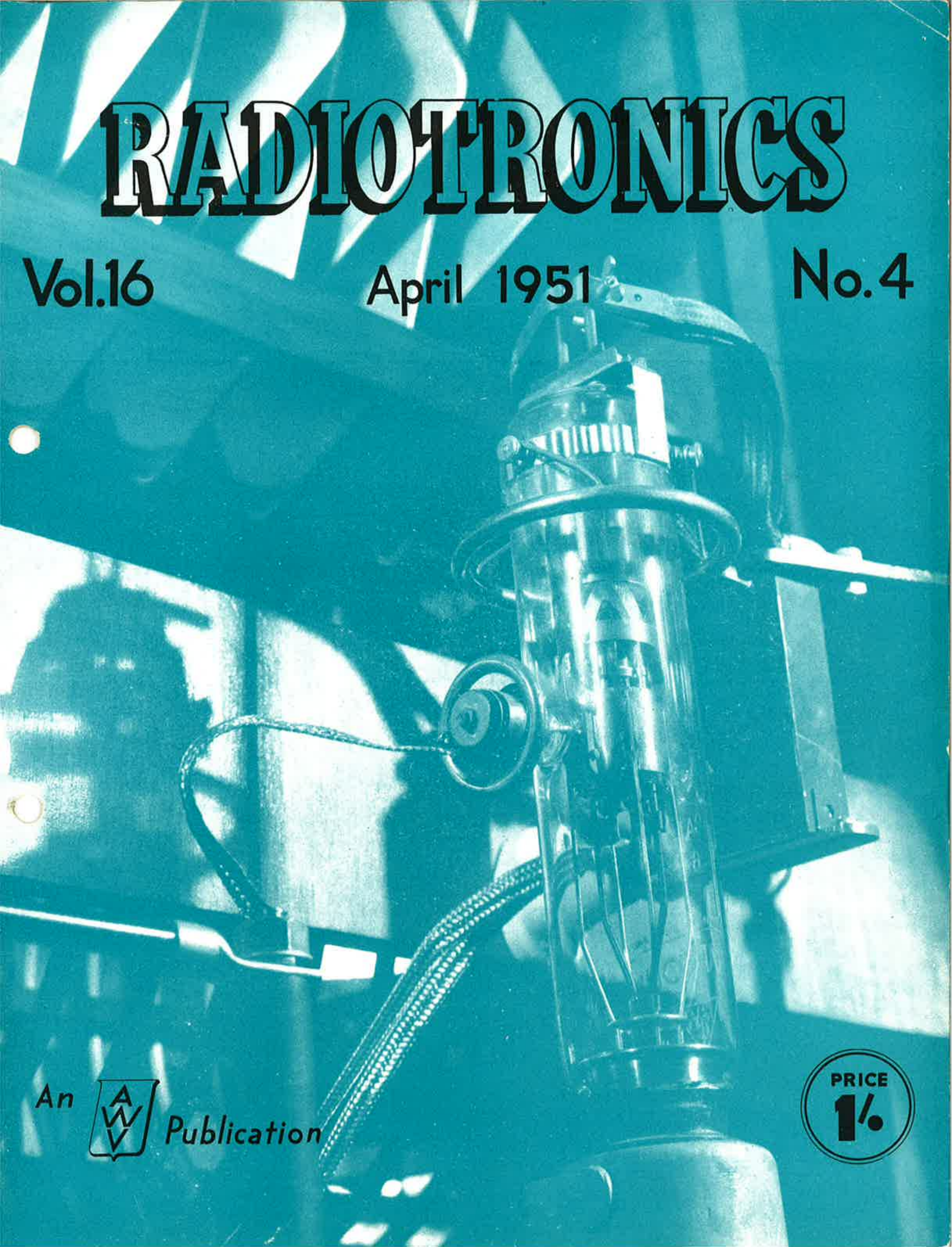
RADIOTRONICS

Vol.16 April 1951 No.4



An AWV Publication

PRICE 1/-

RADIOTRONICS

Volume 16 **April, 1951** **Number 4**

By the way—

The front cover this month shows a large transmitting valve on test after reconditioning.

We are pleased to announce the recent appointment of Mr. Doug. Sutherland to the position of A.W.V. Works Manager.

We wish to complete our Head Office file of Proc. I.R.E. (U.S.A.). Copies required are June, July, August, September, 1942. If any readers can let us have one or more of these issues, we would be pleased to purchase them.

Similarly we would like to obtain some early issues of Radiotronics for binding purpose; numbers 52, 55, 57, 58, 62, 69 and 76. Can any long-term subscriber help us, please?

New RCA releases published from time to time in Radiotronics are intended for information only on valves released in U.S.A. Unless specifically stated otherwise, no stocks of these particular valves are, or will be, held in Australia.

Subscribers are asked to check their address as stencilled on the Radiotronics envelope and advise us immediately if found incorrect. Changes of address should also be advised promptly.

Should a subscriber fail to receive an issue for any reason, this should be brought to our notice as soon as possible. Due to the limited printing of each issue, supplies of back numbers cannot be guaranteed more than a few months after publication.

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CONTENTS

Radiotronics is published twelve times a year by Amalgamated Wireless Valve Company Pty. Ltd. The annual subscription rate in Australasia is 10/-; in U.S.A. and dollar countries $1.25; and in all other countries 11/-. Price of a single copy 1/-.

Address all communications as follows:—

in Australia to:
Amalgamated Wireless Valve Co. Pty. Ltd.,
Technical Publications Department,
G.P.O. Box 2516,
Sydney.

in New Zealand to:
Amalgamated Wireless (Australasia) Ltd.,
P.O. Box 830,
Wellington, CI. N Z-

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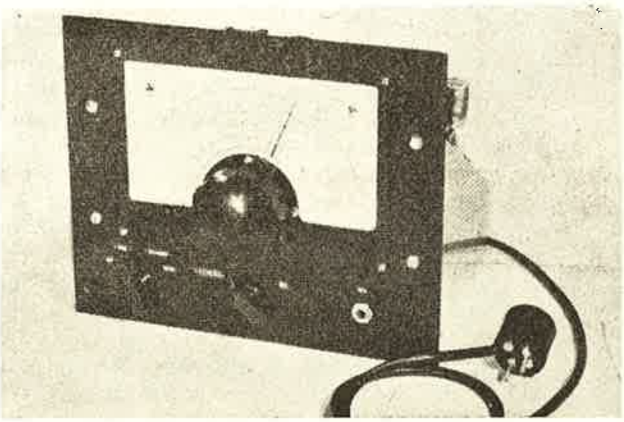
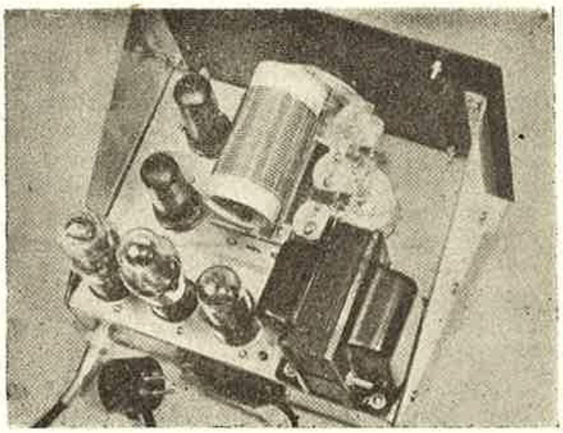
Stable Self-contained All-Band VFO

By Andrew Rau, Jr. — RCA Tube Department



Completely self-contained, this efficient looking VFO has its own power supply, provision for oscillator keying, band spread on the higher-frequency bands, control circuits for both receiver and transmitter, and coupling by coaxial cable to the transmitter crystal socket.

Well planned design of the VFO provides ample space for mounting components. Band-spread and padder capacitors are fixed to a 4-inch strip of polystyrene shown in centre of photograph.



Even a confirmed proponent of crystal-controlled operation will concede that under present-day crowded band conditions, a really stable variable-frequency oscillator is indispensable. The completely self-contained VFO described in this article includes a regulated power supply, provision for oscillator keying, band spread on the higher-frequency bands, control circuits for the receiver and transmitter, and coupling by means of coaxial cable to the crystal socket of the transmitter. This method of coupling permits locating the high-power r-f section away from the operating position.

A really satisfactory VFO has two basic requirements. The first of these requirements is relative freedom from drift or instability, and the second is the ability to key without chirps or other transient effects. A careful choice of components with due consideration to layout, along with a "workmanlike" mechanical job will go a long way toward meeting the first requirement. The recently publicized Clapp circuit[1] will assist in satisfying the second requirement.

Reprinted from Ham Tips by courtesy of Radio Corporation of America.

(1) J. K. Clapp, "An Inductance-Capacity Oscillator of Unusual Frequency Stability," Proc. I.R.E., March, 1948. "Technical Topics," May and Oct., 1948 QST. Nicholas Lefor, "The 'Topics' VFO," Aug., 1948 QST.

Frequency drift considerations

In addition to the effects of component choice, layout, and workmanship, the most troublesome factors contributing to the instability of a self-excited oscillator are the effects of humidity, temperature, and changes in operating conditions such as voltages, currents, etc. The effect of humidity can be minimized by the use of high-quality components of ceramic or other low-loss material in the r-f portions of the circuit. The effects of temperature are most satisfactorily minimized through the use of a frequency-determining coil wound on a ceramic form large enough to give a high "Q" but which will undergo little change of inductance with temperature. In addition, the main tuning capacitor should be of sturdy construction with small plates well spaced in a frame with ceramic end plates and with two bearings. All other capacitors should be silver mica or ceramic types with a low temperature co-efficient.

Because fundamentally it is desirable to obtain maximum "Q" in the oscillator tank circuit, it is important to make all r-f connections in this circuit as short and direct as possible. Moreover, it is undesirable to depend on a steel chassis to conduct r-f tank currents because the high r-f resistance of the chassis will cause a substantial reduction in "Q".

A large portion of the drift due to temperature changes results from expansion, twisting, and warping of the chassis and panel. The heavier the chassis and panel are, however, and the more substantially they are fastened together, the less the frequency drift will be. To appreciate fully the order of stability required, it should be remembered that a shift of only 500 cycles will be 4000 cycles when multiplying from the 3.5 Mc/s band to 28 Mc/s. Also, it is not uncommon for receiver oscillators, particularly of the broadcast variety, to drift as much as several thousand cycles.

