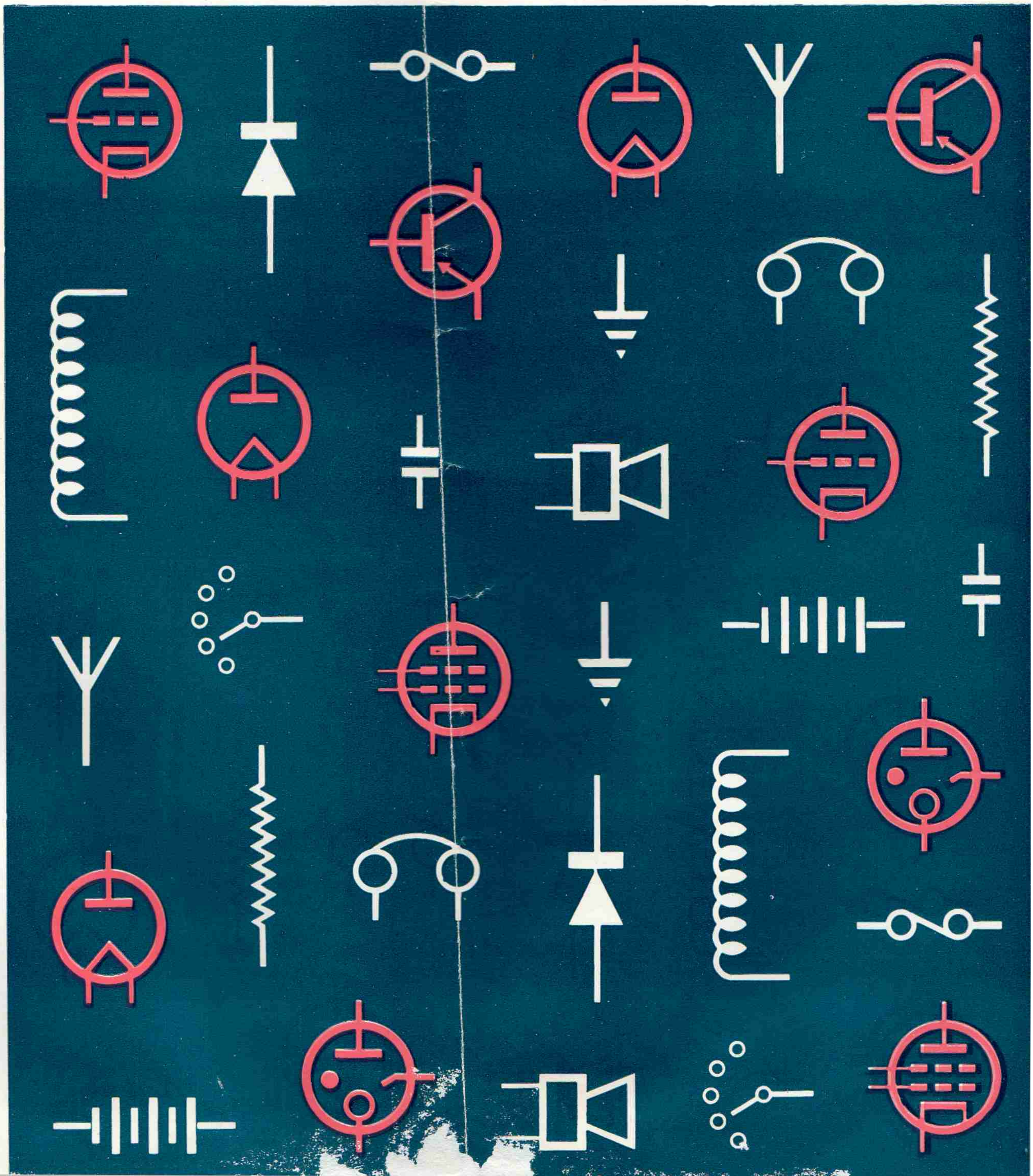
VOL. 26, No. 5

RADIOTRONICS

MAY, 1961

PRICE ONE SHILLING

REGISTERED AT THE GENERAL POST OFFICE, SYDNEY, FOR TRANSMISSION BY POST AS A PERIODICAL



AN AWV PUBLICATION

RADIOTRONICS

Vol. 26, No. 5, 1961

Editor, Bernard J. Simpson

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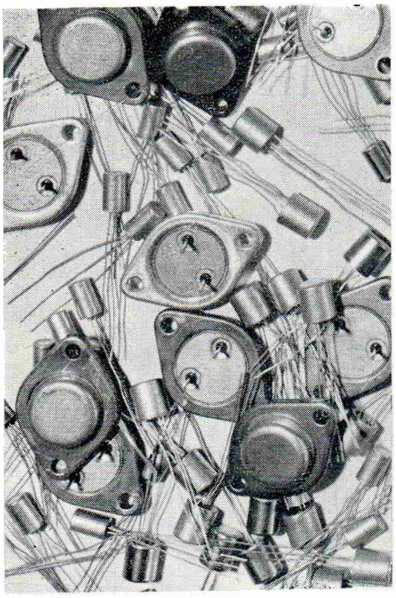
Radiotronics is published twelve times a year by the Wireless Press for Amalgamated Wireless Valve Company Pty. Ltd. The annual subscription rate in Australasia is 10/-, in U.S.A. and other dollar countries $1.50, and in all other countries 12/6.

Subscribers should promptly notify Radiotronics, Box 2516, G.P.O., Sydney, and also the local Post Office of any change of address, allowing one month for the change to become effective.



THE TRANSISTOR "FAMILY" CONCEPT

It is general knowledge these days that transistors are manufactured in "families", and that tests applied after manufacture select the finished units into groups bearing the various commercial type numbers within the particular family. In this way the manufacture of transistors differs from the manufacture of thermionic valves, where a discrete type is made.

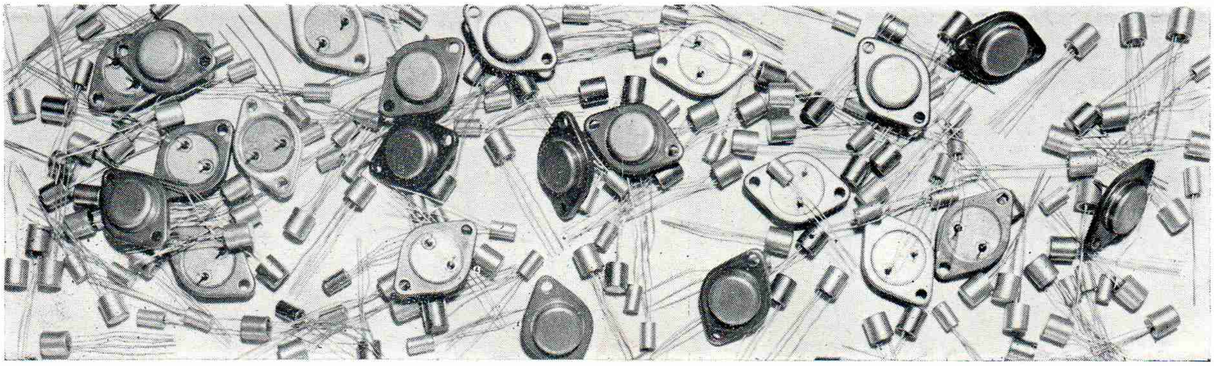
There may be as many as ten or more transistors identified by different commercial type numbers, but belonging to a family group, and all stemming from the same manufacturing run. This fact arises from the complex nature of the doping and other processes which are used to make a transistor, and from the minute variations in material properties needed to produce transistors of varying characteristics.

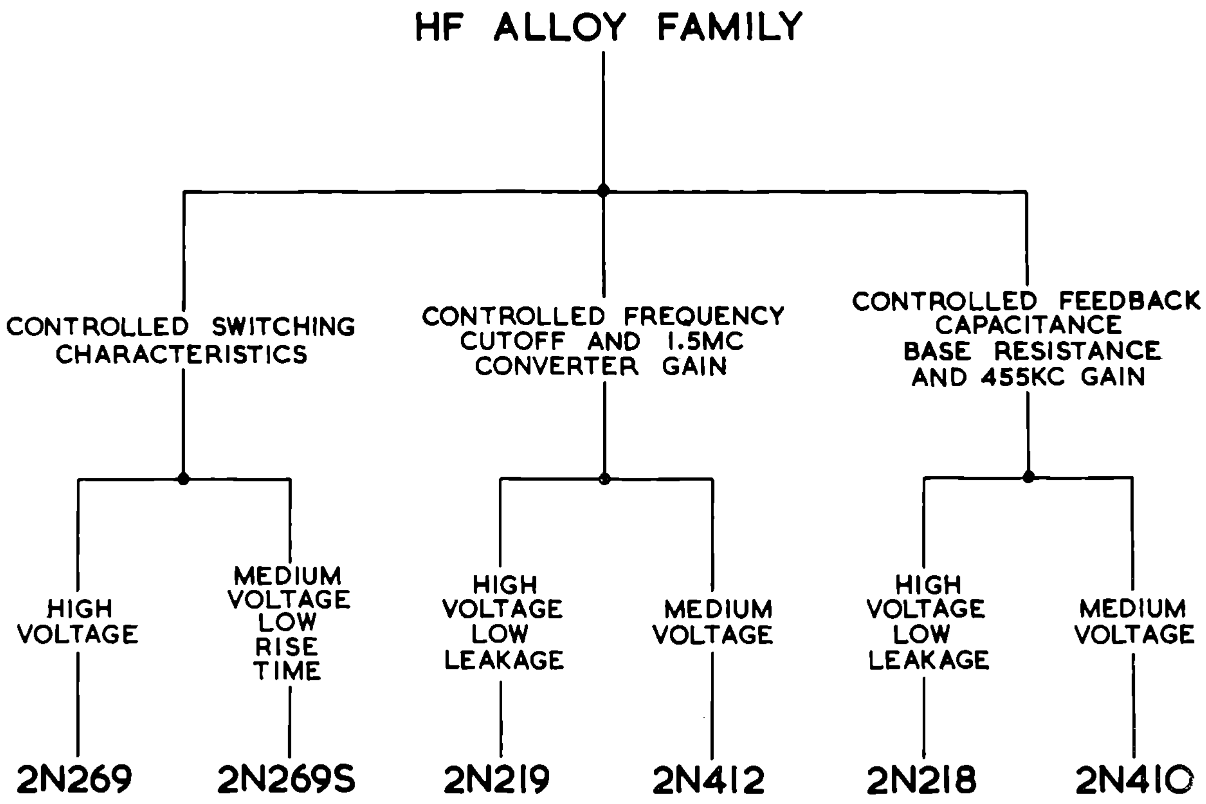
These considerations mean that whilst it would be possible to set out to make one discrete type of transistor, it is neither a practical nor an economic procedure. The "family" concept of transistor production, which is common to all transistor manufacturers, by easing manufacturing problems and ensuring maximum utilization of expensive raw materials, brings the user a high-grade product at a moderate price.

