.

Adjustable Coils

Today, magnetic materials are available for use in coil designs throughout the frequency range of a few kHz to hundreds of MHz. In a resonant circuit where it is possible to change coil inductance by adjusting the core, the need for an adjustable capacitor can be eliminated and a much smaller fixed capacitor used instead. Since the fixed capacitor in parallel is many times the distributed capacitance of the coil, the adjustability of the core permits

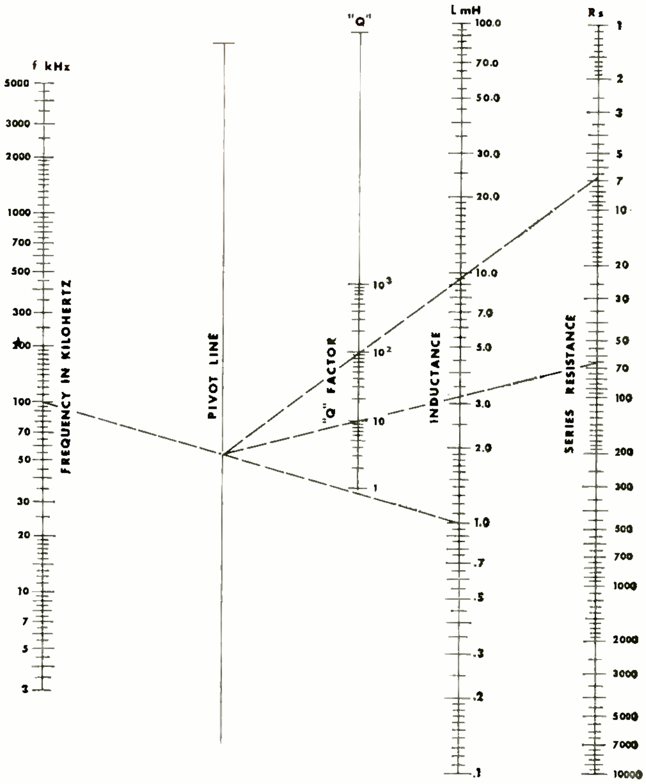


Fig. 6. Nonogram used to determine effective series resistance for various "Q" factors. The example shown is for a 1-mH choke to be used at 100 kHz. A straight line drawn between these two values crosses the pivot line at a certain point. If lines are then drawn from this point through several values of "Q", such as 10 and 100, the effective values of series resistance can be read off. In this case, for a "Q" of 10, R_s is close to 70 ohms; at 100, R_s is near 7.

less critical coil design. Most adjustable coil designs in actual use are compromises among inductance, "*Q*", size, and stability.

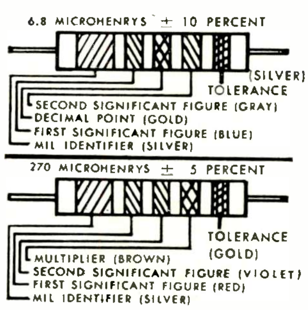
When inductance range is the most important factor, ferrite or high-permeability powdered materials can be used. When stability is most important, a lower permeability core material would be used. In many instances, the core is used only to make slight adjustments of inductance.

In frequency-stable circuits, a highly stable mechanical coil form material is used with a core material that is electrically stable over the temperature range to be covered. Ceramic materials usually meet the requirements for this type of coil form.

Temperature coefficients for air inductors generally vary from 150 to 300 ppm per degree C. This can be improved by special designs and impregnation to better than 25 ppm per degree C.

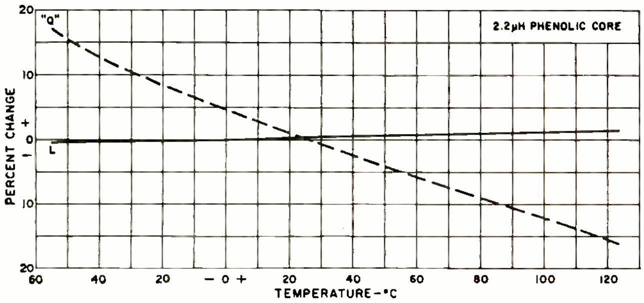
Most coils produced for the commercial market, such as for radio and TV manufacturers, use paper base impregnated forms with internal threading that is used for core adjustment.

Fig. 7. Color coding for molded cylindrical choke coils.



Color	Significant Figure	(1) Multiplier	Inductance Tolerance (Percent)
BLACK	0	1	
BROWN	1	10	
RED	2	100	
ORANGE	3	1,000	
YELLOW	4		
GREEN	5		
BLUE	6		
VIOLET	7		
GRAY	8		
WHITE	9		
NONE (2)			±20
SILVER			±10
GOLD	DECIMAL POINT		±5

(1) The multiplier is the factor by which the two significant figures are multiplied to yield the nominal inductance value.
(2) Indicates body color.



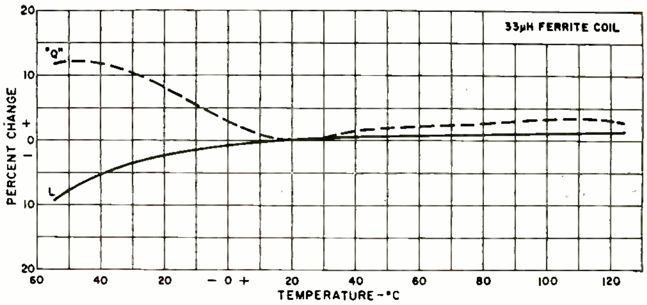


Fig. 8. Variations in "Q" and inductance over a range of operating temperatures for two different choke coils.

Applications by Frequency

Low-Frequency (10 kHz to 100 kHz) Applications: Coils for use at low frequencies can be wound with solid wire to realize values of "Q" that are satisfactory for most applications. However, at 10 kHz, the a.c. resistance of the wire already exceeds the d.c. resistance by a considerable margin. Where appreciable current may circulate, Litz wire can be used to improve coil "Q" by reducing series resistance.

In most instances, "Q" can be further improved by using pot-core construction with a fixed air gap in the magnetic material, or by using a small trimmer slug for final adjustment. It is possible to achieve values of "Q" that approach 800 at 100 kHz and 600 at 10 kHz.

Medium-Frequency (100 kHz to 3 MHz) Applications: Two popular i.f. frequencies fall within this range, 262.5 kHz for auto radios and 455 kHz for home radios. At these frequencies where operating "Q's" of 50 to 80 are useful, solid wire can be employed along with selected magnetic material. The use of solid wire and either an adjustable powdered cup core, or a threaded internal core permits the most economical design. Litz wire is much more expensive than solid wire and is not used to any degree in large runs of i.f. transformers for equipment in the entertainment field.

I.f. transformers built for use in more expensive communications receivers are much more selective and require a greater degree of temperature stability. Generally, Litz wire is used and the magnetic material is of a stabilized grade.

Within the past few years, new grades of temperature-stable ferrites have been introduced and this has resulted in considerable reduction in the size of many inductors. When operated at a fixed frequency, temperature compensating capacitors added to tune the coil to resonance assure very good stability.

To achieve "Q's" greater than 100, Litz wire is almost a necessity. With the proper selection of core material and Litz wire, it is possible to achieve values of "Q" that approach 800 and 100 kHz and 200 at 3 MHz.

All the types of winding outlined earlier can be used through this portion of the frequency spectrum. The use of pot cores allows for the design of extremely efficient filters and other inductive devices throughout the entire frequency range providing they are used with temperature-compensated capacitors.

High-Frequency (3 MHz to 300 MHz) Applications: For use through this range, coils are usually space-wound with solid wire to achieve highest "Q". Generally, the "Q" of the coil increases with an increase in wire diameter.

Selection of core material should be made with care to minimize the introduction of losses. In most applications, magnetic material should be used only for tuning an inductor rather than for shielding.

At the upper end of the frequency spectrum an iron core should be used only to trim inductance rather than make wide inductance changes. The iron core generally produces a lower "Q" than an air core.

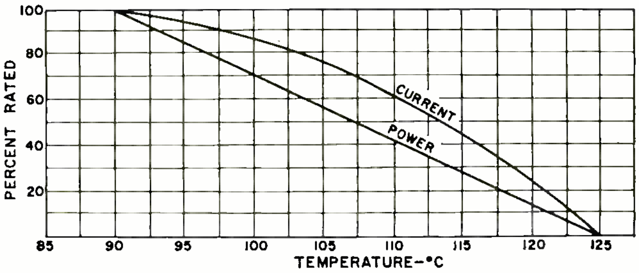
Above 50 MHz, it is common practice to use non-ferrous core material. The core body is either brass or copper with a silver plating to reduce r.f. losses. The non-ferrous core permits adjustment of a coil at these frequencies, but introduces losses like those caused by a shorted turn.

Proper selection of material for use in the core of a coil can improve several electrical parameters and reduce physical size. When a core is fixed in physical relation to a coil winding, the concentration of the magnetic field permits a reduction in the number of turns necessary to provide a given inductance. "Q" is improved because less wire is required for a specific value of inductance. When the proper grade of magnetic material is selected, the losses introduced by the magnetic material are less than the losses in the copper that would have been required for the additional turns on an air coil. However, distributed capacitance usually rises because the dielectric constant of the core material is usually greater than air. This has the effect of lowering the self-resonant frequency of a coil.

Each grade of powdered iron performs best over a different frequency range, and "Q" tends to decrease rapidly at higher frequencies.

Optimum coil design depends upon a compromise in physical size, inductance range, and stability of the device. If inductance range is the most important factor, ferrite or high-permeability powdered materials can be used. If stability is more important, lower permeability material must be used. ▲

Fig. 9. Current and power derating charts for temperature.



PRIMARY CONSIDERATIONS IN SELECTING INDUCTORS

Function coil will perform—oscillator, tuned inductor, filter, choke, pulsed amplifier, other.

Operating frequency range—determines value of inductance required, allowable amount of distributed capacitance, core material to be used.

Self-resonant frequency—determines upper limit of operating frequency range.

Circuit application—approximate coil loading due to amplifying device (tube or transistor) determines in-circuit impedance and gain of stage.

Inductance value—fixed or adjustable; if adjustable, range required.

"Q"—maximum desired value of "Q" consistent with available materials and cost; a compromise of physical and electrical parameters.

Current in circuit—steady-state, pulsed, approximate waveform.

D.C. resistance—minimum d.c. resistance, consistent with available material and cost, gives more efficient performance.

Peak r.f. voltage—when r.f. voltages over 500 volts will be encountered, multi-pi chokes should be considered for advantages of voltage dividing effect.

Mounting location—with respect to other components, chassis and cabinet may change f_o and Z of circuit by distorting magnetic field.

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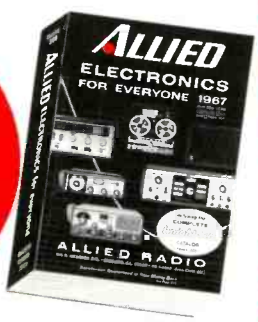

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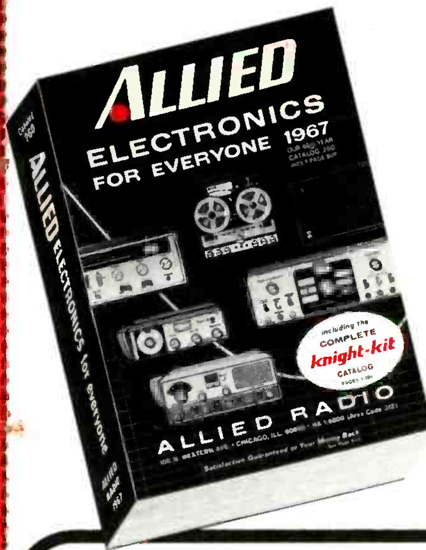

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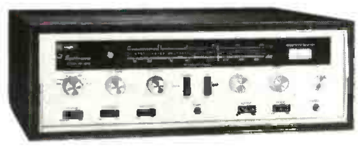

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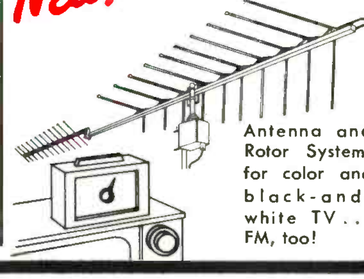

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JOHN FRYE

Television sets, like automobiles, can benefit from regular adjustments of operating controls and checks of components.

TV TUNE-UPS

BARNEY stood in the door of Mac's Service Shop watching his boss trying to find a break in the lunch-hour traffic so he might cut left into the driveway of the radio and TV repair shop. The youth grinned sympathetically as impatient drivers stalled behind Mac began sounding their horns. Finally, a little gap appeared in the near lane, and Mac swooshed through it to the accompaniment of a screaming protest from his tires.

"Daddy-O, you really were laying down the rubber!" Barney said in mock admiration as his employer stepped from his late-model car. "Not a hot-rodder I know could make his tires squall better than that."

"Stow that phony jive talk or something besides my tires will be squalling," Mac growled, a little red in the face. "You know how I feel about bird-brains who abuse their cars by stomping the accelerator when there's no need—which there seldom is. What fooled me was that I just had this car tuned up, and it's about twice as snappy as it was before. But come on back to the service department. I've an idea I want to talk over with you."

Soon they were perched side by side on the service bench, swinging their legs. Mac began to talk:

"I never put much stock in the kind of car tune-up you usually get in a small filling station or alley garage. Many of these are little more than rackets because the mechanics undertaking them have neither the knowledge nor the equipment to restore a modern car to tip-top performance. But the dealer from whom I bought the car in the spring suggested it would be a good idea to bring it in for a tune-up before winter weather set in. While the car was still doing quite well, after driving it all summer I felt it had lost a little of its original zip, and the gas mileage didn't seem as good as it had been at first; so I took the car in and, at the invitation of the dealer, stuck around to watch the mechanics.

"It was an enlightening experience. They used an exhaust analyzer to check and set the carburetion and an ignition analyzer to check the spark plugs, coil, and capacitor. Two doubtful plugs were replaced, as were the distributor points and the capacitor. Timing was reset with a timing light. All fluid levels in the crankcase, automatic transmission, master brake cylinder, power steering, and battery were carefully checked and extra fluid added where needed. The air conditioning was tested. Drive belts were carefully inspected and tightened. All head lamp, tail light, license plate, brake light, back-up light, and parking light bulbs were checked.

"Finally, the car was taken out on the highway and road-checked for acceleration, steering, braking, and automatic transmission shifting. The mechanic made a slight adjustment affecting the latter before turning the car over to me. Everything was done 'by the book.' Time and again a factory manual up-dated with several inserted Shop Notes and Bulletins was consulted."

"All that probably cost some green stamps," Barney suggested.

"It wasn't cheap, but I wouldn't expect a thorough job such as that to be inexpensive. I didn't mind paying the bill when I found how much better the car performed. The engine is much, much peppier and smoother. As I get it, today's high-compression engines are like high-'Q' tuned circuits: they only have to be off a little to cause a considerable reduction in response. But in my case the change had been so gradual and the engine had so much power left I was scarcely aware of the lessened performance."

"Is all this leading up to that idea you wanted to tell me about?"

"Yep. As you know, any time I'm especially pleased by service I receive I try to analyze my satisfaction in the hope of finding something we can use in the service we give. I'm a pretty ordinary kind of guy, and I figure what pleases me will please most other people. So I'm thinking maybe we should try to persuade our customers to let us give their TV sets tune-ups before the heavy winter watching season begins."

"Why just our customers? Why not put an ad in the paper and take on everybody?"

"For one thing, I'd like to use that 'going by the book' procedure that impressed me. We have the makes and model numbers of all our customers' sets; so we can take along the proper service folder and any odd-ball tubes or parts on these jobs. You know what a time Matilda has trying to get the make and model number of a new customer's set over the telephone. Secondly, I think postcards sent directly to our old customers will be more effective. We'll be reaching people who know us and—I hope! have confidence in us. Remember, we'll be trying to sell something the customer probably doesn't realize he needs."

"What will this tune-up include? How long will it take?"

"That's what I want to talk to you about. I was thinking about having one flat price for black-and-white sets and another for color sets. We might try to include those services that will take about an hour on a B&W receiver and an hour and a half on a color set. Any parts used, of course, will be extra. I'll be content if the flat rate breaks even on the actual cost of making the call. I don't mean only your wages; I mean an estimated hourly rate charge arrived at by dividing our annual cost of doing business by 16 times the number of working days in the year. That is the hourly income each of us must have to pay our three salaries, the rent, light, water, telephone, truck costs, taxes, depreciation, insurance, etc., etc."

"Where does the profit come in?"

"From profit on parts sold, from major repair jobs obtained through these calls, and from good will created by them."

"Regarding that last item, I hate to be a meanie but I must make a suggestion. Don't forget you're going to have a few people call up and say something like this: 'My set was working perfectly until you tuned it up; now it won't work at all. You did something to it, and you'd better get out here and fix it before I sic the Better Business Bureau on you!' "

"You got a point," Mac admitted with a grin. "We'll include the cost of a few call-backs in those flat-rate prices. However, careful wording of the cards we send out plus a little in-person customer education on our part should put across the idea that a tune-up is not a major overhaul and does not guarantee the set against developing some serious fault in the near future—not any more than a car tune-up precludes the possibility of a valve sticking, a wheel cylinder starting to leak, or something going wrong with the transmission shortly after the tune-up. But now let's try to decide what our tune-up should include."

"A check of all tubes, of course," Barney said. "And all glass surfaces in front of the picture tube screen should be thoroughly cleaned. The operation of all controls should be checked. The channel oscillator settings should be put on the nose. Any poor linearity in the picture should be corrected, and the hold controls and the a.g.c. should be checked and set. Buzz control adjustments should be made if needed. Ion traps on older sets should be positioned."

"You can add to that, on color sets, the checking of the high voltage and its regulation. The gray scale should be reset if necessary. The picture tube should be degaussed. Minor convergence adjustments may be made, but a major reconvergence should not be included in a tune-up," Mac added. "Those will do for a starter. Let's both mull the idea over for a day or two and try to decide what should and should not be included. What we want are honest services that will make an easily seen improvement in reception."

"Yeah," Barney said, nodding agreement, "and if at all possible the tune-up should be done under the watchful eyes of the customer. Let him see us referring to the service data covering his particular receiver. Permit him to look over our shoulders at the complicated-looking and obviously expensive tube testers, field-strength meters, v.t.v.m.'s and signal generators we use in adjusting and testing his receiver."

"Attaboy!" Mac applauded. "We want to give our customer his money's worth, but a little salesmanship never hurts. If we can impress him the way that mechanic impressed me, we'll be home safe."

There was a little silence, and then Barney said quizzically: "One thing bothers me. Why this sudden attempt to acquire more business? It seems to me we have about all we can handle right now. You expecting a depression or something?"

After a moment's hesitation, Mac asked a question instead of answering. "Barney, do you recall my ever crepe-hanging about the future of radio and TV servicing?"

"No, can't say I do. In fact, I remember hearing you pooh-pooh guys who argued that complicated color-TV meant the end of the freelance service technician, and the ones who said transistors meant the same thing, and those who panicked when printed circuits became popular, or the ones ready to throw in the sponge when a few manufacturers tried plug-in modules and drug stores installed tube testers."

"And back before you came with me, I was denying that the advent of cheap a.c.-d.c. receivers would run us out of business. Well, I am still not crepe-hanging, and I know freelance service technicians will be around for a long time; but I think I see that 'cloud on the horizon, no larger than a man's hand' that poses a serious threat to our kind of work.

"I'm talking about the integrated circuits just starting to be used in radio and TV receivers. As you know, these highly educated chips of semiconductors promise to be highly dependable, long-lived, and impossible to repair. So far, linear IC's are being used only in hearing aids, low-level audio amplifiers, and in the intercarrier audio channel of a TV set; but many manufacturers are working hard to extend the capabilities and applications of these chips. They will probably do it, too. When you consider that the TV set IC replaces 26 parts with one, you can see the direction the wind is blowing. I'm afraid we'll eventually see in servicing what happened to the home refrigeration repair business when the sealed compressor unit was developed. Believe me, this thinned out the ranks of refrigerator repairmen in a hurry. The ones who stayed get most of their income from commercial refrigeration and air-conditioning."

