RADIOTRONICS

AMALGAMATED WIRELESS VALVE CO. PTY. LTD.

BOX No. 2516 BB G.P.O., SYDNEY

TECHNICAL BULLETIN No. 78 — 28th JULY, 1937

In this issue:—

FOR THE RADIO ENGINEER

13.5 WATT PUSH-PULL 2A3 AMPLIFIER

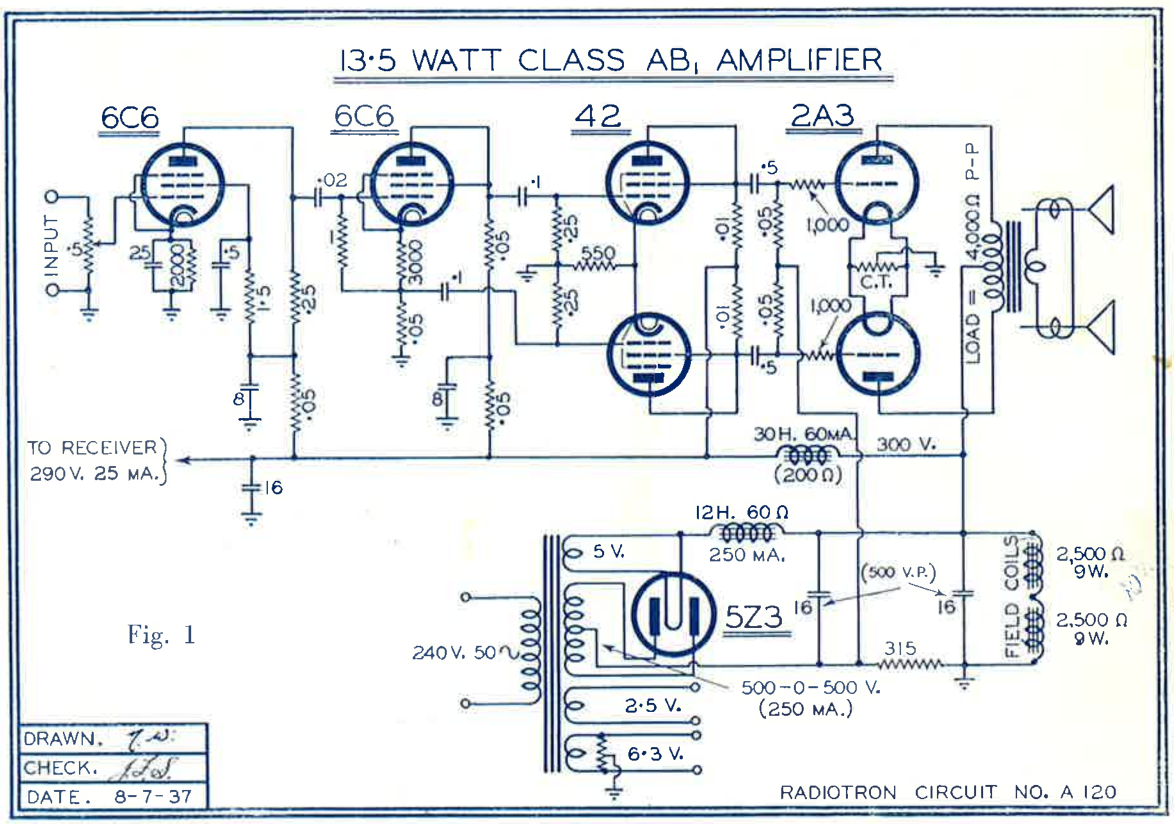


Fig. 1

The 7 watt amplifier described in Radiotronics No. 77 is ideally suited to applications in the average home radio receiver or pickup amplifier. In certain cases a higher output is required and the additional expense is justified in order to obtain this output. The conditions of operation published for Radiotron 2A3 Valves show two typical cases in which an output of 10 watts is

13.5 WATT PUSH-PULL 2A3 AMPLIFIER—Continued

obtained on self-bias and 15 watts with fixed bias. It is obvious that the greater power output and less distortion given by fixed bias operation have distinct advantages but it is necessary to employ a separate rectifier and filter for the bias supply. In the circuit now to be described, a compromise has been made and an output of 13.5 watts has been found possible from two Radiotron 2A3 valves operating on semi-fixed bias. In order to give complete protection to the 2A3 valves the resistance of each grid circuit has been kept to the limit of 50,000 ohms as recommended for fixed bias.