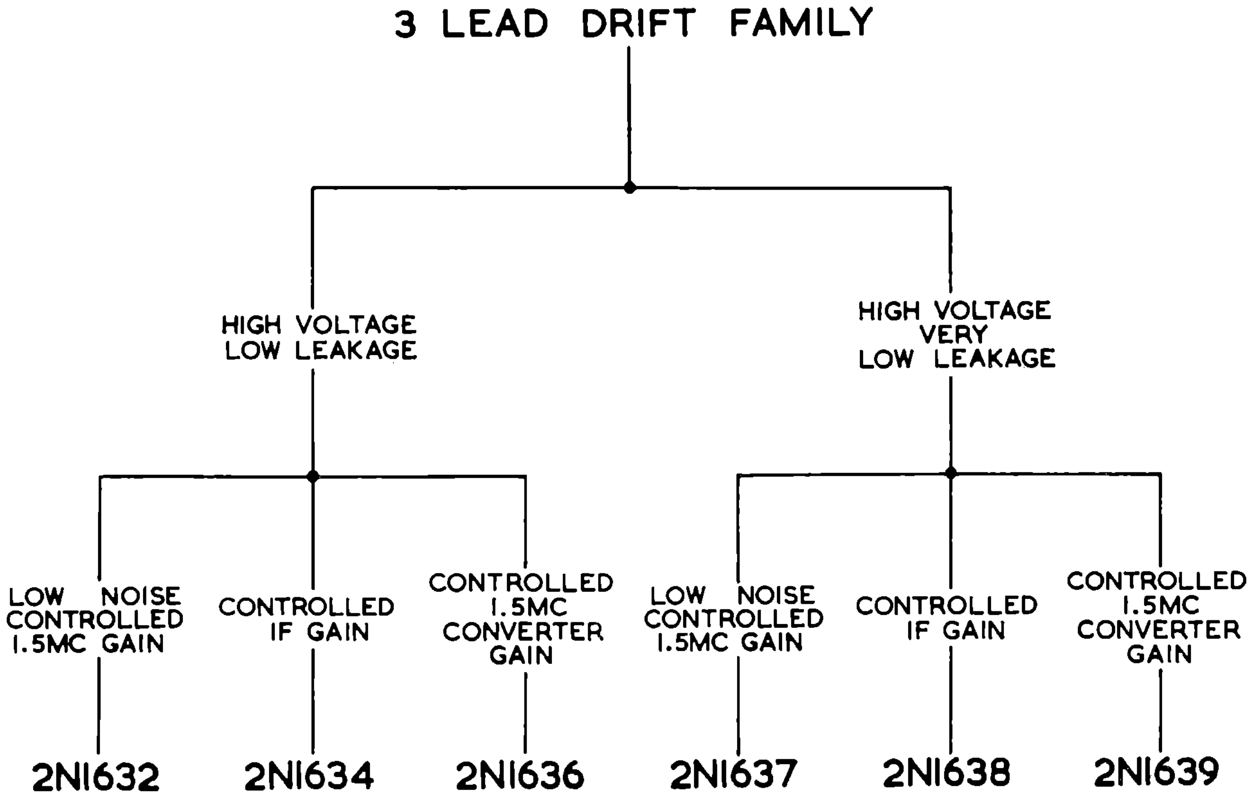
Furthermore, the stringent testing applied in the selection of the finished units into categories representing the various commercial type numbers brings the user another advantage. The tests result in a finished and branded product which offers the user closer limits, with all their attendant advantages, than would otherwise be feasible.

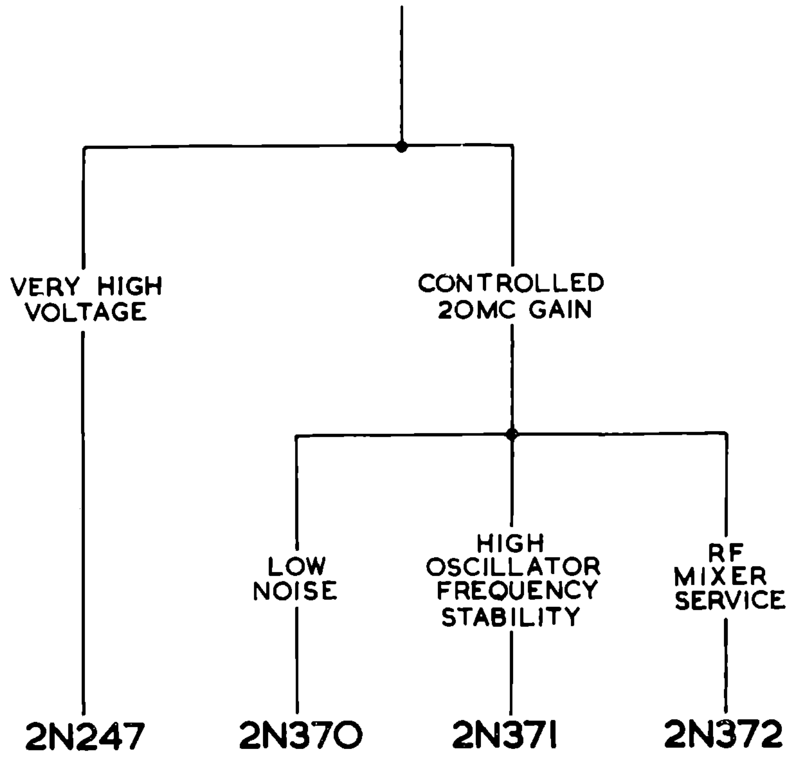
In order for the user to gain the maximum benefit from the advantages of "family" manufacturing techniques, it is of course necessary for him to understand the properties which decide the final type numbering of the members of a group. In this way the most suitable choice can be made, having regard to the job the transistor has to do, and to factors such as price and availability.

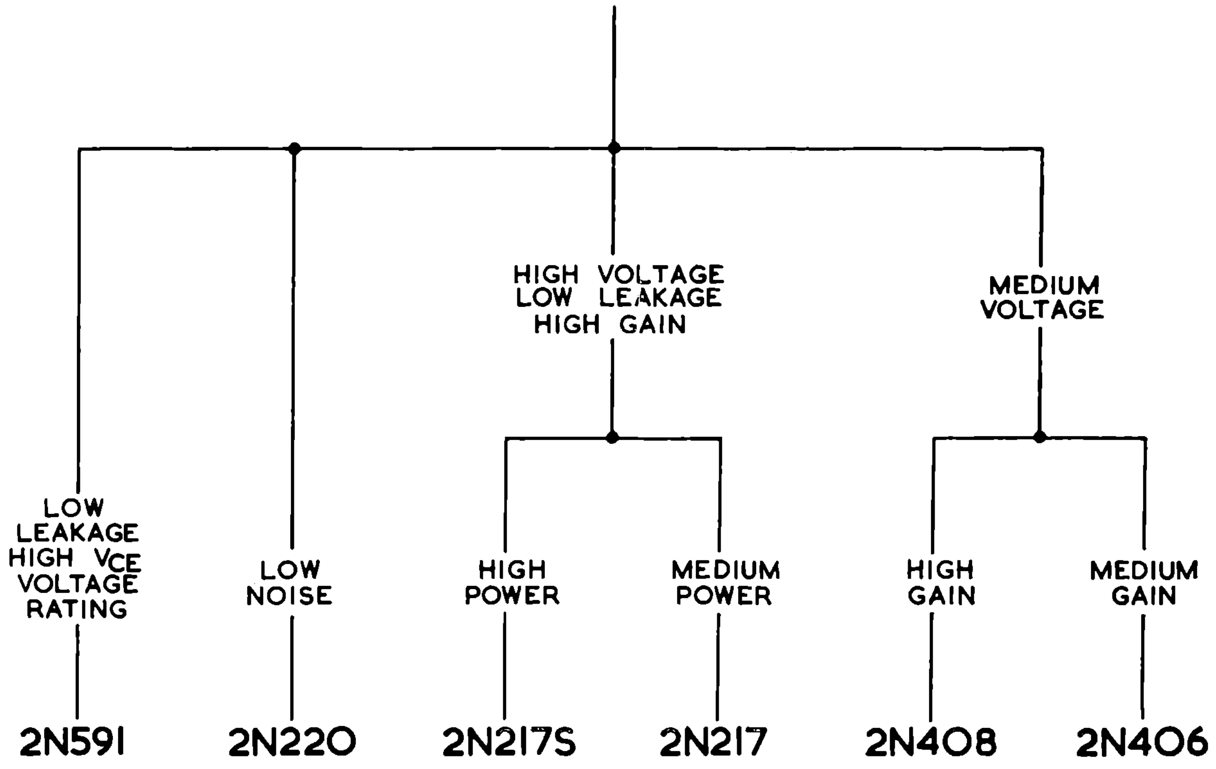
The "family trees" presented here show how some of the more popular AWV transistors are grouped together, and how the characteristics are selected within each group. If, for example, a transistor is required for an audio application, the AUDIO FAMILY chart immediately shows, not only the possible types available, but also guides the selection towards the most suitable type. Naturally the final selection would be made after more detailed examination of the transistor's characteristics.

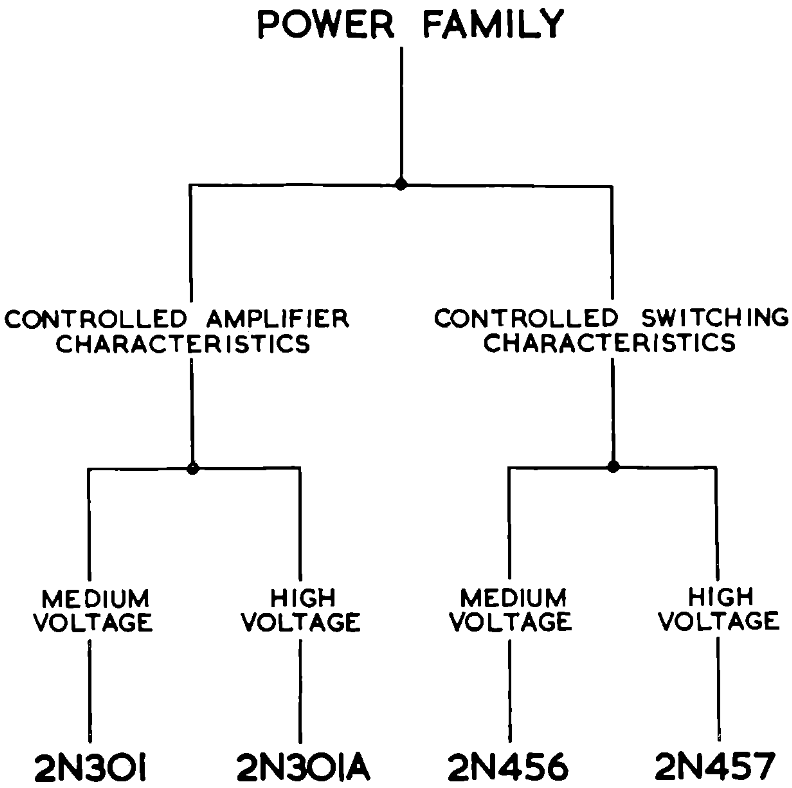



HF ALLOY FAMILY
CONTROLLED SWITCHING CHARACTERISTICS
CONTROLLED FREQUENCY CUTOFF AND 1.5MC CONVERTER GAIN
CONTROLLED FEEDBACK CAPACITANCE BASE RESISTANCE AND 455KC GAIN
HIGH VOLTAGE
MEDIUM VOLTAGE LOW RISE TIME
HIGH VOLTAGE LOW LEAKAGE
MEDIUM VOLTAGE
HIGH VOLTAGE LOW LEAKAGE
MEDIUM VOLTAGE
2N269
2N269S
2N219
2N412
2N218
2N410