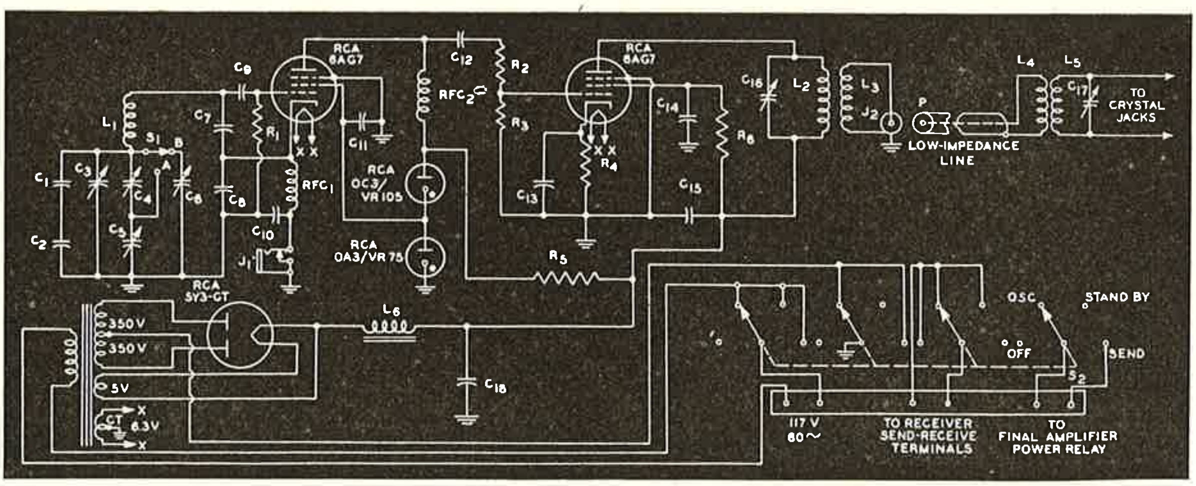
Frequency drift due to changes in operating conditions is minimized by using a well-regulated power supply.

Circuit details

Excellent descriptions of the Clapp oscillator circuit are given in the references and need not be repeated here. The frequency-determining circuit consists of L_1, C_7, C_8, and the series-parallel combination of C_1 to C_6, all in series. Because the capacitive reactance of C_1 to C_6 cancels a portion of the inductive reactance of L_1, a relatively large inductance may be used. This large inductance, plus the fact that the 6AG7 grid No. 1 is effectively tapped across only a portion of the tank circuit, provides a circuit with extremely high "Q". When the 6AG7 is connected as an electron-coupled oscillator, it is possible to use a considerably larger coil for L_1 with a further reduction in the effects of voltage and valve changes on frequency stability. However, if such a circuit is used, the actual tuning capacitance becomes smaller and the effects of temperature and mechanical changes in the chassis and tank circuit are much greater.

Switch S_1 is used in one position (A) for the 3.5 Mc/s band. In the other position (B) the higher-frequency bands are spread out when multiplying in later stages to 7 Mc/s and higher. C_5 is the main tuning capacitor while C_4 and C_6 are the band-spread padders. Considerably greater band spread could be obtained if the 11-metre band were not included. C_3 is the 3.5 Mc/s bandset capacitor. C_1 and C_2 compensate to some degree for changes in temperature. The oscillator operates with a screen current of about 1.5 mA at 75 volts and a plate current of only 5 mA at 180 volts. Keying of the cathode circuit causes no perceptible change in frequency, and no chirp nor other transient.

The 6AG7 was selected as a class A buffer because, due to its high transconductance, it is capable of about 3 watts output with negligible grid power or voltage requirements. Across a 10,000-ohm load, about 70 volts are developed at the output connections of this circuit. This voltage is more than sufficient to drive the regular crystal stage of a transmitter.



Schematic of variable frequency oscillator.

The buffer amplifier plate and screen currents total about 20 mA with the plate operating at 250 volts. A low-value coupling capacitor (C_{12}) plus the use of dropping resistor R_2 prevents the following stages from affecting the oscillator frequency. In fact, the frequency shift, from full load to no load (complete disconnection of the coaxial output lead) is only one or two cycles. The output circuit, L_2 link-coupled through a coaxial feeder to L_4, is low in capacitance and gives nearly uniform output over the entire 3.5 Mc/s band when C_{16} and C_{17} are stagger tuned.

The voltage-regulator valves largely eliminate the effect of variations in line voltage. A decrease of 20 volts in line voltage causes less than a 10-cycle shift in frequency. The power supply, conventional in design, has a total drain in the order of 50 mA. Because it is often desirable to provide complete control of the rig from the VFO unit, switch S_2 was added to provide switching circuits for the receiver and the power relay of the transmitter final. The standby position of the switch permits checking the oscillator frequency before the final is in operation.

Construction details

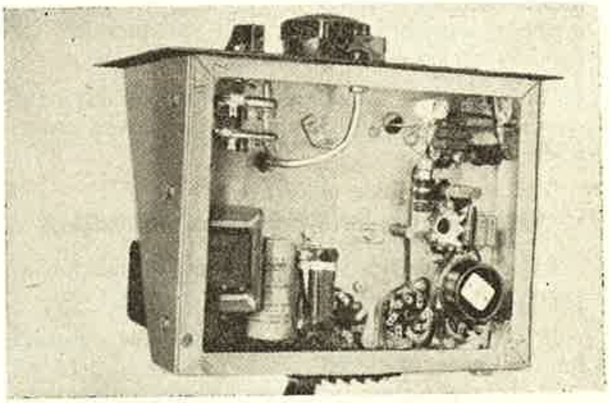
Ample room is provided by a 7″ × 9″ × 2″ chassis, preferably of aluminium, with welded or reinforced corners. If an 8″ × 10″ panel is used, the VFO will fit several types of small standard cabinets. Home-made side brackets of aluminium rigidly tie the panel and chassis together and, to a large degree, prevent warping and twisting. A "U"-shaped aluminium bracket supports the main tuning capacitor at the front and rear more rigidly than the brackets supplied with the capacitor. In addition, the aluminium bracket provides a support for the coil clear of the chassis and panel thereby reducing the effect of temperature changes. The band-spread and padder capacitors are mounted on a 4-inch strip of polystyrene attached to the side of this bracket. (See photograph).

Switch S_1 is mounted face down with the shaft extending through a hole in the top of the chassis. It is controlled from the front panel by means of a flexible shaft. The power supply components are mounted along the rear of the chassis with the filter choke on the underside. The 6AG7 oscillator is directly behind the panel. The two 6AG7 valve sockets are oriented for the shortest possible connections. Except for the usual considerations of providing good mechanical rigidity, short leads, and bringing the r-f returns for each stage to a common point, the wiring is simple and not critical. No trouble should be experienced with self oscillation.

L_2 is wound on a medium-sized octal valve base from which the pins have been removed. The valve base is then fastened to the chassis by means of a screw through the bakelite positioning plug. Capacitor C_{16} is mounted inside the coil. A three-turn link (L_3) wound on L_2 at the low-voltage end is connected to receptacle J_2.

A low-impedance transmission line of any reasonable length connects the output jack to L_5 and L_4. Because high "Q" was not particularly desired for L_4, it was random wound on a form together with L_5, its three-turn link, and inserted in a four-pin valve base with the pin spacing altered to fit the standard crystal pin spacing. If room permits, however, the use of a suitable plug-in type coil form will simplify the construction.

The frequency drift, even without temperature compensation, will not be excessive. Some adjustment of the degree of compensation, however, may be desirable and can be easily accomplished by changing the value of capacitor C_1. Any check of the keying characteristics should include listening on one of the higher-frequency bands because any defects will be considerably accentuated by frequency multiplication.



Aside from the usual considerations of providing mechanical rigidity, short leads, and bringing r-f returns for each stage to a common point, the wiring of the VFO is simple and not critical.

PARTS LIST

C1	15 μμF, zero temp. coefficient.
C2	100 μμF, negative temp. coefficient.
C3	6-75 μμF.
C4	7-100 μμF.
C5	10-75 μμF.
C6	5-50 μμF.
C7, C8	0.001 μF, silver mica.
C9	100 μμF, silver mica.
C10, C11,	0.005 μF, mica.
C13, C14, C15, C12	15 μμF, silver mica.
C16, C17	3-30 μμF, mica.
C18	20 μF, 450 working volts, electrolytic.
R1, R3	100,000 ohms, ½ watt.
R2	27,000 ohms, ½ watt.
R4	100 ohms, ½ watt.
R5	2,000 ohms, 10 watts.
R6	15,000 ohms, 1 watt.

(Continued on page 83)

An Intermodulation Analyzer For Audio Systems

By Roy S. Fine — Radio Corporation of America, Camden.

The intermodulation distortion method of evaluating the quality of amplifiers, loudspeakers, and phonograph pickups is coming into increasing use. The analysis with respect to pickups is the immediate interest of this paper, although the equipment described herein can be used for intermodulation measurements on all audio systems. The design of this analyzer is the culmination of several years' work on the problem of correctly metering intermodulation distortion, and it is felt that the methods described are a good compromise for basically accurate measurements.

Let us look at Amplitude Modulation. Figure 1 represents an amplitude modulated carrier wave where

A = amplitude of carrier.
a = amplitude of maximum modulation.

By definition, the percentage of modulation is (a/A) 100.

If two modulating tones are used, the equation for the carrier wave is:

$$(A + a_1 \sin \omega_1 t + a_2 \sin \omega_2 t) \sin \omega t$$

where A = amplitude of carrier.
a_1 = amplitude of one signal.
a_2 = amplitude of other signal.
ω_1 = frequency of 1st signal.
ω_2 = frequency of 2nd signal.

$$\text{percent modulation} = \frac{a_1 + a_2}{A} \, 100.$$

The carrier and side frequencies are shown by Fig. 2.

If a low- and high-frequency signal are passed through a nonlinear system, the low frequency and its harmonics will modulate the high frequency and its harmonics, giving rise to sum and difference frequencies about the higher frequency. In a nonlinear system let:

Input $= a_1 \sin \omega_1 t + a_2 \sin \omega_2 t$

where ω_1 = low frequency.
ω_2 = high frequency.
a_1 = amplitude of low frequency.
a_2 = amplitude of high frequency.

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The output of this system will be:

Output =

$$A_o + \sum_{r=0}^{\infty} \sum_{s=-\infty}^{\infty} A_{r,s} \sin (r\omega_1 + s\omega_2)t$$

where A_o = amplitude of combination frequencies (intermodulation products).

