# RADIOTRONICS

**BULLETIN No. 116** **Sept.-October, 1941**


*A Popular Article*

## PREAMPLIFIER AND MIXER CONSIDERATIONS

*From time to time the subject of preamplifiers has been mentioned in Radiotronics bulletins and various circuit diagrams have been published. However it is felt that a comprehensive article on the subject should be most helpful to many readers.*

The majority of audio amplifiers in use serve to amplify the output from a radio tuner or gramophone pick-up. Amplifiers intended for use with radio tuners or gramophone pick-ups are usually designed with an overall gain sufficient to allow full output with an input voltage of about 0.25 volt R.M.S. There are definite reasons why such a voltage is chosen:

(a) An amplifier so designed may be used directly with almost any ordinary radio tuner or gramophone pick-up with sufficient reserve of gain.

(b) If the gain is increased beyond this, difficulties are likely to be introduced unnecessarily with hum, noise, instability, and microphony in the first valve.

(c) An ordinary volume control may be connected across the input circuit and will not normally introduce noise when rotated.

In view of these considerations the various general purpose amplifiers, which have been described from time to time in Radiotronics, have each required an input of between the approximate limits of 0.2 and 0.4 volts R.M.S. for full output. The various aspects of circuit design have, in each case, been carefully chosen and no difficulties should be encountered when any one of these circuits is duplicated. The circuits should preferably not be modified since unforeseen complications may be introduced; this is particularly true in the case of amplifier circuits employing negative feedback.

### Preliminary Amplification.

In certain cases it may be desired to use an audio amplifier having average overall gain with an input device having comparatively low output voltage. Such devices would include, amongst others, certain gramophone pick-ups, the majority of microphones, electronic musical instruments and phototube circuits. Under these circumstances it would be essential to provide additional voltage amplification between the input device and the main amplifier.

For most purposes a single additional pentode preamplifier stage is sufficient although, for example, in the case of microphones having very low output or under conditions of distant speaking, one high gain pentode stage and one triode stage may be required. It is suggested that the preamplifier stage or stages should simply be connected ahead of the basic amplifier unit without in any way modifying the latter.

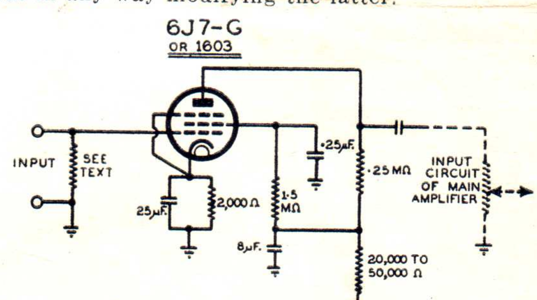


FIG. 1

Figure 1 shows the circuit of a typical single stage preamplifier using the Radiotron type 6J7-G, which is the octal-based equivalent of type 6C6. If, in practice, type 6J7-G is too microphonic for particular applications, the non-microphonic pentode type 1603 may be substituted. Type 1603 is of non-microphonic construction but is otherwise identical physcially and electrically with

type 6C6; it is electrically identical with type 6J7-G but differs as regards the base.

**Grid Circuit Resistance.**

The d-c grid circuit resistance for this particular preamplifier stage may be as high as 10 megohms, although the optimum value will naturally depend on the load requirements of the input device.

In this connection attention is drawn to a note on page 38 of Radiotronics 112 which reads as follows: "For types 1B5/25S, 1D8-GT (triode unit), 1H4-G, 1H5-GT, 1H6-G, 1J6-G, 1K4, 1K5-G, 1K6, 1K7-G, 1N5-GT, 6B6-G, 6B7, 6B8-G, 6C6, 6J7-G, 30, 57, 75, 85 and 1603, the maximum d-c grid resistance may be as high as 10 megohms, **provided that the plate circuit is so arranged that the plate current cannot exceed 1.0 mA.** In the case of pentode operation it is advisable for the screen voltage to be derived through a high-resistance dropping resistor. The d-c grid resistance should not exceed 10 megohms **unless the heater or filament voltage is reduced,** but this reduction may require the selection of individual valves. Radiotron 6J7-G, 6C6 or 1603 valves may be used with a heater voltage as low as 4.5 volts without requiring individual selection and under these conditions a d-c grid circuit resistance higher than 10 megohms may be used."

