Proceedings of
The Radio Club of America, Inc.

Founded 1909

Volume 30, No. 2

1953

TRANSISTOR CIRCUIT CONSIDERATIONS

by

J. G. WEISSMAN

THE RADIO CLUB OF AMERICA

11 West 42nd Street ★ ★ ★ New York City

The Radio Club of America, Inc.

11 West 42nd Street, New York City   Telephone — LOngacre 5-6622

Officers for 1953

President
John H. Bose

Vice President
Ralph R. Batcher

Corresponding Secretary
Frank H. Shepard, Jr.

Treasurer
Joseph J. Stantley

Recording Secretary
Frank A. Gunther

Directors

Ernest V. Amy
Edwin H. Armstrong
George E. Burghard
Alan Hazeltine
R. A. Heising
Sidney K. Hopkins
Harry W. Houck
F. A. Klingenschmitt
O. F. Masin
Jerry B. Minter
W. H. Offenhauser, Jr.
Harry Sadenwater
S. Ward Seeley

Committee Chairmen

Advertising
Edgar M. Weed

Affiliations
William H. Offenhauser, Jr.

Budget
Joseph J. Stantley

Entertainment
Ernest V. Amy

Medals
Harry Sadenwater

Membership
F. A. Klingenschmitt

Year Book and Archives
Harry Sadenwater

Papers
Frank H. Shepard, Jr.

Publications
Jerry B. Minter

Publicity
S. Ward Seeley

MEETINGS

Technical meetings are held on the second Thursday evening each month from September through May at the General Electric Auditorium, 51st Street and Lexington Avenue in New York City. The public is invited.

MEMBERSHIP

Application blanks for membership are obtainable at the Club office. For the Member grade the invitation fee is one dollar and the annual dues are three dollars.

PUBLICATIONS

Subscription: Four dollars per year, or fifty cents per issue. Back numbers to members, twenty-five cents each.

**PROCEEDINGS
OF THE
RADIO CLUB OF AMERICA**

Volume 30 1953 No. 2

TRANSISTOR CIRCUIT CONSIDERATIONS

by

J. G. WEISSMAN*

Presented before Radio Club of America on December 18, 1952

Mr. Chairman, members of the Radio Club and guests. Before commencing this evening I would like to express my appreciation, about 4 years late to the members of the Radio Club for having sponsored the most interesting technical meeting I have ever had the pleasure to attend. Perhaps some of you present here this evening attended a Radio Club meeting held about 4 years ago at Pupin Hall in Columbia University at which Mr. Van Beuren of the Measurements Corp. spoke on "high fidelity audio amplifiers". While Mr. Van Beuren's paper and accompanying demonstrations were most interesting, the discussion period which followed was even more interesting. I have never seen a technical audience enter into a discussion period with as much vim and vigor as occurred that evening. I believe that just about every member there got up and sounded off on 'high fidelity'. Some agreed with the speaker and some didn't. At any rate it showed that the members of the Radio Club are not afraid to take the bull by the horns and express their opinions.

Perhaps one of the reasons for the events of that evening was that "high fidelity" is a fairly controversial topic. Transistors are somewhat of a controversial topic also. Following the announcement by Bell Telephone Laboratories some 4 years ago there were those who declared that the vacuum tube would soon be obsoleted. Well, that hasn't happened yet and it probably won't for a good many years to come. Nevertheless there are many applications where the transistor can do as good a job or even a better job than a vacuum tube can.

As you know there are two generic types of transistors, the point contact type and the junction type, each of which has its own particular characteristics. Each of them can occur as 3,4 or even 5 element devices. There are some samples of various types of transistors from several manufacturers mounted on this board which you may examine later. Of all these possible types of transistors the one type that has been most readily available is the 3 element point contact type and it is this type that I wish to concentrate on this evening.

Before going ahead and trying to apply the point contact triode transistor a discussion of its characteristics and limitations is in order. First off the limitations; there are 3 major ones at the present time: frequency response, power dissipation and noise.

Although laboratory samples have been operated as high as 300 megacycles (as oscillators) the highest commercial rating specified for point contact units at the present time is 5 megacycles. Power dissipations are of the order of 150 milliwatts maximum. This means that the maximum signal power level (assuming a class A efficiency of 20%) is about 30 milliwatts. The noise figure of currently available point contact transistors is of the order of 50 db at 1KC, 20 db at 1MC. Let's calculate what this means in terms of minimum usable signal. Assuming a transistor input impedance of 200 ohms and an operating bandwidth of 10 KC, the Johnson noise voltage appearing across the input should be

$$E = \sqrt{4\ K\ T\ R\ \Delta F}$$
$$= 2\sqrt{1.37 \times 10^{-25} \times 293 \times 200 \times 10^{4}}$$
$$= 2\sqrt{8 \times 10^{-15}}$$
$$= \quad 18 \times 10^{-8} = 0.18\ \mu \text{ volts.}$$

E = RMS value of thermal noise voltage
K = Boltsmann's Constant = 1.37×10^{-23} watt-second/deg.
T = Absolute Temp.
R = Resistive component of input impedance in ohms.