In order to do this without overloading the previous stage, it was found necessary to use a power triode which could be operated on a plate load resistance of 10,000 ohms. Radiotron 42 operated as a triode enabled this to be done with a minimum of distortion. It should be noted that the plate current drawn by each 42 valve is limited by the fact that they are resistance coupled. The 10,000 ohm resistors should each be of 2 watt rating in order to carry the plate current. In order to excite the grids of the two 42 valves, a somewhat similar arrangement to that adopted for the 7 watt amplifier has been used with success. The complete amplifier therefore incorporates one 6C6 resistance coupled pentode followed by one 6C6 connected as a triode and operating as a phase splitter, two 42's operated as push-pull resistance coupled triodes, exciting two 2A3's. Grid stopping resistances, each of 1,000 ohms, are shown in the 2A3 grid circuits in order to minimise the instability occurring at the grid current point on overload.

Provision has been made for a radio tuner to be connected to the power supply.

tortion and power output. A higher load resistance would give slightly less distortion together with a slightly lower output. Provision has been made for exciting two loudspeaker field coils of 2,500 ohms at 9 watts each or alternatively a single field coil of 5,000 ohms at 18 watts. The load provided by the field coils is used in this design to improve the regulation of the power supply, and it is essential to use a load of the value specified. If a smaller wattage is required by the speaker field an additional load should be imposed by means of a resistor so that a total of 18 watts is dissipated.

The linearity curve and the curve of distortion against input are shown in figure 2, and the curves of output and distortion against frequency is shown in figure 3. Both these figures were drawn under conditions of a typical loudspeaker load, consisting of two standard 10in. speakers. The curves of distortion and of output against frequency could have been improved by assuming constant resistive loads but the curves were taken under actual working conditions in order to demonstrate the operation of the amplifier under typical conditions. The distortion is very low indeed for an amplifier of this type and is very nearly inaudible. The performance of the whole amplifier is extremely good, not only as regards harmonic distortion, but also in the response to transients and in having very low phase distortion. A certain amount of distortion and hum has been balanced out by the circuit arrangement adopted and it is emphasised that this arrangement should be utilised without any modification if the best results are required without further development work being done. In cases where resistors are used in push-pull stages,