This note supersedes earlier notes limiting the grid circuit resistance for certain valves to 2 megohms or thereabouts under any condition or stipulating reduced heater voltage for grid circuit resistances between 2 megohms and 10 megohms.

Particular attention, however, is drawn to the phrase, "provided that the circuit is so arranged that the plate current cannot exceed 1mA." For transformer coupled stages or for resistance-coupled stages where the plate load and plate supply voltage are such that the plate current can exceed 1 mA., the grid circuit resistance for most ordinary voltage amplifying valves is limited to 2 megohms or thereabouts.

**Gain or Volume Control.**

No attempt should be made to control the volume at the grid circuit of the preamplifier since a volume control in such a position would almost certainly prove very noisy when rotated. A further difficulty would be that any noise introduced by the preamplifier stage would be apparent in the output irrespective of the setting of the volume control. These difficulties are avoided by including the volume control after the preamplifier and at the input to the main amplifier. A typical volume control in this position should not prove electrically noisy and when turned to the "off" position simultaneously attenuates the signal and any noise which may be introduced in the preamplifier.

It follows that, in order to avoid overloading the preamplifier, the peak a-f input voltage must not under any circumstances exceed a certain maximum value. For example, in the circuit shown in figure 1, assuming an effective plate supply voltage of 250 volts, the maximum peak input voltage for 3% distortion would be 0.48 volt. With lower supply voltages the permissible input voltage would be still less.

**Cathode Bias.**

In the circuit of figure 1 conventional cathode bias is used. Provided the cathode is suitably bypassed, this is normally quite satisfactory and convenient for a single preamplifier stage connected ahead of a conventional amplifier. When a two-stage preamplifier is used, however, there is a distinct possibility that hum may be introduced in the cathode circuit of the first valve; this hum may not be eliminated by using any convenient value of cathode bypass condenser. Hum introduced into the cathode circuit is seldom the result of leakage due to a d-c path, but is more usually the result of electron emission from one electrode to the other. Current due to such emission, and consequently the resultant voltage, is necessarily minute, but may be large enough to cause appreciable hum in the output where the amplification following is high.

Apart from increasing the capacitance of the cathode bypass condenser to its practical limit, the hum may sometimes be reduced by earthing the heater circuit in the most suitable manner or alternatively by bypassing the heater supply and making it a few volts positive or negative with respect to earth. In order to check whether or not hum is being introduced into the cathode circuit of the first valve, the heater of that valve may temporarily be supplied from a suitable d-c source. This test will readily indicate the amount of hum being introduced in the cathode circuit.

**Grid Leak Bias.**

Where, for the above reasons, cathode bias is impracticable the necessary bias may, in certain cases, be derived by the "grid-leak bias" method as described in Radiotronics 94, page 3. This method is particularly useful in connection with high-mu triode valves such as type 6B6-G. It consists of returning the grid directly to cathode through a high resistance of the order of 5 to 15 megohms. A certain bias is developed across this return resistor by reason of a small amount of grid current which flows.

Grid leak bias obviously cannot be used with valves operated under such conditions that they would require a negative bias appreciably higher than would be developed by the flow of grid current; this would not be likely to exceed 1.0 volt. Thus, grid leak bias is unsuitable for use with transformer coupled stages or resistance coupled stages with low values of plate supply resistance, unless the plate supply voltage is very low.

Grid leak bias would probably be quite satisfactory with resistance coupled pentodes although, at present, little or no detailed information is available on the subject. The plate load resistor could conveniently be 0.25 megohm; the series dropping resistor for the screen would need to be adjusted so that the operating plate current was between 0.5 and 0.6 times the current which would flow if the plate were short circuited to the cathode. In practical cases the screen dropping resistor would probably be somewhat higher than that required for cathode biased operation.