If the noise figure is 50 db there will be 316 times this or 57 microvolts of noise appearing at the input. Assuming further that a signal-to-

* Applications Engineer, Physics Laboratory, Sylvania Electric Products, Inc.

noise voltage ratio of at least 5 is desired, the minimum signal that we can amplify is about 280 microvolts.

Therefore we should be able to use a point contact transistor in any application where the signal level required is less than 30 milliwatts, the operating frequency is less than 5 megacycles and the available signal level is of the order of 280 microvolts.

Most of you are undoubtedly familiar with the general construction of a point contact transistor so we'll just go over it briefly. Physically it consists of a piece of suitably treated semi-conductor material, usually germanium, mounted on a large area electrode called the base, upon which 2 contacts or cat's whiskers are brought to bear. One contact is called the emitter, the other the collector. Thus essentially the unit can be thought of as 2 diodes. The emitter and base form one diode with the collector and base forming the other diode. The emitter diode is biased in its forward or low resistance direction and the collector diode is biased in its reverse or high resistance direction. By transistor action, a variation of emitter current causes a variation of collector current. This ratio of collector current change to emitter current change is called the α, or current gain of the transistor. For most point-contact units α is greater than unity.

A convenient equivalent circuit for the transistor is shown in Fig. 1. Here r_e represents the forward resistance of the emitter diode, r_c the back resistance of the collector diode, r_b the base resistance common to both diodes and r_m represents the active element of the transistor and is effectively equal to αr_c. R_g is the resistance of the signal source and R_L is the load resistance. Typical values are indicated below: -

r_e	200 ohms	r_m	30,000 ohms
r_b	100 ohms	α	2
r_c	15,000 ohms		

Under matched conditions the unit can deliver a power gain of about 18 db. When speaking of the gain of transistors it's usually best to talk in terms of power gain, since the gain is due to both an impedance step-up from input to output with the consequent voltage gain together with the inherent current gain.

Let's examine the equivalent circuit of Fig. 1 a little closer to see what we've really got. We have a device whose open circuit input impedance is about 300 ohms and whose open circuit output impedance is about 15,000 ohms. Right away we see that if we are to get that 18 db of power gain we have to face up to an impedance matching problem. Also, there is the factor of r_b. Since r_b is an impedance common to both the input and output circuits it represents a positive feedback element which in turn means that if we are trying to build an amplifier, r_b may cause it to become unstable and oscillate. On the other hand, if we are trying to make an oscillator, r_b helps matters. An analysis of the equivalent circuit leads to the following stability criterion which must be satisfied if we are to have an amplifier free of oscillation: -

$$\frac{R_g + r_e}{r_b} + \frac{R_g + r_e}{r_c + R_L} + 1 > \frac{r_m}{r_c + R_L}$$

The equivalent circuit shown, which is termed the grounded base connection, is only one of the possibilities, since in the same manner as a vacuum tube triode may be used as a grounded cathode, grounded grid or grounded plate amplifier, so a transistor may be connected either as a grounded base, grounded emitter or grounded collector amplifier. The grounded base connection is most commonly used since it is the most stable.

In general we can classify transistor applications into two general categories - one would be c.w., i.e. continuous wave operation where the output signal has the same wave shape as the input signal, for example a.f. and r.f. amplifiers,

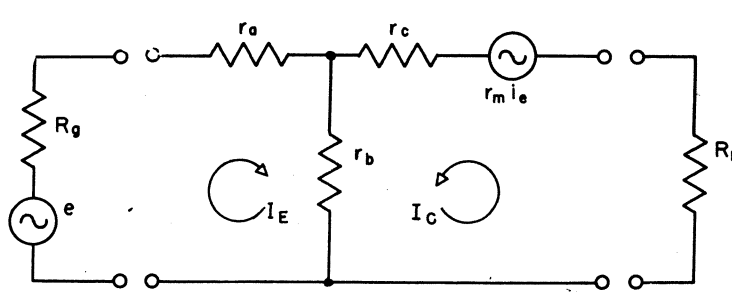


Fig. 1

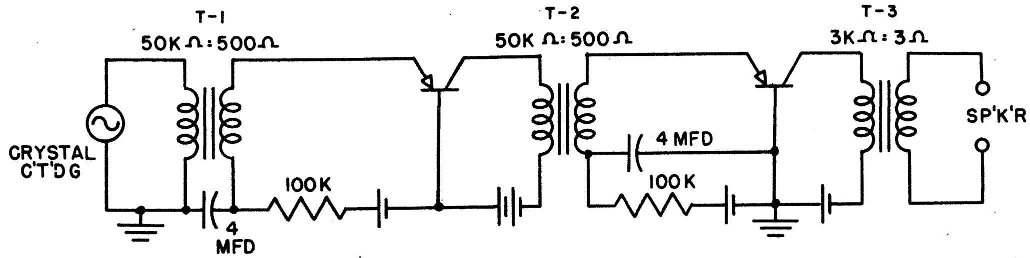


Fig. 2

mixers, modulators and the like; the other category would be switching or non-linear circuitry. Here would fall such devices as relaxation oscillators, flip-flops, counters, frequency dividers, etc.

