RADIOTRONICS

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Volume 19 **May 1954** **Number 5**

APPLICATION CONSIDERATIONS FOR RCA COMMERCIAL TRANSISTORS*

By R. M. Cohen

This paper discusses practical problems involved in the application of RCA point-contact transistors 2N32 and 2N33 and junction transistors 2N34 and 2N35. It is intended primarily for the circuit-design engineer who is considering the use of transistors in commercial equipment and has seen varied, and sometimes contradictory, information on life, interchangeability, effects of temperature and humidity, and similar factors, all of which have a vital influence on the success of a transistorized device. Because application information on point-contact transistors was included in talks given by the author last year,[1] the discussion on these types in this paper is limited to some important information which was not covered previously. This paper is devoted primarily to a discussion of the practical problems involved in the application of the two junction transistors and, in particular, the large-signal operation of these devices at audio frequencies. Some information on complementary-symmetry circuits is also included.

2N32 POINT-CONTACT TRANSISTOR:

Switching Circuits.

The 2N32, intended primarily for switching service in moderately-high-speed digital computers, also finds useful application as a high-frequency oscillator at frequencies to three megacycles and as an amplifier at frequencies to about 1.5 megacycles. Fig. 1 shows the dimensional specifications and mechanical assembly of the 2N32. This figure also applies to the 2N33 point-contact transistor.

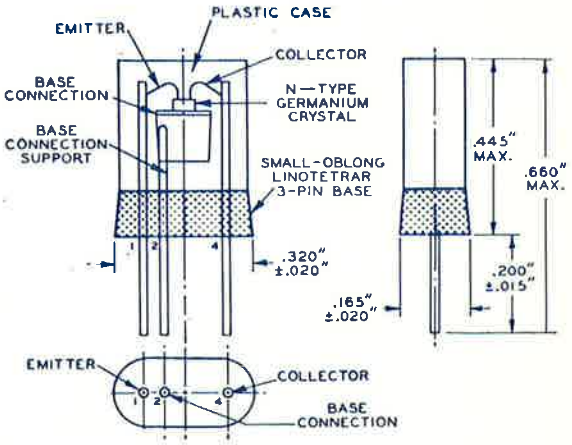

Fig. 1. Diagramatic sketch showing structural arrangement and major dimensions of RCA-2N32 or RCA–2N33 point-contact transistor.

Fig. 2 shows the "N"-shaped emitter characteristic of the 2N32, which determines its performance in large-signal switching circuits.[2,3] Region 1 of the characteristic curve, called "the reverse-emitter-current region", determines the "off" time and depends entirely on the back resistance between emitter and base. This resistance is nominally approximately 100,000 ohms, but its initial value may vary from about 1 megohm to about 25,000 ohms for individual units. In transistors having the higher initial values, the back resistance tends to drop with life. Optimum transistor performance involves the use of a variable emitter-circuit resistance or a diode in series with the emitter to remove the transistor from the circuit during the "off" period. The value of emitter-circuit resistance should be as low as practical to reduce the effect of emitter-to-base back-resistance variations.

Reprinted with acknowledgements to Radio Corporation of America.

* This paper was presented by R. M. Cohen at the I.R.E. West Coast Convention in San Francisco, California, on August 20, 1953, at the Joint Services Transistor Applications Symposium in New Haven, Connecticut, on September 2, 1953, at the I.R.E. Cedar Rapids Section in Cedar Rapids, Iowa, on September 29, 1953, and at the RETMA/IRE Radio Fall Meeting in Toronto, Ontario, Canada, on October 28, 1953.

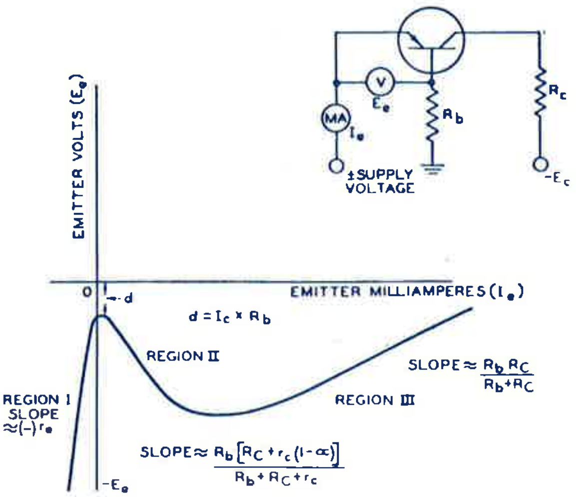

Fig. 2. Emitter characteristic curve for RCA-2N32 point-contact transistor.

The distance "d" from the co-ordinate axis to the point of inflection between region I and region II depends directly on the collector current which flows when the emitter circuit is open, or I_{c0}. This distance, d, can be stabilized, however, by the use of a bleeder current from the collector supply voltage through the external base resistance, R_b. A current of approximately 2 or 3 milliamperes is usually sufficient to minimize effects of variations in I_{c0}. The use of this bleeder current, however, increases the switching-signal power requirements.

The use of a biased diode to provide "clamping" action, preventing the voltage between base and ground from exceeding a preset value, is illustrated in the "gated"-amplifier circuit of Fig. 3.

In the expression for region II of the characteristic curve in Fig. 2, called the "transitional region", it is assumed that the external base resistance, R_b, is large compared to the internal feedback resistance of the transistor. The current amplification factor, α, is controlled within a specific range of values at three points within region II. This factor is reasonably stable, not varying more than 20 per cent. with life and temperature. The internal collector resistance, r_c, varies from 30,000 to 10,000 ohms between units, and may fall as low as 7,500 ohms with life. The use of a high load resistance in the collector circuit reduces the effect of these variations in r_c on circuit performance, as the equation indicates.

The point of inflection between region II and region III occurs when the current amplification factor of the transistor drops to unity. At this point, the emitter current of the transistor is high, the collector current is at its peak value, and the collector voltage is very close to the knee of the collector characteristic curve. The current amplification factor and the collector current at this point can be controlled initially, but pulse operation causes uncontrolled and detrimental effects which reduce the magnitude of the output-current pulse. Operation of the transistor from a high-voltage source and with high-impedance loads minimizes these effects and may result in satisfactory operation. The higher voltage improves hole mobility and thus reduces rise and fall time, making operation at high speeds possible. Average rise times of 0.07 microsecond and fall times of 0.25 microsecond are obtained with 2N32's.