"I read you," Barney said. "You think we should make hay while the sun shines, and you also think this is a dandy time for a service technician to be preparing himself to move gradually into other electronic fields than pure home radio and TV servicing; right?"

"Precisely. Radio and TV sales, industrial electronics, automotive electronics, automation installation and maintenance, medical electronics, servicing commercial mobile equipment, space electronics—these are all spare strings he can attach to his bow, and now is a darned good time to start stringing!" ▲

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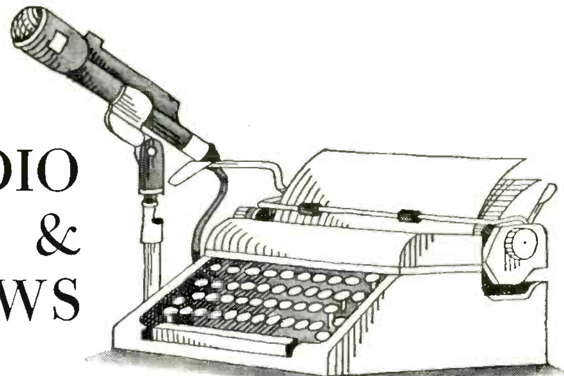
RADIO & TV NEWS



We tend to think of CATV as finding its greatest use in areas remote from TV transmitters where signal strength is minimal and large antennas are needed even for marginal reception. Although the vast bulk of CATV systems are installed in these remote areas, some systems are finding use in very high signal strength areas where severe ghosting is a problem. Such an area exists in some sectors of New York City. Here, the intent of the CATV system is to provide clear, non-ghosted signals for its customers.

The *TelePrompTer Corp.* recently announced New York City's first CATV system to provide this service. Customers pay $19.50 for installation and $5 per month for reception of nine TV signals.

Phono Cartridge Trackability

Using a variable-speed phono turntable (25 to 100 rpm) and a vacuum suction pump to keep a special test record flat on the turntable at high speeds, *Shure Bros.* recently demonstrated the trackability of a new stereo phono cartridge. The cartridge was designed by employing analog techniques in which *LCR* circuits were used to simulate the mass, compliance, and damping. Engineers found it much easier to vary values of inductance, capacitance, and resistance in decade boxes than to measure minute forces with strain gages on a tiny stylus assembly on a phono cartridge tracking a record.

Trackability was determined by gradually increasing the speed of the turntable to increase velocity and frequency. The output of the cartridge was monitored with a scope. At certain critical values of velocity (at a fixed cartridge pressure of ¾ or 1 gram) the output waveform would suddenly break up and show substantial distortion. This represented the maximum velocity that the cartridge would track at its fixed tracking pressure.

A curve was then drawn of the maximum velocities over the entire audio frequency range. The curve was found to exceed 25 cm/sec from about 700 to 6000 Hz, falling to 17 cm/sec at 40 Hz and to 9 cm/sec at 15,000 Hz—all at ¾ gram pressure. At 1 gram pressure maximum velocities were up about 3 to 5 cm/sec. The resultant curve was well above the curve that shows maximum velocity which should be cut on good-quality stereo records, and demonstrates the improved trackability of the new cartridge. Listening tests confirmed the fact that a cartridge with better trackability definitely sounds better, particularly on high-frequency transients.

Microeye

Continuing the trend towards smaller and smaller, NASA has just announced a pair of tiny TV cameras only 1½ by 3 by 4 inches in size weighing only 1½ pounds and completely self contained.

One of the cameras includes a low-power transmitter having a range of about 100 feet. The other "microeye" is cable-connected to a monitor unit.

The "microeyes" are to be used in future space flights to observe both astronaut and spacecraft phenomena.

The Electronics Market

Color-TV sales in April, 1966 totaled 296,485, an increase of 166.3% over the same month last year. Sales for the first four months of 1966 were up 109% from the same period last year.

Monochrome-TV sales in April, 1966 totaled 475,378, down 10.4% from April last year. Sales for the first four months of 1966 were up 1.2% over the same period last year.

Home radio sales in April, 1966 totaled 810,000, up 8.7% from April last year. Sales for the first four months of 1966 were up 20.3% over the same period last year.

FM radio sales in April, 1966 totaled 220,146, up 51.2% over the same month last year. Sales for the first four months of 1966 were up 58.9% from the same period last year.

Auto radio sales in April, 1966 totaled 749,905, down 5.9% from April last year. Sales for the first four months of 1966 were up 5.4% from the same period last year.

Portable/table model phonographs showed a decrease of 28.9%, while console phonographs were up 20.4% from the same period last year.

This information is supplied by the EIA. ▲

Frequency Measurement

(*Continued from page 28*)

greater than the aging rate times the number of days since last calibration and may be much better than this. This is one reason the oscillator should be tracked against NBS.

There is a third possible cause of inaccuracy which is not widely understood. The waveform of the observed signal may influence the triggering of the counter and produce an error. When the clean time-base signal originating inside the counter is used to trigger the measuring gate, as in a frequency measurement, the trigger-point will be well-defined and inaccuracies beyond ±1 count will not ordinarily arise. In the case of period, ratio, or time-interval measurements, however, the unknown signal is used to trigger the measuring gate, while the counter totalizes the output of its own time base. With noise on the signal or "glitches" in its waveform triggering can become uncertain.

Almost all electronic counters use Schmitt trigger circuits. These are very convenient because they can be set to switch only on positive-going or on negative-going signals. Since we want to totalize all complete cycles of a signal, we would not want the gate actuated by both positive- *and* negative-going signals for then we would be totalizing half-cycles. A Schmitt trigger turns out a fast-rise pulse at a particular level of the input signal, regardless of how fast or how slowly this signal may be changing. If "glitches" on the signal fall on or near the trigger point, their presence will cause the trigger to be early or late, and produce an error.

Clean waveforms are essential for high accuracy when making these measurements. A good rule-of-thumb is that total noise and harmonics should be more than 40 dB down, or less than 1% if an accuracy of 0.3% in the time or period measurement of sine waves is to be expected. If many periods are measured, of course, the accuracy with which the corresponding frequency is known increases proportionally.

The "± 1 count error" can be minimized by considering the measurement carefully before making it. At high frequencies, the effect of this error is very small because a great number of counts is being made during any given gate opening. At medium and lower frequencies, however, the use of "period" or "multiple-period averaging" modes of counter operation should be considered. The total number of cycles counted during a measurement can be made high, even though the *frequency* being measured becomes lower by using these modes.

Time-base error can be minimized by keeping records on the performance of the oscillator which is used as a time base and using these to calculate appropriate corrections. The user, however, should carefully analyze the specifications on both long-term and short-term instabilities in the oscillator and be on guard against the possibility that while long-term aging is slow, vagrant short-term drifts during which the measurements are actually taken may be high and unknown.

Errors due to trigger-point "jitter" are best avoided by seeing that the measured waveform is clean. Increasing the amplitude of the input signal without overloading the input will also help since this increases the rate of change of the input signal as it passes through the trigger point. ▲

CALCULATING PARALLEL RESISTOR VALUES

By SHU H. LOUI/Raytheon Co.

THE formula used to calculate the equivalent resistance when two resistors are connected in parallel is: R_T= (R1 R2) / (R1 + R2). Normally, this equation requires three arithmetic steps to arrive at an answer.

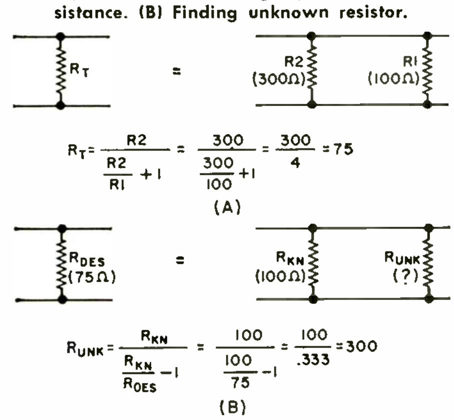
A slight transformation of the equation, R_T=R2/[(R2/R1)+1] facilitates computation and reduces the arithmetic to two movements of a slide rule without readjusting the hairline. In this equation, the larger-valued resistor is used as R2.

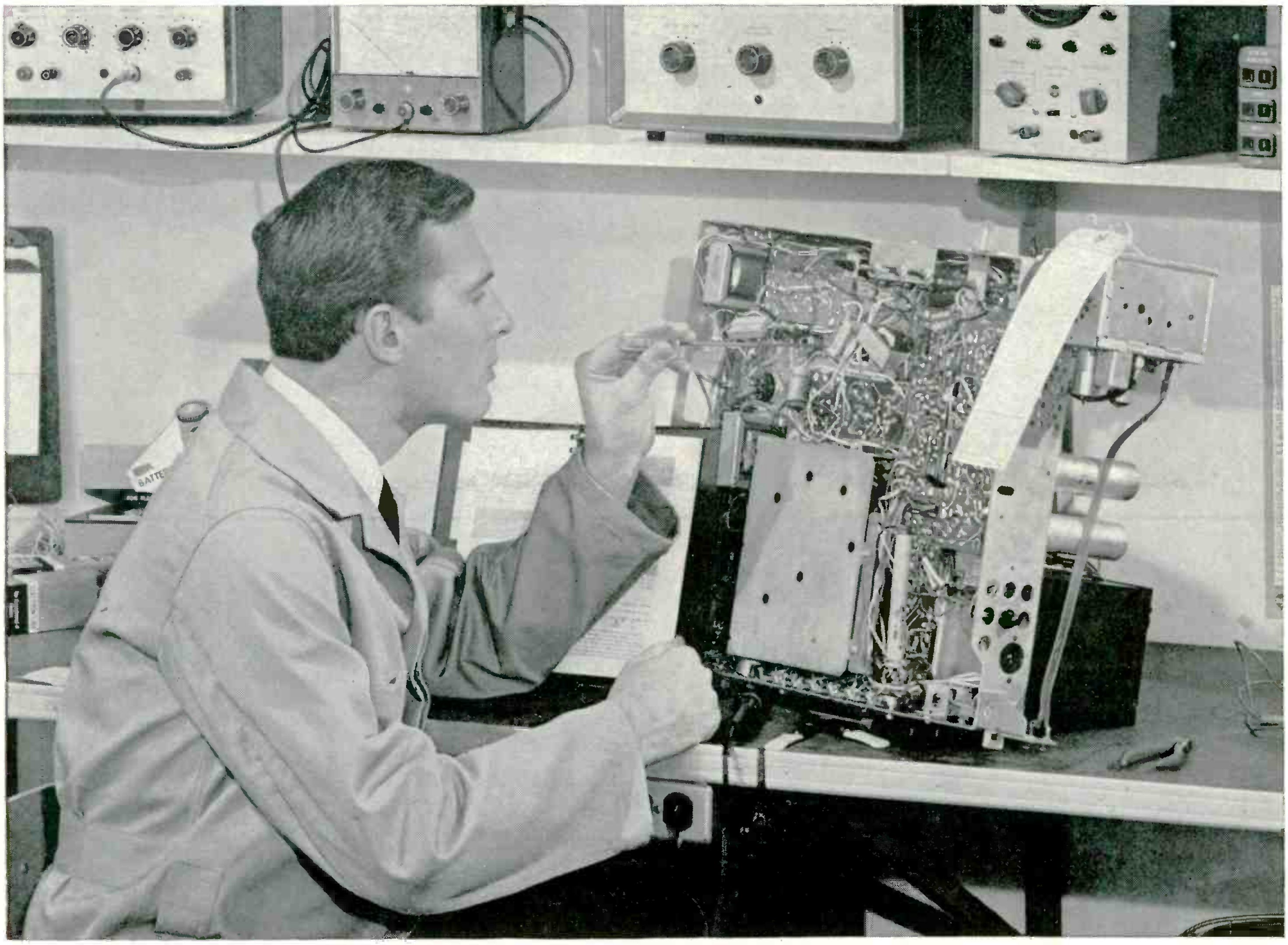
Example: What is the equivalent resistance when a 300-ohm and a 100-ohm resistor are connected in parallel? The answer, 75 ohms, is calculated as shown in Fig. 1A.

To determine what value resistor (R_{unk}) should be connected in parallel with a known value (R_{kn}) to obtain a desired value (R_{des}), the equation R_{unk}= R_{kn}/[(R_{kn}/R_{des}) − 1] is used.

Example: What value resistor should be connected in parallel with a 100-ohm resistor to produce a 75-ohm equivalent. Calculations are shown in Fig. 1B. ▲

Fig. 1. (A) Determining equivalent resistance. (B) Finding unknown resistor.





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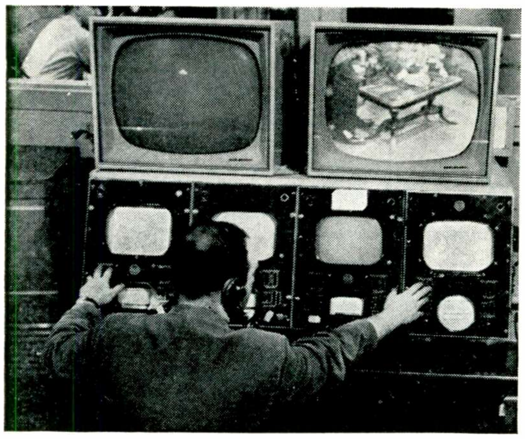

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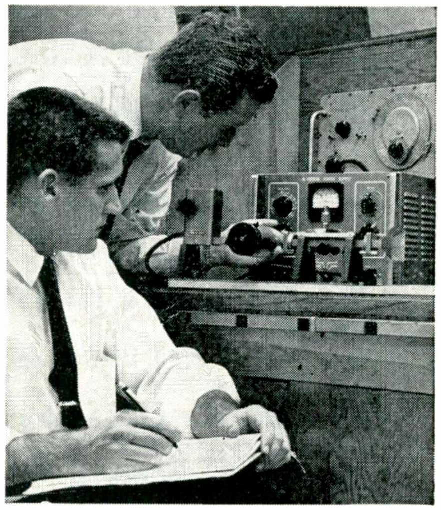

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SAMPLING OSCILLOSCOPE DISPLAYS 12,400-MHz R.F.

First X-band instrument permits direct observation of c.w. signals from d.c. through microwave band.

FOR the first time, it is now possible to directly observe microwave c.w. signals at frequencies never before displayed on an oscilloscope screen. This is because of the development of a new 12,400-MHz sampling scope. Heretofore, such scopes have had a response up to about 4000 MHz.

Pulsed carriers, common at the microwave frequencies, may not only be viewed directly, complete with carrier, but also without degradation. The study of pulse waveshapes in pulsed microwave carriers has always before been handicapped by the characteristics of the crystal detector which had to be used.

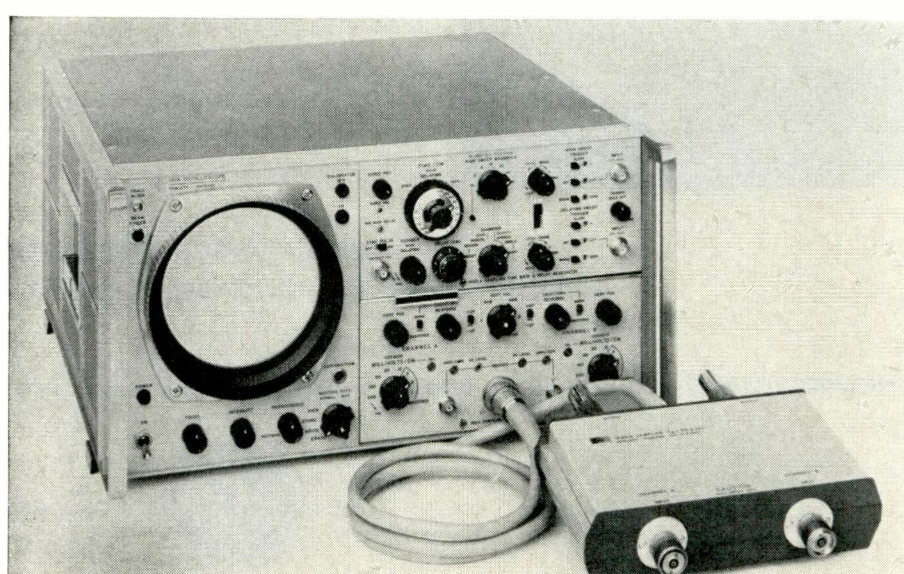
In order to view microwave signals or to observe extremely fast pulses, the sampling technique is used. With this method the r.f. signal is sampled at a much lower frequency (100 kHz, in this case) by means of a pulsing sampler circuit. Every time a sample is taken, however, the sampling point moves along the waveform to be viewed. If enough samples are taken, and these samples are then displayed simultaneously, the effect is to recreate the original waveform. (See "Sampling Oscilloscopes" in our June issue.)

Another important advantage of the new instrument is an increase in resolution capability when time-domain reflectometry is used. With this technique, a voltage pulse is sent down the length of transmission line you are interested in checking. If the line is perfectly matched, there are no reflections when the leading edge of the pulse reaches the termination. Hence, the flat-top portion of the pulse remains perfectly flat. With a mismatch, however, reflection occurs and an extra step is introduced into the waveform. By examining the step and noting the time between the leading edge of the pulse and the step, it is possible to tell what kind of mismatch occurs and exactly where it occurs. (See the article "Time Domain Reflectometry" in our September issue.)

The sampling circuit of the new instrument has a rise time of only 28 picoseconds. When used with a new 20-picosecond-rise-time pulse generator, the system rise time is under 40 picoseconds. This means that it is possible to resolve discontinuities that are only a matter of millimeters apart.

In addition to the sampling scope, which was just introduced by *Hewlett-Packard*, the company demonstrated a new d.c.-to-50-MHz all solid-state oscilloscope built around a special rectangular CRT with a viewing area said to be twice that of other portable scopes. The instrument makes extensive use of new field-effect transistors in the input stages. The scope is in a package smaller than one cubic foot and it weighs 30 lbs. The unit sells for about $2000 with plug-in vertical amplifier and time-base generator. ▲

The new Hewlett-Packard microwave sampling scope shown here consists of a main-frame storage scope into which is plugged a vertical amplifier and a delayed-sweep time-base generator. The outboard unit at the right is a 12,000-MHz sampler plugged into the vertical input. Total price of assembly is near $6600.

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since the advent of stereo

THE TYPE II SHURE V-15

...a new genre of cartridge, analog-computer-designed, and measured against a new and meaningful indicator of total performance:

"TRACKABILITY"

The radically new V-15 TYPE II heralds a new epoch in high performance cartridges and in the measurement of their performance. We call it the era of high *Trackability*. Because of it, all your records will sound better and, in fact, you will hear some recordings tracked at light forces for the first time without distortion.

THE PROBLEM:

While audiophiles prefer minimum tracking forces to minimize record wear and preserve fidelity, record makers prefer to cut recordings at maximum levels with maximum cutting velocities to maximize signal-to-noise ratios. Unfortunately, some "loud" records are cut at velocities so great that nominally superior styli have been unable to track some passages at minimal forces: notably the high and mid-range transients. Hence, high level recordings of orchestral bells, harpsichords, pianos, etc., cause the stylus to part company with the wildly undulating groove (it actually ceases to track). At best, this produces an audible click; at worst, sustained gross distortion and outright noise results. The "obvious" solution of increasing tracking force is impractical because this calls for a stiffer stylus to support the greater weight, and a stiffer stylus will not track these transients or heavy low-frequency modulation, to say nothing of the heavier force accelerating record and stylus wear to an intolerable degree.

Shure has collected scores of these demanding high level recordings and painstakingly and thoroughly analyzed them. It was found that in some cases (after only a few playings) the high velocity high or midrange groove undulations were "shaved" off or gouged out by the stylus . . . thus eliminating the high fidelity. Other records, which were off-handedly dismissed as unplayable or poor pressings were found to be neither. They were simply too high in recorded velocity and, therefore, untrackable by existing styli.

Most significantly, as a result of these analyses, Shure engineers established the maximum recorded velocities of various frequencies on quality records and set about designing a cartridge that would track the entire audible spectrum of these maximum velocities at tracking forces of less than 1½ grams.