Let's look at some of the c.w. applications first. The simplest thing that comes to mind is an ordinary audio amplifier. For example let's design a phonograph amplifier to work with a crystal cartridge and a 3 ohm loudspeaker. A low-level stage driving a power output stage should do the job. The low level stage is quite straight forward; the design of the power output stage requires a little more care. The same approach as used in designing a vacuum tube power output stage is used, namely drawing a load line in the collector voltage vs. collector current family of curves which will yield as large a ΔV ΔI product and as small a distortion as possible while staying within the power dissipation ratings of the transistor. A load impedance of 3000 ohms is usually satisfactory. The schematic of such an amplifier is shown in Fig. 2. Here T_1 is a coupling transformer which matches the high impedance of the crystal cartridge to the low input impedance of the 1st transistor. Similarly T_2 matches the output impedance of the 1st transistor to the input impedance of the 2nd transistor; T_3 is the output transformer. The 1st transistor is biased for low-level operation, i.e. emitter at 0.5 ma and collector at 2.0 ma; the output stage is biased for higher level operation - emitter at 1.5 ma and collector at 3.5 ma. (using Sylvania Experimental Type GT-442 Transistors.) This amplifier will furnish 2 milliwatts output which is surprisingly adequate for a 5" P.M. speaker.

For r.f. applications the same general approach is valid. The big problem here is the proper design of the coupling transformers. For instance suppose we want to design a 455 KC I.F. amplifier suitable for use in a broadcast receiver. The tuned circuit in the collector must tune to 455 KC, be 10 KC wide, present a 15000 ohm impedance to the collector and a 300 ohm impedance to the emitter of the following transistor. If a single tuned circuit is used, impedance matching may be accomplished fairly easily by using split capacity tuning. See Fig. 3.

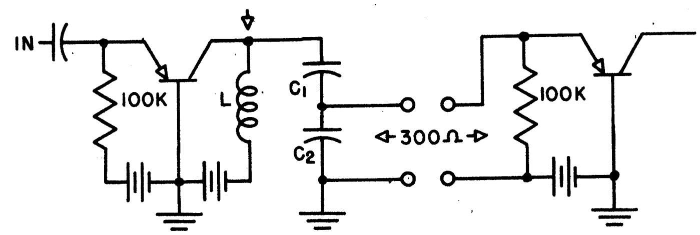


Fig. 3

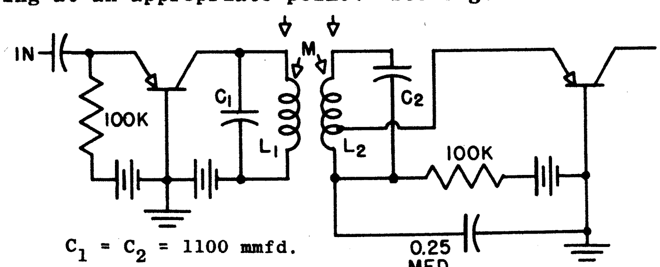
Representative values are

$L = 0.113$ mh

$C_1 = 1100$ mmfd (For 455 KC operation)

$C_2 = 0.025$ mfd

The low L-C ratios in the tuned circuit are occasioned by the comparatively low value of collector impedance. Furthermore, since for a bandwidth of 10 KC at 455 KC we need a loaded "Q" of 45, the actual "Q" of the tuned circuit must be appreciably greater than 45. If we want to improve skirt selectivity we can use a double tuned transformer with split capacity impedance matching on the secondary or we can tap the secondary winding at an appropriate point. See Fig. 4.



$C_1 = C_2 = 1100$ mmfd.
$L_1 = L_2 = 113$ μh.
$M = 15$ μh.

Fig. 4

With practical transformers, the transmission ratio is about 0.5 which means that a 3 db loss is incurred. Use of special core materials for the coils such as ferrites might improve this transmission efficiency.

Mixer circuits are very similar to r-f amplifier circuits. The local oscillator power can be introduced either on the emitter or, preferably, on the base. See Fig. 5.

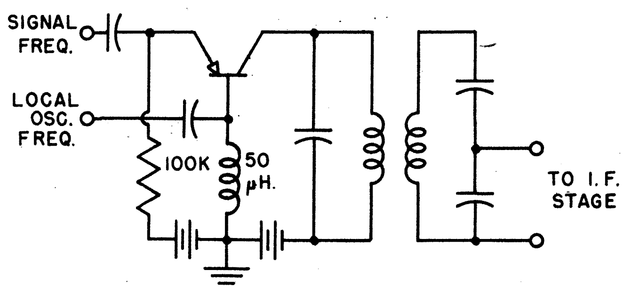


Fig. 5

A rather interesting relationship shows up in transistor mixer operation. If a vacuum tube triode is operated as an amplifier, it exhibits a certain mutual transconductance; when it is operated as a mixer, its conversion transconductance is 28% of its mutual transconductance. In other words a triode has about 12 db less gain as a mixer than it has as an amplifier. A similar situation occurs with transistors. Transistors exhibit about 13 db less gain as mixers than they do as amplifiers. Or, putting it another way, their "conversion transconductance" is about 22% of their amplifier transconductance. In practice, this means about 4 db gain in a mixer stage.