Region III, the conduction region, depends primarily on the external circuit parameters unless circuits having extremely low impedance are employed. Such circuits, however, should usually be avoided.

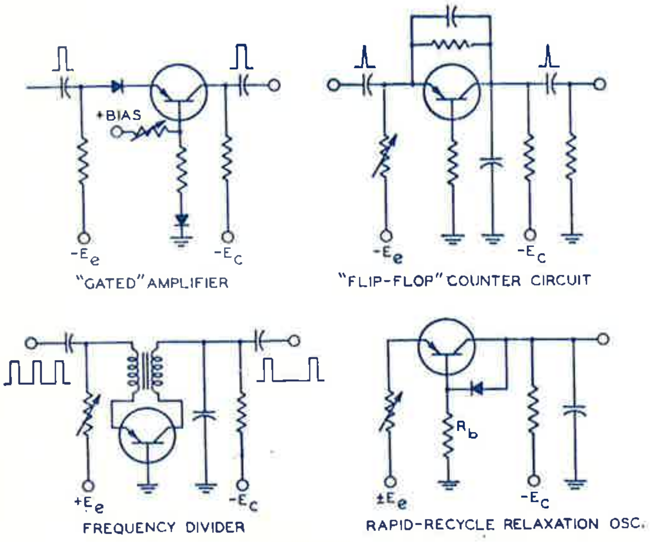

Fig. 3. Typical "large-signal" circuits for RCA-2N32.

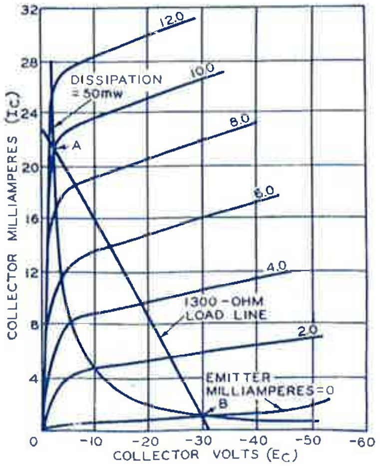

Fig. 4. Operating curve for RCA-2N32 showing load line for large signals.

Fig. 3 shows some typical large-signal circuits and indicates how variable resistances in the emitter circuit may be used to permit the circuits to work with a wider range of transistors. These variable biasing resistances, which are similar to the variable resistances used in the grid circuits of electron-tube blocking oscillators, are essential if any appreciable degree of interchangeability is to be achieved.

Fig. 4 shows the collector characteristic of the 2N32, including a constant-dissipation curve for 50 milliwatts, the rated maximum dissipation of the unit. As shown in Fig. 4, this dissipation could be exceeded during switching intervals even though the "off" condition, "B", and the "on" condition, "A", are within a safe dissipation area. Ratings have not yet been established for peak dissipation or maximum permissible pulse duration at various maximum collector currents.

RF Oscillator Service.

The 2N32 is also used frequently in rf oscillator service; the curve in Fig. 5 gives the performance of a typical unit in the circuit shown. Making the connection to the base of the transistor to a tap down on the oscillator tank coil substantially improves interchangeability by reducing variations in generated frequency and power output. The effects on frequency of variations in base-to-emitter capacitance and impedance are minimized in this connection. In addition, because the base-input impedance is of the order of 5,000 ohms at a frequency of approximately one megacycle per second, a better impedance match is effected at the coil tap. The use of constant-current emitter bias is essential for interchangeability in oscillator applications. The use of this type of bias not only assures that the transistor's initial bias point will not vary from unit to unit, but also permits the insertion of a sufficiently large resistance in series with the emitter to provide automatic biasing. This "automatic bias" is somewhat similar to that provided by the grid-resistor grid-capacitor (grid-leak) action of electron-tube oscillator circuits.

High-Frequency Amplifier Service.

The 2N32 is also useful as a high-frequency amplifier and will probably be used in such applications until a more satisfactory high-frequency junction device becomes commercially available. Because the current amplification factor of point-contact transistors is greater than unity, negative resistances generated in the input circuit pose two serious problems. The first problem is the possibility of oscillation because the 2N32 is not short-circuit stable. Unless there is sufficient circuit impedance in series with either the emitter or the collector, or both in combination, the transistor amplifier stages will oscillate, and the transistor current may increase sufficiently to damage the transistor. When the 2N32 is used in a tuned amplifier, sufficient circuit impedance can be obtained only with series-resonant circuits; parallel-resonant circuits cannot be used. The circuit shown in Fig. 6 effectively provides short-circuit stability and also permits matching the high output impedance of the collector of the first transistor to the low input impedance of the emitter of the second transistor.[4] The coil, L_1, and tuning capacitor, C_1, form a parallel resonant circuit in which the inductance provides essentially the major part of the tuned-circuit series resistance and, therefore, absorbs all of the power delivered to the tuned circuit. The values of L_1 and C_1 for the tuned circuit should be chosen so that the dynamic resistance, L/CR, is equal to the collector impedance of the driving stage, and, of course, so that L_1 and C_1 resonate at the desired frequency. Improved selectivity can be obtained by inserting a coil, L_2, in series with the emitter of the driven transistor and resonating this coil with the coupling capacitor, C_2.

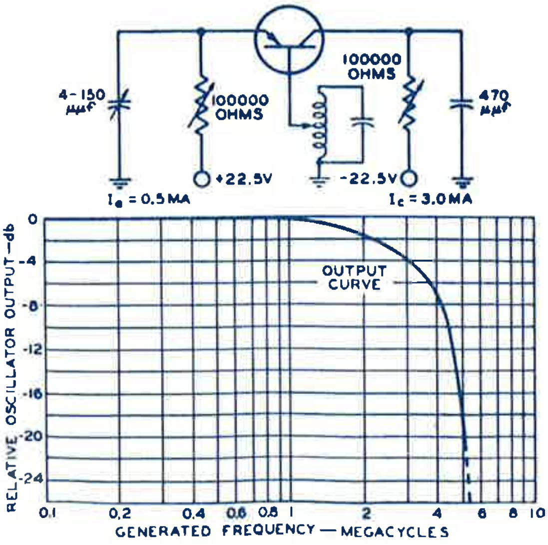

Fig. 5. Oscillator performance of the RCA-2N32 as a function of frequency.