$A_{r,s}$ = integers.

r & s = d.c. component of the output.

The frequencies of greatest interest, as shown in Fig. 3, are:

$\omega_2 \pm \omega_1$ whose amplitudes are $A_{1,1}$, $A_{1,-1}$
$\omega_2 \pm 2\omega_1$ whose amplitudes are $A_{2,1}$, $A_{2,-1}$
$\omega_2 \pm 3\omega_1$ whose amplitudes are $A_{3,1}$, $A_{3,-1}$

When the modulation products come into phase, they will add arithmetically.

Intermodulation distortion is defined in this analysis as the arithmetic sum of the amplitudes of the "in phase" modulation products divided by the amplitude of the high-frequency carrier. Therefore: Per cent. Intermodulation =

$$\frac{A_{1,1} + A_{1,-1} + A_{2,1} + A_{2,-1} + \ldots}{A_{1,o}} \, 100$$

In order to measure the sum of these voltages accurately, it is necessary to use a peak-reading voltmeter. This type will measure the arithmetic sum of the amplitudes of the modulation products involved with no discrimination against the weaker of these modulation products. This is an advantage over the root-mean-square or average-reading type of voltmeter, since all frequencies are given equal attention.

According to the above definition of per cent. intermodulation, a root-mean-square voltmeter will not give the proper reading when two or more modulation products are present simultaneously, since its indication depends on the square root of the sum of the squares rather than the arithmetic sum of the amplitudes. The distortion readings utilizing a peak-reading voltmeter are therefore more critical and will present a larger "Per cent. Intermodulation" figure than will a root-mean-square indicator.

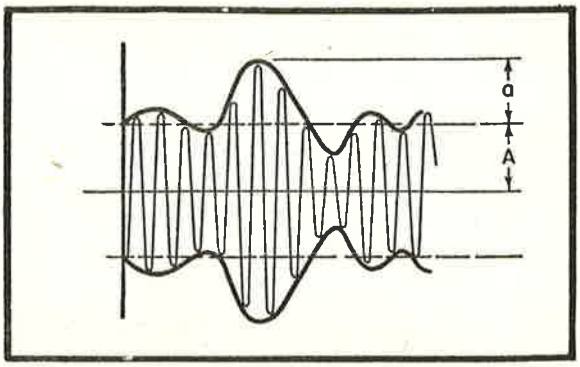


Fig. 1. Waveform of amplitude modulated carrier.

Intermodulation analyzer

The analyzer to be described is for use primarily with frequencies of 400 and 4000 c/s, although it will accommodate frequencies differing slightly from these, since the filters are flat over a considerable range. These particular frequencies were chosen for a number of reasons, the primary consideration being that almost all amplifiers, loudspeakers, and pickups have response in this range. If the equipment utilized a high frequency of 7000 c/s, for instance, it could not be used on a 5000 c/s amplifier or a loudspeaker with a sharp cutoff below 7000 c/s. If also the low frequency were 100 c/s, for instance, a 4- or 5-inch loudspeaker could not be checked. Also, these frequencies are usually between the resonant peaks in pickups and are located in the range of high energy. These conditions, together with the fact that wide variations in results are not obtained when higher or lower frequencies are used, have led us to this choice of frequencies.

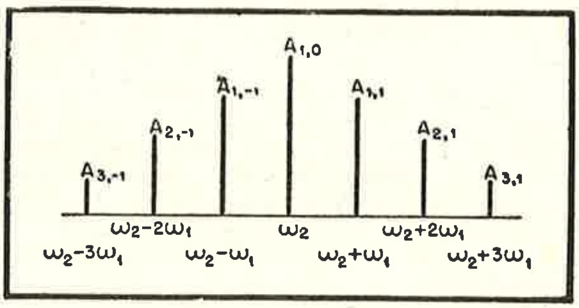


Fig. 3. Amplitudes of carrier and modulation products.

It has been found that almost 100 per cent. correlation exists between intermodulation measurements and listening tests. This is quite noticeable in the case of pickups.

The analyzer consists of a number of circuits, as can be seen from the block diagram of Fig. 4 and the circuit diagram of Fig. 5. Typical waveforms at each section are also noted.

Preamplifier and high-pass filters

The preamplifier serves two purposes: to present a high-impedance input and to make possible the measurement of small voltages without the use of external equipment. There are two voltage amplification stages (6BF6's) and one cathode-follower stage (6AQ5's) matching the input impedance of the high-pass filter. A switch selects the cathode-follower stage with an option of one or both of the preceding amplifiers in addition. Since this is a high-gain circuit, care must be taken to ground the grid of the amplifier stages when not in use as well as to provide adequate shielding of leads.

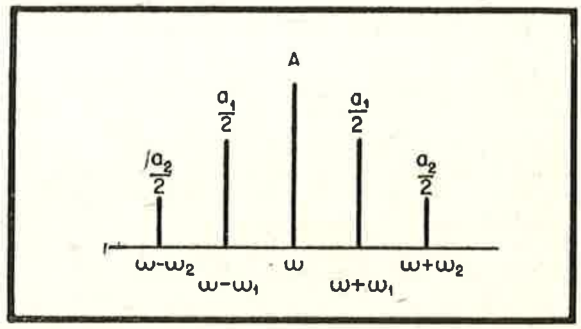


Fig. 2. Signal amplitudes of amplitude modulated carrier.

In order to keep distortion of this preamplifier at a minimum, it is necessary to use a parallel combination of tubes in the cathode follower.

The high-pass filter (Curve A in Fig. 6) is necessary to remove the original 400 c/s. This filter must be capable of passing the 4000 c/s signal plus sum and difference frequencies arising from the 400 c/s modulation, i.e., 3200, 3600, 4400, and 4800 c/s with sharp rejection of the original 400 c/s.

The transformer terminating the high-pass filter is an interstage transformer with an impedance ratio of 500 ohms to 30,000 ohms. The frequency response necessary, of course, is determined by the filter but a standard commercial unit such as a UTC LS-51 should suffice. The transformer feeding the rectifier is an interstage transformer with a primary impedance of 15,000 ohms and a secondary impedance of 95,000 ohms C.T. A UTC LS-19 could be used in this case.

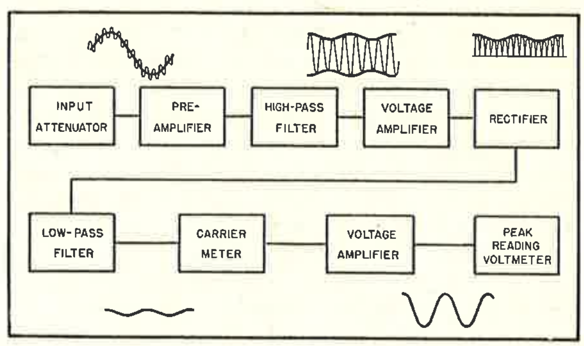
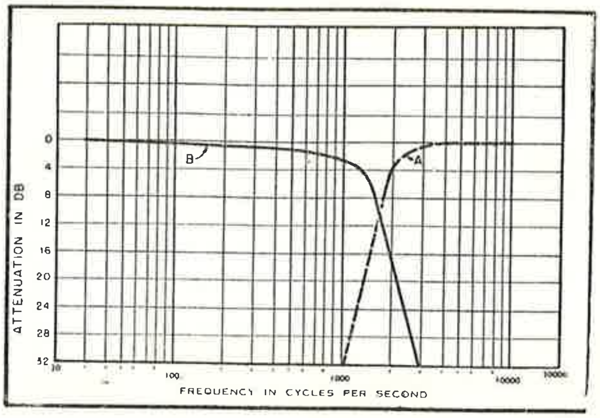


Fig. 4. Block diagram of intermodulation analyzer.

Fig. 6.

Response curves for two filters used in the analyzer.



(A) high-pass;

(B) low-pass.

Voltage amplifier and rectifier

The signal at this point is amplified and fed to a full-wave rectifier. This rectifier is conventional, but care must be taken in selecting the valve to insure maximum possible perveance.

The original carrier is then filtered out in the low-pass filter which must be capable of passing the intermodulation products (400 and 800 c/s) and sharply rejecting any carrier components (3200, 3600, 4000, 4400, and 4800 c/s), as shown by curve B in Fig. 6. The carrier meter, located at the output of the low-pass filter, gives a reading which is almost entirely dependent upon the level of the high-frequency signal introduced to the analyzer. The signal at this point contains only the intermodulation products generated in the equipment under test.

Voltage amplifier and peak-reading vacuum-tube voltmeter

At this point, the signal is amplified again and fed to a selector switch which, for purposes of reading intermodulation, inserts a voltage divider to provide two scales on the dial of the PER CENT. INTERMODULATION potentiometer. This potentiometer is in series with the selector switch and sets the signal level presented to the peak-reading voltmeter circuit. In this circuit the amplified a.c. modulation products are rectified by a 1N34 germanium crystal. The time constant of the *RC* combination in this circuit is such that the capacitor charges up to almost the peak value of the rectified voltage. This d.c. is impressed on the grid of the 6AU6 which in its static state is biased to a point where the valve draws maximum plate and screen current (about 6.0 mA). With an increase in the negative voltage on the control grid, the valve approaches cut-off and the meter reading decreases. The PER CENT. INTERMODULATION control determines the amount of this negative grid voltage. This control is calibrated in such a way that a certain predetermined fixed reading on the voltmeter (5 mA) indicates the magnitude of the intermodulation products as read on the potentiometer dial.

Calibration circuit

A calibration circuit is incorporated in the analyzer to determine the level of the incoming signal. In the CALIBRATE position of the selector switch, a pure 60 c/s signal is inserted at the rectifier. The rectified signal is measured by the CARRIER meter, amplified in a stage with adjustable "calibration gain", attenuated, and measured by the peak-reading voltmeter. The magnitude of the 60 c/s signal is adjusted at the source to give the desired level at the voltmeter (5.0 mA). When the 60 c/s signal is producing the 5 mA indication at the output, it is also producing an indication on the carrier meter (say 170 microamperes). At this point the selector switch is set to the 1-10% scale or the 3-30% scale, and the signal is applied to the input terminals and set by the input attenuator to give the same indication on the carrier meter. This assures that the filters, amplifiers, and rectifiers are running at the proper level. The PER CENT. INTERMODULATION control is adjusted to give a 5.0 mA indication on the output meter, and the dial setting of this control then is a measure of the intermodulation distortion products.