ENTER THE COMPUTER:

The solution to the problem of true trackability proved so complex that Shure engineers designed an analog-computer that closely duplicated the mechanical variables and characteristics of a phono cartridge. With this unique device they were able to observe precisely what happened when you varied the many factors which affect trackability: inertia of tip end of the stylus or the magnet end of the stylus; the compliance between the record and the needle tip, or the compliance of the stylus shank, or the compliance of the bearing; the viscous damping of the bearing; the tracking force; the recorded velocity of the record, etc., etc. The number of permutations and combinations of these elements, normally staggering, became manageable. Time-consuming trial-and-error prototypes were eliminated. Years of work were compressed into months. After examining innumerable possibilities, new design parameters evolved. Working with new materials in new configurations, theory was made fact.

Thus, the first analog-computer-designed, superior trackability cartridge was born: the Shure SUPER-TRACK V-15 TYPE II. It maintains contact between the stylus and record groove at tracking forces from ¾ to 1½ grams, throughout and beyond the audible spectrum (20-25,000 Hz), at the highest velocities encountered in quality recordings. It embodies a bi-radial elliptical stylus (.0002 inch x .0007 inch) and 15° tracking.

It also features an ingenious "flip-action" built-in stylus guard.

It is clean as the proverbial hound's tooth and musical as the storied nightingale.

THERE ARE MANY WAYS TO PROVE ITS SUPERIORITY TO YOURSELF:

(1) Shure has produced a unique test recording called "An Audio Obstacle Course" to indicate cartridge trackability. It is without precedent, and will be made available to Shure dealers and to the industry as a whole. You may have your own copy for $3.95 by writing directly to Shure and enclosing your check. (Note: The test record cannot be played more than ten times with an ordinary tracking cartridge, regardless of how light the tracking force, because the high frequency characteristics will be erased by the groove-deforming action of the stylus.)

(2) A reprint of the definitive technical paper describing the Shure Analog and trackability in cartridges, which appeared in the April 1966 Journal of the Audio Engineering Society, is available (free) to the serious audiophile.

(3) A representative list of many excellent recordings with difficult-to-track passages currently available is yours for the asking. These records sound crisp, clear and distortion-free with the Shure V-15 Type II.

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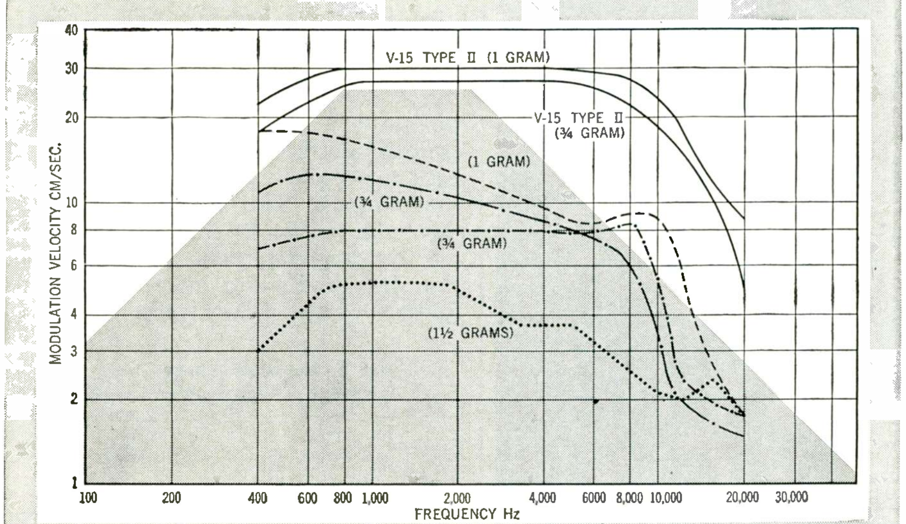
TRACKABILITY AS A NEW SPECIFICATION:



This chart depicts the new performance specification of *trackability*. Unlike the oversimplified and generally misunderstood design parameter specifications of compliance and mass, trackability is a measure of total performance. The chart shows frequency across the bottom, and modulation velocities in CM/SEC up the side. The grey area represents the maximum *theoretical* limits for cutting recorded velocities; however, in actual practice many records are produced which exceed these theoretical limits. The smoother the curve of the individual cartridge being studied and the greater its distance above the grey area, the better the trackability. The trackability of the Shure V-15 TYPE II is shown by the top (solid black) lines. Representative curves (actual) for other high priced cartridges ($80.00, $75.00, $32.95, $29.95) are shown as dotted, dashed and dot-dash lines for comparison purposes.

*T.M.

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Line-Operated TV Sets

(Continued from page 29)

mistor in series with it, determines the feedback between the base and emitter of this transistor and therefore controls the linearity. Potentiometer *R*3 sets the vertical bias which affects height as well as linearity to some extent. Of particular interest is the output circuit. The collector goes to ground through iron-core choke *L*1, and the pulse signal developed across this choke is coupled through *C*1 to the deflection coils which are connected in series. Voltage-dependent resistor (VDR) *R*4 and capacitor *C*2 are shunted across the deflection yoke to maintain constant height, regardless of any voltage variations.

The horizontal output and flyback circuits of both *G-E* models (shown in Fig. 2) are quite similar to each other; however, both circuits are different from those of previously described transistor models. Horizontal output transistor *Q*2 is a *p-n-p* type which drives the deflection yoke and the flyback transformer through its emitter. It is itself driven by horizontal buffer stage *Q*1. Practically all previously described transistor receivers have had an emitter-follower driver that pumps current into the output transistor. In the *G-E* models, the +12-volt supply goes to the collector of the buffer and to the emitter of the output transistor.

Flyback transformer *T*1 consists of three separate windings, with the tapped primary providing the load for the output transistor and a small feedback voltage from the emitter to the base. Output transistor *Q*2 has a special characteristic in its emitter-base junction, which acts somewhat like a zener diode. The amplitude of the positive driving pulse causes this junction to break down and allows a reverse current to flow through the junction which will oppose the collector-to-emitter current flowing at the first portion of the retrace path. This action, in conjunction with resistor *R*1 and the inductance of the tapped portion of the flyback transformer winding, increases the amplitude of the flyback pulse. Because of this "feedback" effect, the horizontal output transistor can be driven with less current than would otherwise be required.

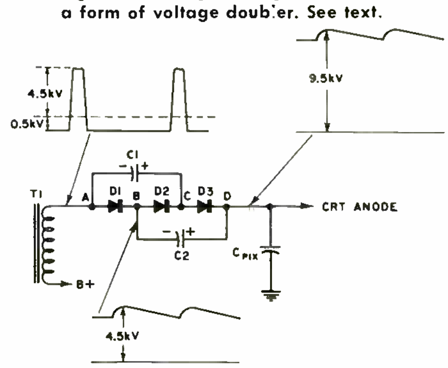

Fig. 3. The high-voltage circuit is a form of voltage doubler. See text.

As in most transistor receivers, the two horizontal deflection coils are connected in parallel. The high positive pulses generated in the primary of the flyback transformer are rectified and filtered to provide +90 volts.

One of the unique circuits found in this receiver is the high-voltage rectifier. As shown in Figs. 2 and 3, this circuit uses three rectifiers and two capacitors in a voltage-doubler connection, but the circuit differs from conventional doublers in its method of operation. As illustrated in Fig. 3, a 5-kV positive pulse appears at the high-voltage winding of *T*1 (point *A*). Because of the short duration of this pulse, the average voltage will only be 500 volts. At point *B*, with first rectifier *D*1 acting as peak detector, a d.c. voltage exists with a ripple reaching up to 4.5 kV. The first and third rectifiers, *D*1 and *D*3, effectively act as peak detectors during the retrace time, with middle rectifier *D*2 passing current during the trace time. Capacitors *C*1 and *C*2 are charged during retrace time and discharged slightly during trace time. They are therefore effectively in parallel with the picture tube. The result of this entire operation is a varying d.c. voltage with a maximum amplitude of approximately 9.5 kV. The capacitance between the second anode and the grounded outer shell (C_{pix}) of the picture tube serves as the output filter. In Model TA, the "cold" side of the transformer winding goes to "B+," while in Model TB the "cold" side goes to the "high" side of the primary winding.

Both the *G-E* TA and TB models use a power transformer and a full-wave rectifier with a transistor voltage regulator. In TA, this regulator utilizes a simple two-transistor circuit with a zener diode and a potentiometer. In TB, three transistors are used for regulation and a zener diode is connected effectively across the +12-volt supply. On some chassis, the zener diode is replaced by the emitter and base junction of an *n-p-n* transistor which has its collector lead disconnected.

With its 9-inch rectangular picture tube, this *G-E* transistorized TV set is probably the smallest line-operated TV set in the industry.

Power Sources

This compact TV receiver can be operated not only from the commercial 120-volt a.c. power line, but also can be operated from a source of 12 volts supplied either by an automobile storage battery, or from a *G-E*-supplied 12-volt battery pack having its own built-in recharger. ▲

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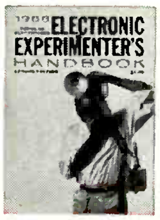

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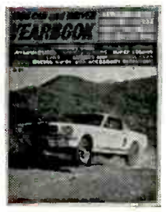

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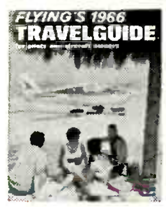

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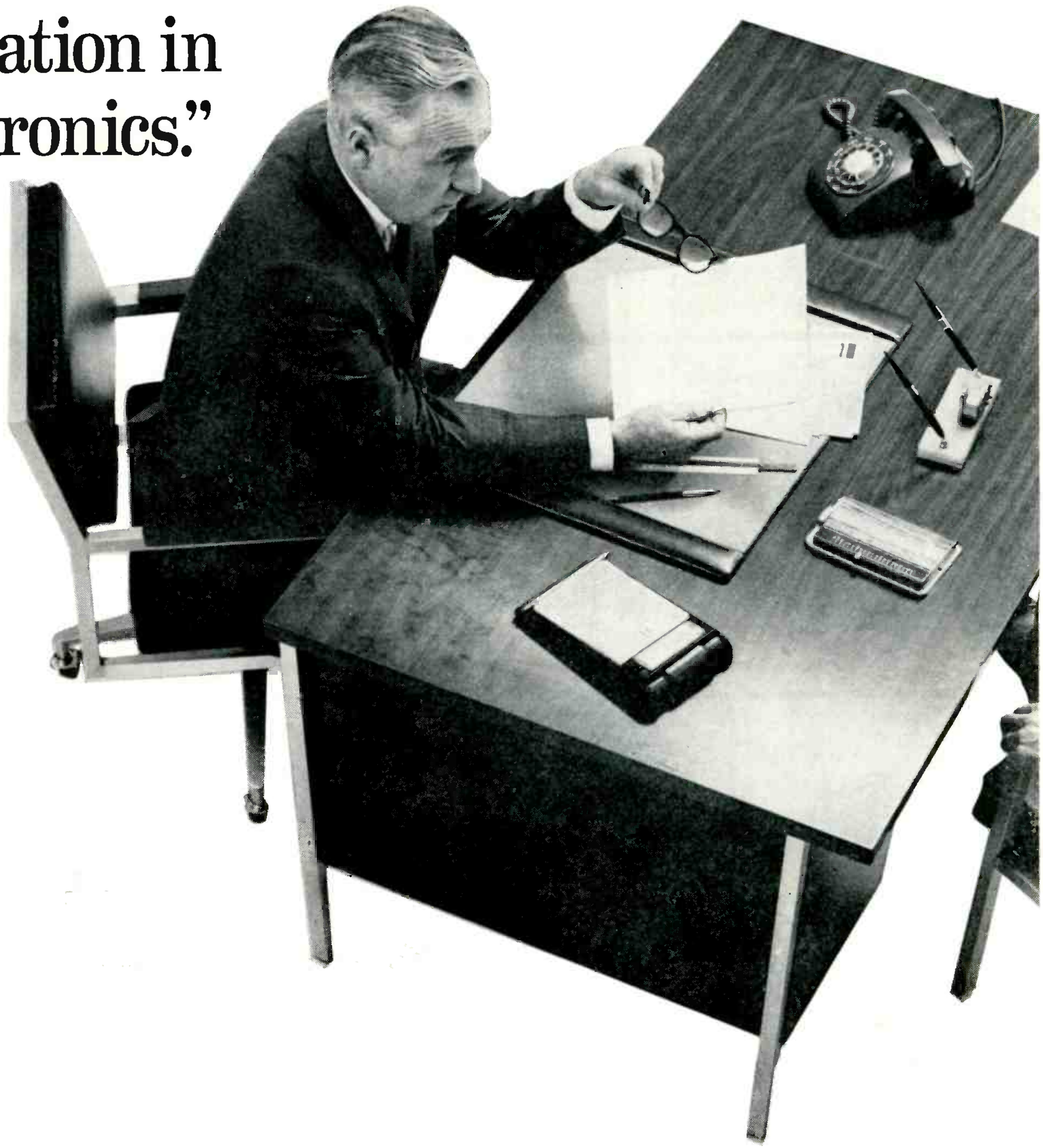

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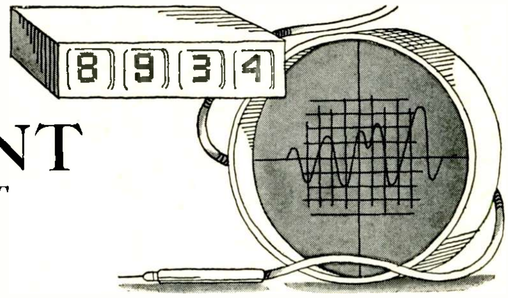

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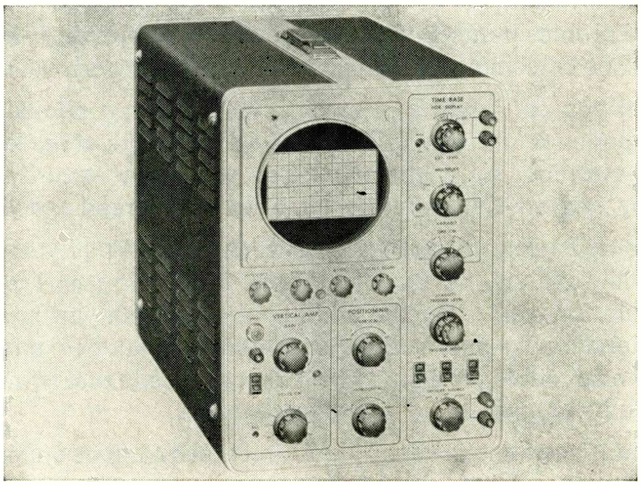


BACK in 1947, the *Heath Company* was advertising surplus equipment in this publication (we were called RADIO NEWS then). Along with this gear the company offered its first test-equipment kit, a 5-inch scope, complete with a surplus 5BP1 CRT, for $39.50. The latest kit to come from the company is also a 5-inch scope, but it bears little resemblance to the 1947 model.

The new scope is a full-fledged professional instrument with a triggered, calibrated sweep, a d.c. to 8-MHz bandwith, and a 40-nsec rise time. Some of the early scope kits we have used were plagued with instability and power-transformer overheating if operated for long periods of time. The new *Heath* IO-14 is as steady as a rock, and it uses a massive power transformer along with a quiet-running blower motor that allows it to operate continuously. A pair of quarter-microsecond delay lines in the vertical circuits permits examination of the leading edges of fast pulses while these same pulses are triggering the sweep circuits.

When the package that the kit comes in is first seen, it's a little forbidding; it looks like it contains a small trunk. However, opening the box will reveal that there are actually eight separate packages of parts. Each package has its own parts list and its own section in the assembly manual. It's almost like wiring eight separate small kits which are then fitted together into a single piece of test equipment. The entire wiring and construction took us 28 hours, plus several more hours for unpacking and checking parts and a couple of extra hours for adjustments and calibration.

Not only is the completed scope a superb laboratory instrument but, equally important to the man who must put the kit together, the 140-page assembly manual is excellent. This handbook illustrates every single construction step required with individual detailed drawings, over-all drawings, and photos. There is an especially fine section on circuit operation that can be studied profitably by anyone using a triggered scope for the first time.

We were very impressed with the stability of the new scope and its immunity to line-voltage changes. The main reason for this is the use of three separate, regulated, low-voltage power supplies and a partly regulated high-voltage supply. One of these supplies delivers a —150 volt reference voltage to the others, and this voltage stayed absolutely constant at its proper value even though we varied the a.c. line voltage from 90 volts to 130 volts. Our waveform trace remained stable and bright over practically this entire range of input voltage as well.

The scope is basically a vacuum-tube instrument with 25 tubes, including some new multi-purpose and compactron types, plus the 5ADP2/31 flat-face, high-brightness CRT. Twelve silicon diodes are used in the low-voltage power supplies along with two selenium diodes in the 4.5-kV high-voltage supply. There are five separate circuit boards on which components must be mounted and soldered. These are for the vertical circuit, the trigger circuit, the sweep and horizontal circuit, the low-voltage regulators, and the low-voltage rectifiers.

The IO-14 provides 18 accurately calibrated triggered sweep rates from a very slow 0.5 sec/cm all the way up to a very fast 0.2 μsec/cm when the five-times magnifier is used. The vertical input attenuator is a nine-position, fully compensated type for signals from 50 millivolts (p-p)/cm up to 20 volts (p-p)/cm.

The scope is large (15" x 10½" x 22" deep) and heavy (40 pounds), but it is no larger or heavier than any of the other comparable 5-inch lab scopes. Any way you look at it, the IO-14 is certainly a lot of scope for the money. The kit is available for $299; an assembled unit costs $399. ▲

Sencore MX11 Stereo Generator

For copy of manufacturer's brochure, circle No. 28 on Reader Service Card.

A NEW FM multiplex generator (the MX11 "Channelizer") has been developed by *Sencore* to allow a technician to set up, check, and see what is actually happening in both channels of a stereo FM tuner or receiver. Two a.c. meters indicate in dB whether the stereo separation is good or poor and if the stereo system is properly balanced. The two meters connect across the existing speaker system, or if the speakers are not desired, there is an 8-ohm load resistor across each meter to substitute for the speaker.

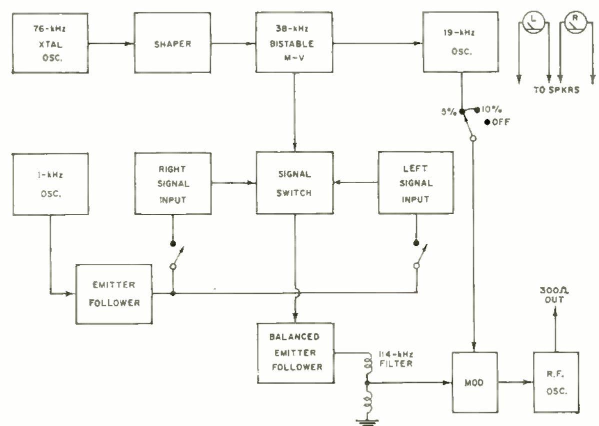
The MX11 is a completely solid-state miniature FM stereo transmitter. It provides both left and right signals and a 19-kHz pilot signal for complete stereo alignment and troubleshooting.

The r.f. oscillator is adjustable from 90 to 105 MHz. The composite stereo signal from the modulator frequency-modulates the r.f. oscillator. The r.f. output cable is terminated with a resistor pad to match the 300-ohm input of the FM receiver.

The power supply consists of 8 "C" cells. These "C" cells are contained within two plastic tubes which are easily accessible from the side of the case.

The operation of the MX11 is very quick and simple. The r.f. cable is connected to the FM receiver's antenna input terminals and the receiver is tuned to the generator frequency. A 1000-Hz tone should be audible from the speakers. With the meters connected to the left and right outputs, the receiver's

volume control is turned up until both meters indicate zero dB. It takes a 3-volt r.m.s. signal to produce this full-scale deflection. If both meters do not read at the same point, the receiver's balance control may have to be adjusted to balance the output. With both channels of the FM stereo receiver properly balanced, the "Pilot" switch is turned to the 10% position. At this time, the stereo tuner's indicator will show the presence of the pilot signal.



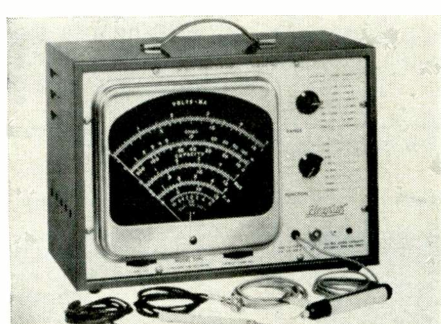
To determine the separation ratio of the FM stereo receiver, either the "Left" or "Right" signal switch is turned off. The amount of crosstalk is indicated directly on the meters employed.