It is interesting to note that when current is flowing in the grid circuit, as for grid leak bias, the input resistance to the stage is approximately equal to one-half the resistance of the grid return resistor. Thus if the return resistor is 10 megohms, the input resistance is approximately 5 megohms.

Where the input device requires a load of lower resistance than the input resistance of the grid leak biased stage, this may be provided by an additional resistance connected across the input terminals; a blocking condenser would then be required to prevent this load resistor short circuiting the grid return resistor. The same precaution would be necessary in cases where the input device itself had finite resistance.

**Fixed Bias.**

An alternative method of providing bias for the first valve is to derive the necessary bias from a "back-bias" source or from one or more dry cells clipped on to the amplifier chassis. Where the bias is obtained from a back-bias network it is normally necessary to provide an effective decoupling network to prevent the introduction of hum voltages from the source of bias. Decoupling may also be found necessary with battery bias because of electrical noise from the battery.

**Decoupling.**

The plate circuit of any amplifier stage normally requires less attention than the grid circuit since the level at the former is so much higher. However, decoupling is usually necessary and a resistance of between 20,000 and 50,000 ohms in combination with a capacitance of 8$\mu$F is suggested as satisfactory for most purposes. The amount of high tension filtering required is related to the gain following the particular plate or screen circuit, better filtering being required as the subsequent gain is increased. With resistance coupled pentodes, the plate and screen supply can usually have a common decoupling network.

In the case of a two-stage preamplifier a single decoupling network usually suffices for both stages. Provided the values of the decoupling resistance and capacitance are large enough, no difficulty should be experienced with instability due to feedback by way of the power supply. Where such difficulty is experienced it is sometimes helpful to use a more complex network and to supply the preamplifier directly from the cathode of the rectifier or from an early point in the main filter system.

**Hum Due to Magnetic Fields.**

In operation, a power transformer or filter choke is surrounded by an appreciable magnetic field; when mounted on an ordinary steel chassis a transformer or choke tends to cause eddy currents in the chassis, with the result that minute voltages at mains or ripple frequency appear between various points on the chassis.

Such voltages are usually too small to cause audible hum in an amplifier having only sufficient overall gain for use with a gramophone pick-up. However, precautions are necessary when a preamplifying stage is added.

Ideally, a preamplifier stage should be mounted on a chassis distinct from that which carries the power supply equipment, the two chassis being separated by a distance of at least eighteen inches. Where all the equipment must be mounted on a single chassis, the preamplifier stage should be separated as far as possible from the power supply equipment. The earth returns for the former should preferably be made to one single point so that hum voltages between various points on the chassis are not introduced directly into the circuit. **It should be noted that decoupling or ordinary shielding methods do not prevent electromagnetic hum pick-up.**

**Hum Due to Capacitive Coupling.**

Hum may also be introduced as a result of capacitive coupling between the grid circuit of the preamplifier and leads carrying alternating voltages. Hum due to capacitive coupling is most likely to be troublesome in high impedance circuits, but can be prevented or minimised by adequate shielding. In circuits having very high overall gain a shielded plug connection is preferable to ordinary input terminals.

In high gain amplifiers adequate shielding of the input circuit is also important for reasons of stability.

**Coupling to Main Amplifier.**

If the preamplifier stage is on the same chassis as the main amplifier there is no difficulty in coupling the two. If the preamplifier is separated from the main amplifier by a distance up to two feet, special precautions are seldom necessary, and it is usually satisfactory to couple the two by a length of shielded wire. For greater distances it becomes necessary to take into consideration the self-capacitance of the shielded cable, which may cause attenuation of the higher frequencies. This is particularly true in high impedance circuits such as the plate circuit of a pentode voltage amplifier. In the case of triode valves having very much lower values of plate resistance, longer lengths of shielded cable can often be tolerated.

In cases where the preamplifier is remote from the main amplifier the two must be connected by a low impedance line. This normally necessitates the use of a preamplifier unit containing at least two valves, the last valve being a triode feeding into the line through a step-down transformer. At the amplifier a step-up transformer may or may not be used, depending on the particular circumstances.