To aid in observing the various phenomena taking place in the analyzer, oscilloscope connections are made at certain strategic points. The first (labelled INPUT) permits observation of the input signal and is located just after the preamplifier; the second (labelled MODULATED CARRIER) shows the modulated carrier and follows the high-pass filter; and the third (labelled OUTPUT) shows the actual intermodulation products and is located at the peak-reading voltmeter. These patterns allow the user to observe visually the various phases of intermodulation analysis.

When using the analyzer, it will be found convenient to use a signal generator providing several high- and several low-frequency signals with provision for mixing any two high and low frequencies and controlling their amplitude individually. A simpler generator would be one supplying only 400 and 4000 c/s with the 400 c/s signal 12 db higher than the 4000 c/s signal.

It is advisable to use a regulated power supply (not shown) to fulfil the requirements of the analyzer. This prevents sudden changes in calibration, as well as maintaining stability in the equipment.

Use of equipment

When the equipment is used to make intermodulation measurements on amplifiers, the procedure is similar to that of making distortion measurements with other types of analyzers. The mixed output of the signal generator is impressed on the input terminals of the apparatus under test. The output signal from the apparatus is then measured with the intermodulation analyzer.

radius of either .001 or .003 in. RL-419 must be used only with a stylus radius of .001 in. The records are banded, each band containing a 400 c/s tone 12 db higher than the 4000 c/s tone. The amplitude of the first band is equivalent to that of the average level of an ordinary music record and is arbitrarily called 0 db level. The succeeding bands vary in steps of 2 db from + 10 db to – 6 db on RL-420 and from + 10 db to – 4 db on RL-419.

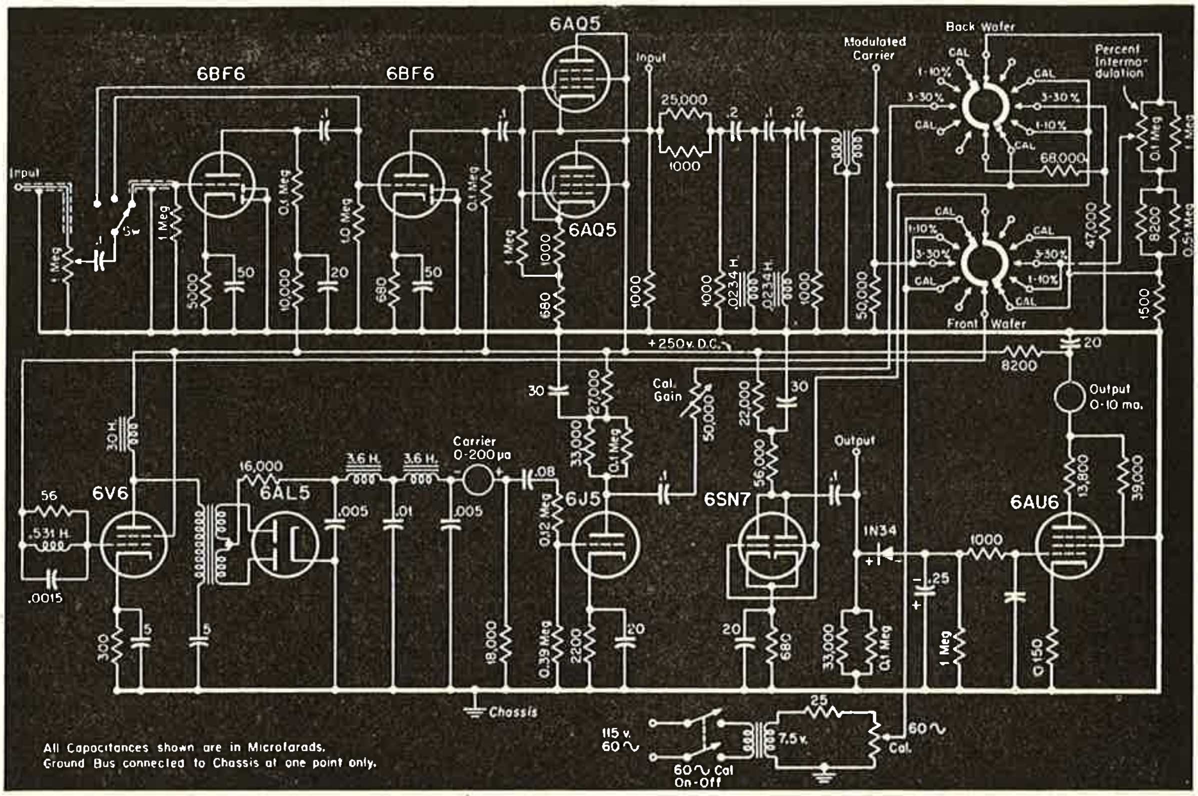


Fig. 5. Complete schematic of intermodulation analyzer described.

When testing loudspeakers, care must be taken to insure low distortion in all equipment associated with the test (power amplifier, microphone, microphone preamplifier, etc.). The intermodulation method is not generally accepted for testing loudspeakers, however, because of the limitation of available frequencies and the irregularity of sound pressure curves.

The equipment is especially useful in evaluating the tracking capabilities of phonograph pickups. It must be used in conjunction with records, and RCA records RL-419 and RL-420 are made for this purpose. They are 7-in. 45-rpm, and 12-in. 78-rpm discs respectively. RL-420 has grooves of such a shape that it can be used with a stylus having a tip

These records can be played by the pickup under test and the output of the pickup measured for intermodulation. The pickup should be connected directly to the input terminals of the analyzer in order to eliminate the effects of distortion in associated playback equipment. The analyzer will accommodate all present-day pickups in common use, i.e., crystal, ceramic, variable reluctance and other magnetic types, etc. In order to eliminate such effects as rumble and tone arm resonance, a high-grade turn-table and tone arm should be used, and the horizontal and vertical pivots of the tone arm should be as free moving as possible without being loose. Undue friction in these pivots will cause increased intermodulation readings.

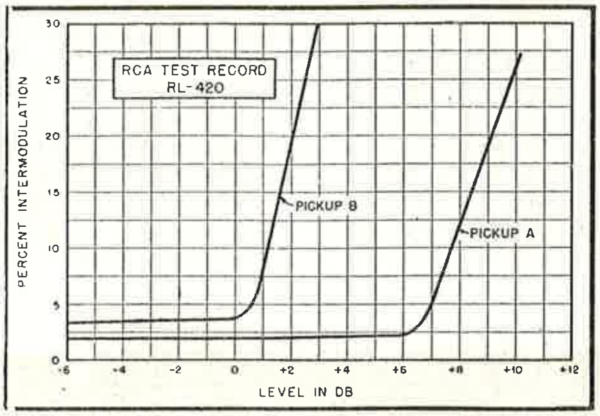


Fig. 7. Distortion curves for two well-known phonograph pickups.

To evaluate the tracking capabilities of a pickup by the intermodulation method, one must determine the band of the highest level that can be tracked with less than 10 per cent. intermodulation. If the level of this band is above the highest velocity reached on the equivalent music record, the pickup is said to track satisfactorily.

Of course, a pickup that tracks most of the record with low distortion (2-4 per cent.) is superior to one which reads about 7 to 9 per cent. over the same part of the record, although both are below the 10-per cent. mark.

Therefore, the relative degree of tracking capability can be determined by this test. Figure 7 shows intermodulation curves for two well-known modern pickups. Pickup A is one that is perfectly satisfactory and is found to track at the highest velocity reached on an ordinary music record. Pickup B presents high intermodulation distortion at all velocities above the average. This is characterized in listening tests by noticeable fuzziness of the high frequencies and generally irritating reproduction.

It will be noticed from the curves that the intermodulation rises sharply once it begins. This is evidently a characteristic of all pickups, so it is necessary to choose one that tracks well at all velocities up to the highest recorded on modern records.

Calibration

The accuracy of the instrument was checked by applying simulated intermodulation products, comprised of three high-frequency signals, to the analyzer. The amplitude of the frequency representing the carrier was made larger compared with the two representing intermodulation products, thus approaching actual operating condition. The amount of intermodulation was read on the dial of the analyzer, and the amplitude of these distortion products was also measured on a wave analyzer. The intermodulation percentage was calculated by adding the two low-amplitude signals arithmetically and dividing by the amplitude of the simulated carrier. The calculated intermodulation was compared with that read on the analyzer and the accuracy of the equipment evaluated. It was found that the average difference between calculated and measured intermodulation on this analyzer is below 1 per cent., and the maximum difference is 1.4 per cent.

Conclusions

It has been found that intermodulation testing equipment is coming into increasing use in evaluating the quality of amplifiers and phonograph pickups. The analyzer described in this paper is believed to be an entirely satisfactory equipment for performing the necessary tests. The circuits employed have been carefully worked out to give accurate as well as critical results, and the instrument is especially valuable in determining the tracking capabilities of pickups. At the present time it appears to be that there is complete correlation between the application of this test and listening tests.

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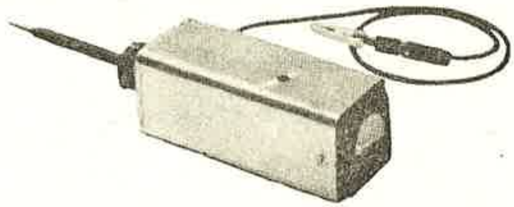
A Useful Volt-ohmmeter



Introduction

No ham shack is complete without a volt-ohmmeter of some sort. Their biggest use is in checking continuity, and reading a.c. and d.c. voltages. An instrument of this sort need not be elaborate, nor is extreme accuracy required.

Fig. 1 shows the circuit for a volt-ohmmeter which will measure 0-10, 0-100 and 0-1000 volts a.c. (switch 3, 2 and 1 respectively); 0-100 and 0-1000 volts d.c. (position 5 and 4) and 0-100,000 ohms (position 6). These ranges can be added to quite easily, as later data will show, but they represent ranges which are used most.

Practically any type of constructional arrangement can be followed, but little effort will produce a very handy device. Fig. 2 shows how the entire volt-ohmmeter may be placed in a shield can, a small $1\frac{1}{2}$ inch meter on one end and the probe and range switch on the other end. In use the device may be held in one hand much like a probe. The wire with the clip is the negative lead, with the probe proper being the positive lead.