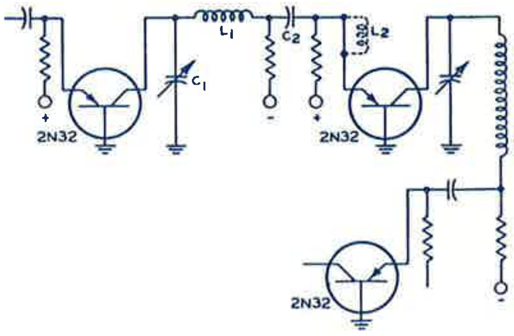

Fig. 6. Coupling method for RCA-2N32 transistor providing stability and impedance matching.

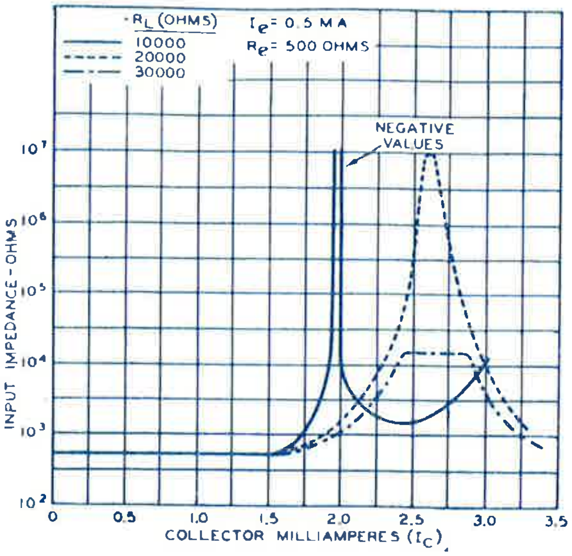

Fig. 7. Input impedance of base-input circuit as a function of collector current for 2N32.

The second problem caused by the high current amplification factor of point-contact transistors concerns the effect of the base-input connection on transistor interchangeability. If a point-contact transistor is used in a base-input circuit, its input impedance can be made very high, or very low, or may even have negative values. When the input impedance is negative, oscillation occurs because the output current is greater than the input current, the output circuit is common to the input circuit, and the energy developed in the output circuit is in phase with the input signal. Fig. 7 shows the input impedance of the base-input circuit as a function of collector current. The curves of Fig. 7 indicate how sensitive this regenerative connection is to variations in one particular circuit parameter, R_L, the effective output load impedance. Similar steep-sided curves could be presented for variations of other circuit parameters such as the signal-source impedance, and also for variations of transistor characteristics such as r_e, r_b, α, and the operating voltages and currents. The base-input connection for a point-contact transistor invariably results in a lack of interchangeability and, in effect, requires custom-built equipment. Even in custom-built equipment, however, the performance varies very rapidly with the slightest changes in the transistor or circuit components.

2N33 HIGH-FREQUENCY OSCILLATOR.

The 2N33, which has extremely close spacing, is intended primarily for a frequency range well above that which is practicable with other commercially available transistors.[4] The extremely close spacing, however, results in the generation of very high base resistances and also accounts for the extremely wide variations between units. This type is intended primarily for oscillator use and, in general, is not satisfactory for amplifier applications, not only because of the large and variable base resistance, but also because the collector characteristic curves on most units have rather severe discontinuities.

Fig. 8 shows the oscillator circuit developed for use in production tests on the 2N33. Units are tested in this circuit for a power output of 1 milliwatt at a frequency of 50 megacycles per second. The small capacitor, C_1, connected from emitter to ground, must be adjusted to a critical value because it compensates for the phase delay between the collector current and the emitter current resulting from carrier transit-time effects.

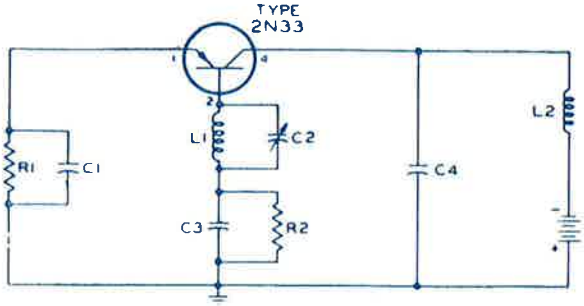

Fig. 8. 50-Megacycle oscillator test circuit for RCA–2N33 point-contact transistor.

THE RCA-2N34 P-N-P AF JUNCTION TRANSISTOR.

Fig. 9 is a diagrammatic sketch of the 2N34 showing its general construction and major dimensions. This sketch also applies to the 2N35 junction transistor.

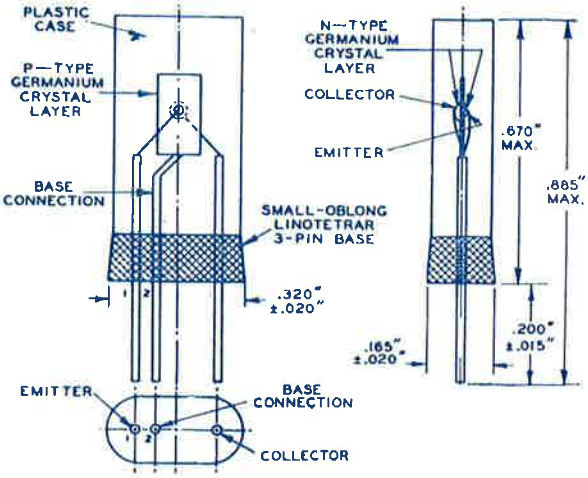

Fig. 9. Diagrammatic sketch showing structural arrangement and major dimensions of RCA–2N34 or RCA–2N35 junction transistor.

When 2N34 transistors are used in small-signal circuits, the effects on circuit performance of variations between units should be considered. The present range of values for base-input current amplification factor, α, allows a variation from about 25 to 135, with the distribution centre at approximately 40 and a normal distribution pattern. This wide range of values obviously imposes some problems on the circuit designer, but it is hoped that the distribution of current amplification factor may be narrower in future transistors.

Another problem requiring careful consideration is the variation in the internal collector resistance, r_c, between units. The collector resistance also has a tendency to decrease in value with increasing temperature, the rate of decrease being approximately 2 per cent. per degree Centigrade in the range from 30 to 50 degrees Centigrade. There is also a decreases in r_c with life on some units. The initial value is usually about one megohm, and the minimum value may be as low as 100,000, ohms. These values are measured in the grounded-base connection with the emitter effectively open-circuited.