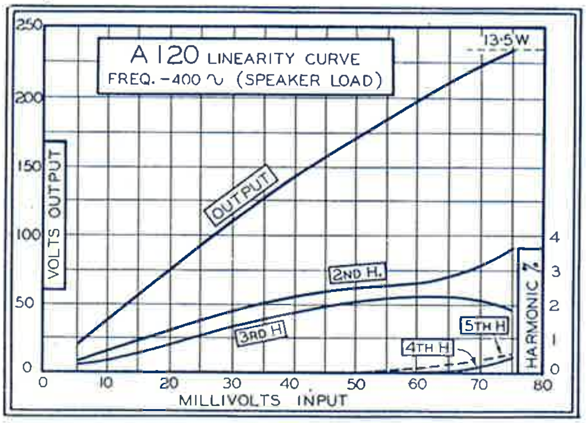


Fig. 2

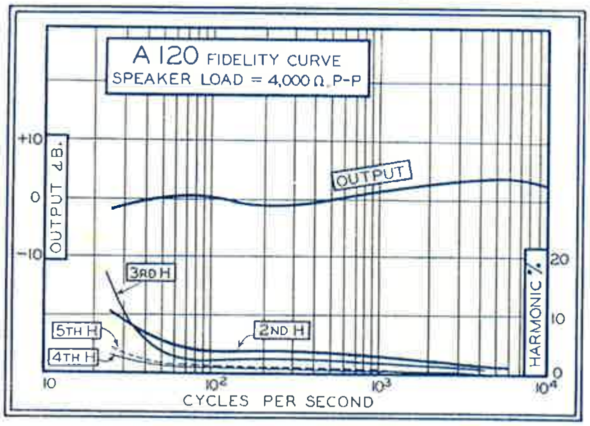


Fig. 3

In order to obtain 300 volts for the plates of the 2A3 valves together with the necessary 60 volts bias, a 500-500 volt transformer and Radiotron 5Z3 rectifier were adopted. The filtering shown in the circuit diagram was found to be adequate and the hum level in the model constructed for test purposes was 52 db below maximum output. The load resistance from plate to plate was taken as 4,000 ohms, being a compromise between dis-

they should be matched against one another within a maximum tolerance of 2%. Other components in the circuit are not so critical and may be within the usual tolerances. Matched pairs of 2A3's and 42's as triodes are necessary for the best results in this circuit. This amplifier is particularly satisfactory for use in very large rooms or in small halls and may be used either in conjunction with a radio receiver or with a pickup.

FOR THE RADIO ENGINEER

DISTORTION WITH A.V.C.

Though A.V.C. has merits which render its use indispensable in modern receiving equipment, there are also some disadvantages which tend somewhat to limit its utility. The most serious fault is, perhaps, the envelope distortion which may be introduced in the last I.F. stage, if its bias is controlled from the A.V.C. line.

There are three factors which tend to distort the envelope of the modulated carrier:

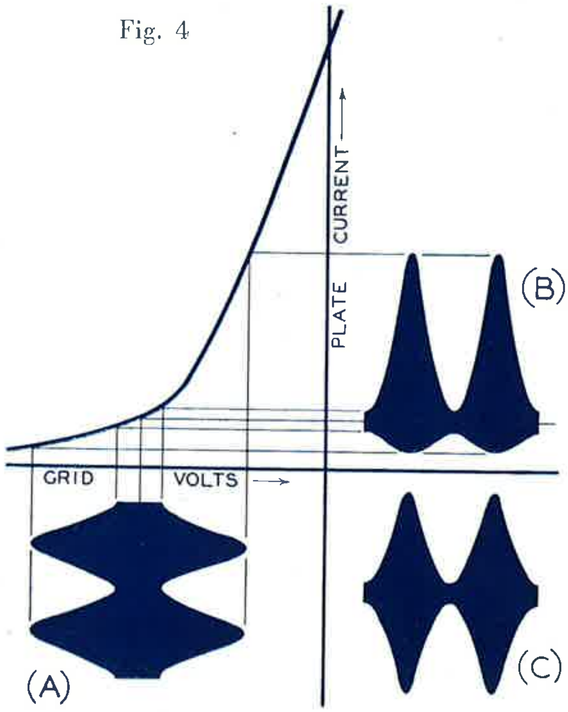
(a) Curvature of the characteristic causing modulation rise.
(b) Grid Current.
(c) Differential loading due to delayed A.V.C.

These are considered in order.

Modulation Rise.

The I_p-E_g curve of a valve necessarily increases in slope with reduced bias so that for any operating bias the positive peaks of modulation are accentuated, thus giving modulation rise. The effect is more pronounced with high bias voltages and high input signals since the input signal traverses through a greater range of curvature of the characteristic.

Fig. 4



This effect is best explained by the graphical illustration, fig. 4. "A" represents the modulated carrier input, with 66% modulation. "B" shows the current in the primary of the last I.F. transformer. When its D.C. and audio components are filtered out by the coupling to the secondary coil, the result "C" is seen to have its envelope distorted, and its depth of modulation increased.

Grid Current Distortion.