Ohmmeter calculations

In deciding what resistance scale can be obtained, it is first necessary to determine how much battery voltage you wish to provide. This, together with the meter, determines the resistance scale. In the ohmmeter shown it was not practical to use more than three volts. Full scale on a one mil meter, with three volts in series, requires a series resistance of 3000 ohms. The ohmmeter will therefore read 3000 ohms at mid-scale. (Mid-scale reading is always the same as the total circuit resistance.)

This 3000 ohms series resistance is made up of the resistance of the meter (100 ohms), R_2 of 2000 ohms and 900 ohms in R_1. To calculate the resistance values indicated by various meter readings, use the formula

$$R = \frac{BR_s}{M} - R_s$$

where R is the resistance to be read, B is the battery voltage (3 volts in this case), R_s is the series resistance (3000 ohms) and M is the voltage read by the meter. This latter voltage is determined from the ratio of meter reading to battery voltage. Full scale is three volts, half-scale (0.5 mA) is 1.5 volts, etc.

Carrying these calculations through for this particular ohmmeter we find the following resistance readings for each 0.1 mA scale division starting from 1.0, 0.9, 0.8, etc.: 0, 333, 750, 1285, 2000, 3000, 4500, 7000, 12,000 and 27,000. The last value is for a meter reading of 0.1 mA. Inasmuch as 0.025 mA may be read, the highest value of resistance which may be read is 117,000 ohms. If desired, values may be calculated for each meter division, and a chart made up which may be pasted to the ohmmeter case.

To design an ohmmeter to read higher values of resistance, it would be necessary to use more batteries, and then calculate the series resistance by dividing the battery voltage in volts by the full-scale meter reading in amperes. The formula given above will then permit you to calculate the resistance range which can be covered.

Voltage calculations

D.C. voltage calculations are very simple. Start with the lowest range (0-100 in this case). The resistance to use in series with a 1mA meter to read 100 volts is merely the voltage divided by the current, or 100,000 ohms. The next scale of 0-1000 volts gives a resistance of 1 megohm. Since these two resistors are in series, the resistor for the 1000 volt range would be 1 megohm less 0.1 megohm, or 0.9 megohm. The resistance of the meter is so small that it may be neglected.

In designing a voltmeter to read above 1000 volts take care that adequate insulation is used with the leads, and also that not more than 1000 volts appears across any one resistor used as a multiplier.

The voltmeter shown has a sensitivity of 1000 ohms per volt on both d.c. ranges. A more sensitive voltmeter can be made only if a more sensitive meter, such as a microammeter, is employed.

For measurement of a.c. voltages, a rectifier is required. The rectifier shown in Fig. 1 consists of two germanium crystal diodes. One acts as the rectifier proper while the other passes current in the opposite direction on the other half-wave so that a high voltage is not built up across the first

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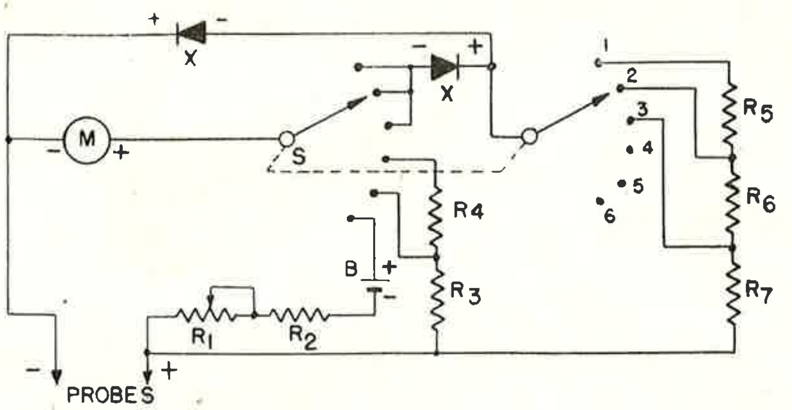

Fig. 1.

Circuit diagram of volt-ohmeter.

diode. The action is that of a half-wave rectifier. Because of this, and because the meter will read the average value of voltage, a multiplying factor of .45 must be used to calculate resistance.

In other words, if 10 volts is applied to the voltmeter circuit, the meter would only read 4.5 volts. In order to make the meter read full scale on 10 volts we therefore calculate on the basis of 4.5 volts. The series resistance to use is therefore 4.5 volts divided by 0.001 ampere or 4500 ohms. Similarly for 100 volts a total resistance of 45,000 ohms is required and for 1000 volts, .45 megohms is required.

Doing the proper subtraction, because the resistors are in series, shows us that we need 4500 ohms, 40,500 ohms and 405,500 ohms. The values need not be that exact, and those specified will be close enough.

Construction

The circuit of Fig. 1 may be used to build a volt-ohmmeter using any size meter in any style of box desirable. However, if a small meter is used a much handier device will result. The volt-ohmmeter pictured in Figs. 2 and 3 was built into a 2 × 2 × 4⅞ inch shield can. No special tools are required. Referring to Fig. 3, the meter fits into a piece of one-half inch thick bakelite. The bakelite is cut 2 inches square and the corners rounded with a file.

The inner case is made by bending a piece of $\frac{1}{32}$ inch aluminium to the shape shown. Before bending the piece is 1⅝ inch wide and 11¼ inches long. The two ends which meet on the bakelite piece are filed out to fit around the meter and the entire aluminium bracket is held to the bakelite piece by the meter mounting screws.

A square angle bracket is made to support R_1 and the two small batteries are held by another clamp made of aluminium. It is also necessary to drill a hole in the end of the inner case to support the rotary switch.

In order to bring the connection from the positive probe into the case it is necessary to drill a hole axially through the switch shaft. This is not a difficult task if the switch is held firmly in a vise and moderate care taken to keep the drill straight.

The next step is to procure a probe which has the same diameter as the shaft on the switch. This is necessary because the switch knob must be capable of sliding off over the probe. Finally the knob must be drilled and tapped so that the probe can be held into the knob by the setscrews in the knob.

When this work has been done the parts may be assembled on the inner case and the wiring completed. The lead which goes through the switch shaft from the probe should be left slack and formed into a loop so that the switch is free to turn. Finally, holes should be drilled in the outer case for the probe, negative lead, and adjustment of R_1. The bakelite piece is drilled and tapped to hold the outer case.

To assemble the unit, remove the switch knob and feed the probe into the hole on the end of the case.

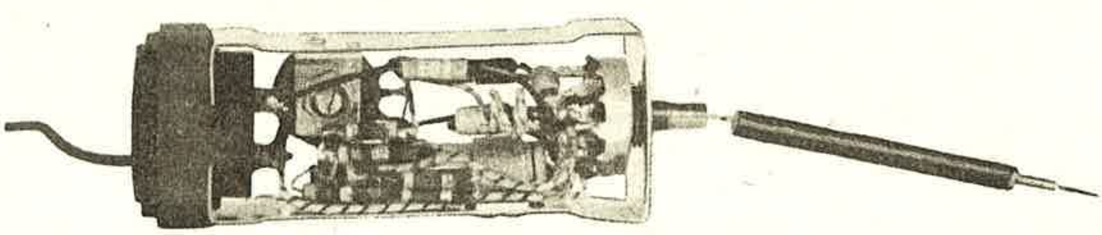

Fig. 3. Internal construction of volt-ohmeter.

Push the unit in at the same time as the negative lead is pushed through its hole. When the unit is together slide the knob over the probe and tighten the setscrews which hold the knob to the shaft and the probe to the knob. Fastening the case to the bakelite completes the assembly.

Calibration

After the volt-ohmmeter is completed it is desirable to check its accuracy. To do this easily, locate another voltmeter that you can trust and check the two together. Some juggling of resistance values may be necessary for extreme accuracy, although the unit described was within three per cent. without changing resistor values.

For the ohmmeter circuit, short the two probes and adjust R_1 so that full-scale deflection of the meter is obtained. While it is possible to now calibrate the meter, for most uses this will be unnecessary. However, you may wish to check some known values of resistance against the calculated meter readings that you have made.

As the battery voltage drops it will be necessary to readjust R_1 for full-scale meter deflection.

PARTS LIST

R_1 = 1000 ohm wire-wound rheostat
R_2 = 2000 ohm $\frac{1}{4}$ watt
R_3 = 0.1 meg. $\frac{1}{4}$ watt
R_4 = 0.9 meg. 1 watt
R_5 = 0.4 meg. $\frac{1}{2}$ watt
R_6 = 0.04 meg. $\frac{1}{4}$ watt
R_7 = 4100 ohm $\frac{1}{4}$ watt
S = Double pole six position
M = 0.1 mA meter
X = Germanium crystal (G.E.X. 44)

A Modern Modulation Monitor

While serving primarily as a guide to proper modulation of a phone station, the device pictured in Fig. 1 is a valuable addition to any shack. It will serve as a carrier shift indicator, a field strength meter, a neutralization indicator, a phone monitor and a sensitive wavemeter.

Referring to the circuit diagram in Fig. 2 meter M_1 which is on the left in the photograph, is a sensitive instrument which reads the carrier level, or indicates the pressure of r-f when the device is used as a field strength meter, a neutralization indicator or a wavemeter. Meter M_2 is used only to give per cent. modulation readings. If the modulation monitor feature is not desired meter M_2 and the copper-oxide meter rectifier *CO* may be omitted, and the device will still retain its versatility.

To use this gadget as a wavemeter, a pickup loop is coupled to the input circuit and switch S_1 is placed on the proper position. Coil L_1 tunes to 80 and 40 metres, L_2 tunes to 20, 15 and 10 metres L_3 tunes to 6 metres and the tap on L_3 tunes to 2 metres. With switch S_1 on the proper tap, condenser C_2 is used to peak the reading of meter M_1. Using a calibrated dial, frequency may be read directly. Switch S_2 should be on the RF position for these readings.

For use as a phone monitor, r-f should be fed into the input via a link or a pickup wire on the positive terminal, and the *LC* circuit tuned to the frequency involved. Earphones inserted in jack *J* will allow you to monitor the signal. S_2 should be in the AF position.

Field strength readings can be taken with this device by using a short pickup antenna on the positive input terminal. Again the *LC* circuit should be tuned to resonance. Meter M_1 will now give an indication of field strength. With S_2 in the RF position the meter is very sensitive, but if the input is too great, switch S_2 can be thrown to the AF position which will greatly reduce the sensitivity of M_1. Sensitivity can be reduced still further by using switch S_1 connected to L_4. This is a 2.5 mH r-f choke, and tunes the input very broadly. C_2 still has some effect and may be used as a vernier adjustment.