One more thought with respect to mixer even though the upper frequency limit of the transistor is 5 megacycles, it may be used as a mixer at much higher frequencies, i.e. the signal frequency and local oscillator frequency may be much higher than 5 megacycles. It is only necessary that the I.F. frequency be less than 5 megacycles. It would appear that the mixing action takes place in the emitter - base region of the transistor, which is essentially a crystal diode, and crystal diodes can operate as mixers at very high frequencies.

Now let's talk about oscillators. If we go back to the stability criterion mentioned previously, namely, that to have a stable amplifier

$$\frac{R_g + r_e}{r_b} + \frac{R_g + r_e}{r_c + R_L} + 1 < \frac{r_m}{r_c + R_L}$$

and reverse it, we have the necessary conditions for oscillation

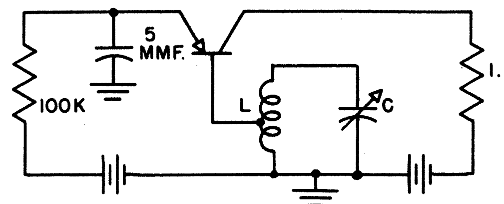
$$\frac{R_g + r_e}{r_b} + \frac{R_g + r_e}{r_c + R_L} + 1 > \frac{r_m}{r_c + R_1}$$

We can do this in a number of ways:

1 - make r_b large by adding external impedance in the base circuit

a parallel tuned circuit resonant at the desired frequency is one possibility. See Fig. 6.

2 - make R_g and/or R_L low - a series tuned circuit in the emitter or collector resonant at the desired frequency is applicable. See Fig. 7.



Note: - This circuit has oscillated to 116 Mc.

Fig. 6

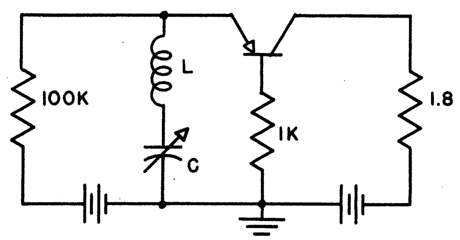


Fig. 7

We can also make a transistor oscillate by providing an external feed-back path from emitter to collector. This can take the form of a series resonant circuit as in Fig. 8.

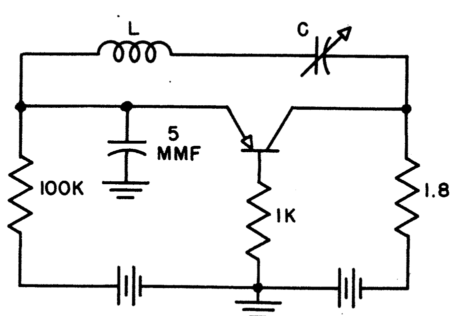


Fig. 8

or alternatively, as in Fig. 9.

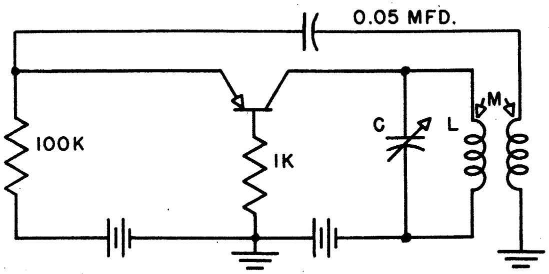


Fig. 9

A crystal can be substituted for any of the tuned circuits provided a D.C. path is maintained.

The oscillator circuit, which, in my experience, has given the best results is the one in Fig. 6.

The one application where the point contact transistor really shines is in the field of relaxation oscillators and trigger circuits, primarily because it is so easy to get a negative resistance characteristic, which is essential to this sort of operation. If the transistor has a current gain greater than unity and we insert some external resistance in the base circuit and make the collector resistance low, a plot of E_E vs. I_E shows a negative resistance characteristic. See Fig. 10.

If R_E is a resistance lower in value than the negative resistance and if we choose V_E properly we have the beginnings of a bi-stable device or flip-flop circuit. All we need is a little positive pulse on the emitter to push the operating point (1) over the hump into the negative resistance region. The operating point will immediately shift to (2). This represents an increase in emitter current and consequently an increase in collector current. The transistor will remain in this high current state until a negative pulse comes along to drive the operating point back down with a consequent drop in emitter current and hence collector current.

To make a monostable relaxation oscillator you can connect a capacitor from emitter to base, make R_E larger than the negative resistance and choose V_E as shown. See Fig. 11.

When a positive trigger comes along it pushes the operating point over the hump as before, but the capacitor resists any fast change in voltage, hence the operating point moves along line (1) until it intersects the characteristic at which point it starts to discharge along line (2) until it reaches the next turning point at which time it travels along line (3) and afterwards slowly returns to the starting point. Thus each time a pulse or trigger comes along a full cycle of opera-