3 LEAD DRIFT FAMILY
HIGH VOLTAGE LOW LEAKAGE
HIGH VOLTAGE VERY LOW LEAKAGE
LOW NOISE CONTROLLED 1.5MC GAIN
CONTROLLED IF GAIN
CONTROLLED 1.5MC CONVERTER GAIN
LOW NOISE CONTROLLED 1.5MC GAIN
CONTROLLED IF GAIN
CONTROLLED 1.5MC CONVERTER GAIN
2N1632
2N1634
2N1636
2N1637
2N1638
2N1639


4 LEAD DRIFT FAMILY


AUDIO FAMILY



VALVE CHARACTERISTICS

The amplification factor and transconductance of a valve are often given to express the merit of using it in a particular circuit of a radio or television receiver. A technician should be familiar with these terms.

The amplification factor of a valve is commonly designated by the Greek letter μ (mu). Valves are generally referred to as being a high-mu, medium-mu, or low-mu valve. A high-mu valve is one supporting an amplification factor of 55 or more; medium-mu valves in the range of from around 8 to around 55 and low-mu valves in the range below 7 or 8.

A valve with a high-mu rating, however, is not necessarily always found to be the best amplifier, since the plate resistance of the valve (resistance of the plate-cathode path through the valve) must be taken into account. The ability of the valve to perform as an amplifier depends on the operation that it is called upon to perform. The best all-round indication of the effectiveness of a valve as an amplifier is its transconductance (sometimes referred to as mutual conductance). This characteristic takes into consideration both the amplification factor (μ) of the valve, and its plate resistance (the resistance of the plate-to-cathode path within the valve). The transconductance of a valve is often used to express the merit of a valve as an amplifier.

Actually, the transconductance (g_m) of a valve is determined by dividing the change in plate current by the change in grid voltage that causes the plate current change (the plate voltage being fixed at the desired operating value). Transconductance is measured in units of conductance, the mho. Practical values of transconductance are very small, so the micromho (one millionth of a mho) is the most commonly used unit. The higher the transconductance the greater are the possibilities of the valve being used as an amplifier.

SILICON

VHF TRANSISTORS

AN APPLICATION GUIDE

The development of the mesa construction technique has made possible the manufacture of transistors having very high frequency capabilities. RCA has applied this technique to silicon material and produced semi-conductor devices that operate from dc to vhf at high temperatures and high power levels. This article describes the new vhf silicon transistors and includes information on construction, characteristics, design procedures, and typical circuits which will enable the circuit designer to take full advantage of the unique features of these devices.

Design Features

RCA silicon vhf transistors 2N1491, 2N1492, and 2N1493 are primarily large-signal units intended for industrial and military applications. These n-p-n devices, which are widely used in power amplifiers, oscillators, and video amplifiers, are capable of dissipating collector power outputs up to three watts at temperatures up to 25 degrees Centigrade. The three types are structurally similar, but differ in maximum ratings and intended applications.

The 2N1491 has a maximum collector-to-base voltage rating of 30 volts and a maximum emitter-to-base voltage rating of one volt. At a frequency of 70 megacycles, it is capable of delivering a power output of 10 milliwatts with a minimum power gain of 13 db. This low-voltage, low-power type has many applications in vhf receivers and transmitters in oscillator, if-amplifier, intermediate power-amplifier, video-amplifier, or mixer circuits. It may also be used in very-low-level high-frequency applications such as receiver rf amplifiers.

The 2N1492 has a maximum collector-to-base voltage rating of 60 volts and a maximum emitter-to-base voltage rating of two volts. At a frequency of 70 megacycles, it is capable of delivering a power output of 100 milliwatts with a minimum power gain of 13 db. This medium-voltage, medium-power type is useful in oscillator, if-amplifier, video-amplifier, and intermediate or final power-amplifier circuits in vhf transmitters and receivers. It is ideally suited to low-power vhf transmitters because it is capable of both high efficiency and gain.

The 2N1493 has a maximum collector-to-base voltage rating of 100 volts and a maximum emitter-to-base voltage rating of 4·5 volts. At a frequency of 70 megacycles, it is capable of delivering a power output of one-half watt with a minimum power gain of 10 db. This high-voltage, high-power type is useful in high-level video-amplifier, if-amplifier, high-power-oscillator, and intermediate or final power-amplifier circuits in both hf and vhf transmitters.

Construction

Fig. 1 shows a cutaway view of an RCA silicon vhf transistor, a diffused-base mesa-type device in which the emitter and base regions are produced by a double-diffusion process on the same face of the wafer. This method of diffusion has an advantage over other methods in that the base width is independent of the thickness of the wafer and, in addition, there is no alignment problem of emitter and collector. Double diffusion from the same face of the wafer also results in a more planar junction and provides higher breakdown voltages.

A high concentration of n-type impurities diffused into the collector side provides a low collector spreading resistance, and an intrinsic region between the collector contact layer and the base reduces collector capacitance by a factor of approximately 6 over the usual n-p-n structure. The relatively high concentration of p-type impurities in the base when used together with double base contacts results in low equivalent base resistance, low saturation voltages, and improved performance at high frequencies.

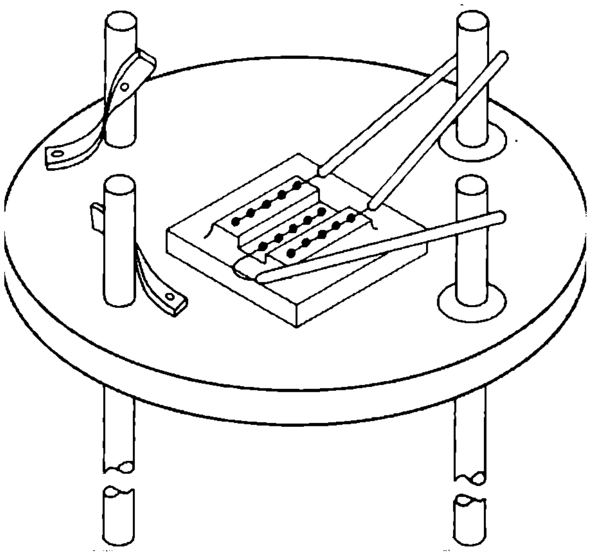


Fig. 1—Cutaway view of an RCA silicon vhf transistor.

In the construction of the devices, improved mesa-etching techniques have resulted in accurate definition of mesa area and consequent lower values of $C_{b'c}$. Lower thermal resistance and higher dissipation capabilities are obtained by alloying the pellet directly to the header. In addition, thermo-compression bonding of the lead wires to evaporated and alloyed aluminium base and emitter stripes results in a secure bond having low contact resistance.

Characteristics

RCA silicon vhf transistors are actually power devices because their maximum collector dissipation at a case temperature of 100 degrees Centigrade is 1·5 watts. These devices are particularly suited to applications in which the high-frequency amplifier is required to have a collector dissipation of more than 100 milliwatts.

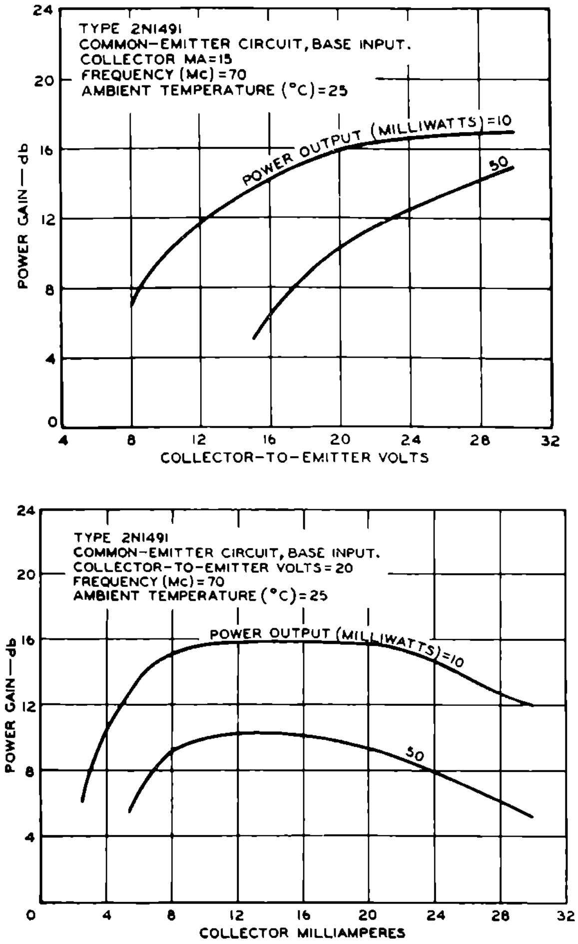


Fig. 2—Variations in power gain as a function of collector voltage and collector current for the 2N1491.

Fig. 2 shows the power gain of a typical 2N1491 transistor as a function of collector voltage and current at a frequency of 70 megacycles, and power outputs of 10 and 50 milliwatts. These curves show that the 2N1491 will operate satisfactorily at low power levels (outputs up to 10 milliwatts) with a minimum collector voltage of from 10 to 15 volts and a minimum collector current of from 3 to 5 milliamperes. As the power output is increased to 50 milliwatts, however, both the collector voltage and the collector current must be increased to provide reasonable gain. For example, a minimum collector voltage of 19·5 volts would be required to provide a minimum power gain of 10 db at an output level of 50 milliwatts. Because maximum power gain is obtained at a collector current of approximately 12 milliamperes, a suitable operating point would be a collector voltage of 20 volts and a collector current of 12 milliamperes.

Either the 2N1492 or the 2N1493 may be used to provide greater power output or gain than can be obtained from the 2N1491. All of these types provide higher power gain as the collector voltage is increased. However, care must be exercised in the selection of collector voltage and current in order that the maximum ratings for the type used will not be exceeded and the dissipation in the transistor will be kept within ratings.

Fig. 3 shows power gain as a function of power output for types 2N1492 and 2N1493. A comparison of Figs. 2 and 3 shows that the 2N1492 is superior to the 2N1491 in both power gain and power output, and the 2N1493 has the highest gain and power output of the three types. The 2N1493 provides high gain at power levels up to 500 milliwatts.