An alternative arrangement which obviates the necessity for a step-down transformer is to include in the preamplifier unit a valve operated with cathode loading (sometimes known as a "cathode-follower"). A "cathode-follower" stage consists essentially of a valve operated with the whole output load between cathode and earth, the input voltage being applied between grid and earth. Owing to the negative feedback present, the output impedance of the stage becomes very much smaller than under normal operating conditions. The approximate output impedance of a stage employing cathode loading is given by the formula

$$R = 10^6/Gm$$

*Where R is the output resistance in ohms and Gm is the mutual conductance in micromhos.*

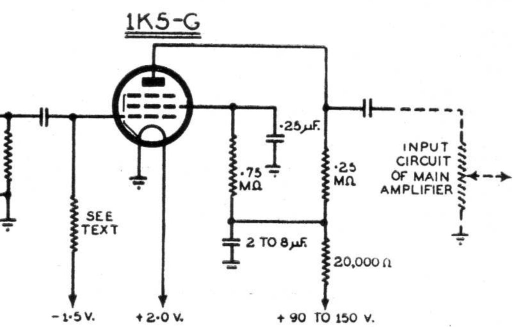


FIG. 2

**Battery Operated Preamplifiers.**

In the case of battery-operated preamplifiers the foregoing discussion also applies although, of course, there are no difficulties in regard to hum. In vibrator operated equipment some precautions may have to be taken in this respect.

Microphony is, however, likely to be more troublesome, firstly because of the comparative lack of rigidity of valve filaments and, secondly, because special non-microphonic directly heated valves are not readily available.

The valve most likely to be satisfactory from this point of view is Radiotron type 1K5-G, which has a special mica support to minimise vibration of the filament. In high gain amplifiers it may be necessary to select individual valves for the first stage and/or to mount the socket on sponge rubber. Figure 2 shows the recommended circuit constants for type 1K5-G as a high gain pentode voltage amplifier. Type 1K5-G may also be operated as a general purpose triode by connecting

# RECORDING CHARACTERISTICS

Chapter II. of the Radiotron Designer's Handbook gives a very condensed description of recording characteristics as affecting the application of pick-ups to amplifiers and combination radio receivers. From correspondence received, it appears that there is need for a somewhat more complete and simple treatment of this subject.

For distortionless reproduction it is obvious that the peak lateral displacement of the cutting stylus or needle point (generally spoken of as the "Amplitude") should be proportional to the sound pressure at the microphone at any frequency. There is, however, no hard and fast overall relationship between amplitudes at different frequencies for constant sound pressure at the microphone. In the early days of recording, the recording characteristic was not designed in any scientific manner. The introduction of electrical recording brought about the common use of a characteristic which is still used, with certain modifications, to-day.

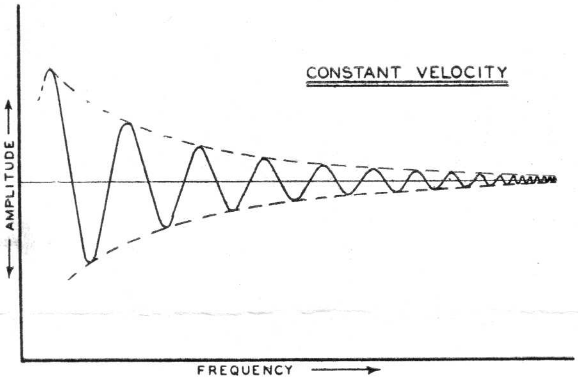


*Figure 1: Depicting the groove displacement of a "gliding tone" record having a "constant velocity" characteristic for constant sound pressure at all frequencies at the microphone.*

Before discussing this further it would be wise to examine the three most important theoretical recording characteristics. These are:—

1. Constant velocity recording.
2. Constant amplitude recording.
3. Constant acceleration recording.

In constant velocity recording, the peak transverse velocity of the cutting stylus remains constant for all frequencies for constant sound pressure at the microphone; consequently the amplitude is inversely proportional to the frequency. With this system of recording the amplitude becomes greater as the frequency is decreased, for constant sound pressure. This is shown diagramatically in figure 1 and it is obvious that some limit must be put to the amplitude at very low frequencies to prevent one groove from running into the next. For this reason, constant velocity recording is not used at very low frequencies.