Should a separation check show a low separation ratio, adjustments of the multiplex adapter can be made while monitoring the two a.c. meters and adjusting for minimum crosstalk or maximum separation. A composite FM signal may be fed directly into the multiplex section of the receiver for troubleshooting this circuit.

The MX11 is styled in a bookshelf design. It is only 3″ high, 10″ wide, and 8″ deep and weighs a mere 5½ pounds. With a handle on one side, the unit can easily be carried into the home. Price of the generator is $99.50. ▲

Hickok Model 209C V.T.V.M.

For copy of manufacturer's brochure, circle No. 29 on Reader Service Card.



THE general-purpose v.t.v.m. is one of the most widely used pieces of test equipment on the service bench because of its ability to measure voltages accurately with a minimum of loading on the circuit being checked. If the instrument can also be employed to measure currents and capacitance, it becomes even more useful.

The new *Hickok* Model 209C is just such an instrument. What is more, the use of a 9-inch display meter makes it simple to read voltages from across the bench. The v.t.v.m. measures d.c., a.c., r.m.s., and a.c. p-p voltages up to 1500 volts; d.c. current up to 1500 mA; resistance up to 1000 megohms; and capacitance from 50 pF to 2000 μF. A dB scale is also provided. There are seven measurement ranges for each function.

High input impedance of 11 megohms on d.c. and a.c. measurements, coupled with 3% accuracy, permits the meter to be used for critical circuits. A.c. measurements can be made up to 200 MHz. The meter incorporates very stable circuitry to eliminate constant readjustments of the zero set during operation.

Price of the 209C is $184.50. ▲

For the Record

(Continued from page 6)

ers, and balance on the ultimate effect of sound reproduction in the home—Mr. Cohen will present a live demonstration on how to properly phase loudspeakers. If time permits, he will present other interesting live demonstrations pertaining to the operation of hi-fi equipment. In addition we have asked Vic Brociner of *H. H. Scott* to add some technical facts that every hi-fi enthusiast should be aware of. He will discuss power ratings—particularly the differences between steady-state, music power, peak, and EIA standards of measurement. He will also review the relationship of properly matching solid-state amplifiers with speakers, and how to add multiple speakers to your present system.

All of these programs are referred to as semi-technical in nature in that, in addition to general comments on hi-fi equipment and its operation, most of the speakers will discuss the various technical characteristics involved in indicating the quality of performance of hi-fi equipment. Not only will these terms be defined but their relative importance will be discussed. In addition to these programs, Len Feldman, engineering vice-president of *Crestmark Electronics* and author of several books (including "Hi-Fi Projects For The Hobbyist"), will cover an "Introduction to Hi-Fi Components." For those who are completely unfamiliar with the subject of hi-fi and want to know much more about the equipment, how it operates, its cost, and installation problems —don't miss Len Feldman's discussions. There will be four identical presentations from 8-9:00 p.m., Thursday and Friday, Sept. 29 and 30; 3-4:00 p.m. on Saturday, Oct. 1; and 2:30-3:30 p.m., Sunday, Oct. 2.

In conjunction with each of the discussions, plans are to permit a 20-minute question and answer period—an ideal opportunity for those who have any problems and would like to question our experts.

In addition to these programs, there will be several floors of new hi-fi equipment on view at the Trade Show Building.

The hi-fi industry encompasses devotees from all walks of life, and enjoys an ever-widening popularity each year. Equipment once available only to a few is now within reach of all, and technological advances are quickly translated into new products for the consumer's listening pleasure, as this year's Hi-Fi Show will illustrate. But with so much available to him, the enthusiast needs some technical knowledge to make an intelligent choice, and these programs are intended to fill the need for consumer education. ▲

SATELLITE-TO-HOME TV ANTENNA

ANALYSIS of pertinent factors indicates that direct home reception of television broadcasts from synchronous satellites will be feasible in the upper u.h.f. channels (that is, 70 through 83).

Because of this, *JFD Electronics* has filed a new satellite-to-home antenna concept with the FCC in response to the FCC's investigation in this area.

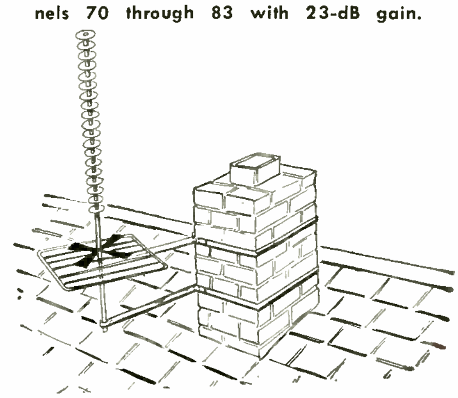
Due to the low transmitter power of previous communication satellites, receiving antennas had to be large and have tracking capabilities. With the development of the Saturn booster, it is felt that very high power, solar-energized transmitters can be placed in synchronous orbit over a point on the Equator.

The new home antenna system is based on array techniques patented by Richard Dale Bogner, consultant to *JFD*, for use at the NASA Wallops Island Tracker/Communications Antenna, and the array techniques employed in the design of the antennas for use in the X-15, Tiros, and Apollo projects.

The satellite system assumes a 25-kW transmitter in the u.h.f. band, and a 10° pencil beam antenna providing 26-dB gain, therefore an e.r.p. of 10 megawatts.

The 23-dB gain of the new home antenna, shown in the illustration, provides approximately 500 millivolts at the antenna terminals of the TV set, sufficient for reliable color reception. The antenna is circularly polarized to compensate for any slight change in satellite orientation, yet is non-critical and easy to install without loading the house support. The antenna has a broad pencil beam that eliminates the need for satellite tracking. The actual antenna is a rod, 8 to 10 feet long, with small circular dipoles attached. It is provided with a reflector, and is mounted so as to point to the satellite which will remain stationary in the sky. ▲

General appearance of the JFD bipolarized or circular-polarized u.h.f. satellite-to-home antenna for use on u.h.f. channels 70 through 83 with 23-dB gain.



ENGINEERING TECHNICIANS SALARY STUDY

GRADUATES of engineering technical institutes can look forward to salaries exceeding $13,000 a year, the Engineering Manpower Commission of the Engineers Joint Council revealed in its just-completed report "Salaries of Engineering Technicians—1966".

While the median salary for all technicians rises gradually from $5500 at age 21 to about $8500 after 12 years of experience, that for technical institute graduates shows a completely different pattern, continuing to increase after 12 years and not reaching its peak until about 28 years.

Technicians who work directly with engineers are becoming increasingly important as members of the engineering teams responsible for the dramatic technological achievements of present-day industry. The number of technical institutes, community colleges, and other institutes offering courses in engineering technology, usually leading to an associate degree after two years of schooling, is growing rapidly. The EJC salary survey shows that there is a ready market for their graduates, with job opportunities at excellent salaries in practically all fields of industry and government.

The 60-page report may be obtained for $5 per copy from: Engineers Joint Council, Dept. P, 345 East 47th Street, New York, New York 10017. ▲

IC for Consumer Products

(*Continued from page* 33)

induces the chroma reference synchronizing voltage directly into the feedback loop of the oscillator, thereby locking the oscillator in phase with the transmitted burst.

Color-TV Sound System

Fig. 6 shows a 4.5-MHz intercarrier sound system, using an integrated circuit, for a color-television receiver. In a color set, the 4.5-MHz sound i.f. is not generated in the video detector as it is in a black-and-white receiver. In this circuit, a separate transistor power sound detector, driven from the final video i.f. amplifier stage is used to develop the 4.5-MHz intercarrier sound i.f. The μA703C driver transformer in the collector of the power detector transistor is tuned to 4.5 MHz. The output of the μA703C drives a conventional ratio detector.

The ratio-detector load presented to the IC is selected to achieve high stage gain. With the resulting relatively high load impedance, the IC output "bottoms" (saturates on a portion of each cycle) at full limiting. The ratio detector provides good AM rejection well below full limiting. Under normal signal conditions, the system operates in full limiting with excellent AM rejection and distortion characteristics. Sound quality is good under reduced signal-strength conditions. ▲

EW Lab Tested

(Continued from page 22)

balance controls as well as an input selector with tuner, auxiliary, and magnetic phono inputs. There are two pairs of magnetic cartridge inputs, for high- and low-output cartridges. A slide switch on the rear of the amplifier chooses between them.

The mode selector switch has positions for stereo, reversed-channel stereo, mono (mixed), or either channel alone through both speakers. Finally, a row of four push-button switches controls power, speaker muting (for headphone listening through the front-panel jack), tape monitoring, and frequency compensation. The latter, marked "Comp," bypasses all tone-control circuits so that maximum benefit may be obtained from the wide, flat frequency response and low phase shift designed into the amplifier. When it is pressed in, the tone controls are usable in normal fashion.

Our laboratory measurements were made on a complete *Acoustech* XI, including the preamplifier section. Where applicable, measurements were made in accordance with the new IHF Standard on Methods of Measurement for Audio Amplifiers.

With the tone controls disabled, the unit had a perfectly flat response, as far as our instruments could detect. It measured within ±0.1 dB from 30 Hz to 20,000 Hz, rising slightly to +0.5 dB at 20 Hz. The RIAA phono equalization was within ±1.5 dB from 50 to 15,000 Hz. The tone controls had a very moderate range, which nevertheless was extremely usable. At 50 Hz the boost or cut amounted to a maximum of 8 dB, while at 10,000 Hz a boost of 5 dB or cut of 8 dB were available. The tone-control characteristics are well chosen so that even at maximum settings of the controls the sound is natural and pleasant. This is not true of most tone-control circuits, in equipment we have checked which soon impart a shrill or tubby character to the sound.

Using the tone controls for loudness compensation similarly produced very pleasing results. The amount of compensation does not change with the setting of the level control, but this can be advantageous since there is no longer any need for external control of program level to suit the characteristics of a compensated volume control. Used as filters, they are less satisfactory due to their gentle slopes. The two sections of the ganged level control tracked within 1 dB over a wide range, so that readjustment of the balance control was not needed as the level control setting was changed.

The power output of the amplifier,

into 8-ohm loads, was 30 watts per channel at less than 1% harmonic distortion over most of the audible range. At full power, the distortion increased below 100 Hz. At half power, distortion was less than 0.5% over the entire range. At one-tenth power (3 watts), the distortion was less than 0.15% at almost all frequencies.

Intermodulation distortion was under 0.5% from 0.1 watt to just over 30 watts. All distortion measurements were made with both channels driven, using a 120-volt line. Noise and hum were completely inaudible, measuring 82 dB below 10 watts on high-level inputs, and 64 dB below 10 watts on phono inputs.

In listening tests, the unit performed in a manner that clearly placed it in the top ranks of modern stereo amplifiers. It was clean and effortless at all power levels, with the same open quality which characterizes its well-known predecessor, the *Acoustech* 1-A. The tone controls were outstanding in their effectiveness. We rarely use tone controls, since most of them impair the musical balance of good program material, but the *Acoustech* XI controls invite use.

The Model XI kit sells for $129.50, and the P/M preamplifier module is $89.50. For less than $220, plus a few hours of pleasant work, one can have the advantages of one of the better solid-state stereo amplifiers we have heard. ▲

Concord Model 300 Recorder

For copy of manufacturer's brochure, circle No. 26 on Reader Service Card.

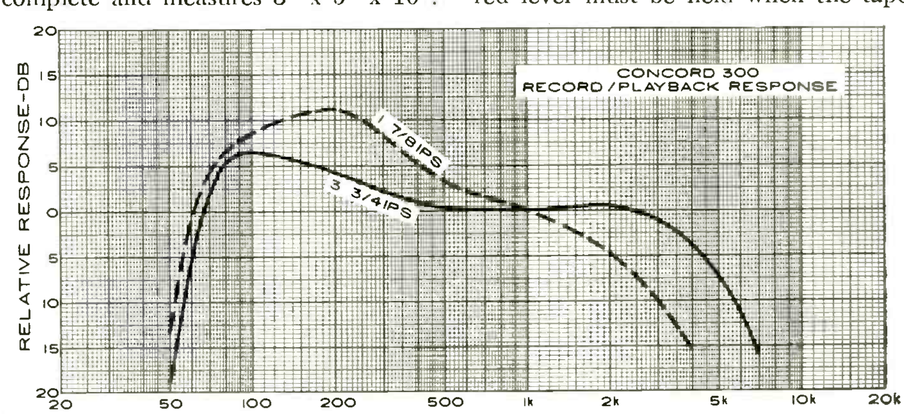
PORTABLE, battery-operated tape recorders come in many types, from toys selling for less than $20 to professional-quality machines costing over $1000. Most people needing a portable tape recorder do not require high-fidelity performance. Applications of portable recorders include recording lectures and conferences, recording and transcribing dictation, talking letters, and many others.

The new *Concord* Model 300 is a versatile, moderately priced machine, readily adapted to many diverse uses. It is powered from six internal flashlight cells or from the 120-volt, 60-Hz power line. When it is plugged into the line, a relay automatically disconnects the batteries.

The recorder weighs only 6½ pounds complete and measures 3″ x 9″ x 10″. It can be carried about with a detachable hand strap and can even be used when in motion. Standard accessories, in addition to the carrying strap, include a remote-control dynamic microphone (whose slide switch starts and stops the tape motion) and a 4-inch tape reel. Optional accessories include a voice-operated microphone, footswitch, earphone, telephone pickup, and carrying case with shoulder strap. A small loudspeaker is built into the recorder case.

The 4-inch reel can hold 300 feet of 1½-mil tape, 450 feet of 1-mil tape, and 600 or 900 feet of "double-play" or "triple-play" tape. With the latter, one can record up to 1½ hours at 3¾ ips or 3 hours at 1⅞ ips. The speed is changed by a removable capstan which stores within the tape recorder when it is not in use.

A unique feature of the machine is "Reverse-A-Track." It has two sets of heads, one for each direction of tape travel. The machine can be operated in either direction, in record or playback, normal or fast speeds. The appropriate set of heads is switched in when the tape direction is changed. This eliminates any need to switch reels at the end of each pass of the tape. A red lever must be held when the tape



is put into motion in order to record. A meter monitors recording level and (in playback) the battery voltage. On the front of the recorder are the volume control, speaker switch, fast-wind button, and jacks for the microphone, auxiliary input, and headphones or external speaker.

We measured the over-all record/playback frequency response of the machine through the "Aux" input and external speaker output. At 3¾ ips, the response was down 7 dB at 60 Hz and 5000 Hz. There was a broad peak of about 6 dB centered at 100 Hz, which probably compensates in some measure for the limited bass response of the built-in speaker. At 1⅞ ips, the low-frequency boost was broader and larger, reaching 11 dB at 200 Hz. The response fell off rapidly above 1000 Hz to −10 dB at 3000 Hz.

At 3¾ ips the wow and flutter were quite low, 0.15% and 0.20%, respectively. This is quite adequate for many music-recording purposes. At 1⅞ ips the wow and flutter were about 0.5% to 0.6%, too high for music but satisfactory for speech. In fast forward, 300 feet of tape were handled in 3 minutes, 30 seconds. The tape slowed down considerably near the end of the process. Rewind was faster, requiring 2 minutes, 13 seconds.

Less than 100 millivolts at the "Aux" input was needed for a zero-decibel recording level. Only 0.2 millivolt was needed from a microphone or telephone pickup. The recorder has an automatic record control ("A.R.C."), or audio a.g.c. system, which can be switched on if desired to control recording levels over a wide range of sound levels. It virtually eliminates the possibility of overloading the circuits. The a.r.c. circuit worked very effectively. With a recording input set for zero decibels without a.r.c., switching it on dropped the meter about 2 dB. An increase of 10 dB in level changed the meter reading by only 3 dB, and a 20-dB increase raised it a total of 4 dB. We found virtually no peak clipping or other distortion when using up to 20 dB of overload with a.r.c.

In operation, the recorder performed very well. The tape could be started or stopped in less than one second by the remote switch on the microphone or by the footswitch. The a.r.c. permitted voice recordings at distances varying from one inch to 20 feet from the microphone without any adjustments. At 3¾ ips, quality was comparable to that of a table-model AM radio on speech or music. It was pleasing and listenable, if not "high fidelity." At 1⅞ ips, voices were somewhat muffled but intelligible. The flutter makes this speed unusable for music.

List price of the *Concord* Model 300 is $124.50 with standard accessories. ▲

Time-Ratio Control of Mobile-Radio Power Supplies

As the input voltage to a mobile power supply can vary considerably, higher voltage components and heavier heat sinks were usually used. This new design eliminates these problems while raising efficiency.

By RAYMOND S. BUNCH / Communications Products Dept., General Electric Company

HOW do you maintain rated r.f. power of a transceiver used on a vehicle whose electrical system swings over a range of 24 to 42 volts and suffers from 1000-volt transients across the battery terminals? These were the problems to be overcome in adapting a *G-E* "Porta-Mobil" transceiver to industrial applications such as battery-powered fork-lift trucks. Such vehicles are powered by high-capacity, multi-cell batteries during an eight-hour work period. The batteries are recharged during a rest period of 14 to 16 hours. The terminal voltage of a 36-volt battery may vary from 42 volts at the end of the charging period to 24 volts under load near the end of the work period.

The problem of extreme voltage variation might have been approached by using high-voltage transistors and a large heat sink. Unfortunately, high-voltage transistors are more expensive than their low-voltage counterparts, and large heat sinks add size, weight, and cost to the finished product. Furthermore, as battery voltage drops, r.f. power output drops proportionally and might be wholly inadequate by the end of the work day.

The use of a simple series regulator to absorb the difference between design voltage and actual battery voltage is fine, as long as battery voltage exceeds design voltage by only a few volts; but what happens when the battery is freshly charged? If the equipment requires 3 amperes at 24 volts, then when the battery voltage is 42 volts, the series regulator must dissipate 3(42−24) or 54 watts. This is a high figure, especially if the unit is exposed to the sun during the summer. Using the regulator scheme, the power required by the radio itself remains the same, in spite of battery-voltage variations.

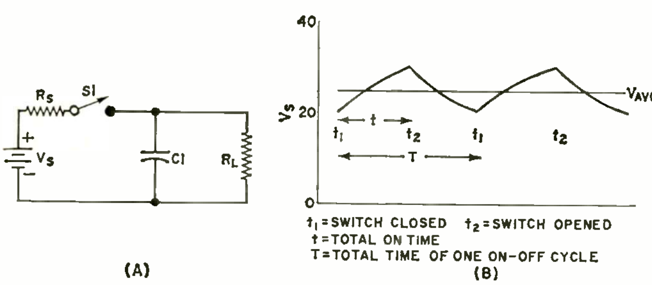
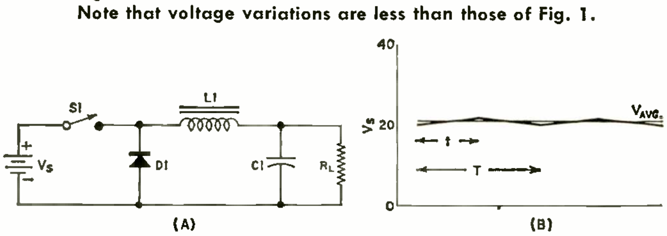


Fig. 1. (A) Basic time-ratio control. (B) Resultant voltage.

Fig. 2. (A) Basic circuit with added inductor and diode. (B) Note that voltage variations are less than those of Fig. 1.



To minimize heat-sink size and weight, a regulator is needed which does not itself consume large amounts of power. Ideally, if the equipment requires 3 amperes at 24 volts (72 watts) it should require 2 amperes at 36 volts (72 watts).

The industrial supply, as designed, furnishes proper operating power to the transmitter and receiver over a battery-voltage range of 24 to 42 volts. When transmitting, actual battery drain at 24 volts is 2.6 amperes or 62.4 watts. At 36 volts, battery drain is 1.9 amperes or 68.4 watts. A bonus for the industrial user who has both 24- and 36-volt vehicles is the fact that the equipment works equally well on either vehicle without any changes, and with little power loss when used on the higher voltage vehicle.