Design Procedures

In the design of vhf amplifiers or oscillators using silicon vhf transistors, the transistor input, output, and load impedances and the generator impedance must be known. The transistor input and output impedances can be determined from published data or measured directly.* Because, in general, the input and output impedances of the transistor are not equal to the generator or load impedance, matching circuits are usually required.

Although maximum power gain is obtained under matched conditions, mismatch may be required to meet other requirements. Under some conditions it may be necessary to mismatch to obtain the required selectivity. In power amplifiers and oscillators, the load impedance presented to the collector, R_{in}, is not made equal to the output resistance of the transistor, but is dictated by the required power output and the peak ac collector voltage. Because the peak ac voltage is always less than the supply voltage, R_{in} may be expressed as follows :

$$R_{in} \leqq \frac{V_{cc}^2}{2\ P_o} \qquad (1)$$

where V_{cc} is the dc collector/supply voltage and P_o is the required power output.

There are many different matching circuits, and each type has its advantages and disadvantages. Although the pi matching network is most widely used, simple L matching networks offer several advantages in high-gain amplifier circuits. Both types are described below, and design equations and examples are given.

L-Matched VHF Amplifiers and Methods of Neutralization

An important advantage of the L matching network is that it greatly simplifies both neutralization and biasing circuits. Although harmonic frequencies are not attenuated to the extent that they would be in a pi matching network, there are many cases in which harmonic attenuation is of little consequence.

The matching circuit shown in Fig. 4 is particularly suited to amplifier circuits in which the gain is high and neutralization is required. It is usually sufficient to neutralize rather than to unilateralize vhf amplifiers using RCA silicon vhf transistors. Fig. 5 shows the biasing and neutralization circuits which may be used with both L and pi matching output networks. The circuits for the pi matching network, shown at (c) and (d), are more complex than those for the L network, shown at (a) and (b). The neutralization circuit shown at (c) requires a capacitive (or inductive) split on the input coil, and the biasing circuit

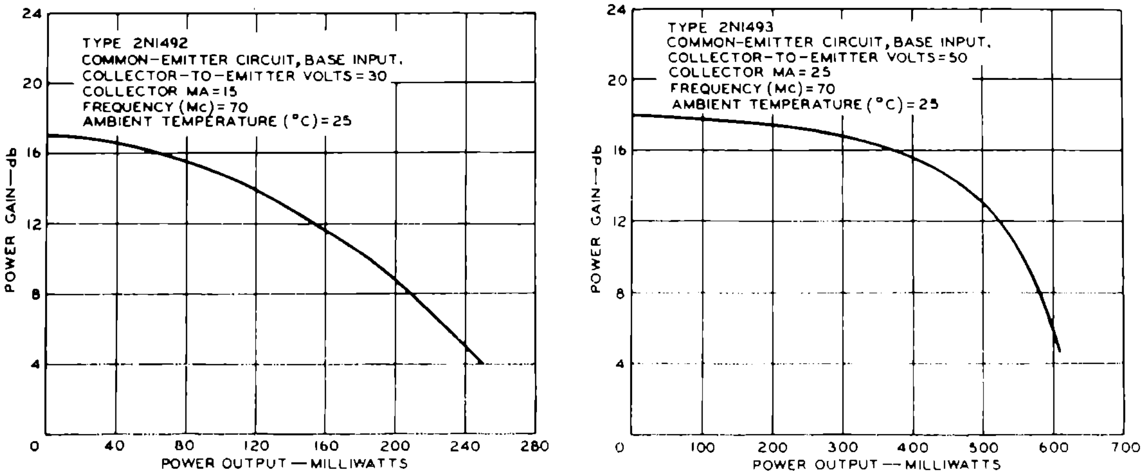


Fig. 3—Power output as a function of power gain for the 2N1492 and the 2N1493.

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* Impedance measurements may be made with such instruments as the Boonton RX Meter, the GR Transfer-Function and Admittance Bridge, and the Wayne-Kerr VHF Bridge.

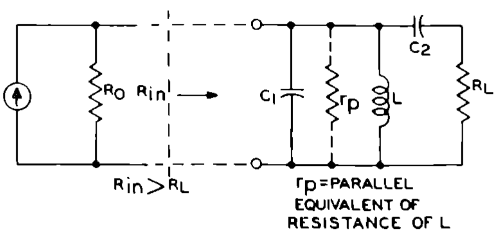


Fig. 4—L matching network.

shown at (d) requires a comparatively high-inductance coil (L_N) with negligible coupling to the other coils. In a practical circuit, it is difficult to achieve this condition of negligible coupling between L_N and the other coils used in the circuit.

The design of L matching networks similar to that shown in Fig. 4 is relatively simple and permits the choice of any practical loaded Q desired. The design equations are as follows :

$$R_{in}' = \frac{R_{in}}{1 - \frac{Q_L}{Q_u}} \qquad 2)$$

$$X_{C2} = R_L\sqrt{\frac{R_{in}'}{R_L} - 1} \qquad (3)$$

$$X_{C1} = \frac{R_{in}}{2\,Q_L - \frac{R_{in}\,X_{C2}}{X_{C2}^2 + R_L^2}} \qquad (4)$$

$$X_L = \frac{R_{in}}{2\,Q_L} \qquad (5)$$

$$\eta = 1-(Q_L/Q_u) \qquad (6)$$

where R_{in} is the desired input resistance of the network, R_L is the load resistance, Q_u is the unloaded Q of the coil, Q_L is the operating Q of the entire circuit, and η is the efficiency of the network.

The following example of a practical design using the L matching network shown in Fig. 4 illustrates the design procedure.

Problem

A 2N1492 is to be used as a common-emitter rf amplifier at a frequency f of 50 megacycles, a collector voltage V_c of 30 volts, and a collector current I_c of 15 milliamperes. The L matching network shown in Fig. 4 is to be used to match a 50-ohm generator to the input of the transistor. Design the network for an operating Q of 10 (neglect the input capacitance C_{in}) ; assume an unloaded coil Q of 75.

Calculation

The input resistance of the 2N1492 may be determined from the published data : at V_c=30 volts, I_c=15 milliamperes, and f=50 megacycles, input resistance R_{in}=100 ohms.

For the matched condition, the input of the network must present a 50-ohm load to the generator and a source resistance of 100 ohms to the base of the transistor. Because a low-resistance generator is being used to drive a higher-resistance load, the circuit of Fig. 4 must be turned around ; the input becomes the output and the output becomes the input, as shown in Fig. 6.

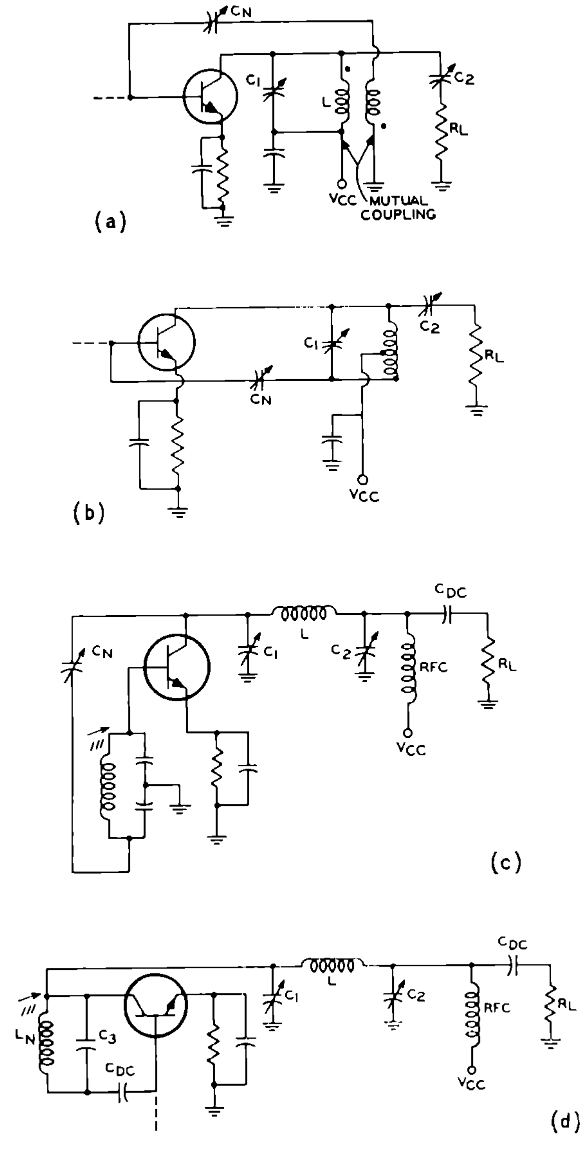


Fig. 5—Neutralization and biasing required with circuits having L and Pi matching output networks.

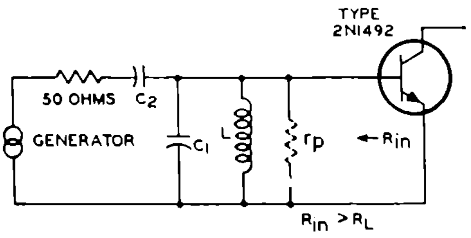


Fig. 6—Input matching network (dc biasing omitted).

Known values are then substituted in the design equations, as follows :

$$R_{in}' = \frac{100}{1 - \frac{10}{75}} = 115 \text{ ohms}$$

$$X_{C_2} = 50\sqrt{\frac{115}{50} - 1} = 57 \text{ ohms} ; \qquad C_2 = 55 \text{ pf}$$

$$X_{C_1} = \frac{100}{(2)(10) - \frac{100\,(57)}{57^2 + 50^2}} = 5{\cdot}25 \text{ ohms} ; \qquad C_1 = 600 \text{ pf}$$

$$X_L = \frac{100}{(2)(10)} = 5 \text{ ohms} ; \; L = 0{\cdot}0159 \, \mu\text{h}$$

$$\eta = 1 - \frac{10}{75} = 0{\cdot}867$$

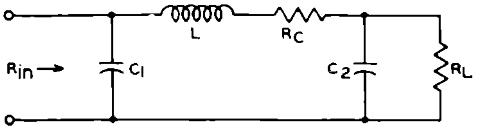


Fig. 7—Pi matching network.