With constant amplitude recording, as implied in the title, the amplitude is constant for constant sound pressure for all frequencies at the microphone. This is shown diagramatically in figure 2 from which it will be seen that the peak transverse velocity becomes very great at high frequencies. This system is satisfactory from the recording point of view for low and middle frequencies, but is inclined to give trouble with the ordinary type of magnetic cutting heads and pick-ups at high frequencies, owing to the inertia of the moving parts. With high fidelity crystal pick-ups and other types having very low moment of inertia, it has

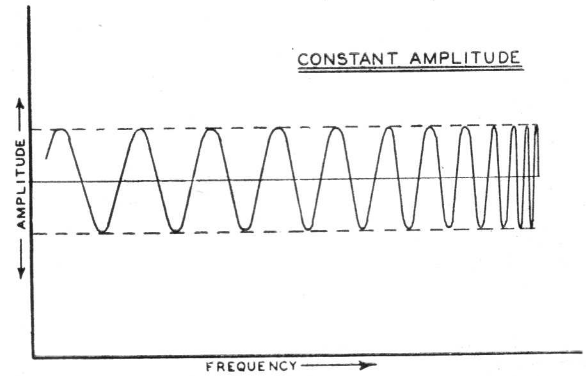


*Figure 2: Depicting the groove displacement of a "gliding tone" record having a "constant amplitude" characteristic for constant sound pressure at all frequencies at the microphone.*

been claimed that operation with this method of recording is possible even at the highest audio frequencies since the sound pressure at these frequencies is normally fairly low. A disadvantage of this system is that it requires a frequency compensation network in both the recording unit and the reproducer when ordinary types of cutters and pick-ups are employed.

In constant acceleration recording, the amplitude is inversely proportional to the square of the frequency. This results in rapidly decreasing amplitude as the frequency is increased. The response of a typical pick-up or cutting head follows approximately a constant acceleration characteristic at frequencies beyond the highest frequency for linear response. This recording system is not used except for intentional attentuation of high frequencies or unavoidable attenuation through the limitations of the cutting head.

The three recording systems may also be compared on the basis of the relative output in decibels over any desired frequency range when used with

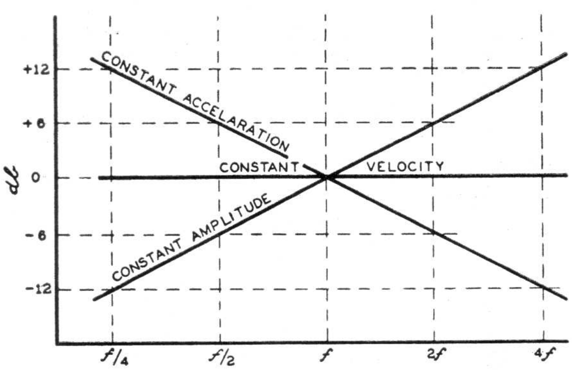


*Figure 3: Depicting the output in decibels from the three principal recording characteristics, when used in conjunction with a pick-up designed for use with a "constant velocity" recording characteristic. The three curves are all taken as 0 db at the cross-over frequency f.*

an ideal "constant velocity" pick-up. In figure 3 the cross-over frequency is taken at "f" and the octaves are shown as f/4, f/2, f,2f, 4f, etc. The constant amplitude characteristic has a slope corresponding with a rise of 6db per octave. The constant velocity characteristic is horizontal and is taken as 0 db. The constant acceleration characteristic has a slope corresponding with a fall of 6 db per octave.

The recording characteristic used with commercial disc records is usually a combination of all three systems. Constant amplitude recording is generally adopted from the lowest frequencies up to about 250 c/s., or even higher in some cases, this frequency being known as the "cross-over frequency". Above this frequency, constant velocity recording is adopted up to about 3,000 c/s. Above this latter frequency, the response may be peaked to a greater or less extent and beyond the peak the recording follows approximately a constant acceleration characteristic. It is shown by figure 3 that the output from a pick-up having an ideal constant velocity characteristic drops by 6 db per octave with constant amplitude recording; if linear response is required it is therefore necessary to add compensation to the extent of 6 db per octave in this region. If "bass boosting" is required it must be additional to the compensation of the recording characteristic (6 db per octave).