More correctly known as "diode line" distortion, this occurs when the grid excitation swings the operating point on the load line on to the crowded portion of the pentode I_p E_p curves (See fig. 5).

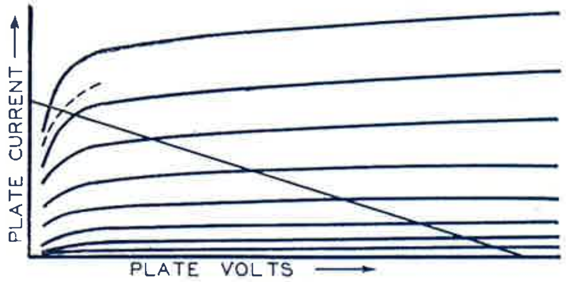


Fig. 5

In fig. 6 the dynamic line is plotted from fig. 4. It is seen that when the voltage on the grid becomes near to, equal to and greater than zero, the current tends to remain constant. When the modulated carrier "A" is applied to the grid, the tops of the positive peaks of the envelope are flattened as in "B". "C" shows the voltage across the secondary of the last I.F. transformer.

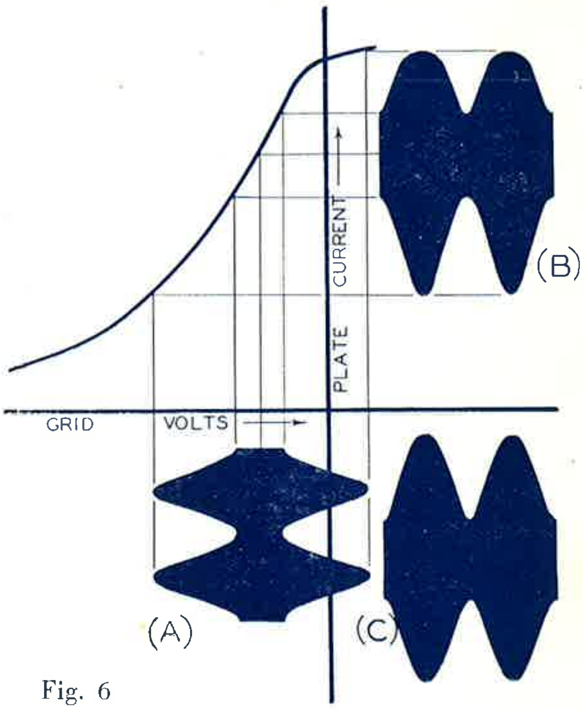


Fig. 6

With the popular anode fed delayed A.V.C. system, the bias applied to the last I.F. stage is very nearly equal to the peak alternating plate voltage. For grid current distortion to occur, the input must therefore be nearly equal to the output voltage. This type of distortion generally occurs with very large signals, larger than those causing modulation

FOR THE RADIO ENGINEER

DISTORTION WITH A.V.C.—Continued.

rise. The combined effect of flattening both peaks and troughs tends to produce third harmonic distortion. There is, in some cases, a point at which the second harmonic becomes zero, after which it changes phase.

Distortion Due to Differential Loading.

When ordinary delayed A.V.C. is fitted to a receiver, the load on the last I.F. valve may change when the current begins to flow in the A.V.C. diode. If the change of loading occurs at a point in the modulation cycle, the output above this point will not rise so rapidly due to the small effective load resistance, and the envelope becomes flattened above this point. Such a mode of distortion is most evident on medium signals which just operate the A.V.C. In its worst form it manifests itself in "peaky" third order distortion, and rarely exceeds 5% total harmonic distortion.*

Cross Modulation.

In the early LC circuits of a receiver, an interfering signal may be much stronger than the signal to which the circuits are tuned. Due to progressive attenuation through the receiver, however, the signal off tune may be many db. down at the second detector.