VHF Amplifiers using Pi Matching

As mentioned previously, the pi matching network is most widely used. Fig. 7 shows a pi matching network having a coil series resistance R_C. The load resistance R_L is reflected as an input resistance R_{in} at the input of the network. R_C may be neglected in the calculation of R_{in} because its effect is small. When the equations for the network are solved, the ratio X_L/X_{C_2} may then be expressed as follows :

$$\frac{X_L}{X_{C_2}} = 1 \mp \sqrt{\frac{R_{in}}{R_L} - \left(\frac{X_L}{R_L}\right)^2} \tag{7}$$

From equation (7) it may be shown that the maximum value for X_L ($X_{L\max}$) is given by

$$X_{L\max} = \sqrt{R_L R_{in}} \tag{8}$$

In all practical cases X_L will be less than or equal to $X_{L\max}$. Lower values of X_L yield higher loaded Q's for the circuit. For given values of R_{in}, R_L, and unloaded Q (Q_u of the inductor L), the operating Q for the entire circuit is expressed as follows :

$$Q_L = \frac{R_{out}}{R_{in} + R_{out}}\left[\frac{X_L}{R_L} + \frac{R_L}{X_{C_2}}\left(\frac{X_L}{X_{C_2}} - 1\right)\right] \tag{9}$$

where R_{out} is the output resistance of the transistor or the driving circuit. In power amplifiers or oscillators, the operating Q is usually between 7 and 10. Lower values of Q result in more efficient transfer of power to the load, but do not attentuate harmonics as much as higher values. The efficiency of power transfer, η, is given by

$$\eta = \frac{1}{1 + \frac{R_C}{R_L}\left[1 + \left(\frac{R_L}{X_{C_2}}\right)^2\right]} \tag{10}$$

Equation (10) indicates that loss is directly proportional to the ratio R_C/R_L. This loss is minimized when Q_u is made as high as possible. It may be shown with the use of equations (7) and (8) that if the minimum Q_L is specified, the resulting low ratios of R_{in}/R_L will require very small values of X_L and X_{C_2} and result in a low efficiency of power transfer. This difficulty may be overcome by use of a second pi matching network to reflect R_L as a lower input resistance. The second matching circuit increases the ratio R_{in}/R_L and results in less loss for the same specified Q. C_1 may be calculated for a given loaded Q by means of the following formula :

$$X_{C_1} = \frac{R_{in}\,R_{out}}{R_{in} + R_{out}}\left(\frac{1}{Q_L}\right) \tag{11}$$

Examples of some typical circuits are given below to clarify the design procedure.

Problem

A 2N1491 is to be operated as an if-amplifier at 70 megacycles using a pi matching network for output matching. Maximum power gain is required with an operating Q of 10 and a load resistance R_L of 50 ohms. The transistor is to be operated with a collector voltage V_c of 20 volts and a collector current I_c of 15 milliamperes. Calculate the values for C_1, C_2, L, and η.

Calculation

The published data for the 2N1491 show that, at the specified conditions, the output resistance

R_{out} is 2000 ohms and the output capacitance C_{ob} is 3 picofarads.

For maximum power gain,

$$R_{in} = R_{out} = 2000 \text{ ohms}$$

Then,

$$X_{L\max} = \sqrt{(50)\,2000} = 316 \text{ ohms}$$

$$\frac{X_L}{X_{C_2}} = 1 \mp \sqrt{\frac{R_{in}}{R_L} - \frac{R_L R_{in}}{R_L^2}} = 1$$

$$X_{C_2} = 316 \text{ ohms}$$

$$Q_L = \left(\frac{2000}{2000+2000}\right)\left(\frac{316}{50}\right) = 3{\cdot}16$$

Because Q_L is lower than required, a smaller value must be substituted for X_L ; assume $X_L =$ 100 ohms. Then,

$$\frac{X_L}{X_{C_2}} = 1 \mp \sqrt{40 - \left(\frac{100}{50}\right)^2} = 1 \mp \sqrt{36} = 1 \mp 6$$

The negative value for X_L/X_{C_2} is rejected ; therefore

$$\frac{X_L}{X_{C_2}} = 7$$

$$X_{C_2} = 100/7 = 14{\cdot}3 \text{ ohms}$$

Then,

$$Q_L = \frac{1}{2}\left[\frac{100}{50} + \frac{50}{14{\cdot}3}(7-1)\right] \cong 11$$

This value is close enough, in most applications, to the required Q of 10.

$$L = 0{\cdot}22\,\mu\text{h}$$

$$C_2 = 150 \text{ pf}$$

$$X_{C_1} = 1000/10 = 100 \text{ ohms}$$

$$C_1 = 22 \text{ pf}$$

Assume an unloaded Q of the coil $Q_u = 150$; then,

$$R_C = \frac{X_L}{Q_u} = \frac{100}{150} = 0{\cdot}66 \text{ ohm}$$

$$\eta = \frac{1}{1+\dfrac{0{\cdot}66}{50}\left[1+\left(\dfrac{50}{14{\cdot}3}\right)^2\right]} = \frac{1}{1{\cdot}174} = 0{\cdot}85$$

This result indicates a loss of 0·7 db.

Fig. 8 shows the complete 70-megacycle if-amplifier output circuit having the required radio-frequency choke for biasing and coupling capacitor C_3 for dc isolation of the load. In practice, capacitor C_1 should be variable over a small range to compensate for variations in the wiring capacitance and C_{ob} of the transistor. If some variation in the load resistance R_L is expected, C_2 can also be made variable.

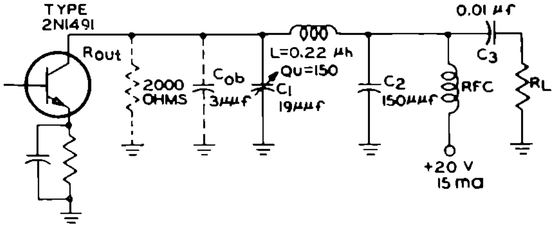


Fig. 8—70-megacycle if-amplifier output circuit.

Another example, the design of a vhf power amplifier, will help to demonstrate the design methods for both power amplifiers and oscillators.

Problem

A 50-megacycle power amplifier is to have a power output of one-half watt into a 50-ohm antenna. The minimum loaded Q is to be 7, and the circuit is to be made adjustabe for transistors requiring slightly different values of load resistance. Find the matching-circuit efficiency and the approximate power gain.

Calculation

The published data for the 2N1493 indicate that a minimum power gain of 10 db can be obtained at conditions of one-half watt output and a frequency of 70 megacycles. At 50 megacycles, therefore, the transistor should be capable of a power output P_o of more than one-half watt and a minimum power gain of more than 10 db. The collector voltage V_c is 50 volts and the collector current I_c is 25 milliamperes.

The minimum collector efficiency η_c in per cent is given by

$$\eta_c = \frac{100\,P_o}{V_c\,I_c} = \frac{(100)\,(0{\cdot}5)10^3}{(50)\,(25)} = 40\%$$

$$R_{in} \leqq \frac{V_c^2}{2\,P_o} = \frac{50^2}{2(0{\cdot}5)} = 2500 \text{ ohms}$$

An output of one-half watt may be obtained with all 2N1493 transistors, regardless of varying percentages of the maximum ac collector voltage swing, if R_{in} is variable from 2000 to 500 ohms.

The calculation for L should be made with R_{in} equal to 500 ohms because this value provides the lower Q_L.

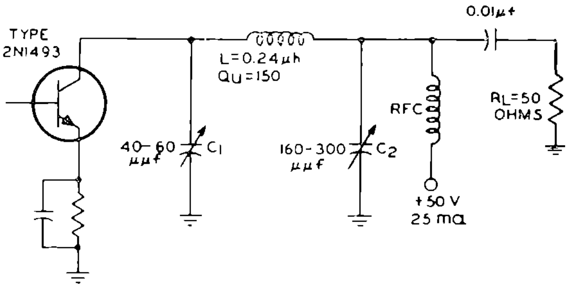


Fig. 9—50-megacycle-amplifier output circuit.

$$X_{L\max} = \sqrt{(50)\,500} = 158$$

$$\frac{X_L}{X_{C_2}} = 1$$

If R_{out} is neglected, then

$$Q_L = \frac{1{\cdot}58}{50} = 3{\cdot}16$$

Because this value of Q_L is too low, a smaller value of X_L must be used. Assume X_L=75 ohms ; then

$$\frac{X_L}{X_{C_2}} = 1 - \sqrt{\frac{500}{50} - \left(\frac{75}{50}\right)^2} = 3{\cdot}79$$

$$Q_L = \frac{75}{50} + \left(\frac{50}{19{\cdot}8}\right)\left(2{\cdot}79\right) = 8{\cdot}5$$

$$L = 0{\cdot}2 \text{ ph}$$

$$C_1 = 54 \text{ pf}$$

$$C_2 = 160 \text{ pf}$$

$$\eta = 0{\cdot}93 \text{ for } Q_u = 150$$

For R_{in}=2000 ohms and X_L=75 ohms,

$$Q_L = 30$$

$$C_1 = 50 \text{ pf}$$

$$C_2 = 300 \text{ pf}$$

$$\eta = 0{\cdot}83$$

Fig. 9 shows the complete output circuit for a one-half watt 50-megacycle amplifier. C_1 and C_2 are adjustable so that the proper load may be presented to transistors having characteristics which vary slightly from unit to unit.

(With acknowledgements to RCA)

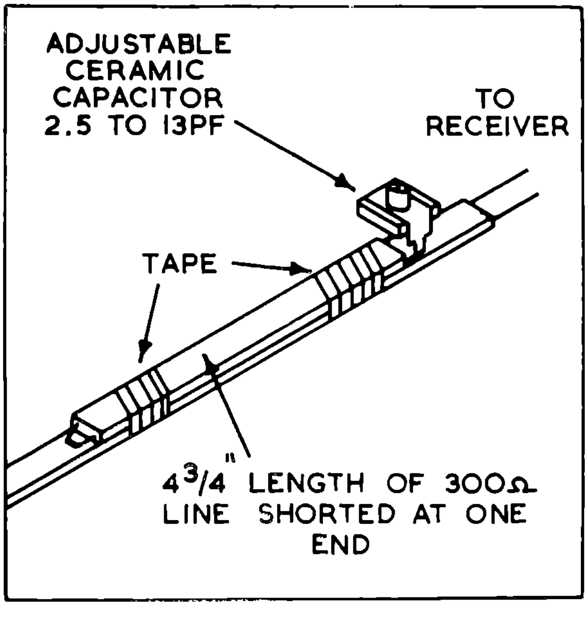
(TO BE CONTINUED)

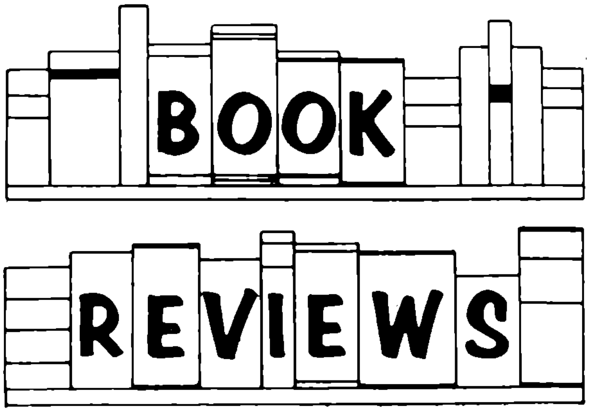
RF TRAP FOR TV

A very high-Q rf trap can be used to eliminate or minimize FM interference and some other types of rf interference which may be spoiling your picture, and which is entering the receiver via the antenna terminals. The trap consists of a 4-inch length of 300-ohm transmission line which is taped to the transmission line. One end of the trap is shorted, whilst a 2.5 to 15 pf adjustable ceramic trimmer connected across the other end allows the trap to be tuned.