This performance is made possible by the use of a low-loss type of regulator, which employs the principle known as time-ratio control (TRC) to regulate the input voltage before it is applied to the input of a conventional d.c.-to-d.c. converter. The outputs of the converter are of the proper voltage and current to operate the transmitter and receiver.

Consider the diagram of Fig. 1A. If switch S1 is closed, the voltage across capacitor *C*1 will increase exponentially toward supply voltage V_s. If S1 is now opened, *C*1 will discharge through R_L exponentially toward zero. If the ratio of time closed to the total time of one "closed-open" cycle can be controlled, the average voltage across *C*1 can be maintained at some voltage between V_s and zero. However, the voltage excursions will depend upon the rapidity with which S1 can be opened and closed. If the switch is opened and closed too slowly, the voltage excursions will be large (high ripple). If the switch is opened and closed too rapidly, excessive heating and losses in the switch will occur. Fig. 1B shows the waveforms which occur when operation is stabilized.

In Fig. 2A, inductor *L*1 and diode *D*1 have been added. When the switch is closed, the rate at which the capacitor will charge is limited by the impedance of *L*1. Diode *D*1 is reverse-biased. When the switch is opened, energy stored in *L*1 is released to *C*1 and load R_L. Diode *D*1 is now forward-biased and completes the circuit for the energy released by *L*1. The voltage variations across *C*1, shown in Fig. 2B, are now much smaller than in the circuit of Fig. 1.

If the ratio of time "on" (t) to total time of one "on-off" period (T) is varied, average voltage V_{avg} is varied. Also, if V_s is varied, V_{avg} may be held constant if t/T is varied at the same time.

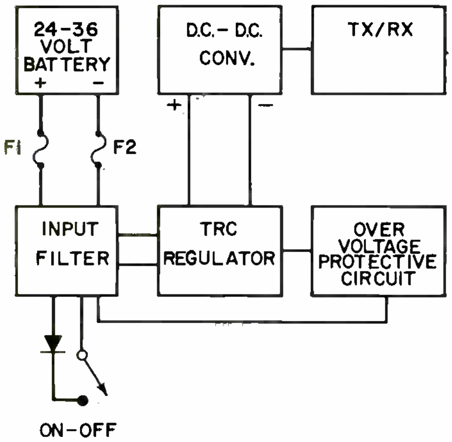


Fig. 3. The basic block diagram of regulated power source discussed.

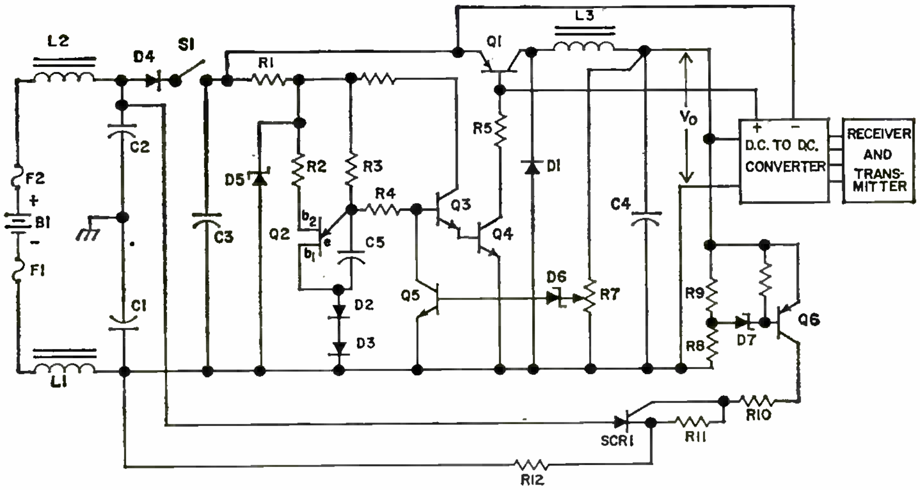


Fig. 4. Over-all schematic of the time-ratio control power regulator. The output of the basic regulator supplies a controlled d.c. to the d.c.-to-d.c. converter.

Fig. 3 shows a block diagram of the complete power supply. Fuses are placed in each battery-cable lead to protect the unit against damage due to accidental shorts or component failure. Two fuses are used because the input circuit is not grounded in the supply. This permits operation, without change, from ungrounded systems or grounded systems of either polarity. Of course, proper polarity must be observed. However, no harm will be done if the leads are inadvertently connected to the reverse polarity. A diode in series with the "on-off" switch makes it impossible to apply power to the regulator unless polarity is correct.

An input filter consisting of $L1$, $L2$, $C1$, $C2$, and $C3$ (Fig. 4) attenuates and renders harmless any transient voltages which may be generated elsewhere in the vehicle electrical system. Transients of 1000 volts have been measured across the 24-volt battery terminals of a battery-powered fork-lift truck when the motors were switched "on" and "off."

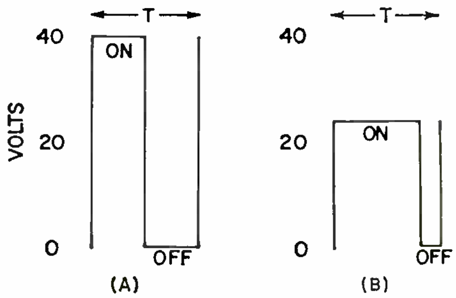
Regulator

The switch in Fig. 2A becomes $Q1$ in Fig. 4. The ratio t/T depends upon the power required by the receiver-transmitter at any given time and the battery voltage available. Figs. 5A and 5B show the waveforms across $Q1$ and $L3$ when the transmitter is operating and the supply voltage is at 40 volts and 24 volts.

Timer, Driver, and Error Detector

The regulator tends to switch at a frequency determined by the natural resonance of $L3$ and $C4$ (Fig. 4) and the output load. To ensure a relatively constant switching frequency of 2500 Hz, a timer is introduced in conjunction with the driver and error detector. Resistor $R1$ and diode $D5$ maintain a fixed supply voltage to a relaxation oscillator (timer) consisting of $R2$, $R3$, $C5$, and $Q2$. The saw-tooth waveform appearing across $C5$ is applied through $R4$ to the base of $Q3$. Emitter current of $Q3$ flows into the base of $Q4$. When $Q4$ is conducting, $Q1$ is biased "on" through $Q4$ and $R5$. Transistor $Q5$ functions as a variable resistance, forming a voltage divider with $R4$ and controlling the base current of $Q3$. The effective resistance of $Q5$ is determined by the amount of base current supplied through $D6$ and the upper portion of $R7$. When the voltage at the rotor of $R7$ is greater than the breakdown voltage of $D6$, plus the emitter base voltage of $Q5$, current flows through $D6$ and the base of $Q5$, causing $Q5$ to conduct, lowering the voltage at the base of $Q3$, and forcing $Q3$ off. $Q3$ remains off until such time as the saw-tooth voltage across $C5$ rises sufficiently to force enough current through $R4$ to satisfy the requirement of $Q5$ and to turn $Q3$ on. The "on" time of $Q1$ with relation to period T of the relaxation oscillator is thus established, and $R7$ may be adjusted to set voltage V_o across $C4$ to the desired level. This level is then

Fig. 5. (A) Waveform across Q1 and L3 when input is 40 V. (B) Waveform when input is 24 volts. Note that the ratio of "on" to "off" time varies to maintain a constant voltage output.



maintained over a wide range of load and input voltage conditions.

If the battery voltage drops to a level below the normal setting of V_o, $D6$ no longer conducts, $Q5$ is turned off, and the current through $R4$ biases $Q3$ on for the full period T. The relatively constant voltage drop across diodes $D2$ and $D3$ ensures that the minimum valley voltage across $C5$ is sufficiently high to hold $Q3$ on under these conditions. Reverse bias to ensure holding $Q1$ cut off except when $Q4$ conducts is supplied from a special output from the converter.

Converter and Filter

The d.c.-to-d.c. converter circuit is quite conventional and its operation similar to others already well covered in the literature. The voltage across $C4$ is applied to the input of the converter. Thus, for battery voltages from 18 to 23 volts, the output voltage of the converter is proportional to the battery voltage. At about 23 volts, the regulator begins to function and the converter output voltage remains practically unchanged over the voltage range of 24 to 42 volts.

Overvoltage Protection

In the event that a collector-to-emitter short should develop in $Q1$, or if $R7$ should be incorrectly adjusted, damage to the supply and to the transmitter-receiver is prevented by a protective circuit. The values of $R8$, $R9$, and $D7$ are chosen so that the voltage appearing across $D7$ is below its breakdown voltage when V_o is at the correct level. If V_o increases by about two volts, $D7$ conducts, applying base current to $Q6$. This applies a positive voltage to the gate of $SCR1$ through $R10$ and $R11$, triggering $SCR1$ into conduction. Heavy current flows through $SCR1$ and $R12$, exceeding the rating of $F1$ and $F2$. One or both fuses blow quickly, averting damage to the power supply, transmitter, and receiver.

Before the start of quantity production, prototypes were exhaustively tested in the laboratory and also underwent a six-month field test on a diesel locomotive (one of the most exacting applications for radio equipment) with a highly successful performance record. ▲

Audible Continuity and Semiconductor Checker

By JOHN B. FROST and RICHARD W. BAILEY/Ohio State University

As audio tone is a function of an external resistance value, a simple continuity tester can be made. Slight modifications enable the testing of semiconductor diodes and transistors.

ALTHOUGH many devices are available for continuity checking, the simple test set covered in this article offers several unique advantages. Unlike the ohmmeter, which requires the reading of a meter scale, or a series battery light-bulb resistance checker, the audible continuity checker allows the user's eyes to be focused on the test leads or on a schematic diagram.

For continuity checking, the light-bulb detector has the advantage over the ohmmeter of smaller physical size and weight; also, the former is more shock-resistant than a meter movement. However, the light bulb has a serious drawback in that it will respond usefully only when the total series resistance is very low, typically 10 ohms or less.

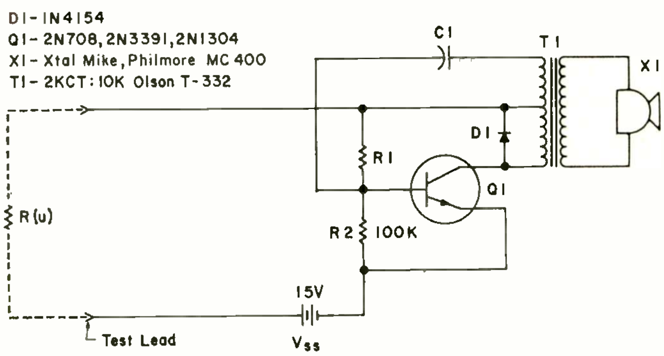
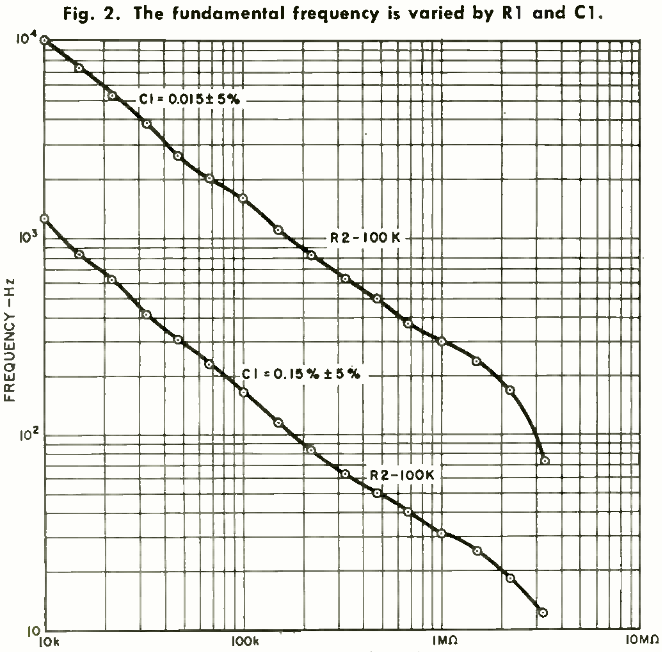


Fig. 1. The basic instrument is a blocking oscillator whose frequency is varied by the value of an external resistor.

Fig. 2. The fundamental frequency is varied by R1 and C1.



This drawback is overcome with the audible continuity checker.

The audible detector to be described will respond with up to approximately 1500 ohms series resistance, allowing for a limited-range audio ohmmeter.

Operation

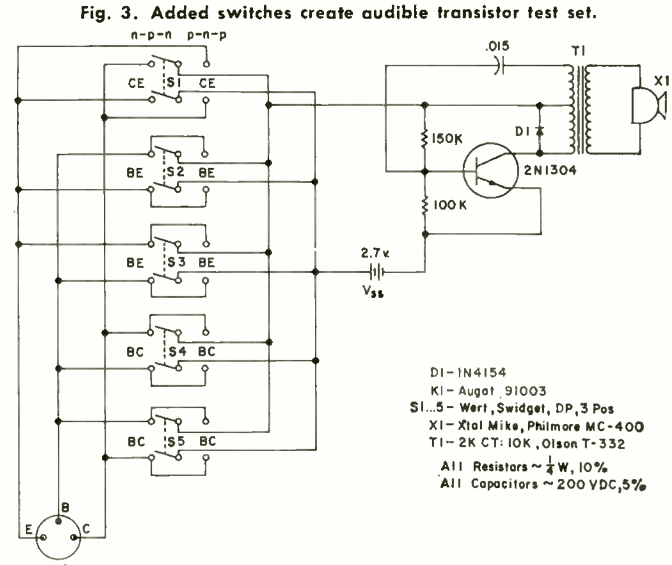
While virtually any audio oscillator will work as an audible continuity checker, a blocking oscillator was chosen because of its simplicity, frequency dependence on applied voltages, and ease of changing frequency to suit individual tastes. Fig. 1 shows the basic schematic diagram. Transistor $Q1$ serves as the oscillator with a period determined by the transformer characteristics, $R1$, $R2$, $C1$, and the applied voltage.

For normal operation, the values of the components are fixed, and frequency is then a function of the applied voltage. As more resistance (represented by R_u in Fig. 1) is added between the battery and oscillator, more voltage is dropped across this resistance, reducing the voltage at the oscillator and causing its frequency to become higher. Diode $D1$ limits the amplitude of the turn-off spike across Q1 to a value that is safe for the transistor.

The basic oscillator frequency is easily changed for a fixed transformer and battery by varying either $R1$ or $C1$. Fig. 2 shows the frequency dependence of these two components. In this case, the unknown external resistance (R_u) is zero.

Once a frequency is chosen, then values of R_u up to about 1500 ohms will produce a tone which rises in frequency as R_u increases. Using known values of R_u, it is

Fig. 3. Added switches create audible transistor test set.



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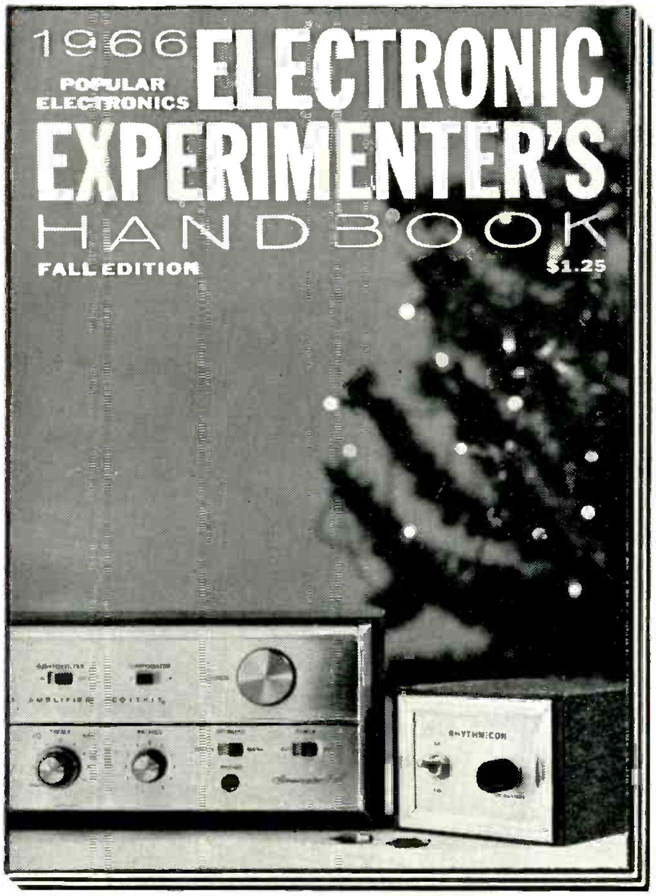

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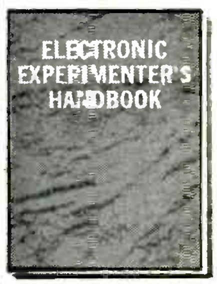

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possible to calibrate the audible continuity tester on a resistance/tone basis.

Semiconductor Checker

While the circuit is designed to provide audible signals whose frequency is proportional to an unknown external resistance, it may be extended in application to yield analysis of active components as well. More specifically, the front-to-back resistance ratio of a solid-state signal diode can be found quickly by reversing the test leads after determining the frequency associated with the forward resistance of the diode. If the difference in tone is relatively small, then the difference in resistance will also be small.

Several comparative checks may be made on transistors, such as a qualitative check of I_{cbo} or current flowing between the collector and base with the emitter open, the short test, or even the leakage test. It must be realized that these checks are performed in a limited sense; that is, the indication of a test parameter will be limited by the aural signal and the operator's sense of tone comparison to make a quick "go/no-go" decision.

As shown in Fig. 3, a switching network has been added to the basic circuit. Note that the battery voltage has been lowered to 2.7 volts. The test socket was chosen to accept the standard TO-5 transistor lead configuration. For a typical testing operation on a common low-power *p-n-p* transistor, the emitter-collector condition is determined by inserting the transistor in the socket and placing S1 in the *p-n-p/CE* position. Since the threshold of an audible signal corresponds to about 500 microamperes of leakage current, any tone heard will provide justification for immediate rejection.

If no tone is heard, proceed to the next test, which determines the presence or absence of a base-emitter junction and gives an indication of I_{ebo}. Switch S2 in the *p-n-p/BE* position, if accompanied by a tone, indicates conduction through the base-emitter junction when it is forward-biased. If a tone is heard when switch S3 is placed in the *p-n-p/BE* position, this indicates an I_{ebo} in excess of 500 microamperes. While the I_{ebo} test is primarily used when the transistor is intended for oscillator or class-B application, it does add significant information to the transistor's general condition.

The last test is for the base-collector junction and measures the parameter I_{cbo}. If a low-frequency tone is heard when switch S5 is placed in the *p-n-p/BC* position, this would be sufficient cause for rejection, and the presence of a tone in the S4 *p-n-p/BC* position would indicate the existence of a forward-biased junction. ▲

SIMPLIFIED TREMOLO

By WILLIAM R. SHIPPEE

THE circuit to be described was originally designed for use with a guitar, but can be used with any type of musical instrument employing a magnetic or ceramic pickup.

The circuit of *Q*2 is a straightforward one-stage amplifier powered by an oscillating supply.

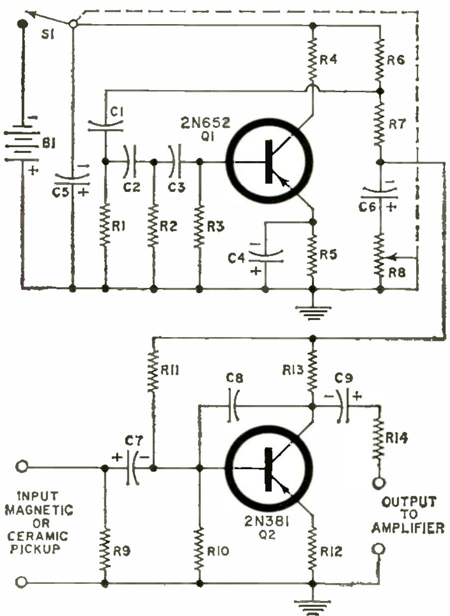
The tremolo effect is obtained from the circuit associated with *Q*1 which is a conventional phase-shift oscillator operating at approximately 6 Hz.

The tremolo level, that is, the amount of variation of the output is controlled by *R*8. This is done by bypassing varying amounts of the oscillator output, depending on the setting of *R*8, to ground through capacitor *C*6.