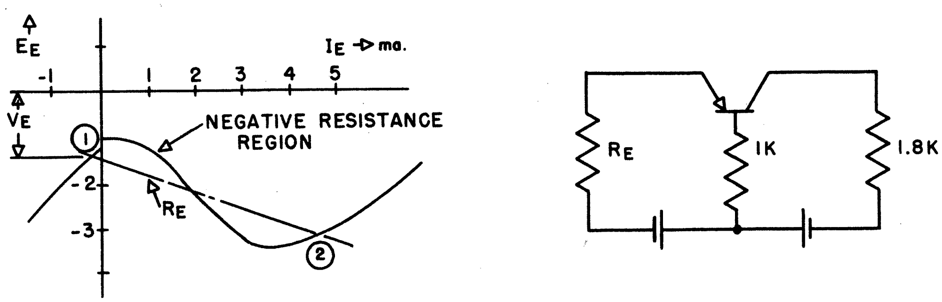


Fig. 10

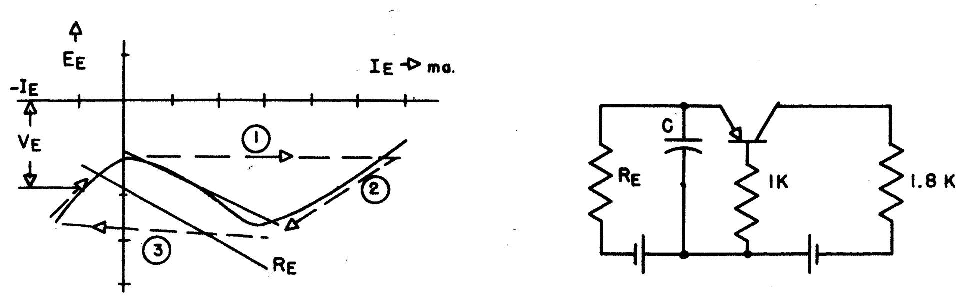


Fig. 11

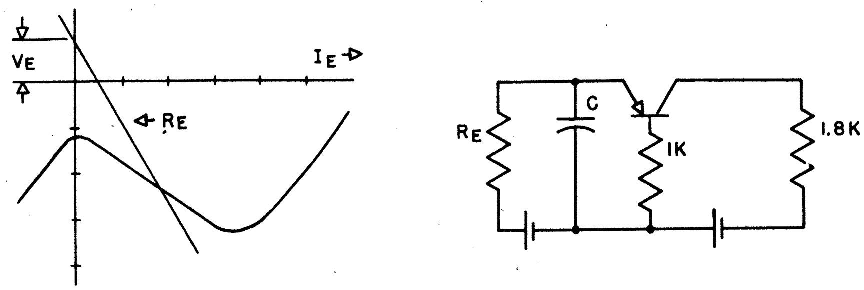


Fig. 12

tion takes place. In other words it acts like a single shot multi-vibrator.

To make a free running relaxation oscillator this sort of operation is employed. See Fig. 12.

R_E is made larger than the negative resistance and the bias V_E is so chosen that R_E intersects the negative resistance characteristic at one point. Since the operating point is always positive it follows the characteristic continuously, at a rate determined by the RC time constant. This sort of oscillator gives a sawtooth waveform on the emitter and base and a pulse on the collector.

These basic negative resistance circuits just described are building blocks which can be adopted to various applications, especially in the computer field. For example I have here a frequency divider using 5 stages of Sylvania Experimental Type GT-442 point contact transistors. See Fig. 13. The first stage is a crystal oscillator providing a clock frequency of 100 KC. The circuit is similar to that of Fig. 8 except that a 100 KC crystal is used in place of the series resonant circuit. This 100 KC signal synchronizes a 20 KC stable oscillator as in Fig. 12. This stage in turn synchronizes a 4 KC oscillator, etc. Thus a stable frequency division of 5 /stage is achieved. Total power consumption of this divider is less than 100 milliwatts. With proper care larger division ratios may be secured.

In conclusion we can say that while point contact transistors can be used successfully in many c.w. applications, they are especially useful in switching circuit applications. It would appear that junction transistors might prove better for c.w. applications. Perhaps we can talk about them some other time.

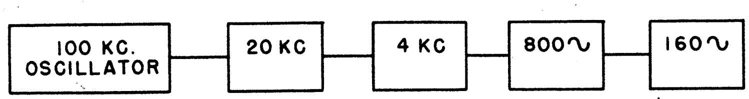


Fig. 13

SPECIAL RADIO CLUB
PUBLICATIONS TILL AVAILABLE

"The Story of The First
Trans-Atlantic Short Wave Message"
(1BCG Commemorative Issue)

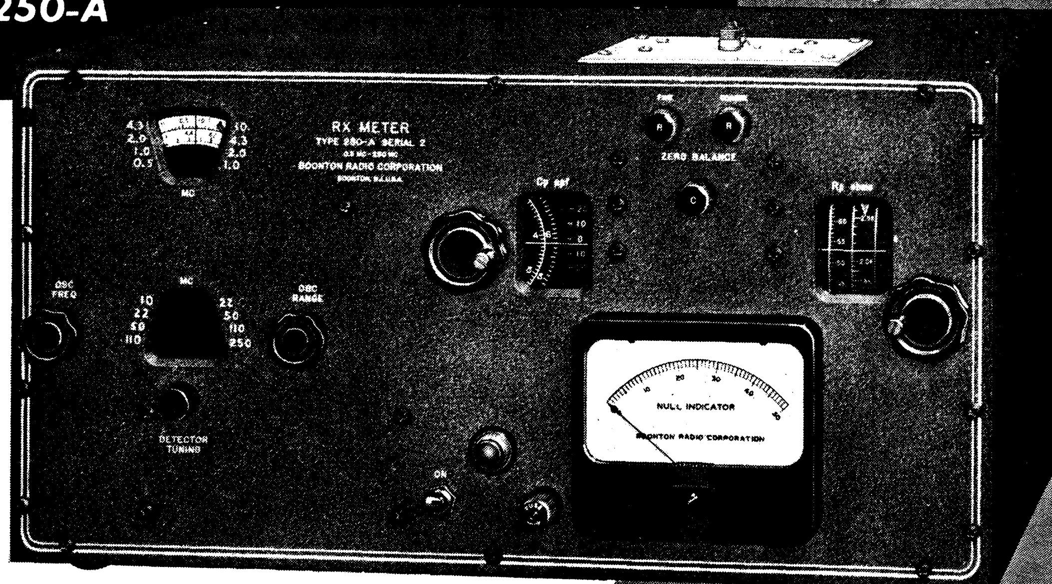
"Survey of Radio-Frequency
Transmission Lines and Wave Guides"
$1.00 per copy each
Write or call Radio Club office