If the pick-up has not an ideal characteristic it is also desirable to use a compensating network so that the overall voltage output is uniform and linear over the desired frequency range.

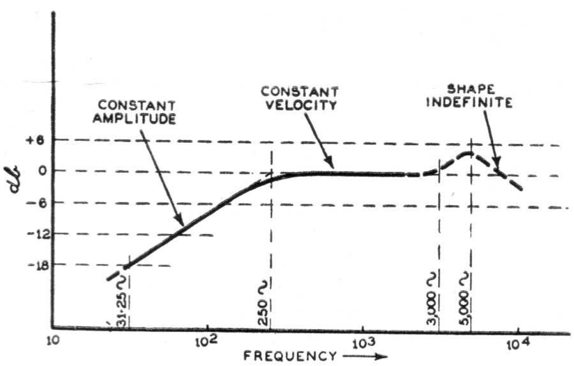


*Figure 4: The frequency characteristic of a typical disc record.*

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## MICROMHOS PER MILLIAMP

When gain is the only consideration, every effort is made to increase the mutual conductance of r-f amplifier valves even though in so doing the plate current may also be increased. In battery operated receivers, or in very compact a-c receivers, it is advisable to pay special attention to the plate and screen currents as well as to the mutual conductance. Since the ratio of screen to plate currents is fairly constant, it is quite satisfactory to work on the basis of plate current only. It is thus desirable to obtain the highest possible ratio of trans-conductance to plate current or, in other words, the greatest number of micromhos per milliamp.*

If an r-f pentode has a higher transconductance than is necessary for a particular application the screen voltage may be reduced or the grid bias increased until the transconductance reaches the minimum permissible level. With super-control pentodes in particular it is advisable to decrease the screen voltage rather than to increase the negative grid bias, but with sharp cut-off pentodes either method may be adopted.

It is interesting to note that battery-operated valves under their published typical operating conditions give considerably higher ratios of micromhos per milliamp than a-c types, although an increased ratio in the case of the a-c types may be obtained by operating them with lower screen voltages. The highest figure shown under the typical operating conditions is 925 micromhos per milliamp, which is for type 1M5-G with a plate voltage of 135 volts, a screen voltage of 30 volts and zero bias. Of course, under these conditions the mutual conductance of 600 micromhos is considerably less than the maximum obtainable from this type of valve, but this is sufficient for many applications while the extraordinarily low plate current of 0.65 mA. is very attractive for certain purposes. With plate, screen and bias voltages of 135, 67.5 and zero respectively, type 1M5-G has a ratio of 400 micromhos per milliamp and a mutual conductance of 1,000 micromhos.

In the a-c series, type 6U7-G operating with voltages of 250, 100 and -3 respectively, gives 195 micromhos per milliamp, an extremely low figure when compared with that for type 1M5-G. Other a-c types under typical operating conditions give ratios between 125 and 250 micromhos per milliamp. In the case of sharp cut-off types, a very considerable increase in the ratio of micromhos per milliamp is obtainable by operating them with over-bias; a figure of over 1,400 micromhos per milliamp is obtainable with type 6J7-G under these conditions. The plate current for this latter figure is of the order of .25 mA. and only a very small grid swing can be handled without running into difficulties owing to the curvature of the characteristic.

* The transconductance is approximately proportional to the cube root of the plate current, hence the improvement in micromhos per milliamp as the plate current is reduced.

## "-GT" VALVES
## Provision for Alternative Base

Although all GT valves manufactured in Australia are at present fitted with bakelite bases with a maximum diameter of 1.275", valves of American origin are sometimes fitted with bases having a metal sleeve and a maximum diameter of 1.312". It has been found that, in some cases, the holes cut in the chassis are too small to permit this larger base being used. It is therefore recommended that, even in cases where there is no intention of using the base with a metal sleeve, the holes cut in the chassis should be sufficiently large to accommodate the larger base.