The layout and construction of the circuit is not critical. The unit can be mounted within the power amplifier used and can be powered by a negative 10-volt source within the amplifier. Power drain is 1 mA.

The 6-Hz tremolo frequency cannot be heard in most systems, however, the effects of varying an input signal at this rate is very noticeable and will provide added depth to any musical instrument. ▲

Schematic and parts list for tremolo unit



R1, R2, R3—22,000 ohm, ½ W res.
R4—330,000 ohm, ½ W resistor
R5, R14—1000 ohm, ½ W resistor
R6—6800 ohm, ½ W resistor
R7, R10—20,000 ohm, ½ W res.
R8—5000 ohm audio taper pot
R9—100,000 ohm, ½ W res.
R11—270,000 ohm, ½ W res.
R12—150 ohm, ½ W res.
R13—4700 ohm, ½ W res.
C1, C2, C3—1 µF., 100 V capacitor
C4—100 µF, 3 V capacitor
C5—200 µF, 15 V capacitor
C6, C7, C9—10 µF., 10 V capacitor
C8—.0018 µF disc capacitor
S1—S.p.s.t. switch (on R8)
B1—10.5 V battery (7 "C" cells)

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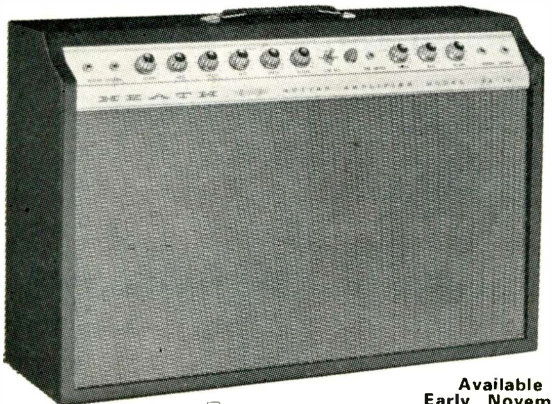

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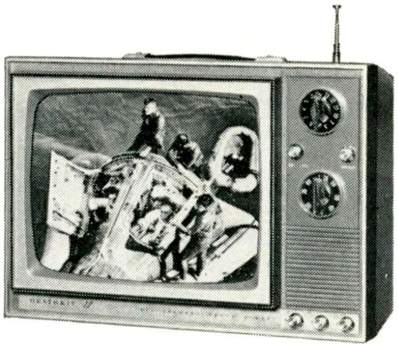

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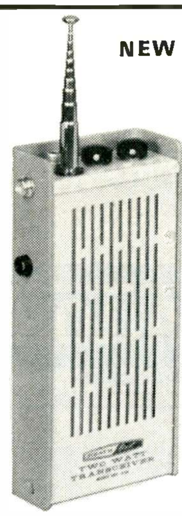

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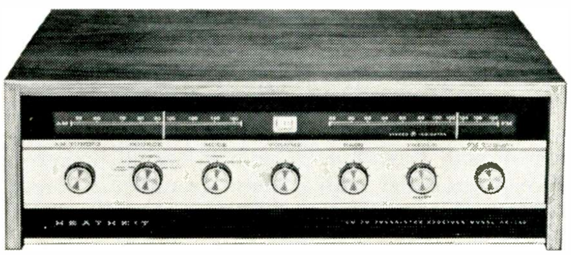

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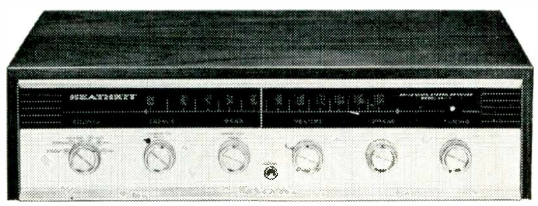

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Silicon-Transistor Amplifiers

(*Continued from page* 36)

sistor reduces its storage time and also increases the effective breakdown voltage from its $V_{CEO(sus)}$ value to its $V_{CER(sus)}$ value.

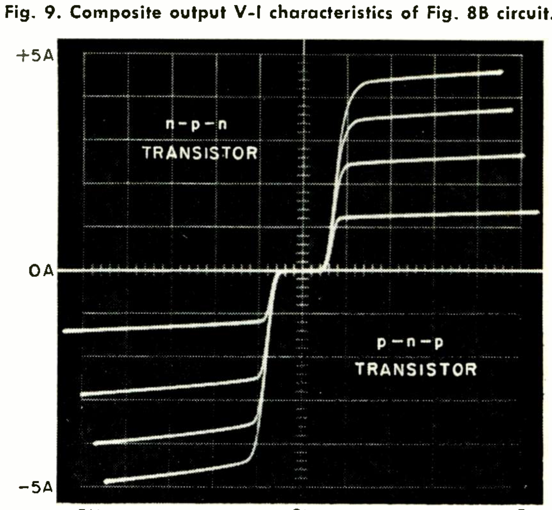
A typical quasi-complementary amplifier is shown in Fig. 10. Capacitor *C* performs two functions essential to the successful operation of the circuit. First, it acts as a bypass to decouple any power-supply ripple from the driver and predriver stages. Second, it is connected as a "bootstrap" capacitor to provide the drive necessary to pull the upper Darlington pair of transistors into saturation. This latter function results from the fact that the stored voltage of the capacitor, with reference to the output point "A", provides a higher voltage than the normal collector supply voltage to drive transistor *Q*2. This higher voltage is necessary during the signal conditions that exist when the upper transistors are being turned on, because the emitter voltage of transistor *Q*2 then approaches the normal supply voltage and the base voltage must be increased above this level in order to drive the transistor into saturation.

Resistor *R*1 provides the necessary d.c. feedback to maintain point "A" at approximately one-half the nominal supply voltage. Over-all a.c. feedback is coupled from output to input by resistor *R*2 to reduce distortion and to improve low-frequency performance.

As previously indicated, series-output circuits can be employed with separate positive and negative supplies, and no series output capacitor is then required. The elimination of this capacitor may result in an economic advantage, even though an additional power supply is used, because of the size of the series output capacitor necessary in the single-supply case to obtain good low-frequency performance (*e.g.*, a 2000-μF capacitor is required to provide a 3-dB point at 20 Hz for a 4-ohm load impedance). Split supplies, however, do pose certain problems which do not exist in the single-supply case. The output of the amplifier must be maintained at zero potential under quiescent conditions for all environmental conditions and devices parameter variations. Also the input ground reference can no longer be at the same point indicated in Fig. 10, because in a dual-supply system, this point is now at the negative supply potential.

If the ground-point reference for the input signal were to be the common point between the split supplies, any ripple present on the negative supply would effectively drive the amplifier through transistor *Q*1, which would operate as a common-base amplifier with its base grounded through the effective impedance of the input signal source. To avoid this

Fig. 9. Composite output V-I characteristics of Fig. 8B circuit.



condition, the amplifier must include an additional *p-n-p* transistor as shown in Fig. 11. This transistor (*Q*6) effectively reduces the drive effects of the negative supply ripple because the high collector impedance (1 megohm or higher) it presents to the base of transistor *Q*1 effectively isolates the input source impedance from transistor *Q*1. In practice, transistor *Q*1 may be replaced by a Darlington pair in order to reduce the loading effects on the *p-n-p* predriver.

Negative d.c. feedback is applied from the output to the input stage by *R*1, *R*2, and *C*1, to maintain the output at essentially zero potential. (Actually, the output will be maintained at approximately the forward-biased base-emitter voltage of transistor *Q*6, which may be objectionable in some cases, but this can be eliminated as will be shown subsequently.) Capacitor *C*1 effectively bypasses this feedback at all signal frequencies. Resistor *R*3 provides a.c. feedback to reduce distortion in the amplifier.

In next month's concluding installment, we will present some practical amplifier circuits and show their level of performance.

(*Concluded Next Month*)

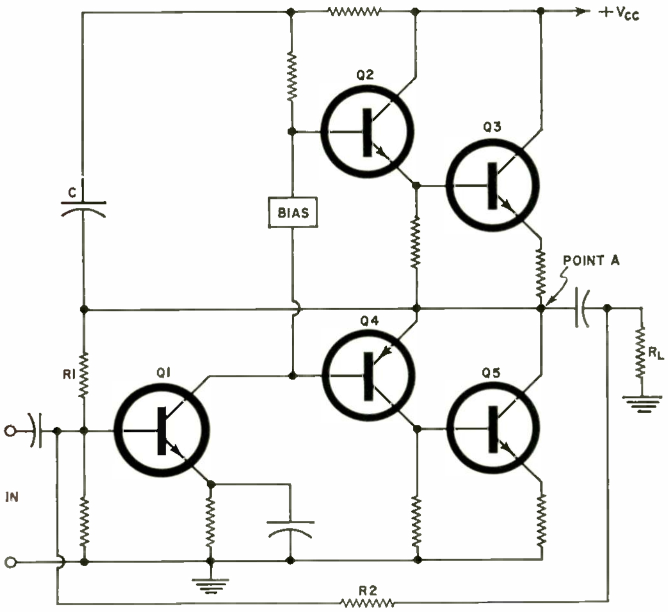
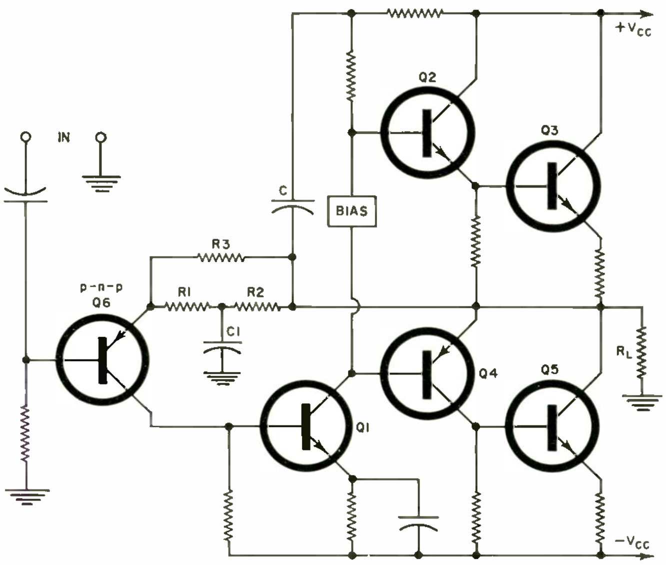
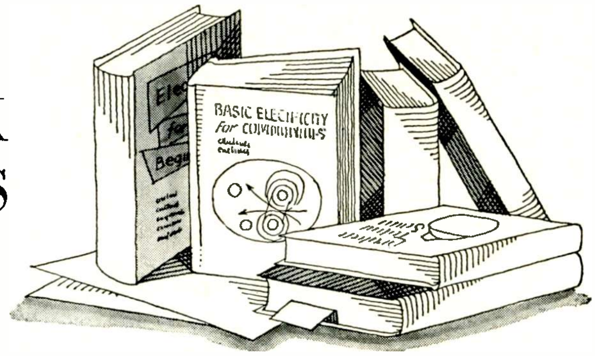


Fig. 10. A typical quasi-complementary audio power amplifier which is here shown operating from a single d.c. power supply.

Fig. 11. Quasi-complementary amplifier operating from positive and negative supplies. The "p-n-p" transistor in input stage is required to prevent ripple component from driving amplifier.



BOOK REVIEWS



"INTEGRATED CIRCUIT PROJECTS FROM MOTOROLA" compiled and published by *Motorola Semiconductor, Inc.*, Box 955, Phoenix, Arizona 85001. 96 pages. Price $1.00. Soft cover.

This handy manual is divided into three basic sections: an introduction to integrated circuitry including a glossary of terms; a section on construction techniques using IC's; and finally a section covering actual projects that can be built with the company's HEP integrated circuits. The projects include computers, musical instruments, and test equipment.

The text is well illustrated with simplified schematics, wiring diagrams, and pictorials. Complete parts lists and details for preparing the required chassis or breadboards are also included to make the construction of IC circuit projects easy and interesting.

* * *

"TRANSISTOR CIRCUIT ANALYSIS AND DESIGN" by Franklin C. Fitchen. Published by *D. Van Nostrand Co., Inc.*, Princeton, N.J. 403 pages. Price $8.50.

This is the second edition of a volume which originally appeared in 1960 as part of this publisher's Electronics and Communications Series. Written as a classroom text for electrical engineering students at the junior and senior level, the author has assumed that the reader has a working knowledge of the fundamentals of electric circuit theory and math.

The book is divided into 13 chapters covering an introduction to transistors, semiconductor physics and devices, the operating point, equivalent circuits and their parameters, analysis, design, large-signal amplifiers, multistage amplifiers, gain stability, feedback, communications amplifiers, communications circuits and systems, and pulse circuits. Two appendices carry selected transistor data and matrix analysis. Problems and references are provided for each chapter with answers to selected problems given at the back of the book.

* * *

"JUNCTION TRANSISTORS" by John J. Sparkes. Published by *Pergamon Press Inc.*, Long Island City, N.Y. 246 pages. Price $3.95. Soft cover.

The volume has been prepared with students of engineering and physics in mind and is written at the level of second-year undergraduates. The text is divided into nine chapters covering conduction in semiconductors, the *p-n* junction (steady-state properties), the *p-n* junction (transient and signal properties), the junction transistor (steady-state properties), fundamental aspects of transistor action, transistor action and its representation, a summary of circuit design parameters, different transistor structures, and additional features of transistor behavior, including noise.

The treatment is mathematical and fairly rigorous and the American reader will need a little time to switch over to British terminology, but on the whole this book offers much information of pertinence.

* * *

"HEATING WITH MICROWAVES" by H. Puschner. *Philips Technical Library.* Distributed in U.S. and Canada by *Springer-Verlag New York Inc.*, 175 Fifth Ave., New York, N.Y. 10010. 316 pages. Price $10.80.

This book is written for engineers concerned with the introduction of the new types of microwave heating devices and installations used for the dielectric heat of non-conducting substances. The purpose of the book is not only to acquaint the reader with the current state of the art, but to provide useful hints to stimulate further developments in the field.

Since microwave heating involves different techniques and components, the author devotes considerable space to the practical manipulation of continuous wave magnetrons and the high-frequency circuits in which they are used in the microwave range. He also discusses in detail the necessary measuring techniques.

As this book is another volume in the *Philips Technical Library* series, the author has assumed that his readers are practicing or graduate engineers.

* * *

"ELECTRICAL AND ELECTRONICS DRAWINGS" by Charles J. Baer. Published by *McGraw-Hill Book Co.*, New York. 389 pages. Price $6.50.

This is a second edition of a book originally published in 1960. Its content has been considerably expanded and much of the original copy revised and updated.

The material is presented in textbook form but the book can equally serve as a reference work for those currently engaged in electrical and electronic drafting.

The book is divided into eleven chapters and two appendices. The subjects covered include techniques and lettering, pictorial drawing, device symbols, production drawings, block diagrams, schematic diagrams, miniaturization and microelectronics, industrial controls and automation, drawings for the electric power field, electrical drawings for architectural plans, and the graphical representation of data. All of this material is lavishly illustrated with examples of the various techniques under discussion.

* * *

"INTRODUCTION TO ELECTRONICS" by V.A. Suprynowicz. Published by *Addison-Wesley Publishing Company, Inc.*, Reading, Mass. 01867. 317 pages. Price $12.50.

This book is subtitled "For Students of Biology, Chemistry, and Medicine" which gives some indication of the inroads electronics has made in these disciplines. It is the author's contention that such students should understand the basic principles governing the operation of the many electronic instruments used in today's scientific communities.

After an introduction to the more important electronic fundamentals, the student is immediately involved in their application with respect to commonly used instruments. The inherent limitations of these instruments are discussed in some detail and the student is then provided with a basis for discussing his needs and difficulties with the electronics designer or technician. Of these discussions, the section on oscilloscopes is especially well done and informative.

* * *

"RCA LINEAR INTEGRATED CIRCUIT FUNDAMENTALS" compiled and published by *RCA Electronic Components and Devices*, Harrison, N.J. 238 pages. Price $2.00. Soft cover.

This latest addition to the company's technical manual series is intended primarily for equipment and system designers but will be of interest to anyone who is currently involved in the IC "explosion".

The text is divided into four main chapters covering general design considerations; basic configuration—the differential amplifier; integrated-circuit operational-amplifier configurations; and characteristics and applications of *RCA* linear integrated circuits.

Schematics, operating characteristics, and performance data are also included, covering a broad family of multiple-function *RCA* silicon integrated circuits. ▲

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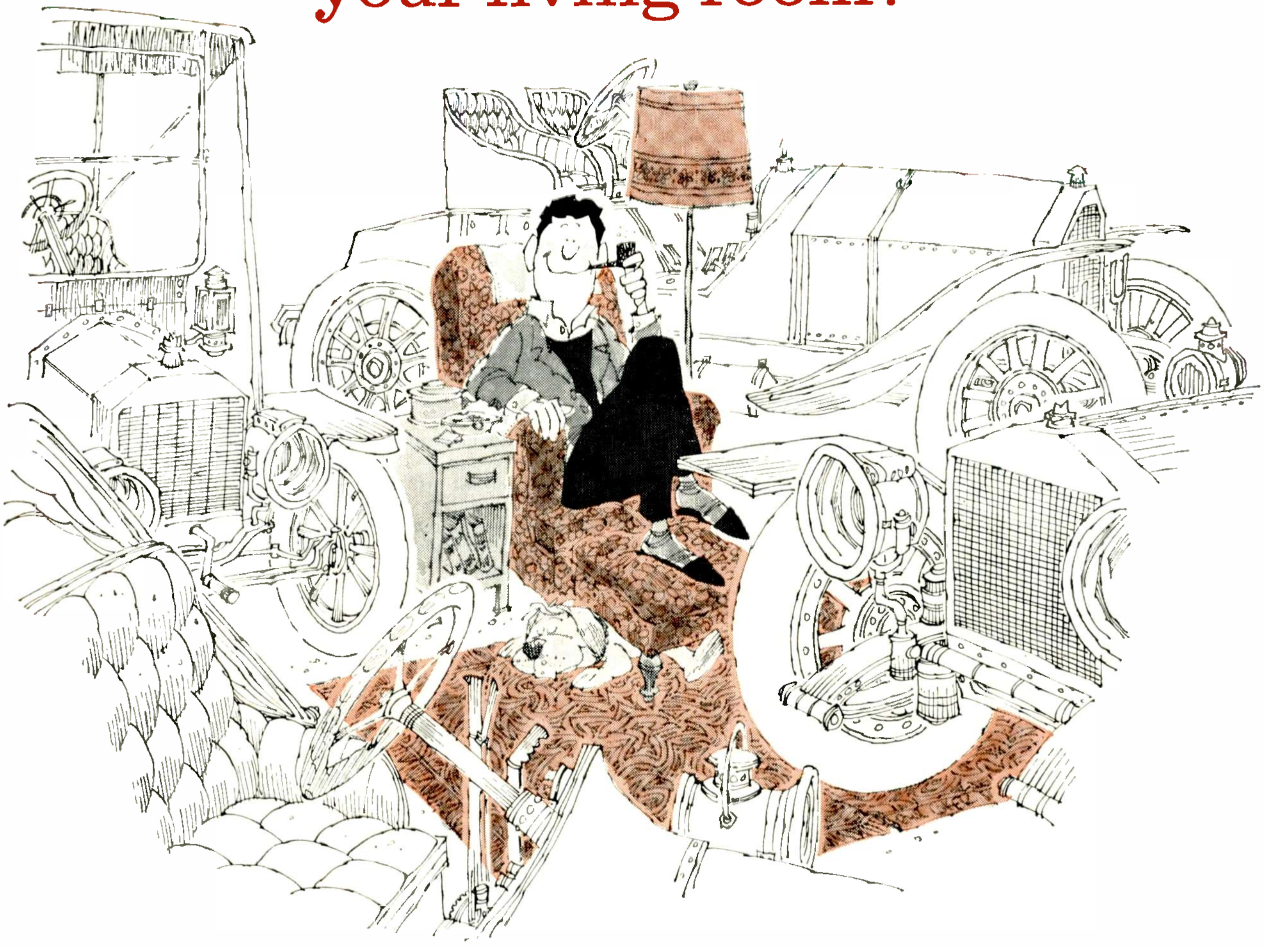

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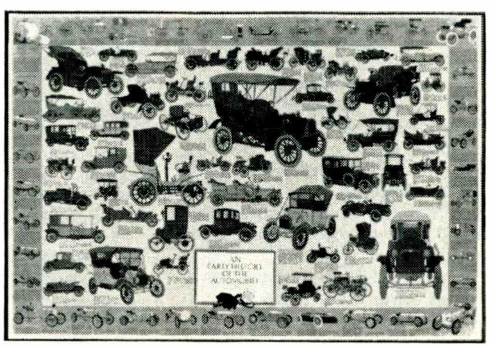

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NEW PRODUCTS & LITERATURE

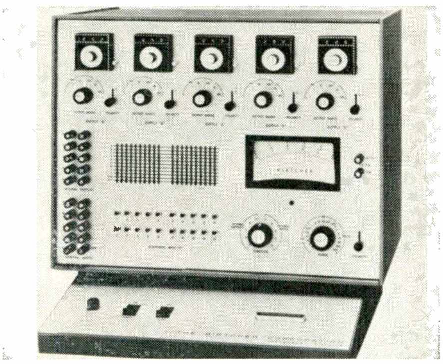
Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, fill in coupon on the Reader Service Card.