Fortunately, the variation in internal collector resistance is not a factor in applications in which the load impedance is small compared to the collector resistance. It should be considered, however, whenever transformer coupling is employed, or in arrangements which employ the transistor in the emitter is terminated in an impedance of 2,000 latter case, the input impedance of the device approaches the value of the collector resistance when the emitted is terminated in an impedance of 2,000 ohms or more, which is the normal case, and individual variation in r_c can have a pronounced effect on the circuit performance. The use of a resistor of approximately 250,000 ohms in shunt with the collector limits the maximum developed impedance to values normally ranging to about one-half the impedance produced by the transistor alone, and appreciably improves the stability and interchangeability.

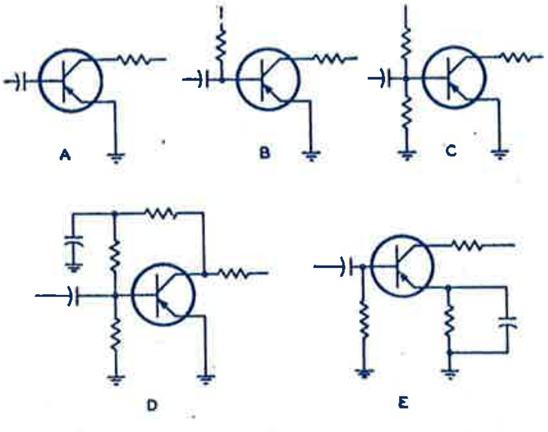

Fig. 10. Methods for biasing junction transistors.

Another factor which should be considered is the collector current which flows when the emitter is open-circuited. This current, designated as Ic_0, consists of a leakage current between collector and base and a current due to the effects of surface recombination. In many transistors, the surface recombination effects are dominant when the transistors are employed in the base-input circuit. The current generated by surface recombination is magnified by α in this type of connection, and can reach seriously large values, especially when the value of α is high. Unless special biasing arrangements are employed to reduce this effect, this current increases the battery drain and, in severe cases, can result in excessive dissipation. Life tests indicate that Ic_0, although low initially, increases substantially with life in an appreciable number of units. Typical values for Ic_0 at a collector voltage of 3 volts are about 20 microamperes. These values can be magnified by the current amplification factor to produce waste collector current of the order of 1.0 milliampere. Ic_0 also increases substantially with temperature, and biasing circuits must be designed to compensate for the detrimental effects this increase would produce.

Fig. 10 shows various methods of biasing junction transistors in the base-input connection. This connection is the poorest from the standpoint of temperature considerations, but offers the best performance with respect to power gain.[5]

The method of biasing shown in Fig. 10 at "A" is the most critical with respect to temperature effects, depending entirely on the internal transistor impedances and leakage currents to establish the operating point. The method shown at "B" is slightly better provided the external resistance is small compared to the internal collector resistance, r_c. The method shown at "C" represents a further improvement, provided the bleeder current is large compared to the base current. This method, however, has practical limitations because it wastes power and can reduce the input impedance of the stage. The method shown at "D", which is appicable when there is appreciable resistance in the collector circuit, provides dc degeneration and is effective at a bleeder current of only two or three times the base current. The filter network in "D" is used to remove the signal voltage from the feedback network, preventing the degeneration from reducing the ac stage gain.

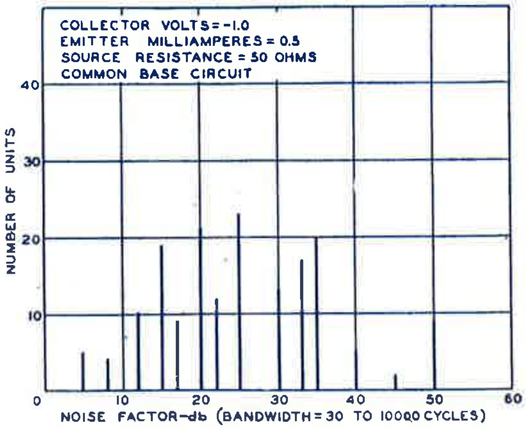

Fig. 11. Distribution of noise measurements for RCA junction transistors.

When the dc resistance in the collector circuit is not large enough for method "D" to be applicable, method "E" can be used in combination with "C" or "D" to provide dc degeneration and satisfactory stability with temperature without the consumption of excessive power from the collector supply. This method is somewhat similar to the use of a by-passed cathode resistor with high-transconductance electron tubes to provide automatic correction for plate-current variations due to changes in inter-electrode spacings.

Fig. 11 shows data on the noise performance of the 2N34. These noise measurements were made over an audio-frequency band from 30 to 10,000 cycles per second. The noise in transistors follows the well-known I/F relationship, but the results do not change significantly if the upper limit of the audio bandwidth is somewhat different from the figures mentioned above. No significant change occurs unless the bandwidth is reduced to very small values, as is the case in an amplifier designed for narrow-bandpass or single-frequency operation. The significance of the noise distribution data can probably be best understood with the aid of the following discussion. This discussion applies primarily to the hearing-aid type of application, but can easily be applied to any high-gain amplifier service.

Hearing aids operate within a bandwidth of approximately 5000 cycles per second at a power gain of approximately 85 db or 3.15×10^{8}, and produce a power output of approximately 10 milliwatts. The signal-input power to the transistor, therefore, is approximately 3.2×10^{-11} watts. Transistors operating in an emitter-input, grounded-base connection with a 50-ohm matched input and having a noise figure of 25 db produce a noise power in the input circuit equal to 4.13×10^{-15} watts, and thus have a signal-to-noise power ratio of approximately 3.8 : 1 or a signal-to-noise voltage ratio of 14 : 1. This signal-to-noise ratio is so poor that it represents about the minimum acceptable performance. On the basis of the data shown in Fig. 11, it is obvious that special tests must be made to select satisfactory units for the first stages of hearing aids and other high-gain applications.

In general, the choice of base- or emitter-input circuit for the first stage does not affect the noise figure. The impedance of the signal source and the operating conditions for the transistor, however, appreciably affect the results. A signal source which provides approximately matched input will produce nearly optimum results because the effects of mismatching are only very slightly beneficial and the optimum values usually fall close to the values required for matching. Operation of the transistor at the lowest practical value of collector supply voltage and at a very low value of collector current, such as 0.2 milliampere, will provide optimum noise performance.

Large-Signal Considerations.

There are a number of factors which must be considered if transistors are to be used successfully in applications which develop appreciable output power. Such applications include the power-output stages of audio amplifiers, audio oscillators, and similar equipment.