Neutralization measurements are made by coupling the device through a pickup link to the tank coil, with S_2 in the RF position. When the *LC* circuit is tuned to resonance, the gadget acts as a very sensitive r-f indicator. As a matter of fact, it is so sensitive that it is doubtful whether any stage could be sufficiently well neutralized so that the meter could be made to indicate zero r-f.

To use the device as a modulation monitor, use a pickup link to couple in r-f energy. Tune the *LC* circuit to resonance on the proper band, and then adjust the pickup link coupling until meter M_1 reads your calibrated point value. (Calibration procedure will be discussed later). Now, meter M_2 will respond to voice modulation and permit a constant check on the percentage of modulation. In addition, meter M_1 will give a constant check on the carrier level, which normally should stay constant.

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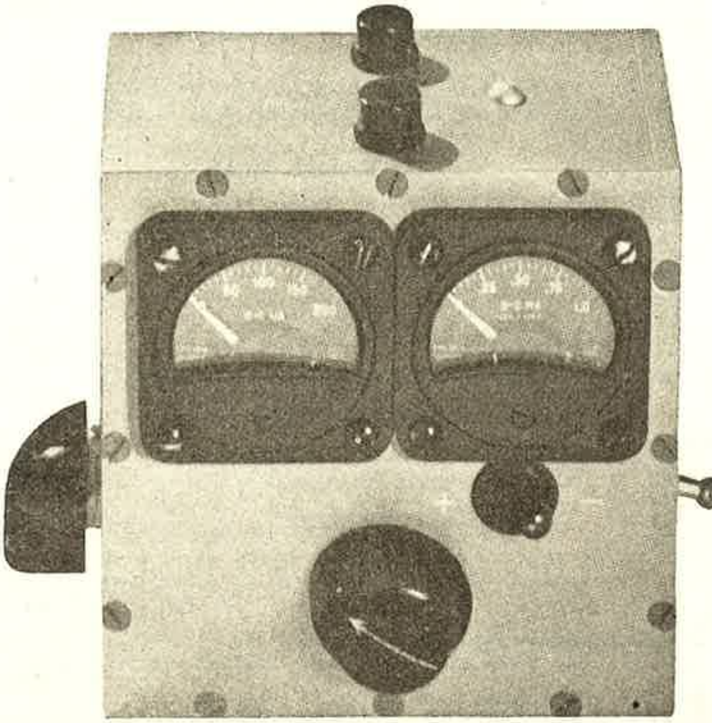

Fig. 1.

Front view of modulation monitor.

Electrical circuit

The part of the circuit to the left of the germanium crystal X, referring to Fig. 2, is the r-f pickup and tuning section, C_1 is employed as a blocking condenser and C_2 acts as a tuning condenser. The crystal acts as a half-wave rectifier, while C_3 and L_5 serve as an r-f filter, so that the input to resistors R_1 and R_2 is d-c with a superimposed audio waveform.

When switch S_2 is in the RF position, the d-c current which flows through M_1 is a measure of the r-f in the input circuit. With S_2 in the AF position, meter M_1 is shunted with resistor R_1 and again reads a value of current which depends upon the r-f input, but M_1 is now much less sensitive. The portion of d-c voltage with superimposed audio which exists across resistor R_2 is now picked up by the full-wave copper-oxide rectifier, rectified, and given as a d-c current to the per cent. modulation meter M_2. Condenser C_4 acts as a d-c blocking condenser so that audio voltage only is presented to the copper-oxide rectifier. The phone jack at this point permits the insertion of earphones for monitoring purposes.

Construction

The unit shown in Fig. 1 was constructed in a 4 × 4 × 2 inch chassis. The particular chassis shown is not a commercial chassis but one made up of aluminium. A switch is shown on the front panel marked plus and minus. This was used in an earlier version and is not included in the present circuit.

One precaution only should be observed when laying out the unit. The r-f section should be separated from the meter circuits to prevent stray fields from injuring the meter movements.

Although a 0-200 microammeter is specified for meter M_1, a 0-1 mA meter will work just as well and no circuit changes need be made. The unit will be less sensitive when it is used as a field strength meter, neutralization indicator or wavemeter. Operation will be unaffected for modulation monitoring use, as resistor R_1 acts as a shunt and can be adjusted to accommodate either a 0-200 μA meter or a 0-1 mA meter.

With reference to Fig. 1 the band switch is placed on the left panel and the RF-AF switch is on the right panel. The front panel contains the two meters, the tuning condenser in the centre, and the phone jack is placed where the switch is shown.

Wavemeter calibration

To check coil L_1, the unit should be coupled to a source of 3.5 megacycle energy, and meter M_1 peaked for maximum current. The condenser setting should be such that most of the capacitance is in use. If this is true, put 7 megacycle r-f in and again resonate the LC circuit. The condenser should now be approaching minimum capacitance. The coil should be adjusted until both bands can be resonated with the condenser. The same procedure is followed with coil L_2. The 15 metre band should peak with the condenser approximately half-way meshed, in which case the 20 and 10 metre bands should fall each side. In position 3 the six metre band will be found, and the tap on L_3 can be adjusted until the 2 metre band is peaked when the switch is in position 4.

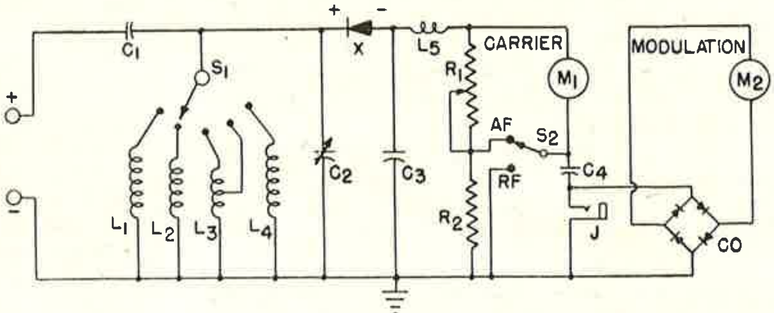

Fig. 2. Circuit diagram of modulation monitor.

Modulation meter calibration

To prepare for the job of calibrating the modulation meter, it is first necessary to use an oscilloscope pattern. This is discussed fully in radio handbooks and will not be repeated here. Once this setup is complete, the modulation monitor should be coupled lightly to the final tank coil and the *LC* circuit in the modulation meter brought to resonance. S_2 should be in the AF position. The coupling should now be adjusted so that meter M_1 reads half-scale.

The rig should now be voice modulated, and the voice level maintained so that the trapezoid pattern indicates 100% modulation on the audio peaks. Under these conditions, check the maximum deflection of meter M_2. If the maximum deflection is full scale, you may consider this as the 100% point and calibration is completed for that one point. However, if the meter does not read high enough on voice peaks, adjust the shunt R_1 on meter M_1 so that more resistance is in use.

Following this, readjust the link coupling to the final until M_1 again reads half-scale. Again check meter M_2, and repeat the above until M_2 reads full-scale, when M_1 is at half-scale and the trapezoid pattern is indicating 100% modulation voice peaks.

Inasmuch as meter M_2 will not read in a linear manner, it will be necessary to repeat the above calibration procedure for other percentages of modulation. Suggested values might be 75%, 50% and 25%. In other words, when R_1 has been adjusted so that 100% modulation is approximated by full scale deflection of M_2, it should be kept at this value of resistance.

By changing the voice level so that the trapezoid pattern indicates 75% modulation peaks, the reading of meter M_2 can be noted which corresponds to 75% modulation. This same process may be carried out for other modulation percentages.

The unit pictured read 100% modulation at full-scale, when M_1 was adjusted to half-scale, and the value of R_1 was 42 ohms.

Inasmuch as there is a possibility that some error will be introduced if the meter is calibrated on 75 metre phone and then used on 2 metre phone, it is advisable to make the calibration on the band that will be the most widely used.

After the unit is calibrated, it will always give the same readings as a modulation indicator, whenever the *LC* circuit is resonated and the pickup adjusted so that M_1 reads at mid-scale.

PARTS LIST

C_1 = 25 $\mu\mu$F mica
C_2 = 75 $\mu\mu$F variable
C_3 = 0.001 μF mica
C_4 = 0.1 μF paper
J = Open circuit jack
L_1 = 65T No. 30 enamel wire close wound on $\frac{1}{2}$ in. diameter form
L_2 = 14T No. 30 enamel wire close wound on $\frac{1}{2}$ in. diameter form
L_3 = $6\frac{1}{2}$T No. 14 wire space wound $\frac{1}{4}$ in. diameter, $\frac{1}{2}$ in. long with tap $1\frac{1}{2}$ turns from ground end
L_4, L_5 = 2.5 mH r-f choke
M_1 = 0-200 μA meter
M_2 = 0-1 mA meter
R_1 = 50 ohm semi-adjustable
R_2 = 5000 ohm $\frac{1}{2}$ watt
S_1 = Single-pole, five-position switch
S_2 = SPDT toggle switch
X = Germanium crystal (G.E.X. 44)
CO = Full wave copper-oxide meter rectifier

(Continued from page 73)

VFO

PARTS LIST

T1	Transformer, 350-0-350 volts at 90 mA, 5 volts at 2 amps, 6.3 v at 3.5 amps.
L_1	28 turns, No. 18 enamel, spaced over $2\frac{3}{8}''$, on $1\frac{3}{4}''$ dia. $\times$ $3\frac{1}{2}''$.
L_2	No. 26 enamel close wound $\frac{13}{16}''$ on $1\frac{5}{16}''$ dia. form.
L_3	3-turn link wound on L_2 at low-voltage end.
L_4	56 turns No. 26 enamel, random wound approx. $\frac{3}{4}''$ on $1\frac{1}{8}''$ dia. form.
L_5	3-turn link, wound on L_4.
RFC_1, RFC_2	Choke, 2.5 mH, 125 mA.
L_6	Choke, 8-24 henry, 80 mA.
S_1	Switch, 4-position, 1-section.
S_2	Switch, 2 gang, 4 circuit, 4-point rotary.
J_1	Closed circuit jack for key.
J_2	Coaxial receptacle.
P	Coaxial plug.

Tube Ratings as Applied to Industrial Equipment Design

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The objective of this paper is to make the industrial equipment designer realize the importance of tube ratings, to make him aware of the serious limitations in the ratings of certain types of tubes, and to convince the tube designer of the desirability of adequate fundamental ratings to remedy some of the present deficiencies. Although it applies primarily to industrial electronic control, many of the conclusions apply equally well to other fields, such as communications.