Valves fitted with bases having metal sleeves frequently have the sleeve internally connected to pin 1 which should consequently be earthed. Pin 1 should not be used for anchoring purposes at high voltage since the metal sleeve would then also be connected to a point of high voltage and there is danger of shock to the user or of short-circuiting the B supply. Even if there is no high voltage applied to pin 1, the anchored circuit could still be shortcircuited or unwanted capacitance effects introduced. Attention is drawn to an earlier warning given in Radiotronics 105, page 48.

## RADIOTRON NEWS

**Radiotron 5V4-G:** Production of this type has now recommenced.

**Radiotron 45:** Three new data sheets for type 45, intended for inclusion in the loose-leaf Valve Data Handbook, are released concurrently with this issue. For further information see article elsewhere on this page.

**Radiotron 83V:** Production of this type has now recommenced.

## DATA SHEETS

Four data sheets are released concurrently with this issue. These are:—

| | | |
|---|---|---|
| 42, 45 | sheet 1 | data |
| 45 | sheet 2 | data |
| 45 | sheet 3 | curves |

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The data sheets for type 45 show additional operating data for type 45 in push-pull class $A_1$ operation, push-pull class $AB_1$ operation, and push-pull class $AB_2$ operation.

The "List of Contents" sheet shows in detail the sheets which should be included in the handbook at the date of issue (October, 1941). **In order to ensure the maximum utility from the handbook, the sheets should be arranged exactly as shown in the index and out-of-date sheets removed. Retention of out-of-date sheets in the handbook will inevitably lead to confusion between up-to-date and superseded information.** Adequate information on all Radiotron types not normally included in the handbook is given in the Radiotron Characteristics Chart available at a cost of 3d. posted or free on application.

Subscribers may obtain missing data sheets free on application to the Head Office of the Company. A complete set of sheets is available at a cost of two shillings and an imitation leather ring binder at a cost of three shillings, post free.

## RADIOTRONICS BINDER COVERS

Enquiries are frequently being received regarding the availability of binder covers for Radiotronics Technical Bulletins. Specially imprinted binder covers for these bulletins are available to subscribers at a cost of 1/2 posted. Reasonable stocks are held at present, but it is anticipated that, when these are exhausted, it may not be possible to produce a further quantity owing to rationing of paper and cardboard.

## RADIOTRON 45 Additional Data

New data sheets for Radiotron type 45 are released concurrently with this issue. Examination of these sheets will show that a number of new operating conditions have been added and the maximum plate voltage increased to 300 volts. The maximum plate dissipation of 10 watts remains unchanged.

As a class $A_1$ amplifier a maximum power output of 2 watts per valve is obtainable, but with push-pull class $A_1$ operation this reaches 5.5 watts with 275 volts on the plates. With class $AB_1$ operation and fixed bias a power output of 7.5 watts is obtainable from two valves with 300 volts on the plates. This is particularly interesting since it is exactly half that obtainable from two type 2A3 valves under the same conditions. With four type 45 valves in push-pull parallel an output of 15 watts is obtainable with a load resistance of 1,925 ohms from plate to plate. The grid bias is, however, considerably higher in the case of type 45.

With class $AB_1$ operation and self bias a power output of 7.4 watts is obtainable with a plate voltage of 300 volts. This may be compared with a power output of 10 watts for two type 2A3 valves under similar conditions. It will be seen that the load resistance from plate to plate is 5,000 ohms, being identical with that for two type 2A3 valves. The only change necessary to replace two type 2A3 valves in class $AB_1$ operation with self bias is to increase the cathode resistor from 780 ohms to 1,000 ohms. The decrease in power output from 10 to 7.4 watts is not very serious.

In class $AB_2$ operation with fixed bias a power output of up to 19.1 watts is obtainable with a plate supply having zero resistance. This power output will drop seriously with normal types of power supply units.

With self-bias operation a power output of 13.2 watts is obtainable with zero plate supply resistance, but the effect of this resistance in the plate supply is not nearly so marked as in the case with fixed bias. With a plate supply resistance of 1,000 ohms a power output of from 11.2 to 12.7 watts is obtainable.

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