The peak-to-peak output voltage which can be developed by a transistor is limited by the so-called "Zener effect".[6] When a strong electric field applied to a transistor is gradually increased, there is a certain value known as the "critical field potential" beyond which the transistor's collector current increases very rapidly with only a slight increase in collector voltage unless there is sufficient dc resistance in the collector circuit to provide current limiting. This critical potential is sufficient to enable electrons from the valence band to cross the energy gap which separates them from the conduction band. The collector characteristic is influenced by this Zener effect, as shown in Fig. 12. The initial value of this critical potential, or Zener voltage, may be as high as 60 volts, but it may drop to values as low as 30 volts during life. In some cases, the collector characteristic curves do not have

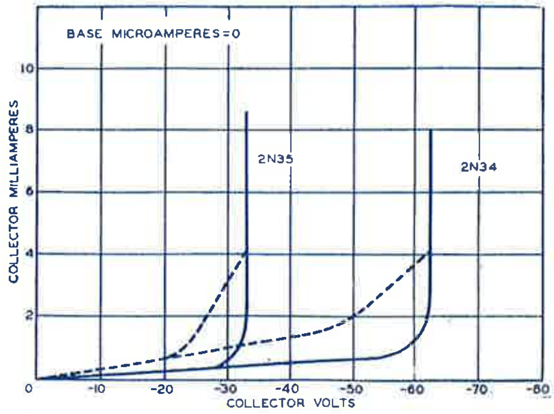

Fig. 12. Curve showing "Zener" effect on collector characteristic of RCA junction transistors.

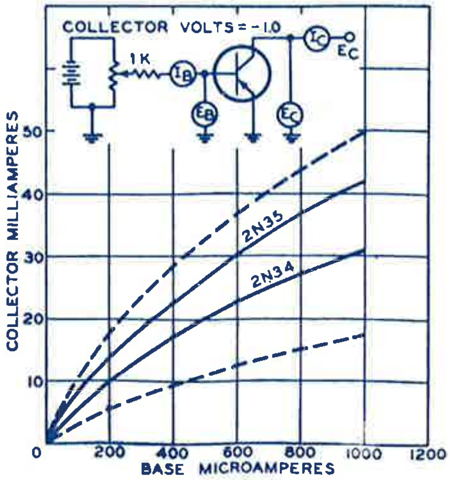

Fig. 13. Large-signal current-amplification-factor characteristic of RCA junction transistors.

sharp knees because of shunt leakage. In order to avoid excessive distortion when large signals are used, it is advisable to limit the applied voltage so that the peak voltage does not exceed the 30-volt value which represents the minimum limit. The Zener voltage does not seem to be appreciably affected by temperature, nor do the effects observed follow any particular trend.

When circuits are designed for operation of the transistor over a large signal excursion, it is desirable to have available information on the relationship of collector current to base current, base current to base voltage, and collector current to base-to-emitter voltage. Examples of this type of data are shown in Figs. 13, 14 and 15.

Fig. 13 is typical of the relationship between collector current and base current in the base-input circuit for values of collector current as high as 50 milliamperes. This curve is sometimes called the large-signal base-to-emitter current amplification characteristic because the slope of the curve at any point has a mathematical value equal to the base-input current amplification factor. It seems to be characteristic of these devices that the current amplification factor at the high currents is approximately one-half that which occurs at the low currents. This effect has been analyzed by Webster and others and will appear in published form in the near future.

Data are also presented in Fig. 13 for the 2N35 junction transistor, which is the n-p-n counterpart of the 2N34. The development of this transistor, incidentally, makes possible a wide variety of new applications, such as complementary-symmetry circuits,[7] which will be discussed later in this paper. The dotted lines in Fig. 13 represent the possible variations in individual 2N34 and 2N35 transistors for this characteristic. The non-linear relationship between collector current and base current indicates that the use of a constant-current signal source which would produce a sine wave of input current from a sine-wave voltage source is not desirable with 2N34 and 2N35 transistors. Large-signal operation is adversely affected by a large impedance in the base lead as a result of degenerative effects.

Fig. 14 shows the relationship of base current to emitter-to-base voltage; this curve is sometimes called the input-conductance characteristic. The 2N35 has an appreciably lower value for input conductance than the 2N34, primarily because the 2N35 has a higher value of extrinsic base resistance, or base-lead resistance, which is undesirable because it reduces the power gain. It is interesting that the slopes of the α characteristic and the input-conductance characteristic are such that they compensate for their individual lack of linearity, producing a relationship between collector current and emitter-to-base voltage, or a transfer characteristic, which approaches linearity over a substantial portion of the large-signal area. This transfer characteristic, shown in Fig. 15 for typical units, indicates that the large-signal characteristics of the 2N34 and 2N35 are not exactly equivalent. The difference between the two types has important implications in some types of circuitry, as will be discussed presently, but it is desirable to recognise that the 2N34 is a more efficient transistor than the 2N35 for large-signal audio applications.

The fact that the base-input transfer characteristic approaches linearity indicates that a sine-wave voltage source will produce a sine-wave output current provided the proper quiescent operating point is selected.

Variations in temperature tend to displace the position of the transfer characteristic curve without changing its general shape, increased collector current resulting from increased temperature. Temperature effects do not cause any severe difficulty provided the proper bias methods are employed and the maximum temperature rating for the transistor of 50 degrees Centigrade is not exceeded.

THE 2N35 AF N-P-N JUNCTION.

The development of the 2N35 n-p-n junction transistor, which has characteristics somewhat similar to those of the 2N34, makes available a combination which circuit engineers have long desired: two similar but electrically opposite devices which can produce output current flowing in opposite directions. Dr. Sziklai of the RCA Research Laboratories has proposed a number of interesting applications for the p-n-p and n-p-n transistors which he calls "complementary-symmetry" operation.

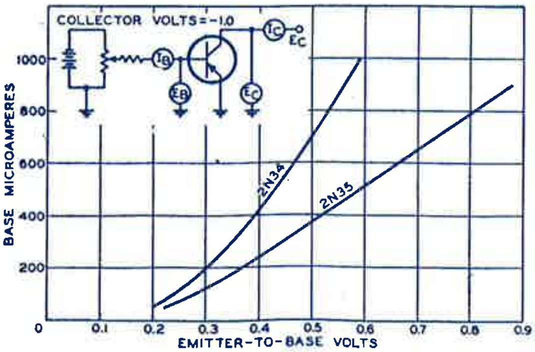

Fig. 14. Large-signal base-to-emitter conductance characteristic of RCA junction transistors.