1. What are tube ratings?

For the purpose of this discussion, we will consider tube ratings to be the entire statement of the tube designer or manufacturer which specify not only maximum and minimum applied conditions to the tube, but also maximum variations of characteristic relations within the tubes.

While it is probably impossible to have ratings cover every possible applied condition and characteristic, it is highly desirable to have them cover as many as practical. At present this information is generally distributed in "Technical Information Sheets" and in "Specifications". The former frequently contains sections entitled "Typical Operating Conditions" which generally are not ratings but rather design engineering data for particular applications. In certain fields, such as communications, where the tubes are frequently used in a relatively few typical arrangements, these may be helpful, but in the industrial control field the variety of circuits is so great and differs so widely from the "typical" uses given, that this information is seldom of any value. The specification generally indicates the variation of the characteristic limits together with tests which may be used to determine this variation. In the case of some large purchasers of tubes, the specification has been used as an acceptance test to satisfy the user that his tubes meet a certain quality of design, material, and workmanship. It may even indicate to one skilled in tube construction, the probability of a satisfactory life.

However, the increasing use of tubes in industrial applications has frequently led tube manufacturers to specify definite life warranties or expectancies during which time the characteristics should remain within the specific maximum limits. This would seem to be more satisfactory arrangement, since the equipment designer would then merely have to see that he did not exceed the maximum applied conditions, and that the maximum permissible characteristic variation would still give satisfactory operation. He would not be put in the position of trying to determine whether the tests applied would insure satisfactory life, a problem concerning which he probably has little knowledge.

2. The purpose of tube ratings

The purpose of tube ratings is to accurately define the divisions of responsibility between the tube designer or manufacturer and the equipment designer or manufacturer so that they may co-ordinate their efforts to produce equipment which satisfactorily performs the functions required by the user.

In general the tube information necessary for the design of tube equipment consists of two basic parts. The first part is a tabulation of maximum conditions, such as voltage, current, wattage, temperature, and time, which the equipment designer is admonished not to exceed. The second part is an indication of the limiting characteristics, either mechanical or electrical, which the tube designer agrees will be maintained over a certain useful life.

This former part is sometimes referred to as "Maximum Ratings" and the latter part as "Characteristic Limits". However, in this paper it is the intent to use the term "Tube Ratings" to cover both of these parts.

The equipment designer has both the responsibility and the authority to see that his equipment is so designed that it does not exceed the "Maximum Ratings" and that it operates satisfactorily with any tubes having the stated "Characteristic Limits". The tube designer, on the other hand, has both the responsibility and authority to see that the tubes are so designed, built, and tested that they will stay within the prescribed limits for an average life expectancy or a definite warranty period. A division of responsibility which follows these lines of authority seems the only sound basis for a field in which the tubes and the tube equipment are frequently made by different manufacturers.

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3. Limitation of tube testing by equipment manufacturers

The necessity of complete tube ratings may not be immediately appreciated by a manufacturer of equipment who in the past has frequently used other components, such as transformers, resistors, and capacitors, supplied by another manufacturer. If there is any question about ability of such components to perform satisfactorily, it is quite possible to make tests on either these components or on the complete equipment containing these components to determine their suitability for the service intended. This procedure is not practical with electronic tubes for two basic reasons:

(a) The tubes are limited-life, replaceable components. Tests only indicate the performance of a particular tube or tubes under test which may not be representative of other tubes of the same type designation, currently being made by the same or other manufacturers; they almost certainly are not representative of what will be supplied under that same type number in the future, since most industrial apparatus is expected to have a life of 10 to 20 years. It is not generally appreciated that over a period of years the tube manufacturer continually makes changes in a given tube type in an effort to improve its quality or lower its cost. In making these changes an effort is made to maintain or extend maximum ratings and to maintain or diminish the spread of the characteristic limits. However if the equipment manufacturer, either in ignorance or on the strength of his own tests, made use of some unspecified characteristic, he might find at some future time that tubes of this type had been so affected by "improvements" that they will no longer work in his equipment. This situation might become very serious if a number of these equipments had been installed in "user's" applications. Unless the equipment manufacturer assumed the responsibility and either modified or replaced the equipment to the user's satisfaction, possibly at considerable expense, his reputation, or for that matter the reputation of all industrial electronic equipment, would suffer.

(b) A second difficulty involves the interpretation of data obtained from tests. Few equipment design engineers have had the training and experience with tube design and manufacture that would permit them to evaluate tests on a given limited number of tubes, generally of unknown origin and date of manufacture, to predict the characteristic spread likely to be encountered in currently manufactured new tubes, let alone to predict the variation with life, or possible future design changes.

Ratings and performance ability

The possible performance ability of a device, such as an electron tube may be very difficult to express completely and may not be fully known or understood in some cases. A "Rating", on the other hand, is or should be, a clear statement of characteristic limits under specified applied conditions made and checked by the tube engineer.

"Tube Ratings" generally differ from the possible performance ability of the tube in a number of important respects. First they generally include a safety factor to take care of variations in manufacture and possibly deterioration during life. Second they may limit part of the possible performance ability in the interests of simplification and easy application of the ratings, particularly where the portions sacrificed are not considered of practical importance. Third they may omit any mention of a certain characteristic variation either due to the belief that it is immaterial to all the present uses of the tube or due to their failure to recognize the characteristic.

4. Types of ratings

"Tube Ratings" may be broadly classified into two general types which we will refer to as "Application Ratings" and "Fundamental Ratings".

An "Application Rating" is specifically intended to define the limiting characteristics under specified applied maximum or minimum conditions in a specific circuit, class of circuits, or application. Part of the rating may define limiting values of circuit components.

A "Fundamental Rating" is a rating in which the applied minimum and maximum conditions and the limiting characteristics are all expressed in terms of voltage, current, wattage, temperature, and time, as applied to the tube and without reference to any particular circuit or application.

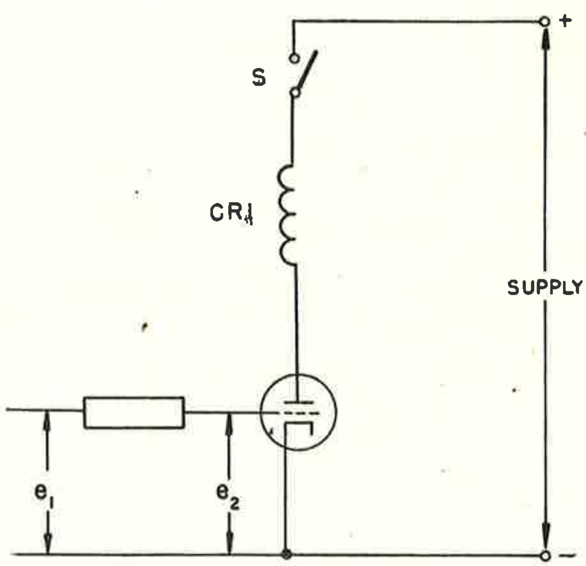

Fig. 1. Thyratron Relay Circuit.

An example of an "Application Rating" might be the specification of a maximum value of a grid resistor for a tube. The purpose of this resister is generally to limit the change of actual grid voltage from that supplied by the rest of the grid circuit, due to the *IR* drop through the grid resistor caused by the flow of grid current. A fundamental rating covering this situation would give the maximum value of grid current that could flow under these conditions.

The desirability of a maximum grid current characteristic rather than a maximum value of grid resistance can be illustrated by the circuit shown in Fig. 1. This is a very simple circuit using a thyratron tube to operate a magnetic relay from a direct-potential source of anode supply. The effective grid-circuit resistance is shown concentrated in resistor R although it should be understood that it might be distributed throughout the grid circuit. The signal voltage is indicated by e_1 and the actual grid voltage by e_2. In the event that no grid current flowed in R there would be no IR drop, and e_1 and e_2 would be identical.

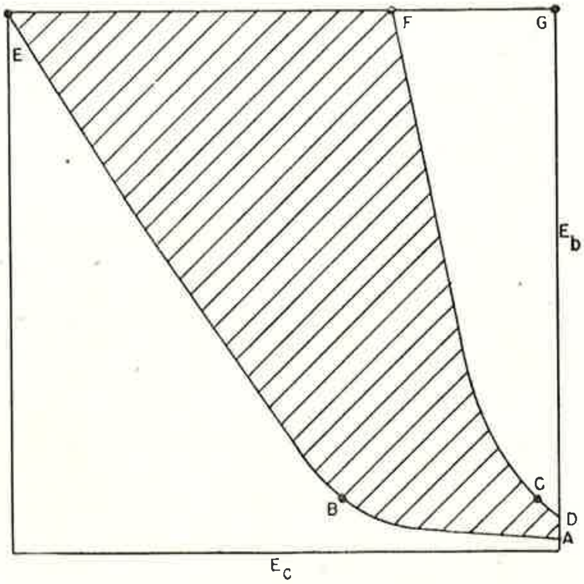

Fig. 2. Limiting critical grid characteristics.

The function of this circuit, which might well be a fragment of a more complex control, is to turn on the normally nonconducting thyratron when the normally negative value of e_1 changes a certain amount in the positive direction in response to some previous control function or measured value. However, e_2 rather than e_1 is the actual grid voltage and determines whether the thyratron will start conduction. If the value of R is equal to 10 megohms and the maximum value of grid emission current (negative grid to cathode current inside the tube) is 5 microamperes the value of e_2 would differ from e_1 by as much as 50 volts:

$$10^7\text{ohms} \times 5 \times 10^{-6}\text{amps} = 50 \text{ volts.}$$

This current might always have this value but might vary from 0 to 5 microamperes, depending upon several uncontrolled factors. This means that with no change in e_1, the value of e_2 could not be predicted within 50 volts. Now if it were necessary to turn the thyratron on with a change in signal voltage of not more than 20 volts, such an effective grid resistance would be too large since the possible unpredictable variation of e_2 exceeds the maximum value of the desired tripping signal.

On the other hand, if the grid signal could change as much as 100 volts when it was desired to turn on the thyratron, the 10-megohm resistor would not be excessive since we have only a 50-volt band of uncertainty.

Obviously many other examples could be given to show that the permissible value of the grid current but also on the details of the application and consequently is not a "tube" rating. Fortunately most modern thyratrons are rated in terms of grid current but this is frequently not given in the case of small, high-vacuum tubes where a maximum value of grid resistance is sometimes given, generally for a "typical operating condition". It is most unfortunate that many, if not most, of the uses of these tubes in industrial control equipment are not "typical".