This arrangement covers the approximate range of 40 to 200 Mc; if a different coverage is wanted, the length of line can be made shorter or longer, and/or the ceramic trimmer can be given a wider range of adjustment. The trap tunes very sharply and must be carefully adjusted. It should of course be taped as close to the antenna terminals as possible.

If required, the attenuation of the trap may be reduced by connecting a resistor in lieu of the short circuit at one end, an increase in resistance value decreasing the attenuation; it will also of course tend to broaden the tuning of the trap. A variable resistor connected temporarily would enable the degree of attenuation required to be determined.





BOOK REVIEWS

Books reviewed in these pages (except AWV publications) are complimentary copies received direct from the publishers. All enquiries for these books should be directed to your local technical booksellers, and not to AWV.

"All About Crossover Networks", H. M. Tremaine, Howard W. Sams and Co. Inc. Size 8½" x 5½". 80 pages, numerous charts, tables and diagrams.

Howard Tremaine is the author of the monumental work on audio, "The Audio Cyclopedia", and is therefore eminently qualified to write this book. The subject of crossover networks has too-long been buried in obscurity; this book seeks to remedy this, and does so in a lucid way and at a well-chosen time. With the steady growth of hifi systems towards multiple speaker arrangements, and now that stereo is with us, what serious audiophile can afford to remain in the dark on such a vital subject?

This book, though small in physical size, is an impressive collection of data on crossover networks. It contains basic principles, design and construction data. Charts and tables make it easy to arrive at the component values required in the various types of network without tedious calculation. In this way even the non-technical person is able to set up a network to suit his requirements, and thus get the best out of his multiple-speaker set-up.

"Experiments in Industrial Electronics", Melvin Whitmer, Howard W. Sams and Co. Inc. Size 8½" x 5½". 94 pages. 61 diagrams.

This book is intended to fill the gap between the diverse, yet similar, servicing fields of entertainment and industrial electronics. The technician who has worked on television, radio, and audio equipment is not capable of stepping directly into industrial electronics. In addition to considerable background study, he needs bench experience on representative equipment. This book is intended to provide that experience.

Some electronic schools are training technicians for entry into the industrial field. For these students practical experience, plus fundamental concepts learned from actual circuits, is the pathway into this exciting and lucrative area.

Who doesn't like to build things, especially if they are electronic and useful? Melvin Whitmer takes the direct route in introducing you to the mushrooming field of industrial electronics. He not only describes how various representative industrial devices work through text and drawings, but also lets you pitch in and build the equipment yourself, for first-hand knowledge of the principles involved.

"Industrial Electronics", Paul B. Zbar, McGraw-Hill Book Co. Inc. Size 11" x 8½". 201 pages, 267 figures.

This is another of the excellent Electronic Industries Association/New York Trade School Publications, of which other titles have been reviewed already in these pages. One of the interesting developments we are witnessing today is the growth of electronics into industrial processes and machinery of all kinds. Lifts, printing presses, packaging machinery, machine tools of all kinds, and other applications and processes too numerous to mention are now being more and more controlled and supervised electronically. The point is that all this equipment needs installation and maintenance, and who is going to do it?

The logical thing, and the thing that is happening, is for electricians to study up industrial electronics. This is logical because the applications of the equipment take it into fields where electricians have been working for years, for example, electronic control of motor speeds. Your reviewer understands that courses for tradesmen in industrial electronics have already been inaugurated at some technical colleges.

The study of industrial electronics offers the electrical tradesman an opportunity to advance himself and to branch out into a new and interesting field, the potentialities of which are enormous. It is for such people that this book has been prepared. It is written in the form of a series of "jobs" or experiments which illustrate the theory, and covers all essential aspects of the subject. Whilst primarily intended for use in an organized class, private study will also produce an excellent grounding in the subject.

NEW GERMANIUM POWER TRANSISTORS

2N173 2N174 2N277 2N278 2N441 2N442

2N443 2N1099 2N1100 2N1358 2N1412

These transistors are alloy-junction power transistors of the germanium p-n-p type utilizing the JEDEC TO-36 single-ended stud-mounted package. These transistors are intended for a wide variety of applications in industrial and military equipment requiring transistors having high voltage, current, and dissipation ratings. They are particularly useful in power-switching, voltage-regulator, dc-to-dc converter, power-supply, and relay-actuating circuits, and in low-frequency oscillator and audio-amplifier service.

The JEDEC TO-36 stud-mounted package employed for these transistors provides positive heat-sink contact and has a cold-weld seal to insure reliable performance under severe environmental conditions. These power transistors can be subdivided into groups as follows:

Typical Power Supply Voltage:

28 or 12 volts (For applications involving high transient voltages)	2N174, 2N1099 2N1100, 2N1358, 2N1412
12 volts (For applications involving low transient voltages)	2N173, 2N277, 2N278, 2N441, 2N442, 2N443

Maximum Collector-to-Base Volts:

-40	2N277, 2N441
-50	2N278, 2N442
-60	2N173, 2N443
-80	2N174, 2N1099, 2N1358
-100	2N1100, 2N1412

Maximum Transistor Dissipation (Watts):

87.5	2N174, 2N1099, 2N1100, 2N1358, 2N1412
70	2N173, 2N277, 2N278, 2N441, 2N442, 2N443

DC Current Transfer Ratio:

20-40	2N441, 2N442, 2N443
25-50	2N174, 2N1100, 2N1358, 2N1412
35-70	2N173, 2N277, 2N278, 2N1099

INDUSTRIAL SERVICE

Such as in dc-to-dc converter, inverter, chopper, voltage and current-regulator, dc and audio amplifier, relay and solenoid-actuating circuits.

Maximum Ratings, Absolute Maximum Values:

	2N277 2N441	2N278 2N442	2N173 2N443	2N1742N1358	2N1099	2N1412	2N1100	
COLLECTOR-TO-BASE VOLTAGE:								
With emitter-to-base reverse bias of -1.5 volts	-40	-50	-60	-80	-80	-100	-100	volts
EMITTER-TO-BASE VOLTAGE	-20	-30	-40	-60	-40	-60	-80	volts
COLLECTOR CURRENT	-15	-15	-15	-15	-15	-15	-15	amp
EMITTER CURRENT	15	15	15	15	15	15	15	amp
BASE CURRENT	-4	-4	-4	-4	-4	-4	-4	amp
TRANSISTOR DISSIPATION:								
At case-seat temperature of 25°C and for operation with heat sink (See Rating Charts Fig. 1 and Fig. 2)	70	70	70	87.5	87.5	87.5	87.5	watts
CASE-SEAT TEMPERATURE:								
Operating:								
Continuous	-65 to +95							°C
Intermittent	-65 to +100							°C
Storage	-65 to +100							°C

Typical Operation in Power-Switching Service:

At a Case-Seat Temperature of 25°C
Common-Emitter Circuit, Base Input

DC Supply Voltage	-12	volts
DC Base Bias Voltage	6	volts
"On" DC Collector Current	-12	amp
"Turn-On" Base Current	-2	amp
"Turn-Off" Base Current	0	amp
Switching Time:		
Rise Time	15	μsec
Fall Time	15	μsec

OPERATING CONSIDERATIONS

The metal shells of these transistors operate at the collector voltage. Consideration, therefore, should be given to the possibility of shock hazard if the metal shells of these transistors are to operate at a voltage appreciably above or below ground potential. In such cases, suitable precautionary measures should be taken.

These transistors are provided with a single-ended stud for mounting to a heat sink and for electrical connection to the collector; refer to mounting diagram. Electrical connection to the base and to the emitter is made to their respective lugs.

Maximum recommended torque on the mounting stud is twelve inch-pounds.

Continued overleaf

ELECTRICAL CHARACTERISTICS, at case-seat temperature of 25°C -----------

Characteristic	Symbol	TEST CONDITIONS					LIMITS											
		DC Voltage (volts)			DC Current (amperes)		Type 2N173			Type 2N174			Type 2N277			Type 2N278		
		V_{CB}	V_{CE}	V_{EB}	I_C	I_E	Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.
Collector-Cutoff Current	I_{CBO}	-2				0		-100			-100			-100			-100	
		-30				0												
		-40				0								-2	-8			
		-50				0											-2	-8
		-60				0		-2	-8									
		-80				0					-2	-8						
		-100				0												
		★				0			-15			-15			-15			-15
Emitter-Cutoff Current	I_{EBO}			-20	0									-1	-8			
				-30	0												-1	-8
				-40	0			-1	-8									
				-60	0						-1	-8						
				-80	0													
DC Current Transfer Ratio†	h_{FE}		-2		-5		35		70	25		50	35		70	35		70
			-2		-12			25			20			25			25	
Base-to-Emitter Voltage‡	V_{BE}		-2		-5			-0.65			-0.65	-0.9		-0.65			-0.65	
Emitter-to-Base Voltage	V_{EB}	-40				0									-1			
		-50				0												-1
		-60				0		-0.15	-1									
		-80				0						-1						
		-100				0												
Collector-to-Emitter Saturation Voltage:† With base current = -2 amperes	V_{CE}				-12			-0.3	-1		-0.3	-0.9		-0.3			-0.3	-1
Collector-to-Emitter Breakdown Voltage: With base connected to emitter	BV_{CES}				-0.3		-50			-70			-40			-45		
With base open	BV_{CEO}				-0.3 ▲-1		-45	-50		-55			-25	-40		-30	-45	
Punch-Through Voltage	V_P						-60			-80			-40			-50		
Beta-Cutoff Frequency†	$f_{\alpha e}$		-6		-5			10			10			10			10	
Thermal-Resistance: Junction-to-case	R_T							0.7	1		0.5	0.8		0.7	1		0.7	1
Thermal Capacity: For pulses of 1 to 10 milliseconds								0.075			0.075			0.075			0.075	

★ At 71° C and for value of V_{CB} shown above.

▲ Sweep voltage used to perform test.

□ At V_{CB} = 12 volts and I_C = 1 amp.

■ At 71° C.

● At I_C = 1.2 amp.

† Measured in a common-emitter circuit, base input.

‡ V_{BE} at V_{CB} = -2 volts, I_C = 1.2 amp; 0.35 (typical), 0.5 (maximum).

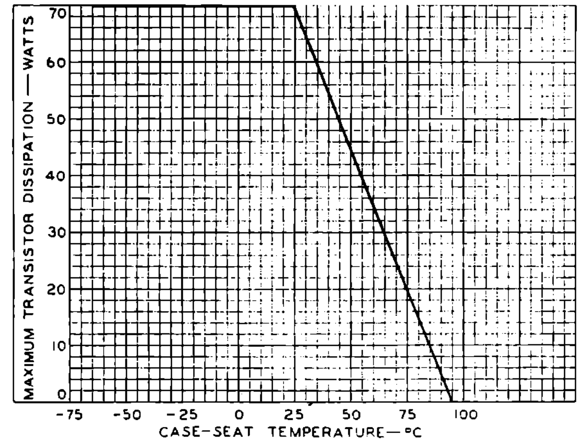


Fig. 1 — Rating Chart for Types 2N173, 2N277, 2N278, 2N441, 2N442, and 2N443.