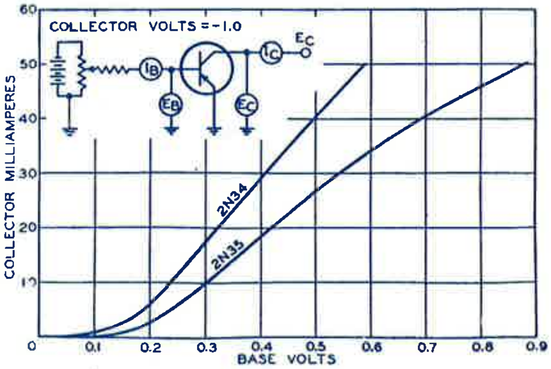

Fig. 15. Large-signal base-input transfer characteristic of RCA junction transistors.

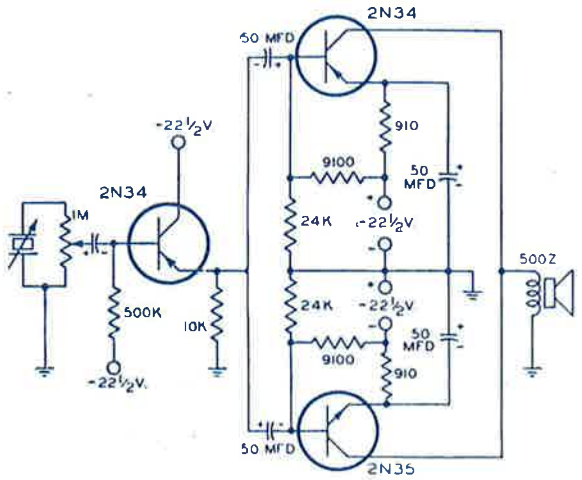

Fig. 16. Class A push-pull audio amplifier driven by RCA–2N34 junction transistor.

Fig. 16 is a circuit diagram of a three-stage phonograph amplifier developed by Dr. Sziklai and his associates.[7] The principle of complementary-symmetry operation employed in the output stage of this amplifier is based on the fact that the application of a positive voltage to the input of one of the transistors causes an increase in output current, but the application of the same positive voltage to the input of the second transistor causes a corresponding decrease in its output current. Because of this effect, it is possible to connect the transistors in parallel as regards the signal circuit and obtain the equivalent of push-pull operation without the need of a phase-splitting input signal source such as a driver transformer or a phase-inverter stage. This arrangement also effects economies in the output circuit by the elimination of a three-terminal output device such as a push-pull output transformer.

The two output transistors shown in Fig. 16 utilize a combination of biasing methods which provide for temperature stability and also compensate to some extent for variations in I_{c0}. The insertion of a small unbypassed resistor in series with the emitter of the 2N34 helps to balance the circuit if the transistors have radically different α characteristics. Although the circuit shows a loudspeaker having a 500-ohm impedance, it may be more practical to use a standard-impedance speaker and a small matching transformer. It should be noted that direct current does not flow through the output load impedance when the transistors have approximately equal collector currents. It is possible, therefore, to use an output transformer which is less expensive and also to use direct drive to the two-terminal voice coil, as shown, without displacement of the voice coil due to dc magnetization effects.

The driving transistor in Fig. 16 is operated with an emitter-output connection into an impedance which is substantially higher than the internal impedance of the transistor in this type of connection. When common-collector, emitter-output circuits operate in this manner, the input impedance is very nearly equal to the collector resistance. The 500,000-ohm biasing resistor and the potentiometer across the crystal pickup are effectively in shunt with this collector load resistance. This arrangement is beneficial because it minimizes the effect on circuit performance of variations in r_c.

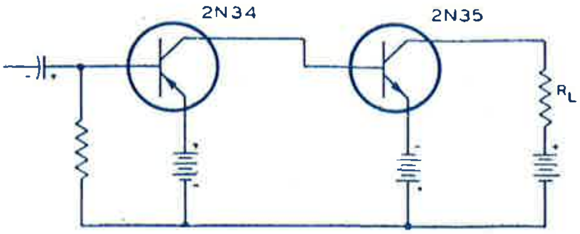

Fig. 17. Direct-coupled amplifier based on "Complementary-Symmetry" principle.

An investigation was also made of the use of some developmental junction transistors in an amplifier consisting only of four transistors, two batteries, an input signal source, and an output load having a 16-ohm impedance. This circuit, however, requires transistors having a closer degree of similarity than that provided by the 2N34 and 2N35.

Fig. 17 shows the so-called "complementary-symmetry" principle applied to a direct-coupled transistor amplifier. In addition to the reduction in the number of components, the use of n-p-n and p-n-p transistors in this manner provides substantially improved temperature-drift characteristics because the flow of I_{c0} in the input unit compensates for the flow of I_{c0} in the output unit, the two currents having opposite polarity. To be effective, of course, the compensation action depends on transistors having similar but opposite I_{c0} characteristics. The range of I_{c0}, however, varies considerably between units of the same type. This arrangement, therefore, although interesting, is somewhat limited at this time in terms of practical results.

Class B Operation of Transistors.

In applications in battery-powered portable equipment, class B operation of the transistors offers very promising opportunities to reduce battery drain and provide more power output than is practical in class A operation. The circuit of Fig. 18 shows a class B amplifier using two 2N34's. Some information on the performance of the circuit is also included. In class B operation, the quiescent operating point is selected so that it appears just beyond the nonlinear region of the transfer characteristic. Under these conditions, the base current is approximately 50 microamperes per unit and the average collector current is approximately 2.5 milliamperes per unit. The method of biasing the class B stage is different from those previously discussed for class A operation. In class A operation, it is desirable to provide an approach to a constant-current bias source which makes the operating point independent of variations in transistor characteristics. This biasing method is feasible because the dc currents do not change appreciably as a result of variations in signal level in class A service. In class B operation, however, the base and collector currents are very low when no signal is applied, but may increase depending on the signal magnitude and wave shape. Obviously, a constant-current bias supply would not permit class B operation, and an approach to a constant-voltage bias supply having a low internal impedance is essential. A convenient method for obtaining such a bias is shown in Fig. 18. The use of a balancing control provides for the variations in the transfer characteristics of the transistors from unit to unit. Transfer characteristics, which represent the relationship between input voltage and output current, are usually expressed in terms of mutual conductance. The unit having the higher mutual conductance should be placed in the socket having the balancing control which provides both dc and ac degeneration. The proper setting of this control can easily be determined by the application of a fairly large signal to the input of the amplifier and adjustment of the balancing control for minimum distortion.