NOTICE TO ALL MEMBERS

Please fill out and return the "YEARBOOK" questionnaire as soon as possible. If you have mislaid it or did not receive a questionnaire, secure another form from the Club office. Your cooperation will help make the "YEARBOOK" a success.

NEW RX METER.....

TYPE 250-A



FREQUENCY RANGE: 0.5 mc to 250 mc

The 250-A RX Meter is a completely self-contained instrument for use in measuring the equivalent parallel resistance and capacitance or inductance of two terminal networks over a wide frequency range. It includes an accurate continuously tuned oscillator, high frequency bridge, "unbalance" detector and null indicator.

All variable components of the bridge are high quality capacitors, which are driven by carefully designed anti-backlash gear trains. The Capacitance indicating dial can be read to 0.05 mmf, and the Resistance indicating scale is expanded to cover 28 inches in length. No corrections are required over the frequency range for the Resistance readings.

USES

The 250-A RX Meter can be used to measure the equivalent parallel resistance and capacitance of resistors at high frequency. If the reactance is inductive the value can be determined. By very simple formulas the equivalent series parameters can be deduced. The instrument will also measure components which are primarily inductive or capacitive. The characteristic impedance, attenuation and velocity of propagation of transmission lines can be determined.

Specifications

FREQUENCY: 0.5 mc to 250 mc in eight ranges.
Rp RESISTANCE RANGE: 15 to 100,000 ohms.
Cp CAPACITANCE RANGE: +20 μμf to—100 μμf.*

*Capacitance range may be increased to ±120 μμf by use of external coils or condensers.

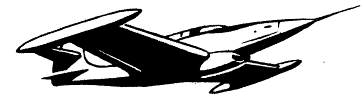
Price: $1250.00 F.O.B. Boonton, N. J.

FEATURES

- Measures equivalent parallel resistance and capacitance or inductance of two terminal networks.
- Operates over a Wide Frequency Range.
- Includes self-contained oscillator, bridge, detector and null indicator.
- Null Indicating Meter has automatic gain control which maintains on scale readings under all conditions to avoid meter damage and permit indication of proper direction of adjustment for reaching bridge balance.
- Wide spread resistance dial scale covering total of 28 inches.
- Power Supply internally regulated.

BOONTON RADIO Corporation
BOONTON · N · J · U · S · A ·

AIRCRAFT
RADIO
CORPORATION



TYPE H-16

STANDARD COURSE CHECKER

FOR VOR (OMNIRANGE) MODULATION

Purpose of the Instrument

To provide a means for precisely checking the phase-accuracy of the modulation on VOR (Omnirange) Signal Generators.

Features a Built-in Self-Checking Circuit

Background

A great deal of work on omnirange receivers and signal generators has been done since 1946, but it now becomes necessary to have a device for general use which will check the accuracy of the phase relationship in the VOR modulation; in particular, a means for measuring the phase differences between the 30 cps envelope of the 9960 $\pm$ 480 cps reference modulation and of the 30 cps variable modulation. Such a measurement has of course been necessary since the start of work on the omnirange, but the amount of equipment and the difficulty of measurements have been great. The H-16

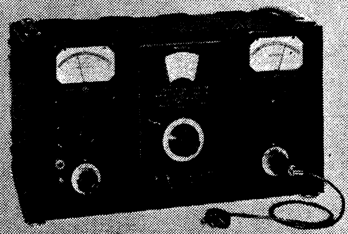
IN EVERY FIELD

There is a Leader!

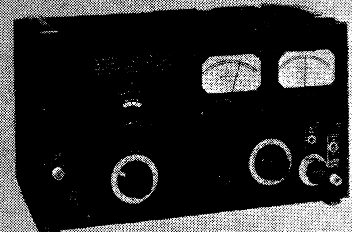
—and following every leader are those who would rather copy than create!