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

INTEGRATED-CIRCUIT TESTER

The Model 800 integrated-circuit tester features internal power supplies and push-button test sequencing. It will handle all present IC configurations and is designed to accommodate any foreseeable future developments in the field.

The tester features a 10 x 20 cross-bar matrix, which can be programmed to check up to 20



parameters. The sequencer permits rapid repetitive testing without reprogramming. The five built-in power supplies are available with optional digital programming. The built-in direct-reading meter for voltage and current is accurate to 1% of full scale.

A connection is provided for hook up of an external d.v.m., and the matrix has provision for up to five inputs or outputs which can be connected to external signal sources and oscilloscope for measurements of both digital and analog devices. Birtcher

Circle No. 126 on Reader Service Card

SHIELDED COIL LINE

The new standard-wound coil, Type 3387, is a printed-circuit shielded variable coil with optional overlapping inductances ranging from 1.5 μH to 100 mH. Thirty-seven different inductances (nominal values of L) are available.

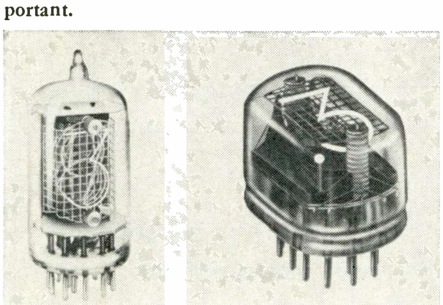
For use in tight-spot circuits, the coil is less than 0.5" above a circuit board and has a 0.100" printed-circuit grid mount. Cambridge Thermionic

Circle No. 127 on Reader Service Card

10-DIGIT READOUT TUBES

Two new 10-digit readout tubes, one side viewing and one end viewing, have been added to the "Digitubes" line.

The BA-809 is an end-viewing, neon-glow numerical display tube intended for use in instruments or displays where close spacing, an integral decimal point, and readability are important. The BA-803 is a side-viewing, neon-glow numerical display tube for use in instruments where good readability and close spacing are important.



The large character size and bright neon glow combine to provide easy readability at viewing distances greater than 30 feet. Over-all heights for the tubes are 2.065" for the BA-903 and 1.120" for the BA-809. Character size is 0.610" for each. Baird-Atomic

Circle No. 128 on Reader Service Card

HEAT-SHRINKABLE TUBING

"Insultite CP-150" is a new, low-cost, flexible, heat-shrinkable tubing designed for use in virtually all electronic and electrical parts. Made of irradiated polyolefin, specific applications recommended for this new tubing include wire and cable harnessing, the insulation and protection of connectors, splices, electromechanical connections, and motor leads. Solid-state and other electronic components can be quickly encapsulated with CP-150.

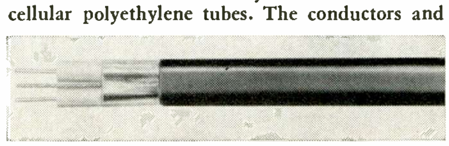
The tubing has high temperature resistance (UL rated to 125° C) and excellent low temperature flexibility. It is available in sizes $\frac{3}{64}$" to 2" expanded i.d. Electronized Chemicals

Circle No. 129 on Reader Service Card

SHIELDED TV LINE

A new ultra-low-loss all-channel shielded TV transmission line which requires no standoff insulators in installation for interference-free reception in black-and-white or color is now being marked as "Shielded Permafoam."

The line has its two high-strength copper-plated steel conductors individually encased in low-loss cellular polyethylene tubes. The conductors and



tinned copper ground wire (attached at set) are wrapped in an aluminum Mylar shield for 100% effective coverage, while the line is protected against weathering by means of the Permaline jacket.

The line may be taped directly to the antenna mast and run by the most convenient route to the set, without insulators. The new line is being marketed in 50-, 75-, and 100-foot coils. Columbia Wire

Circle No. 1 on Reader Service Card

NEW MOSFET'S

Two developmental-type insulated-gate MOS field-effect transistors (MOSFET's), one a single-gate and the other a double-gate device, are expected to have broad application in the consumer and military communications markets.

Nineteen of these new devices are being used in an experimental transistorized color-TV receiver, performing circuit functions in the r.f., i.f., video, sync, keyed a.g.c., chroma, burst amplifier, color killer, 3.58-MHz oscillator, and color demodulator stages. Both devices, which are "n"-channel, depletion-type insulated-gate transistors, are now available for sampling.

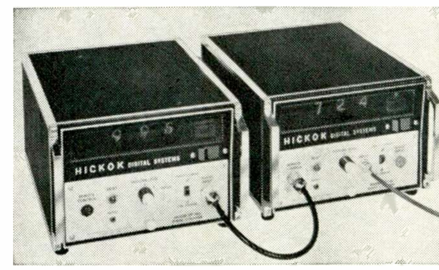
The single-gate device, developmental type TA2840, is designed for v.h.f. amplifiers and oscillators in commercial and industrial applications. It is also suited for use in low-frequency amplifier applications requiring a transistor having high power gain and very high input impedance.

The double-gate device, developmental type TA2644, is intended primarily for amplifier applications at frequencies up to 250 MHz. The internal circuit configuration and performance of this device are similar to those of two vacuum-tube triodes in a cascode circuit arrangement. RCA

Circle No. 130 on Reader Service Card

PLUG-IN "EVENT COUNTER"

The new DP-140 event counter and slave plug-in extends the application of the DMS-3200 digital measuring system to provide inexpensive all-



electronic counting and display of totalized count of events in both industrial and laboratory applications.

A single plug-in/main frame combination provides a three-digit display and additional combinations may be added in cascade to provide six-, nine-, or twelve-digit display.

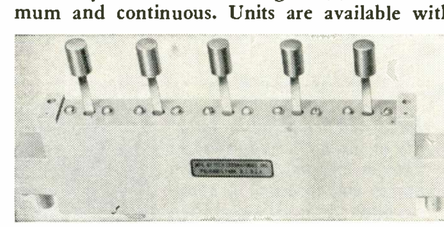
Up to one million pulses per second can be counted by the DP-140 and its operation may be remote-controlled to "start count", "stop count", "resume count", or "reset". Sensitivity is 100 millivolts. Hickok

Circle No. 131 on Reader Service Card

PUSH-BUTTON ATTENUATORS

New push-button type attenuators for r.f. and video are being offered in impedances of 50 or 73 ohms with constant input and output. The attenuators are the resistive type with unwanted reactive effects eliminated. They are suggested for use in the laboratory or production line, or as controls in proprietory instruments and equipment for either pulse or wide-band applications in r.f. or video frequency range. They can be used in series without affecting other circuit characteristics and consist of unbalanced pi networks in shaped cavities, individually shielded.

Each network has individual locking push-buttons for addition or subtraction of loss. Frequency response is essentially flat from d.c. to 225 MHz with very low v.s.w.r. Wattage is $\frac{1}{4}$ watt maximum and continuous. Units are available with



either Type N or BNC connectors and can be furnished with solenoid for remote operation. Tech Laboratories

Circle No. 132 on Reader Service Card

MOTOR-SPEED CONTROLLER

The Model EP #100 is a full-wave solid-state electronic light dimmer and motor control housed in an aluminum case for use with universal a.c.-d.c. motors rated to 5 amperes and incandescent lamps to 600 watts a.c.

The unit will control motor speeds from zero to full motor rating. It has a 6-foot cord with grounded pin plug and grounded pin receptacle.

The circuit contains a noise filter. The unit measures 3" x 5" x 2" high and is designed for use on 120-volt a.c. lines only. Slocum

Circle No. 2 on Reader Service Card

LOW-NOISE FET'S

Two new lines of "n"-channel FET's for r.f. and audio amplifier applications have been introduced. Types 2N4220-22 (audio and general-purpose) provide low audio noise and high input impedance. The r.f. types (2N4223-24) provide low cross-modulation and intermodulation distortion as well as low noise and high gain.

In applications such as a tone control for hi-fi amplifiers, the high input impedance of the 2N4220 series allows for vacuum-tube design principles in the selection of tone-control elements. As a result, high resistance values and small, low-cost, more reliable capacitors can be used. The low 1/f noise of these types provide a definite advantage over bipolar transistors, according to the company. The noise figure is 2 dB (typical) at 100 Hz.

For applications in low-noise r.f. amplifiers, types 2N4223-24 have a noise figure of 5 dB (max.), plus a minimum gain of 10 dB at 200 MHz. Motorola Semiconductor

Circle No. 133 on Reader Service Card

LONG-LIFE BATTERY

A new line of mercuric oxide-cadmium primary batteries, tradenamed "Mercad", with long wet-stand life and temperature characteristics has just been developed. According to the company, the significant advantages of the new system over conventional mercury-zinc cells include: very long wet-stand life with superior charge retention up to several years; wide operational temperature range (−65° to +165° F); stable discharge voltage; and sealed construction with no outgassing.

The batteries are used in button form in the smaller capacities and for low- and medium-rate applications. For high capacities and high rates of

discharge, prismatic cells are recommended. Batteries of any desired voltage and in sealed form can be assembled. Electrochimica

Circle No. 134 on Reader Service Card

"LID" TRANSISTOR FAMILIES

Three families of LID transistors, a new microelectronic package which permits mechanical production of hybrid circuits, are now available in production quantities for immediate delivery. These are high-speed switches, types LDS 200/201; high-gain, low-level amplifiers, types LDA 400/401; and general-purpose amplifiers, types LDA 402/403. The transistors are silicon planar epitaxial types.

The LID (leadless inverted device) is an all-ceramic package that is smaller (0.075" x 0.045" x 0.032") and less costly than any existing metal package. Its size and shape offers the circuit manufacturer worthwhile economies because it reduces labor time in assembly, improves over-all yield, and saves on substrate size. Amperex

Circle No. 135 on Reader Service Card

SILICON TRANSISTOR CHIPS

A new line of 15 silicon transistor chips for hybrid circuit applications is now on the market. The chips are pretested to one of eleven transistor specifications and are gold plated on the collector surface for easy mounting. They are also available premounted on gold-plated Kovar tabs 0.050" square by 0.006" thick.

The following "n-p-n" silicon transistors are available in the new chip series: 2N918, 2N1890, 2N1893, 2N2218A, 2N2369A, 2N2483, 2N2484, 2N3011, and 2N3252. The following "p-n-p" chips are available: 2N2904A, 2N2905A, 2N3250, 2N3251, and 2N3244. Raytheon

Circle No. 136 on Reader Service Card

MINIATURE RELAYS

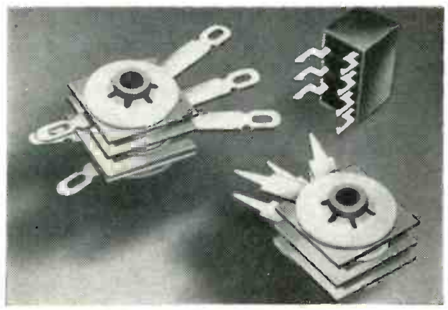
The new 600 series miniature relay has PC terminals and a unique snap-on nylon dust cover. Coil and contact terminals are set at right angles for rapid assembly into mass-produced equipment. The center terminal forming provides a spring-loaded effect, securing the unsoldered relay to the PC board to allow handling, insertion of other components, and inspection before soldering. A thin translucent window offers visual check of contact operation under load.

Descriptive Sheet 240.05 contains full specifications on the 600 series and will be forwarded upon request. Cornell-Dubilier

Circle No. 137 on Reader Service Card

COLOR-TV RECTIFIERS

Four new exact-replacement selenium convergence rectifiers for color-TV have been added to the company's line.



The Type S-855 replaces Admiral 93B53-2, Emerson 817149, G-E M128J753, Hoffman SR-37, Motorola 48D66653A, Muntz, Packard Bell, RCA 1470990, Philco 34-8058, Setchell Carlson, Sylvania 13-17569, Warwick (Sears) 86-55-3, Wells Gardner (Ward, Grant) 41-001, and Westinghouse 295V031. The Type S-420 replaces Zenith 212-25 while the Type S-798 replaces Zenith 212-63 and the S-781 replaces Admiral 9361-21 and 93C1-20. Sarkes Tarzian

Circle No. 3 on Reader Service Card

EPITAXIAL TRANSISTOR FOR U.H.F.

A new "n-p-n" silicon planar epitaxial transistor, the A485, meets the application requirements of low noise, high gain, and low intermodulation distortion throughout the u.h.f. frequency spectrum.

The A485 has an f_T of 1500 MHz typically and h_{fe} of 100 at both 2 and 20 mA. These linear performance characteristics permit the designer to optimize his circuit at the operating point of his choice while maintaining known gain. Typical applications are in small-signal r.f. amplifiers, telemetry, test equipment, and any equipment requiring high gain and low noise. Noise figure is 3.5 dB at 200 MHz and 4.5 dB at 450 MHz. Typical intermodulation distortion rating is —53 dB. Amperex

Circle No. 138 on Reader Service Card

"PEANUT" INDICATOR LIGHTS

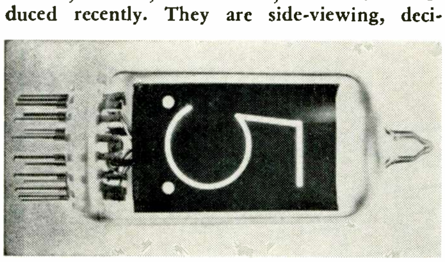
A new series of indicator lights, offered in both neon and incandescent styles, feature low cost, simple and fast assembly, and versatility of application. The new units consist of a plastic shell with a cylindrical cap into which a T-2 neon lamp is placed. It is held in position by means of shoulders molded into the butyrate shell. In the incandescent lamp version, a high-temperature polycarbonate shell is used with either a cylindrical or a macrodome cap. The T-1¾ lamp, in a wide range of voltages up to 28 V, is permanently potted into the shell.

Speed clips are provided for quick and easy mounting into the panel. The plastic shells and caps are available in a choice of several colors. Chicago Miniature Lamp

Circle No. 139 on Reader Service Card

LOW-COST "NIXIE" TUBES

Three new low-cost "Nixie" tubes, Types B-5440, B-5441, and B-5442, have been introduced recently. They are side-viewing, deci-



mal-input, cold-cathode types and measure 0.75" maximum width (permitting less than 0.80" center-to-center tube spacing), and 1.8" high when seated, providing improved instrument-panel packaging density.

The character size is a full 0.6", giving a maximum viewing distance of 30 feet. The B-5441 has internal decimal points which are independently operable and the B-5442 has "+" and "—" indication. There are three types of sockets for the B-5440 series, SK-182-SK-185 is designed for chassis mounting; the SK-194-SK-196 for "motherboard" mounting; and the SK-197-SK-200 for right-angle mounting. Burroughs

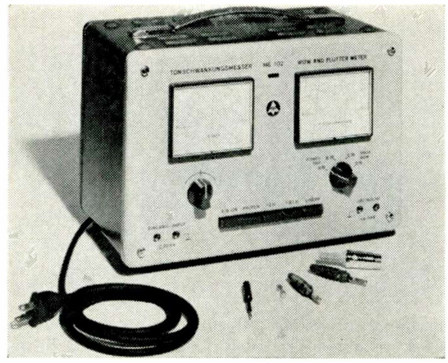
Circle No. 140 on Reader Service Card

HI-FI—AUDIO PRODUCTS

WOW & FLUTTER METER

Two models of a new and inexpensive wow and flutter meter have been put on the market as the ME-101 and ME-102.

The new instruments are intended for the measurement of the wow and flutter content of



all types of recording and reproducing devices. They are fully transistorized, simple and convenient to use. They are well suited for production testing and service work as well as laboratory testing.

An internal signal generator provides the standard frequency of 3150 Hz. For the purpose of static and dynamic recalibration of the measuring unit, the generator can be detuned in a definite manner or can be frequency modulated from the power line.

Tone fluctuations from ± 0.02 to ± 2.5% for the ME-101 and ± 0.01 to ± 0.75% for the ME-102 can be read linearly or weighted as quasi-peak values.

Besides the normal measuring connections on the front of the instrument, the back is provided with a connector for testing home tape recorders and record players. Other connectors are provided for the connection of external filters, oscilloscopes, and graphic recorders. Gotham Audio

Circle No. 4 on Reader Service Card

HEAVY-DUTY MICROPHONE

The new Model 600 cardioid microphone features five separate damping adjustments and a four-stage blast filter to eliminate popping and feedback.

Classified as a heavy-duty mic and unaffected by normal heat or humidity, the 600 is designed for hand or stand operation. It comes complete with "on-off" (line-shorting) switch, has a response of 50-15,000 Hz, and weighs only 14 ounces. Turner

Circle No. 5 on Reader Service Card

ELECTRONIC SAXOPHONE

The first successful attempt to wed a woodwind to an electronic device has been demonstrated to the public. The "Varitone" permits the player to produce a wide variety of effects heretofore not possible with a saxophone.

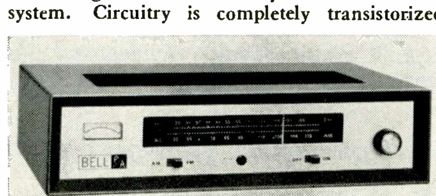
The instrument utilizes a unique preamp electronic "tone-prism" that breaks a single tone into its multi-tonal colorings. By means of seven variable controls, compactly mounted on the instrument, the "Varitone" places at the player's fingertips a wide spectrum of over 60 completely different instrumental effects, which are then projected by the instrument's amplification system.

The heavy-duty, solid-state preamp and amplifier components have been especially designed for rigorous use. A patented ceramic microphone, embedded in the neck of the instrument, captures the tone inside the saxophone. The new instrument is being offered in alto and tenor models. H. & A. Selmer

Circle No. 6 on Reader Service Card

SOLID-STATE AM-FM TUNER

The TT-100 AM-FM tuner is designed to provide background music for any commercial sound system. Circuitry is completely transistorized



and designed to handle strong input signals. Wide-band frequency response and high-level reception is assured through FM sensitivity of 3 μV and 200 kHz bandwidth. AM sensitivity is 10 μV and 8 kHz bandwidth.

Precision tuning is accomplished with the flywheel-balanced dial, log scale, and sensitive tuning meter. An adjustable output level control and multiplex adapter output for stereo reception are provided on the back panel.

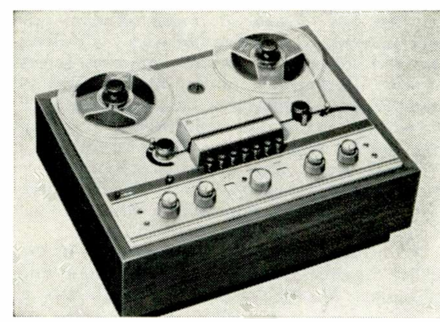
The instrument comes in a dark gray metal cabinet with a brushed anodized aluminum control panel. Bell P/A

Circle No. 7 on Reader Service Card

TAPE DECK/PREAMP KIT

A do-it-yourself kit version of a professional-type 4-track transistorized stereo tape recorder is now being offered as the AD-16.