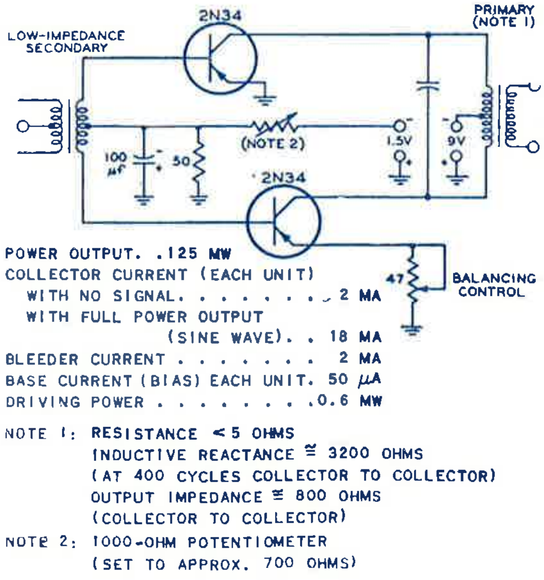

Fig. 18. Class B audio amplifier.

Because the impedance placed in series with the base lead is degenerative, it has an adverse effect on the transfer characteristic. The impedance can also generate additional distortion and reduce power output. It is desirable that the push-pull output stage be driven from a constant-voltage source having very low internal impedance. The maximum impedance of the driving transformer should not exceed 200 ohms.

The primary impedance of the output transformer should be determined by the supply voltage and the power output desired. At present, it appears that a peak current of 50 milliamperes at a collector-to-emitter voltage of approximately 1 volt represents safe operation for audio service. This value of collector-to-emitter voltage is also very close to the knee of the collector characteristic when the common-emitter termination is employed. If the amplifier is designed to produce maximum power output, the load impedance of each half should be approximately equal to the supply voltage minus one divided by 50 milliamperes $Z_1 = (Ebb-1) / (50 \times 10^{-3})$. Because of Zener-voltage effects, the supply voltage should be limited to approximately 15 volts so that the peak voltage will not exceed 30 volts. The output impedance of the full winding is, of course, four times the impedance for each half determined by the method discussed above. The dc resistance of the winding must be sufficiently low so that the peak current of 50 milliamperes will not produce an appreciable voltage drop compared to the supply voltage; otherwise, poor efficiency will result. The input and output transformers for transistors are considerably smaller and less expensive than their counterparts designed for electron tubes, because the transistor impedances are much smaller. The frequency response of the transformers can also be made to cover a much wider range because their smaller size results in less distributed capacitance.

The complementary-symmetry principle is also satisfactory for class B operation, but the bias requirement of a low dc resistance requires the use of an input transformer or a choke, either of which may be costly, or special dc degenerative compensation. An output transformer is also required unless speakers having high-impedance coils can be developed at a cost which is less than the sum of a conventional speaker and the required output transformer. The input transformer for the complementary-symmetry stages costs slightly less than the input transformer for a conventional class B stage because of the extra terminal required for the latter unit. The problem of balance between the two transistor units is adversely affected when a 2N34 and a 2N35 are involved because of the difference in the input characteristics mentioned previously. Degeneration in the emitter circuit of the 2N34, or an unbypassed resistor placed in series with the base lead of the 2N34, should be used to provide for characteristic variations.

CONCLUSION.

In general, it appears that the junction-transistor types discussed in this paper are in a more promising position as regards the problems of reliability and interchangeability than are the point-contact types. The main obstacle to the widespread application of these units seems to be the problem of producing transistors in high volume, at low cost, and under processing controls which will ensure a more favourable situation regarding interchangeability.

Some basic differences between the 2N34 and 2N35 large-signal characteristics limit the use of complementary-symmetry circuits at this time. Because there is still too wide a variation in the noise performance of transistors, selection may be necessary to provide satisfactory units for the first stage of high-gain audio amplifiers.

It is hoped that the material presented here has not tended to over-emphasize the negative aspect of transistor applications at the expense of their merits and considerable advantages. Although it is always desirable to "keep one's best foot forward", it would be most misleading to indicate that transistors have already reached the advanced state of development enjoyed by the electron tube. However, great confidence for the future appears to be justified in view of the phenomenally rapid rate of scientific progress and engineering accomplishment in this new field of semi-conductor devices.

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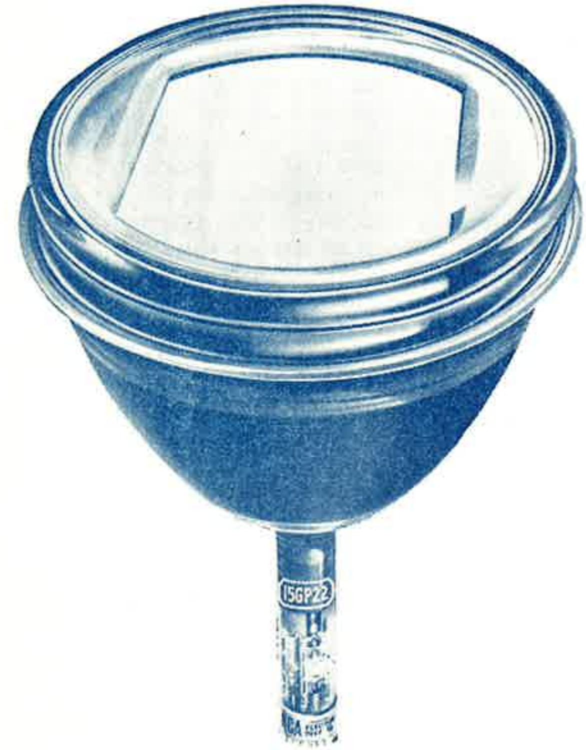
New RCA Releases



Radiotron–15GP22 is a directly viewed picture tube of the glass-envelope type for use in colour television receivers. It is capable of producing either a full colour or a black-and-white picture 11½″ × 8⅝″ with rounded sides.

The 15GP22 utilizes three electrostatic-focus guns spaced 120° apart with axes parallel to the tube axis, together with an assembly consisting of a shadow mask and a plane, tricolour, filter-glass phosphor-dot (screen) plate located between the shadow mask and a clear-glass face-plate.