Substitutes are not acceptable where precision instruments are required, that is why engineers the world-over specify the MEASUREMENTS' line. They know that—

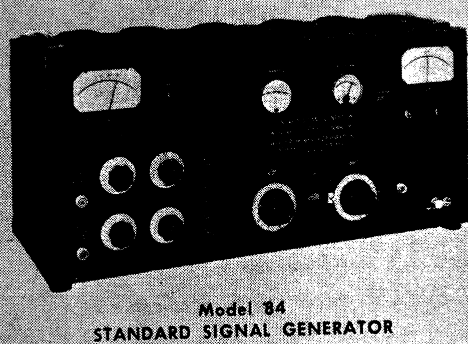
STANDARDS ARE ONLY AS RELIABLE AS THE REPUTATION OF THEIR MAKER



Model 65-B
STANDARD SIGNAL GENERATOR



Model 80
STANDARD SIGNAL GENERATOR



Model 84
STANDARD SIGNAL GENERATOR

MEASUREMENTS "FAMOUS FIRSTS" in *Laboratory Standards*

1939 MODEL 54 STANDARD SIGNAL GENERATOR—Frequency range of 100 Kc. to 20 Mc. The first commercial signal generator with built-in tuning motor.
MODEL 65-B STANDARD SIGNAL GENERATOR—This instrument replaced the Model 54 and incorporated many new features including an extended frequency range of 75 Kc. to 30 Mc.

1940 MODEL 58 UHF RADIO NOISE & FIELD STRENGTH METER—With a frequency coverage from 15 Mc. to 150 Mc. This instrument filled a long wanted need for a field strength meter usable above 20 Mc.
MODEL 79-B PULSE GENERATOR—The first commercially-built pulse generator.

1941 MODEL 75 STANDARD SIGNAL GENERATOR—The first generator to meet the need for an instrument covering the I.F. and carrier ranges of high frequency receivers. Frequency range, 50 Mc. to 400 Mc.

1942 SPECIALIZED TEST EQUIPMENT FOR THE ARMED SERVICES.

1943 MODEL 84 STANDARD SIGNAL GENERATOR—A precision instrument in the frequency range from 300 Mc. to 1000 Mc. The first UHF signal generator to include a self-contained pulse modulator.

1944 MODEL 80 STANDARD SIGNAL GENERATOR—With an output metering system that was an innovation in the field of measuring equipment. This signal generator, with a frequency range of 2 Mc. to 400 Mc. replaced the Model 75 and has become a standard test instrument for many manufacturers of electronic equipment.

1945 MODEL 78-FM STANDARD SIGNAL GENERATOR—The first instrument to meet the demand for a moderately priced frequency modulated signal generator to cover the range of 86 Mc. to 108 Mc.

1946 MODEL 67 PEAK VOLTMETER—The first electronic peak voltmeter to be produced commercially. This new voltmeter overcame the limitations of copper oxide meters and electronic voltmeters of the r.m.s. type.

1947 MODEL 90 TELEVISION SIGNAL GENERATOR—The first commercial wide-band, wide-range standard signal generator ever developed to meet the most exacting standards required for high definition television use.

1948 MODEL 59 MEGACYCLE METER—The familiar grid-dip meter, but its new design, wide frequency coverage of 2.2 Mc. to 400 Mc. and many other important features make it the first commercial instrument of its type to be suitable for laboratory use.

1949 MODEL 82 STANDARD SIGNAL GENERATOR—Providing the extremely wide frequency coverage of 20 cycles to 50 megacycles. An improved mutual inductance type attenuator used in conjunction with the 80 Kc. to 50 Mc. oscillator is one of the many new features.
MODEL 112 U.H.F. OSCILLATOR—Designed for the many applications in ultra-high frequency engineering that require a signal source having a high degree of frequency accuracy and stability. Range: 300 Mc. to 1000 Mc.

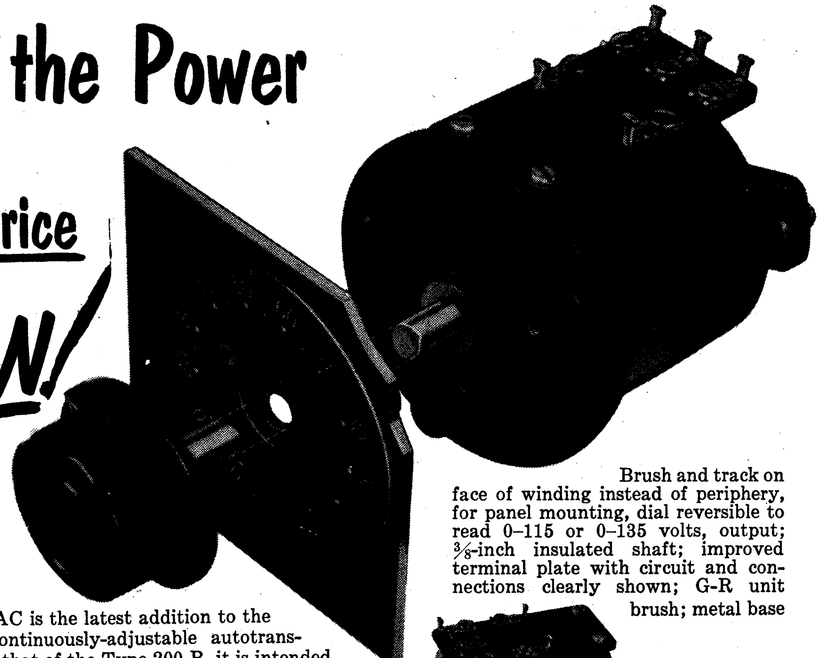
1950 MODEL 111 CRYSTAL CALIBRATOR—A calibrator that not only provides a test signal of crystal-controlled frequency but also has a self-contained receiver of 2 microwatts sensitivity.