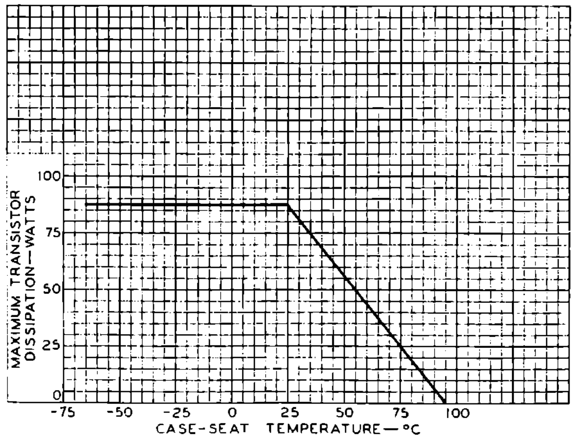


Fig. 2 — Rating Chart for Types 2N174, 2N1099, 2N1100, 2N1358, and 2N1412.

LIMITS																					Units
Type 2N441			Type 2N442			Type 2N443			Type 2N1099			Type 2N1100			Type 2N1358			Type 2N1412			
Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.	Min.	Typical	Max.	
	-100			-100			-100			-100			-100			-100	-200		-100		μa
																-4■	-6■				ma
	-2	-8																			ma
				-2	-8																ma
							-2	-8													ma
										-2	-8					-2	-8				ma
													-2	-8					-2	-8	ma
		-15			-15			-15			-15			-15			-15			-15	ma
	-1	-8																			ma
				-1	-8											-4■	-6■				ma
							-1	-8		-1	-8										ma
																-1	-8		-1	-8	ma
													-1	-8							ma
20		40	20		40	20		40	35		70	25		50	25	35		25		50	
	20			20			20			25			20		40●	55●	80●		20		
	-0.65			-0.65			-0.65	-0.9		-0.65	-0.9		-0.65	-0.9	‡	-0.65	-0.9		-0.65	-0.8	volt
		-1																			volt
					-1																volt
								-1													volt
										-0.15	-1					-0.15	-1				volt
														-1						-1	volt
	-0.3			-0.3			-0.3	-1		-0.3	-0.7		-0.3	-0.7		-0.3	-0.7		-0.3	-0.7	volt
-40			-45			-50			-70			-80			-70			-80			volts
-25	-40		-30	-45		-45	-55		-55	-60		-65			-40			-65			volts
-40			-50			-60			-80			-100			-80			-100			volts
	10			10			10			10			10		-100				10		Kc
	0.7	1		0.7	1		0.7	1		0.5	0.8		0.5	0.8		0.5	0.8		0.5	0.8	°C/ watt
	0.075			0.075			0.075			0.075			0.075			0.075			0.075		watt-sec/ °C

V_{CB} = Collector-to-base voltage. V_{BE} = Base-to-emitter voltage. I_C = Collector current.
V_{CE} = Collector-to-emitter voltage. I_E = Emitter current.

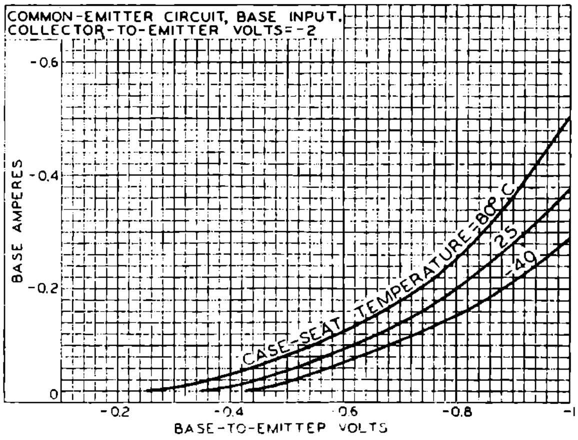


Fig. 3 — Typical Characteristics for Types 2N173, 2N277, 2N278, and 2N1099.

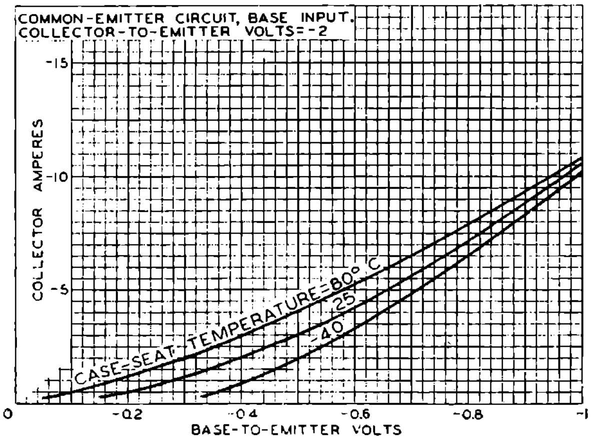


Fig. 4 — Typical Characteristics for Types 2N173, 2N277, 2N278, and 2N1099.

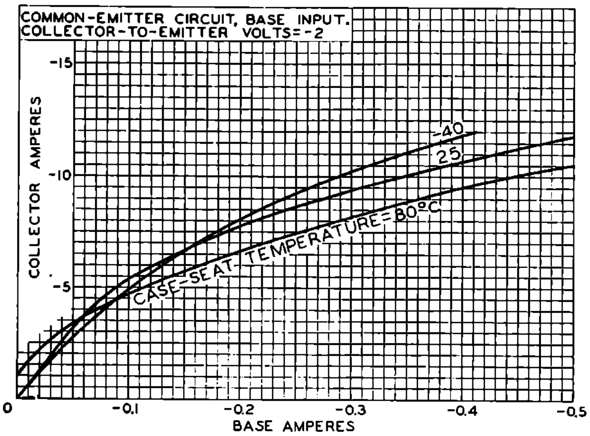


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Fig. 5 — Typical Characteristics for Types 2N173, 2N277, 2N278, and 2N1099.

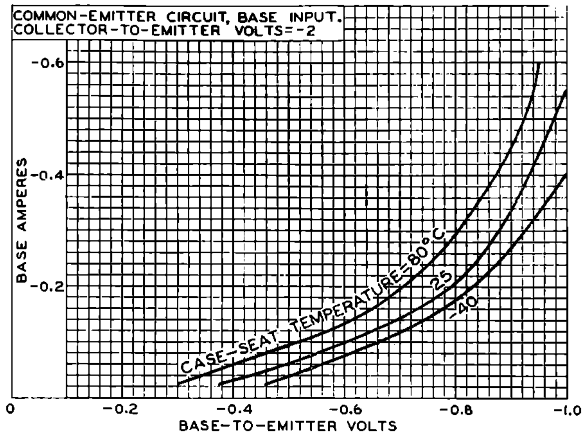

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Fig. 6 — Typical Characteristics for Types 2N174, 2N1100, 2N1358, and 2N1412.

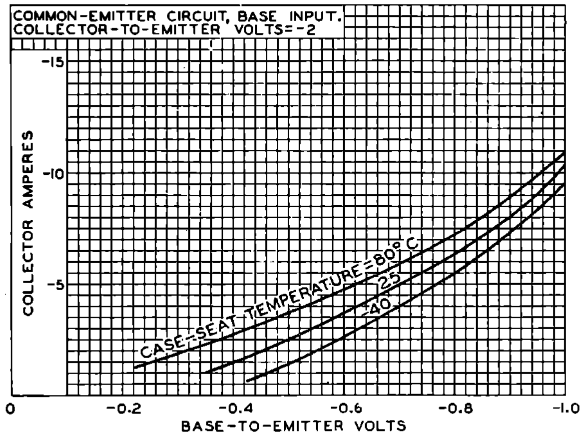

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Fig. 7 — Typical Characteristics for Types 2N174, 2N1100, 2N1358, and 2N1412.

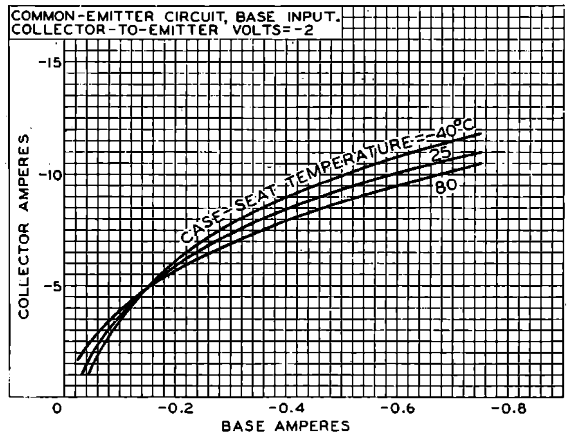

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Fig. 8 — Typical Characteristics for Types 2N174, 2N1100, 2N1358, and 2N1412.

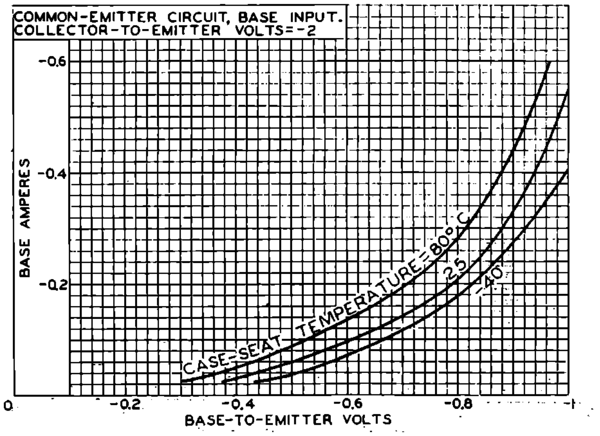

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Fig. 9 — Typical Characteristics for Types 2N441, 2N442, and 2N443.

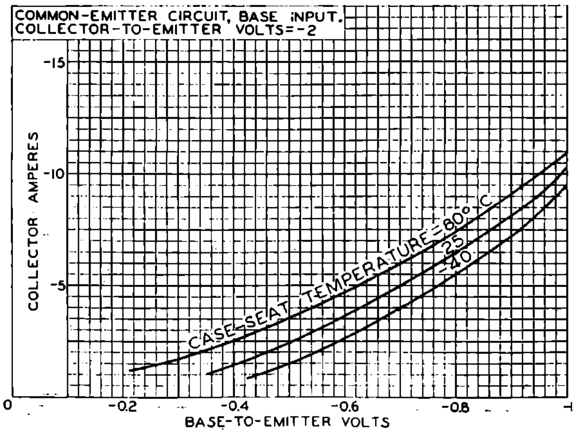

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Fig. 10 — Typical Characteristics for Types 2N441, 2N442, and 2N443.