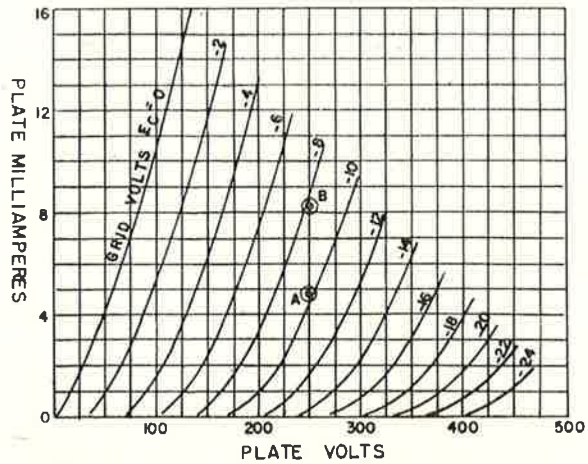

Fig. 3. Average anode characteristics.

5. Examples of adequate and inadequate control characteristic limits

Chronologically the development and use of the modern gaseous discharge tube, particularly of the controlled type, followed that of the high-vacuum tube. This, together with the fact that many of the initial uses of the gaseous tubes were in a wide variety of circuits, may have forced the ratings of these tubes to be more complete, and of a more fundamental nature than commonly found in high-vacuum tubes. Perhaps the fact that the principal users of these tubes were in the industrial field has made the tube designers willing to use fundamental ratings and to add to their ratings as the necessity became evident such terms as "Maximum Surge Current", "Maximum Negative Voltage During Conduction", "Commutation Factor", to name a few, were added as their necessity became understood.

Figure 2 shows typical limiting grid characteristics

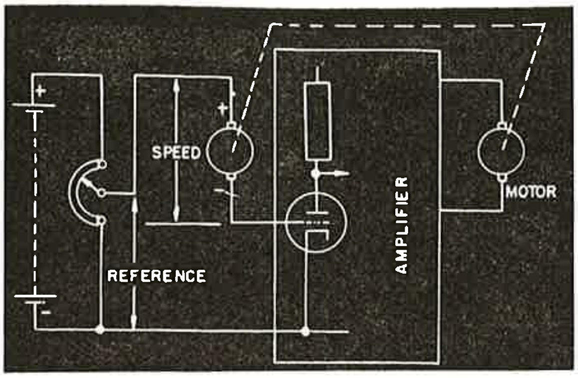

Fig. 4. Speed regulator block diagram.

of a Hot Cathode Thyratron which is an example of a very satisfactory method of defining the grid characteristic of such a tube. Originally these limits were not available in as clear a fashion. The "Specifications" originally indicated that at some anode voltage, such as G, the critical grid voltage was between E and F; at the voltage D, it was between B and C; and the zero grid voltage intercept was below the anode voltage of A. For intermediate values of anode voltage this information was not as complete as the curves, particularly if the user was not familiar with the shape the curves might take between the test limits. However with the limit curves as shown there can be no ambiguity. This is an interesting example of the tube designer specifying more complete limits than covered by the tests in the specifications. Actually the test points indicated in the specification probably indicate to the tube designer that the tube will fall inside the curves indicated. However the tube user is not interested in where the tube was tested, or how it was tested, or even perhaps if it was tested for a particular characteristic, as long as a reputable tube designer or manufacturer assures him that it will fall within the limit curves. Actually it is the tube engineer's responsibility to decide whether to test each tube, to test only a percentage of them, or how to check the tube in order to meet the published limits.

Figure 3 shows an average plate characteristic curve of a simple vacuum triode. This type of curve is clearly "data" not a "rating", since it merely indicates the characteristics of a typical tube and does not indicate how much variation may be expected. This tube does have some indication of possible characteristic limits in that the anode current, with an anode potential of 250 volts and a grid voltage of –9 volts, may be any place between 4.8 and 8.2 milliamperes. However this is rather inadequate since we do not know how to draw limit curves through these two points to represent the limit anode voltage-current relationship for the particular grid voltage involved. Neither do we know whether or how this can be applied to other grid voltage lines. For use in typical communication circuits involving such great importance as it is in circuits frequently used in industrial control where the tubes are used as d.c. amplifiers. Limiting values of *gm*, which is the rate of change of anode current, are frequently given for a particular value of grid and anode voltage. If an a.c. amplifier is designed for these values of d.c. grid and anode voltage, this characteristic limit may be used to determine the variation of amplification likely to be encountered. This, however, is not adequate to cover the d.c. amplifier.

Another factor inadequately covered in these tube types is the slow variation of the characteristic with time, sometimes called drift. This may be thought of as the variation of the grid voltage with respect to time for constant anode voltage and current. The importance of this may be illustrated in the simplified diagram of the input circuit of a speed regulator shown in Fig. 4. In this circuit the speed signal obtained from the difference is supplied to the grid cathode circuit of the first amplifier tube. If the reference and speed potential are both about 100 volts, a tube characteristic drift of the first tube of one volt, referred to the grid, means that change of speed of one volt will be required to bring the anode current and voltage back to the former value. This results in a speed change of one percent which cannot be improved by increasing the gain of the amplifier. The only way the effect of this drift may be decreased is to increase both the reference and the speed feedback which presents practical difficulties, or to somehow reduce the tube drift. Certain measures such as regulating the tube heater voltage may be taken to minimize this effect but no limits of this drift have been specified by the tube designers under any conditions. Thus, when the ultimate user of the equipment very properly wants to know what accuracy can be guaranteed, the tube equipment engineer generally must give some figure based on his past experience. This puts him in the position of guaranteeing the maximum tube drift.

This seems to be a very unsound practice since he is guaranteeing a characteristic of a device over which he has no control and which is unspecified by the tube engineer. If changes are made in the tube to lower its cost or improve some other characteristic which makes the drift worse, a very serious situation might develop.

Conclusion

The initial stages of the application of electronic tubes to industrial control problems have been passed. While there will always be new developments in the electronic art and new applications in industry the designer of electronic equipment finds himself increasingly designing equipment to compete with other well established methods of control or new methods such as magnetic amplifier techniques. He must design equipment for superior performance, reliability, or cost to meet this competition. In doing this, it becomes necessary to use his electronic "tools" to their best advantage. Thus the necessity of more complete and accurate ratings will become increasingly important.

The ratings on most of the gaseous type tubes have been reasonably complete and fairly satisfactory. Many of them are of such fundamental nature that they have been applied to a variety of circuits and uses unknown when the ratings were established. Additions have been made as limitations have become known or appreciated. High-vacuum tube ratings on the other hand, probably due to their initial use in another field, have not been as satisfactory. In many cases maximum or minimum limits have been omitted or described in fundamental terms so that they apply to only a limited class of circuits. In other cases, characteristic limits frequently have been omitted or inadequately defined. Improvement in these ratings would be very helpful so that the equipment designer can realize the most effective use of the tubes without danger of unsatisfactory performance.

New RCA Releases

Radiotron type 3MP1 is a 3-inch cathode-ray tube having an overall length of only 8 inches, and utilizing electrostatic focus and electrostatic deflection. The 3MP1 employs phosphor No. 1 which has green fluorescence and medium persistence.

Radiotron type 6BC5 is a sharp-cutoff, r-f amplifier pentode similar to the 6AG5 but it has higher transconductance to provide more gain in the r-f and i-f stages of television receivers designed to use it.

Radiotron type 6BD6 is a remote-cutoff pentode of the 7-pin miniature type used as an r-f or i-f amplifier in radio receivers. It is the miniature equivalent of the metal type 6SK7.

Radiotron type 6BQ6-GT is a beam power amplifier valve of the double-ended type intended primarily for use as a horizontal-deflection amplifier in television receivers.

Radiotron type 12BD6 is a remote-cutoff pentode like the 6BD6 except that it has a 12.6 volt, 0.15-ampere heater. The 12BD6 is the miniature equivalent of the 12SK7.

Radiotron type 19BG6-G is a beam power amplifier particularly useful as the output amplifier in horizontal-deflection circuits of "transformerless" television equipment. The 19BG6-G is like the 6BG6-G except that it has a peak heater-cathode voltage rating of 250 volts.

Radiotron type 5675, the new "pencil-type", medium-mu triode, is for use in grounded-grid circuits at frequencies as high as 3000 megacycles per second. As a local oscillator, it is capable of giving a power output of 475 milliwatts at 1700 megacycles per second, and about 50 milliwatts at 3000 megacycles per second.

Unique in design, the 5675 utilizes 'pencil-type' construction which not only meets the requirements of a good u-h-f tube as to minimum transit time, low lead inductance, and low interelectrode capacitances, but also provides other desirable features such as small size, light weight, low heater wattage, good thermal stability and convenience of use in circuits of the coaxial-cylinder, line, or lumped-circuit type. In grounded-grid circuits, the grid flange permits effective isolation of the plate circuit from the cathode circuit.

The 'pencil-type' design employs a coaxial-electrode structure of the double-ended type in which the plate cylinder and the cathode cylinder, each only $\frac{1}{4}$ inch in diameter, extend outward on opposite sides of the grid flange. The overall length of the structure is only $2\frac{3}{8}$ inches maximum.

The sensitivity of the head-on multiplier phototube **Radiotron type 5819** for scintillation counters has been increased nearly 5 times over that of the first 5819's introduced about a year ago.

In addition, the improved 5819 features greater cathode-collection efficiency, higher current amplification, strengthened mount structure, shorter overall length, and cathode-lead termination in a base pin instead of in a recessed cavity cap as used in the older design.

With its improved features, the 5819 is a superior multiplier phototube of the head-on type for use in scintillation counters for the detection and measurement of nuclear particle radiation, as well as in other applications involving low-level, large-area light sources.

The high sensitivity of the 5819 to blue-rich light makes the 5819 well suited for use with organic phosphors such as anthracene and with inorganic materials such as silver-activated zinc sulfide.

The 5819 can be utilized to advantage in the scintillation type of nuclear radiation detector because it has a large, essentially flat cathode area which permits good optical coupling between the phosphor and the cathode. As a result, the scintillation pulses are larger in amplitude than the majority of the dark-current pulses and thus discrimination against the dark-current pulses is facilitated. Furthermore, the 5819 permits the design of a scintillation counter with high efficiency and a resolving time of only a small fraction of a micro-second.