This tape deck/preamp unit takes about 25 hours to assemble and involves wiring two circuit boards and the mechanical mounting of the transport components. The kit has pre-cut, pre-stripped and marked connecting wires and shielded cables. Even the connectors are installed where necessary for simple plug-in assembly. The unit will record and play back from mic, tuner, phono, or TV inputs in 4-track stereo or mono at either 7½ or 3¾ ips. The unit also has sound-on-sound, sound-with-sound, and echo



capabilities. There are three tape heads: erase, record, and playback. For playback, an amplifier and speakers must be added. Heath

Circle No. 8 on Reader Service Card

AUTO REVERB UNIT

The "Duo-Vox Sound-A-Rama" reverb unit is designed to add depth and realism to auto radio reception. One knob controls "on-off" and speaker phasing. The circuit uses 3 silicon transistors and is designed to be used on all 12-volt cars, negative or positive, by means of a built-in polarity switch.

The unit comes complete with cables and pilot light. It is available with the standard 6" x 9" oval speaker with or without the chrome grille or without a speaker. Duosonic Corp.

Circle No. 9 on Reader Service Card

FM STEREO SIGNAL GENERATOR

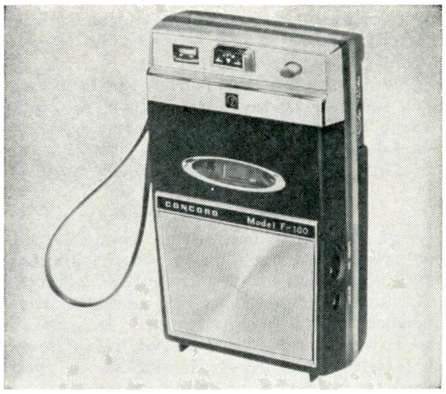
The new Model SM-109 FM stereo multiplex signal generator weighs only 13 pounds and measures a mere 6¾" wide x 10½" high x 10½" deep. It is designed especially for service calls or for use in laboratories.

The generator has a built-in audio oscillator which enables modulation internally at either 1000 Hz or 50/60 Hz, a built-in FM signal generator which produces a carrier wave of 98 MHz ± 2 MHz, and a pre-emphasis circuit of 75 μsec which offers an actual demonstration by applying a stereo musical signal on the external input terminals. Kenwood

Circle No. 10 on Reader Service Card

CARTRIDGE RECORDER

A new portable, instant-loading cartridge recorder is now being offered as the F-100. This battery-powered machine features solid-state electronics, uses a standard C-60 tape cartridge which is interchangeable with those of other cartridge recorders on the market, records or plays for a full hour, and stops automatically. The 2-ounce cartridge is mailable.



A dynamic microphone with remote start/stop control makes the F-100 especially suited for business dictation, classroom notes, reports and correspondence, as well as music recording.

The unit measures 3" x 5" x 8" and weighs 3 pounds. Its ruggedized construction makes it a good traveler. An a.c. adapter is available as an accessory. Concord.

Circle No. 11 on Reader Service Card

OVERSIZED TAPE REEL

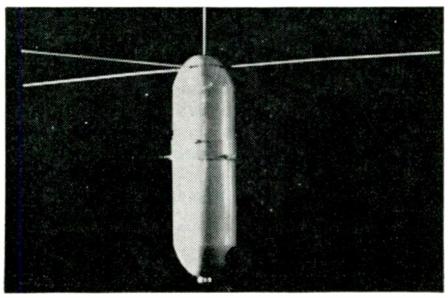
The new "8-Plus" reel provides 50% more tape storage capacity than a standard 7-inch reel, permitting up to 10 hours of programming on a single reel. A full 2½-hour opera can be recorded without interruption. One of the new reels can store four complete operas or up to 200 average-length musical selections. It can play 1½ hours in stereo at 7½ ips or 2½ hours in stereo at 3¾ ips. Magnecord

Circle No. 12 on Reader Service Card

TRANSMITTING MICROPHONE

The TM 805 transmitting microphone is a battery-powered unit which can measure and transmit sound pressure levels in hazardous environments and transmit them to a receiving-recording station two to fifteen miles away.

The microphone weighs only 2.8 pounds, is completely self-contained, and can be attached to structures, poles, and weather balloons without the use of cables. Low-cost batteries permit 20 hours of continuous SPL monitoring over the frequency range of 1 to 10,000 Hz. The unit is especially useful for continuous acoustic survey in



remote and hazardous locations including sound-level measurements of large rocket motor environments, acoustic test chambers, sonic booms, airport noise surveys, and similar applications. Datacraft.

Circle No. 141 on Reader Service Card

AM-FM STEREO RECEIVER

A 120-watt solid-state AM-FM stereo receiver which uses 44 transistors and 31 diodes is now on the market as the LR-1200T. The unit features automatic stereo switching with an amber stereo indicator light on the dial face. FM sensitivity is 1.5 μV; stereo separation is 40 dB at 400 Hz, and capture ratio is 2.2 dB. Frequency response is 20-50,000 Hz ± 1 dB at 1 watt.

The receiver has an illuminated d'Arsonval tuning meter for both AM and FM and there is a slide-rule station dial. The instrument has standard operating controls and stereo inputs for tape head, magnetic/crystal or ceramic phono cartridges, and high-level aux. Power output is 60 W per channel (IHF) and HD is less than 1%. IM distortion is 0.3% at 1 watt.

The receiver is housed in a walnut-grained metal case and measures 16" x 5" x 14½" deep. Lafayette

Circle No. 13 on Reader Service Card

CB-HAM-COMMUNICATIONS

CB ACCESSORIES

A new CB antenna matching system, consisting of an antenna meter and a CB "Matchbox," is designed to correct an improper impedance match between the transmitter and antenna of any base or mobile CB station.

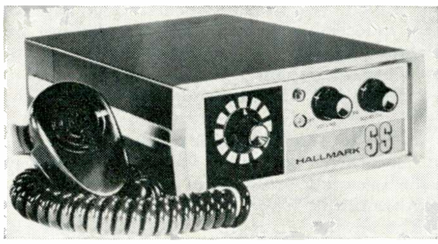
The antenna meter is a small measuring unit that is inserted temporarily in the feedline between the transmitter and the antenna. The meter measures both forward and reflected power in the feedline, giving a direct reading of s.w.r. The meter can read an s.w.r. as high as 10:1 and requires only 2 watts of power to be present in the feedline. Connection is through two standard SO-239 coax connectors.

The "Matchbox" is intended to become a permanent part of any CB installation where an impedance mismatch occurs. Two simple controls allow an s.w.r. of as high as 5:1 to be corrected to 1.1:1 or less. E. F. Johnson

Circle No. 14 on Reader Service Card

12-CHANNEL CB TRANSCEIVER

The new Model SS is an all-solid-state, 12-channel, crystal-controlled CB transceiver which utilizes pre-aligned, plug-in circuit modules, thus virtually eliminating field maintenance problems. The receiver is a high-gain, double-conversion



superhet using low-noise germanium transistors. It has a crystal-controlled oscillator, linear r.f. amplifier, and an effective noise limiter. An ultrasensitive squelch is achieved through the use of silicon transistors in a temperature-compensated circuit.

Other features are high-level modulation (95 to 100%), 3.7 watts r.f. power output, and excellent receiver sensitivity for clean signal without adjacent-channel splatter. Optional operation for any widely used a.c. or d.c. source; a fully regulated power supply is available. Hallmark

Circle No. 15 on Reader Service Card

SSB RECEIVING ADAPTER

A new SSB converter, the CV-1982/TSC-26, is designed to adapt standard communications receivers, such as the Hammarlund SP600 or military R390 type receivers, to SSB reception.

An all-electronic a.f.c. is incorporated which has a very rapid correction speed, allows reduction in errors caused by ionospheric Doppler shift, and equipment instability. A special quick-tune device is also incorporated. Kahn

Circle No. 16 on Reader Service Card

CRANK-UP TOWER

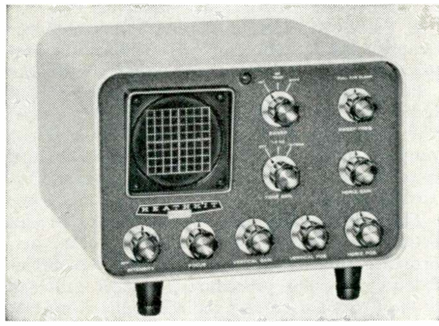
The new Model CZ crank-up tower can support a tri-band beam at 60 feet without the use of guy wires. When bracketed to a building, the tower becomes self supporting. It can be quickly and easily lowered for very high wind conditions.

The new style gear winch has an automatic locking disc brake which provides safety and positive control when raising or lowering the tower. The new construction features diagonal braces of round steel rod on all three sides, plus extra-heavy steel channel step braces, providing maximum strength and rigidity. A large top section permits mounting most rotors inside on a removable pre-drilled plate. Tristao

Circle No. 17 on Reader Service Card

HAM MONITOR SCOPE

The SB-610 signal monitor visually displays both transmitted and received signal waveforms. It shows over-modulation or other forms of distortion by displaying the actual signal envelopes



or trapezoid patterns from ham radio transmitters and will give an equally complete picture of signals being received.

The new scope is designed to perform with virtually any communications receiver on the market today. It can be used with transmitters from 160 to 6 meters and with receiver i.f.'s as high as 6 MHz.

The instrument comes in kit form complete with step-by-step construction and hook-up information plus instructions for use and a series of characteristic waveforms. Heath

Circle No. 18 on Reader Service Card

MANUFACTURERS' LITERATURE

MINIATURE RELAY DATA

A preliminary catalogue describing two new 1"-diameter, 1"-high 6-pole d.t. and 4-pole d.t. relays, is now available.

The four-page literature includes electrical, environmental, and mechanical characteristics of the Series 300 and 350 relays. Also included are six standard mounting styles and detailed ordering information.

The "wedge action" contact mechanism used in these low-level-to-2-amp relays provides a dry circuit confidence level of 90% based on a failure rate of 0.001% per 10,000 operations. Electro-Tec

Circle No. 142 on Reader Service Card

CHASSIS PUNCHES

A complete line of standard and special chassis punches for radio, TV, and electrical work is described in a new 8-page catalogue, E-730-15.

Standard round, square, "key", "D", and double "D" punches are covered in detail. A variety of specials are presented, including punches for 15.2 to 60 mm round punches, punches for Potter & Brumfield KHP miniature relay sockets, 2" square punches for Micro Switch manual control units, and metal punches for oiltight controls. Greenlee

Circle No. 19 on Reader Service Card

SUBMINIATURE LAMPS

Aged and selected lamps, including T1, T1¼, and T1¾—both based and unbased, are described in new two-color brochure just published.

Power requirements for these subminiature incandescent lamps range from 5 to 28 volts with life ranges from 2500 to 100,000 hours. IEE

Circle No. 143 on Reader Service Card

BUSHING & SHAFT SPECIFIER

A free specifier chart makes it easy to select bushings and shafts for auto radio replacement controls. With the new chart, it is no longer necessary to know the part number of the auto radio control in order to replace it with an exact equivalent.

With the plastic-laminated guide, the correct bushing is found by inserting the bushing of the old control in a template which indicates the diameter, then measuring the bushing length on the template which indicates the replacement part number. Correct inner and sleeve shafts are similarly determined with the template. Centralab

Circle No. 144 on Reader Service Card

MARINE RADIOTELEPHONE GEAR

A guide to selecting marine radiotelephones for m.f., v.h.f., CB, and SSB applications has now been released in updated and revised form.

Entitled "How to Use and Choose Marine Radiotelephones", this 24-page booklet carries new sections on v.h.f.-FM, SSB, CB, as well as a complete up-to-date listing of all marine channel frequency allocations in the U.S., Alaska, and the Caribbean area.

This information has been added to revised sections on how a radiotelephone works, performance information, noise problems, operational laws, licensing procedures, services provided by the Coast Guard and the telephone company, and a listing of all FCC field offices. Pearce-Simpson

Circle No. 20 on Reader Service Card

PANEL INSTRUMENTS

A 12-page, two-color catalogue on "G", "M", and other series panel meters, including d.c. voltmeters, millivoltmeters, ammeters, milliammeters, microammeters; a.c. voltmeters, milliammeters, r.f. thermo ammeters, a.c. rectifier voltmeters, vu meters, dB meters, and other portable meters for schools, labs, and shops, is now available.

Catalogue D-66-I provides both electrical and mechanical specifications on the various units covered, along with illustrations of the meters themselves. Triplett

Circle No. 21 on Reader Service Card

APPLICATION NOTES

Five new application notes covering design considerations for several circuits using new transistor types are now available.

AN-3163 covers a 4-watt line-operated stereo amplifier using the RCA-40424 high-voltage silicon transistor; AN-3185 deals with a high-quality, low-cost 15-watt complementary-symmetry power amplifier; AN-3191 describes practical and usable methods for evaluating thermal runaway in transistor audio output stages; AN-3196 provides information on a 5-stage, 6.2-watt stereo amplifier using a complementary-symmetry output stage; and AN-3198 is a description of an FM multiplex demodulator using RCA-40359 transistors. RCA Electronic Components and Devices

Circle No. 145 on Reader Service Card

COIL CATALOGUE

A new 156-page general catalogue plus 16-page replacement guide have been issued as Form 860.

The catalogue provides a numerical index to the various audio transformers, chokes and reactors, coils, power transformers, TV sweep components, and transistor transformers offered by the company.

The replacement section lists some 81 manufacturers (and their brand names) whose parts can be replaced by components listed in the catalogue. Merit

Circle No. 22 on Reader Service Card

RELAY BROCHURE

A new illustrated booklet and short-form relay catalogue is now available on request. A representative list of 18 different relays is illustrated with their specifications in an easy-to-read, quick-locator table. A special section details some of the firm's production facilities and processes. Filtors

Circle No. 146 on Reader Service Card

RESISTOR NETWORKS

A series of metal-film precision resistor networks which permit substantial savings of space over equipment assembled with individual components is illustrated and described in Engineering Bulletin No. 20,000.

Physical specifications and performance characteristics are detailed in this 4-page brochure. Sprague

Circle No. 147 on Reader Service Card

CAPACITOR GUIDE

A new 8-page brochure describing the firm's complete line of glass capacitors is now available. The guide lists complete parameters in a two-page spread for the CYFM, CYFR, TYO, CY and the new CYKO, or Glass-K, styles of capacitors. A table compares performance of glass dielectric with performances of ceramic, mica, paper and paper plastic, and two tantalum dielectrics.

Also included in the illustrated brochure are applications, performance curves, and a failure-rate chart. Corning Glass

Circle No. 148 on Reader Service Card

RELAY APPLICATION NOTES

A new bulletin describing the uses of "Ugon" relays—fast, sensitivity, subminiature units—in applications such as u.h.f. signal switching, metering relays, and instrumentation systems is now available.

The relays which occupy a space of only 2 cubic centimeters operate on as little as 5 mW and the contacts are capable of switching loads up to 15 watts. Airpax

Circle No. 149 on Reader Service Card

PUSH-BUTTON SWITCHES

New catalogue numbers are provided in the 12-page illustrated push-button switch catalogue, L-169C. Detailed specifications and data, including lamp and legend information, are furnished on momentary contact s.p.s.t., n.o. or n.c., and s.p.d.t. two-circuit switches. The switches have independent lamp connections. Ratings are 3 amps @ 125 V a.c.; 3 amps @ 30 V d.c. (non-inductive). Dialight

Circle No. 150 on Reader Service Card

450-MHz TWO-WAY RADIO

The benefits of using 450-MHz for two-way radio operation are outlined in an 8-page brochure entitled "Why UHF".

The advantages of u.h.f. operation, from excellent coverage to less crowded channels, are told in the booklet. Now the radio user can choose from a complete line of u.h.f. mobile units, portable radios, base stations, and repeaters the right unit to meet his particular needs. Some of this equipment is illustrated and described briefly in the brochure. Motorola

Circle No. 23 on Reader Service Card

ELECTROLYTIC CATALOGUE

A 112-page "Twist-Prong" electrolytic reference catalogue has just been published to assist in solving the major problems of the immediate availability of proper electrolytic replacements.

The company has developed a line of 230 cans that will meet almost all replacement requirements and this catalogue details these recommended replacements for "Twist-Prong" ratings in current use. Cornell-Dubilier

Circle No. 151 on Reader Service Card

REPLACEMENT RECTIFIERS

A new catalogue listing silicon and selenium rectifiers for replacement applications and tube replacement silicon rectifiers has just been issued.

In addition to carrying detailed information on a full line of standard replacement rectifier devices, the catalogue lists many of the newer rectifier replacements designed especially for color-TV.

Copies of catalogue No. 66-DL-3 will be forwarded on request. Sarkes Tarzian

Circle No. 24 on Reader Service Card

COMPACTRON DATA

A new, condensed "1966 Catalogue of Compactrons" (ETG-3983A) is now available to designers of television and audio communications products. This 24-page publication lists general and maximum ratings of 121 compactrons, plus characteristics and typical operation on an easy-to-read chart.

Cost savings and reliability are cited for these multi-function devices. Also shown are compactron basing diagrams and outline drawings. General Electric

Circle No. 152 on Reader Service Card

DESIGNER'S MANUAL

A photoconductive cell design manual providing photocell design, theory, and application data, information on photoconductive materials, cell resistance curves, data on variation of conductance with light history, color temperature and power derating curves, light measurement, photometry, and order information, has been issued for the benefit of design engineers.

Catalogue data is provided on a wide range of the company's cells including material, peak spectral response, resistance, minimum dark resistance, maximum voltage rating, and measurement voltage. Clairex

Circle No. 153 on Reader Service Card

TRANSISTOR CATALOGUE

A 12-page illustrated catalogue and pricing schedule, created especially for use by product engineers and purchasing agents, has been issued.

Every 2N epitaxial mesa and planar, Philco-type germanium, silicon alloy, silicon alloy diffused, silicon epitaxial, and germanium and silicon consumer-type transistor made by the firm is listed in numerical order. Lansdale

Circle No. 154 on Reader Service Card

RECTIFIER RATING NOMOGRAMS

As a customer service, the company is offering to designers, free of charge, two nomograms which enable the user to determine any of three variables relating to the rating of semiconductor microminiature general-purpose rectifiers. The variables are: maximum average forward current, distance from body of device to point of contact with lead, and heatsink temperature of the device.

A straight line extending through any two scales on the nomogram to the third column will accurately indicate the remaining variable. Hoffman Semiconductor

Circle No. 155 on Reader Service Card

SHORT-FORM CATALOGUE

An 8-page, short-form catalogue describing a complete line of trimmers, precision pots, miniature switches, and turn-counting dials is now available on request.

Basic specifications relating to square, rectangular and round trimmers as well as single, 5-, and 10-turn industrial and military pots are given. A table outlining nonlinear specifications is also provided. Spectrol

Circle No. 156 on Reader Service Card

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JAPAN & Hong Kong Electronics Directory. Products, components, supplies. 50 firms—just $1.00. Ippano Kaisha Ltd., Box 6266, Spokane, Washington 99207.

CANADIANS, transistors, all semiconductors and components. Free catalogue contains reference data on 300 transistor types. J.&J. Electronics (Dept. EW), P.O. Box 1437 Winnipeg, Manitoba, Canada.

TRANSISTORS—Miniature Electronic Parts. Send for Free Catalog. Electronic Control Design Company, P.O. Box 1432M, Plainfield, N.J.

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3	.14	.22	.28	.40
15	—	.75	1.20	1.55
35	—	1.30	2.00	2.70

Amps	700 PIV	800 PIV	900 PIV	1000 PIV
.75*	.25	.32	.40	.55
3	.49	.58	.67	.78
15	1.70	1.85	2.25	
35	3.15	3.60	4.50	4.80

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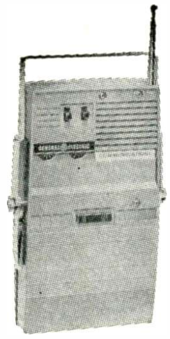

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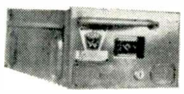

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- *NEW—additional switch for further attenuation of crystal oscillator output*
- The Optional Distributor Resale Price is only $65.00. Kit Form, $45.00, includes pre-assembled range switch with pre-aligned coils and trimmers. See the RCA WR-50B at your authorized RCA Test Equipment Distributor.

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