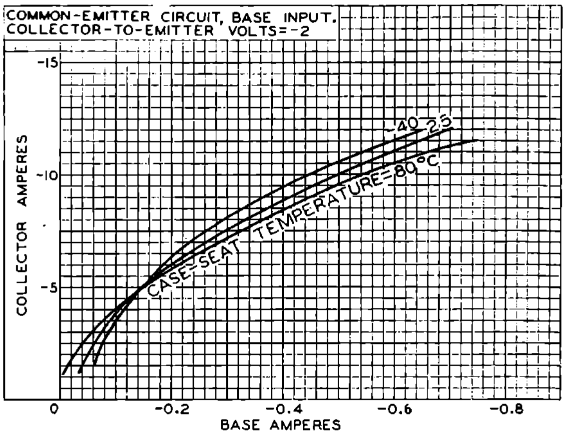

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Fig. 11 — Typical Characteristics for Types 2N441, 2N442, and 2N443.

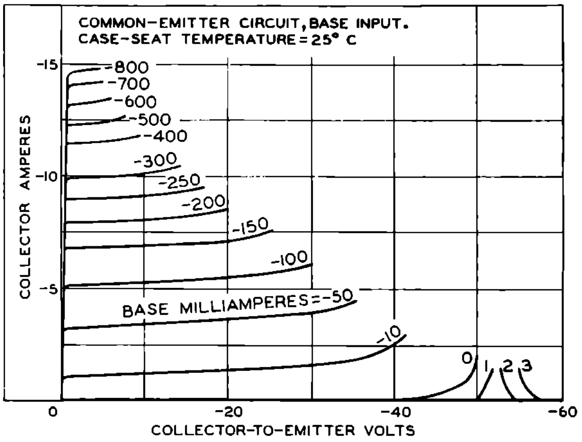

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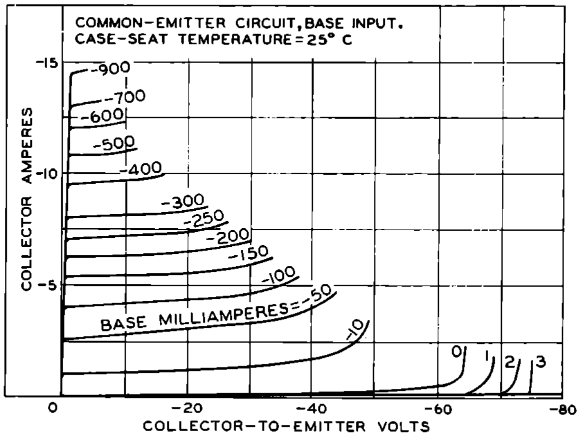
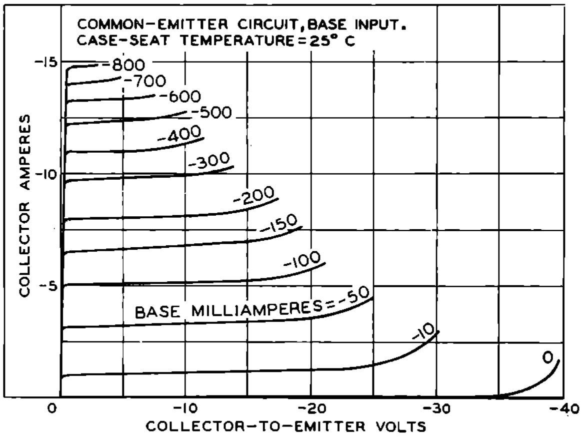
Fig. 12 — Typical Characteristics for Type 2N173.



92CS-10736

Fig. 13 — Typical Characteristics for Types 2N174, and 2N1358.



92CS-10725

Fig. 14 — Typical Characteristics for Type 2N277.

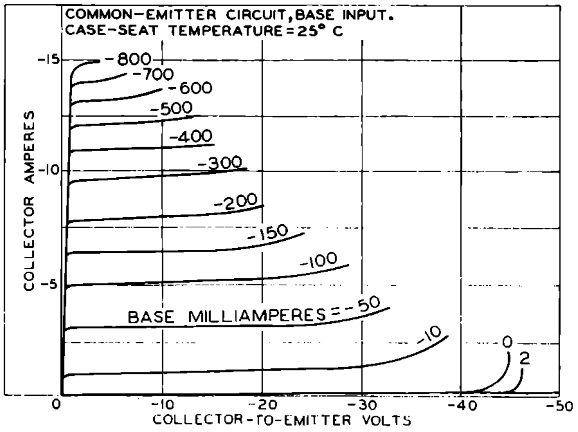


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Fig. 15 — Typical Characteristics for Type 2N278.

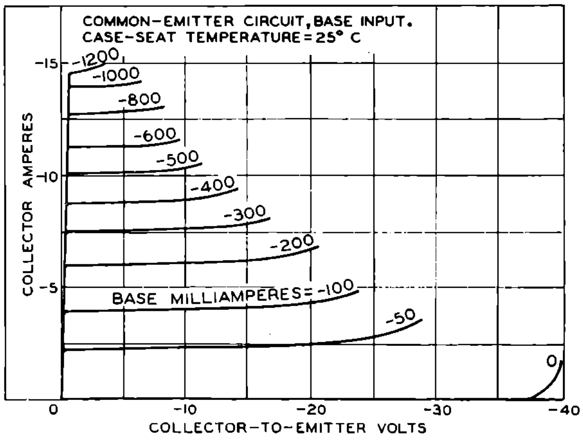

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Fig. 16 — Typical Characteristics for Type 2N441.

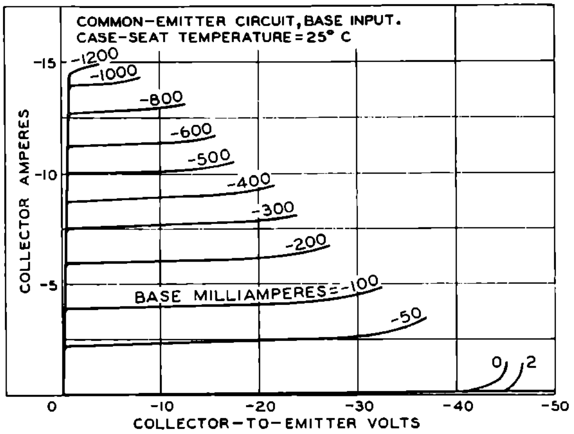

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Fig. 17 — Typical Characteristics for Type 2N442.

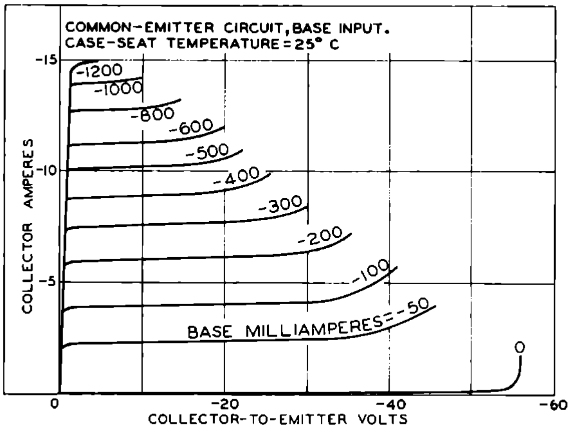

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Fig. 18 — Typical Characteristics for Type 2N443.

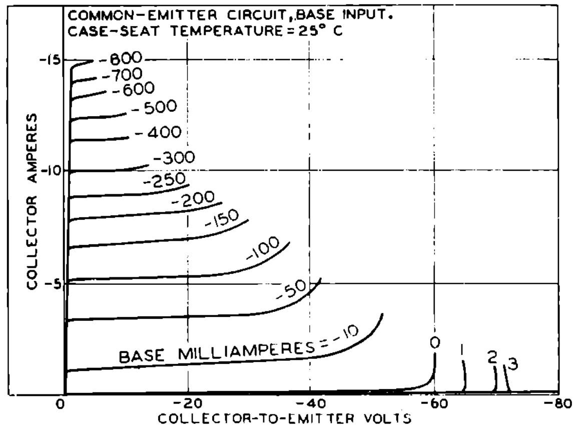

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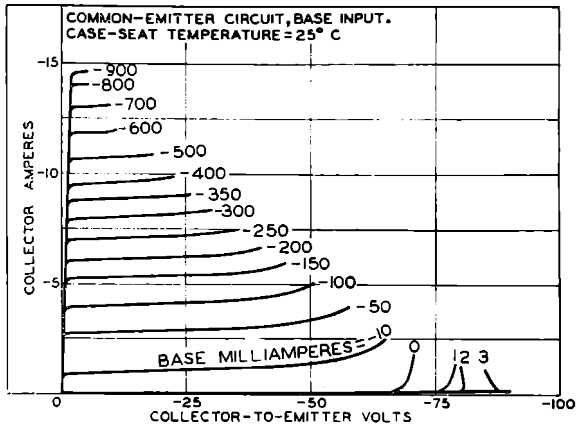
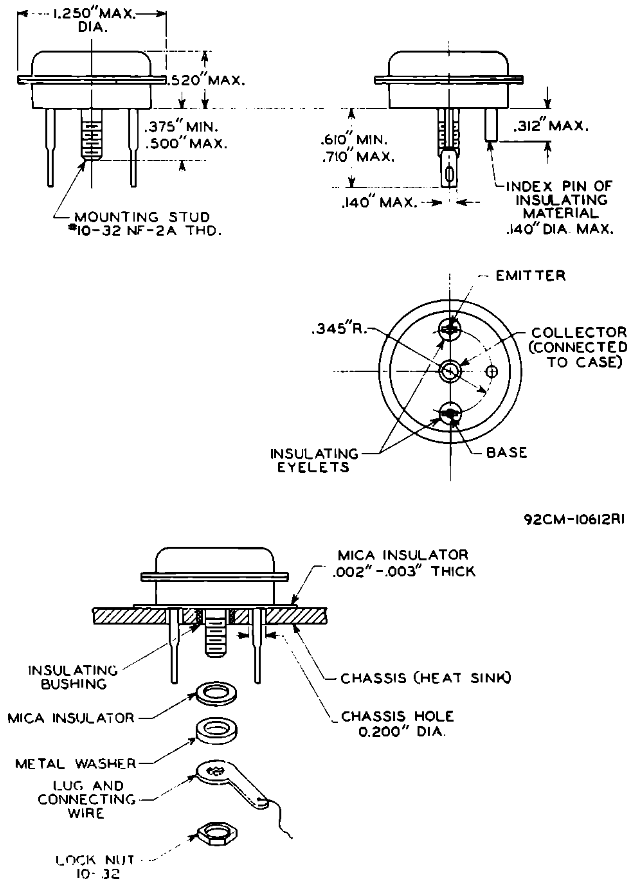
Fig. 19 — Typical Characteristics for Type 2N1099.



92CS-10724

Fig. 20 — Typical Characteristics for Types 2N1100, and 2N1412.



Dimensional Outline and Suggested Mounting Arrangement.


AWV