1951 MODEL 31 INTERMODULATION METER—With completely self-contained test signal generator, analyzer, voltmeter and power supply. Model 31 aids in obtaining peak performance from audio systems, AM and FM receivers and transmitters.

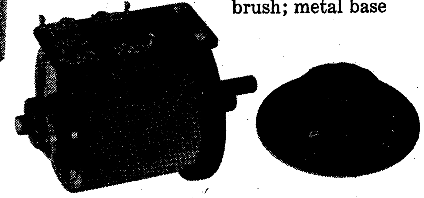
1952 MODEL 84 TV STANDARD SIGNAL GENERATOR—With a frequency range of 300-1000 Mc., this versatile new instrument is the first of its kind designed for the UHF television field.

MEASUREMENTS CORPORATION
BOONTON • NEW JERSEY

Twice the Power for the Same Price with the *NEW* type V-2 Variac



Brush and track on face of winding instead of periphery, for panel mounting, dial reversible to read 0–115 or 0–135 volts, output; 3/8-inch insulated shaft; improved terminal plate with circuit and connections clearly shown; G-R unit brush; metal base

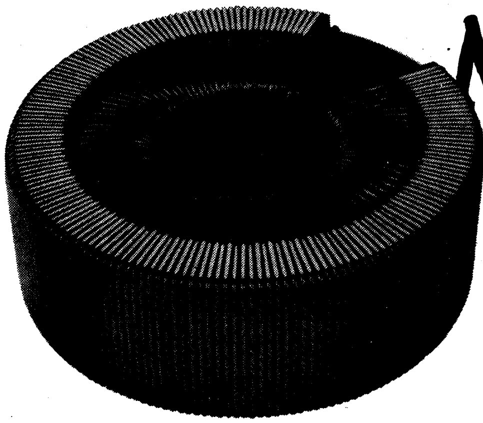


The *new* Type V-2 VARIAC is the latest addition to the popular "V" series of VARIAC continuously-adjustable autotransformers. With a power rating of *twice* that of the Type 200-B, it is intended eventually to supplant the latter.

The Type V-2 represents a considerable improvement over the 200-B, making it even more adaptable to a wide variety of applications where a relatively low-power, moderately-priced, a-c voltage control with all of the latest exclusive VARIAC features is needed. Its electrical and mechanical features include:

- ★ New DURATRAK brush-track coating
- ★ Load rating of 0.345 kva (instead of 0.17 kva)
- ★ Output voltages continuously adjustable from 0 to 135 v, or 0 to 115 v.
- ★ Line frequency 50 to 60 cycles; no load loss at 60 c.: less than 3.5 watts
- ★ Standard mounting holes (interchangeable with Type 200-B)
- ★ Considerably less panel space
- ★ Metal Base for improved cooling and added strength
- ★ More rugged stops
- ★ G-R Unit Brush construction
- ★ Terminal board with circuit and connections clearly shown
- ★ Molded knob-pointer and reversible dial plate for panel installation
- ★ Meets applicable requirements of Military Specification for Transformers: MIL-T-27
- ★ **Moderate Price: $12.50**

NOW ALL "V" TYPE VARIACS HAVE *New* Duratrak CONSTRUCTION for Increased Performance Even Longer Life



The new DURATRAK coating is one of the most important improvements in VARIACS; another step in the continuing process of development which makes the VARIAC the best voltage control available

The new DURATRAK brush-track coating eliminates all brush track oxidization problems which formerly might become critical under severe conditions of operation.

DURATRAK construction adds these features to increase the utility of VARIACS:

Long Life — *insures a life as long as that of fixed-ratio power transformers operated at rated loads*

Unaffected By Surges — *VARIACS with DURATRAK will withstand initial surges as high as ten times rated current*

Minimum Maintenance — *the brush track will not deteriorate under normal operation — only maintenance needed is occasional wiping of track with alcohol-moistened rag*

Write for the NEW VARIAC BULLETIN for Complete Specifications

GENERAL RADIO Company

275 Massachusetts Avenue, Cambridge 39, Massachusetts, U. S. A.

90 West St. NEW YORK 6 · 920 S. Michigan Ave. CHICAGO 5 · 1000 N. Seward St. LOS ANGELES 38

Admittance Meters ☆ Coaxial Elements ☆ Decade Capacitors ☆ Decade Inductors ☆ Decade Resistors ☆ Distortion Meters ☆ Frequency Meters ☆ Frequency Standards ☆ Geiger Counters ☆ Impedance Bridges ☆ Modulation Meters ☆ Oscillators ☆ Variacs ☆ Light Meters ☆ Megohmmeters ☆ Motor Controls ☆ Noise Meters ☆ Null Detectors ☆ Precision Capacitors ☆ Pulse Generators ☆ Signal Generators ☆ Vibration Meters ☆ Stroboscopes ☆ Wave Filters ☆ U-H-F Measuring Equipment ☆ V-T Voltmeters ☆ Wave Analyzers ☆ Polariscopes