Mention has been made of the audio component in the plate current of an I.F. or R.F. stage, in the section on Modulation Rise. When a strong interfering signal impresses its audio envelope on the plate current of an R.F. stage or converter valve, the gain rises and falls with the plate current, and the wanted signal is modulated by the other in a fashion similar to the early Van der Bjil modulator.

Valves having the most gradually curved plate current characteristics tend least to exhibit this phenomenon, which is rarely experienced with modern valves, but is mentioned here for completeness.

Application.

Experimental evidence shows that as much as 30% total harmonic distortion may occur in the last I.F. stage with 1 volt of 100% modulated signal applied to the aerial terminal. The distortion is worst in I.F. stages having low gain between grid and A.V.C. diode plate. It is advisable for that reason to feed the A.V.C. diode plate from the plate of the last I.F. stage, thus avoiding the otherwise inevitable loss in the I.F. transformer.

If the gain between A.V.C. line and last I.F. grid is increased by another stage, the distortion may be reduced still further. Such arrangements are termed amplified A.V.C. systems usually abbreviated to A.A.V.C. The control characteristic also may be improved in this manner.

In one method of A.A.V.C., a steady voltage is developed across a diode load, and used to bias a valve, generally a triode, as a D.C. amplifier. The A.V.C. line is connected to the plate or cathode of the D.C. amplifier in which the current varies with the bias provided by the carrier, producing changes in current, and consequent changes in the potential of the A.V.C. line. The load of the D.C. amplifier is chosen to realise a gain of up to ten times, that is to say, the potential of the A.V.C. line may be ten times as great as the rectified voltage which produces it. The D.C. amplifier may be used simultaneously as an audio or I.F. amplifier, and may be combined with the diodes in a multiple valve.

In all cases, the principle is the same, as outlined above, and in all cases the H.T. supply voltage must be 300 volts or more, to provide negative voltage for the cathode of the D.C. amplifier, which is normally operated at a potential negative with respect to the cathodes of the controlled stages.

Another disadvantage of all D.C. amplifiers is that the bias voltages of the other valves are dependent largely upon the D.C. characteristics of the valve itself. When it begins to lose emission, the bias on all the controlled stages may vary sufficiently to render the A.V.C. useless, or even worse, allow them to run with positive bias in some cases. It is the D.C. amplifier characteristic which limits the use of direct coupled audio circuits.

Another method of increasing the gain between the grid of the last controlled stage and the A.V.C. line is the inclusion of an uncontrolled I.F. stage between the last controlled stage and the A.V.C. and signal rectifiers. The extra tuned circuits involved tend to improve selectivity, and the extra I.F. gain permits the use of better (band-pass) I.F. filters. As fixed bias is used, Radiotron 6C6 may be employed in this application. It has been shown in Radiotronics 77 that the addition of a final uncontrolled I.F. stage tends to improve the control characteristic.

* See "Distortion Produced by Delayed Diode A.V.C."—K. R. Sturley—Wireless Engineer, January, 1937.

HIGHER OUTPUT FROM VIBRATOR SETS

When a higher output is required than can be given by Radiotron 1D4, it is suggested that type 33 be adopted. This valve is capable of giving an output of 0.7 watt on 135 volts supply and approximately 1 watt on 150 volts supply. Although the plate current is somewhat high, this is not beyond the capabilities of a vibrator and the additional power output is very desirable. Radiotron 1K6 as a resistance coupled amplifier is capable of exciting type 33 without any difficulty while still providing ample audio gain.

ITEMS OF GENERAL INTEREST

RADIOTRON 6V6G

New High Gain Power Pentode.

There are a number of applications in which Radiotron 42 is not found to give sufficient output or in which a valve with a higher grid sensitivity is desirable. Radiotron 6V6G, which has recently been released, is now available for such applications. This new valve delivers a maximum power output of 4.25 watts on a plate and screen voltage of 250. The grid bias is –12.5 volts and the plate and screen currents 45 and 4.5 mA respectively. The load resistance for a single valve is 6,000 ohms. The heater is operated at 6.3 volts and draws 0.45A and it therefore has a special application in automobile receivers where the heater current is of importance. Two Radiotron 6V6G valves may be used in a push-pull amplifier class AB1 to give a maximum output of 8.5 watts on 250 volts and 13 watts on 300 volts supply. These outputs hold with fixed bias only and less output would be given where self-bias is employed.