The tricolour phosphor-dot plate, which serves as the directly viewed screen, carries an orderly array of small, closely spaced, phosphor dots arranged in triangular groups (trios). Each trio consists of a green-emitting dot, a red-emitting dot, and a blue-emitting dot. The phosphor-dot plate has approximately 195,000 dot trios or 585,000 dots and is metalized after application of the phosphor dots to give increased light out-put and contrast as well as to prevent ion-spot blemish.

The metal shadow mask, interposed between the electron gun structure and the phosphor-dot plate, contains round holes equal in number to and centred with respect to the dot trios. Fig. 1 illustrates the manner in which the mask holes are lined up with the colour dots.

The axes of the beams from the three electron guns are made to converge at the shadow mask (grid No. 6) by an electrostatic lens produced by the voltage difference between grid No. 4 (converging electrode) and grid No. 5 (neck coating).

From Fig. 2, it is seen that the three beams must be made to converge at the hole corresponding to the dot trio being scanned at any moment. The three beams are converged as a unit by adjustment of grid-No. 4 voltage. Individual positioning of each beam to accomplish proper convergence usually requires the use of three small external magnets located near the guns.

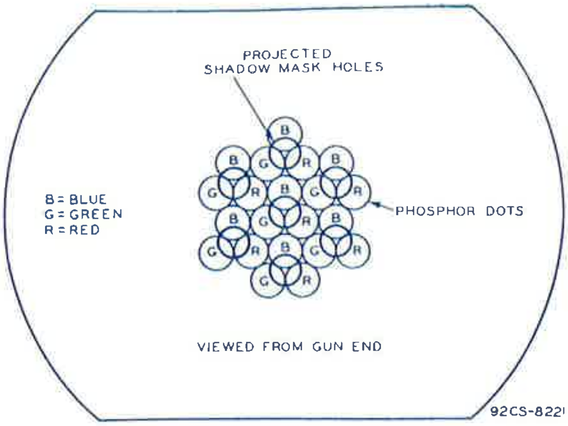


Fig. 1 - Orientation of Projected Mask Holes with Phosphor Color Dots.

Because the shadow mask and the phosphor-dot screen are flat, the beam-path length from the converging lens to the mask is a function of the position of the trio being scanned. The path is shortest to the centre and longest to the corners of the shadow mask. Therefore, it is necessary that the focal length of the converging lens be made to vary as a function of the position of the trio being scanned. This dynamic converging is accomplished by applying voltage derived from the horizontal and vertical deflection circuits so as to vary the potential applied to the converging electrode (grid No. 4).

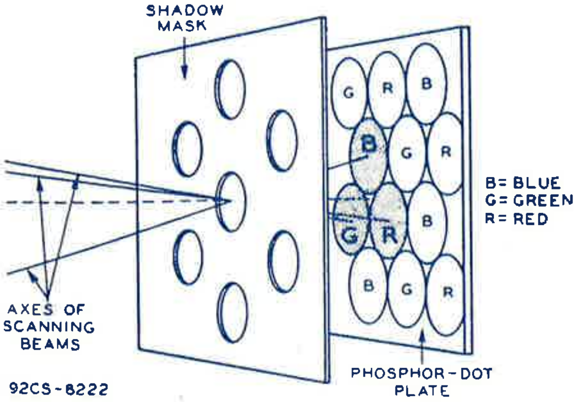


Fig. 2 - Effect of Approach Angle on Color.

The different angles at which the beams from the three guns reach the shadow mask determine the particular colour phosphor dot which is energized by each beam. Thus, one gun is associated with each of the primary colours so that control of the beam current from that gun controls the amount of the primary colour developed. Fig. 2 illustrates the effect of approach angle of the three beams. The shadow mask is oriented so that with correct approach angle electrons from one of the three beams can strike phosphor dots of only a single colour no matter which part of the phosphor-dot plate is being scanned. Thus, three colour signals controlling the three beams produce independent pictures in the primary colours. These primary colours from the three phosphor dots comprising a picture element (trio) appear to the eye to blend because of the close spacing of the dots and as a result the eye sees a full-colour picture.

Focusing of the three beams is accomplished electrostatically by adjustment of the voltage applied to the three No. 3 grids which are inter-connected within the tube and have a common pin terminal. Because the beam-path length from the focusing lenses to the screen assembly is a function of the position of the screen area being scanned, and because these lenses are affected by the dynamic converging voltage applied to grid No. 4, it is desirable that the grid No. 3 voltage be varied as a function of the position of the trio being scanned. This dynamic focusing is accomplished by applying voltage derived from the horizontal and vertical deflection circuits so as to vary the potential applied to the focusing electrodes (grids No. 3).

A deflecting yoke, consisting of four electromagnetic coils, is required for deflecting the three electron beams simultaneously after they pass through the converging lens. The coils are used in pairs; the coils for each pair, located diametrically opposite each other, produce a field of essentially uniform flux density. The axes of the two fields should intersect at right angles to each other and to the tube axis.

Radiotron–6AN8 is a general-purpose, multi-unit tube of the 9-pin miniature type containing a medium-μ triode and a sharp-cutoff pentode in one envelope. It is intended for diversified applications in colour television receivers.

The triode unit with its relatively high zero-bias plate current is useful in low-frequency oscillator, sync-separator, sync-clipper, and phase-splitter circuits. The pentode unit with its high transconductance may be used as an i-f amplifier, video amplifier, agc amplifier, and reactance tube. The basing arrangement and internal construction of the 6AN8 are designed so that coupling between the triode unit and the pentode unit is virtually eliminated.

Radiotron–3A3 is a half-wave vacuum rectifier tube of the glass-octal type designed for use as a rectifier of high-voltage pulses produced in the scanning systems of colour television receivers.

Rated to withstand a maximum peak inverse plate voltage of 30,000 volts, the 3A3 can supply a maximum peak plate current of 80 milliamperes and a maximum average plate curent of 1·5 milliamperes.

Radiotron–6BD4 is a low-current beam triode of the sharp-cutoff type designed specifically for the voltage regulation of high-voltage, low-current dc power supplies, such as the power supply used with the Radiotron Tricolour Kinescope 15GP22.

The 6BD4 has a maximum dc plate-voltage rating of 20,000 volts, a maximum dc plate-current rating of 1.5 milli-amperes, and a maximum plate-dissipation rating of 20 watts.

Actual Size.

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