Radiotron 6V6G is fitted with an octal base, the socket connections being identical with type 6F6. Further information on this valve is available on request to the Unified Sales-Engineering Service.

NEW RADIOTRON 6.3 VOLT .15 AMP. SERIES

Five new types of Radiotron valves have been released and are now available from stock. These all have heaters rated at 6.3 volts 0.15A and are primarily intended for use in receivers operating from 6 volt accumulators. They are not intended for use in A.C. receivers or in A.C./D.C. receivers and it is recommended that their application should be limited to cases where it is essential to economise in heater current. The types included in this new series are given below:—

Type	Description.
6D8G	Pentagrid Converter.
6L5G	General Purpose Triode.
6N5	Magic Eye Tuning Indicator.
6S7G	Super Control R.F. Pentode.
6T7G	Duo-diode high-mu triode.

All these new types, with the exception of the 6N5, are fitted with octal bases. Technical data on these new valves is available on request to the Unified Sales-Engineering Service.

TRANSFORMER DESIGN

We receive a number of requests for information on the method of design of transformers and wish to point out that this subject is dealt with in ample detail in the Radiotron Designer's Handbook, available at 1/- post free.

COMMENTS ON MERCURY VAPOUR RECTIFIERS

Mercury vapour rectifier valves require to be handled with care and certain precautions are advisable. When a valve is first received it is possible that mercury will be deposited on the plate and on the filament and it is advisable to shake the valve while it is held in a vertical position so that any mercury will tend to fall to the bottom of the bulb. After this is done, *it is strongly advisable to run the valve for a period of several minutes for the smaller valves and up to half an hour for the larger types, in order to vapourise any remaining mercury on the filament and plate.*

All mercury vapour rectifiers should be shielded from R.F. fields particularly when these valves are used in transmitters in close proximity to R.F. equipment. These fields tend to produce break down in mercury vapour rectifiers and are detrimental to the valve life and performance. Metal shields should be employed whenever a mercury vapour rectifier is in proximity to high voltage high frequency fields. It is also advisable to incorporate R.F. filters so as to prevent R.F. currents being fed back into the rectifier valves.

Certain types of mercury vapour rectifiers used in transmitters incorporate internal shielding of the filament and these types are therefore less likely to fail under adverse conditions. These types are Radiotrons 866A, 872A, 869A and 857. Even in these cases it is advisable to incorporate all the precautions outlined above.

Mercury vapour rectifiers must always be used with a choke input filter and advice regarding the correct values of choke and condenser for special cases will be supplied upon application to the Unified Sales-Engineering Service.

OPERATING DATA ON POWER TRIODE VALVES

In order to assist designers to obtain the best combinations of valves for various applications, some tables have been prepared is loose-leaf form covering the most usual types of triode valves with a wide range of operating conditions for each type. A number of these conditions have not hitherto been published and an inspection of the tables should prove of interest to all. The types covered include Radiotrons 45, 2A3, 50 and 845, giving a range of power outputs from less than 1 watt to 105 watts. For fidelity and satisfactory performance under arduous conditions, triodes are recommended either as single amplifiers or in push-pull. The given conditions of operation are limited to class A and class AB1 in all of which conditions

ITEMS OF GENERAL INTEREST

OPERATING DATA—Continued.

a high impedance grid circuit may be used. In each case the maximum grid circuit resistance is given and this value should not be increased under any circumstances. Generally, in cases where the grid resistor is less than .25 megohm it will be preferred to employ transformer coupling to the grid. As an alternative a large power triode valve may be used with resistance coupling, but it is preferable that the plate load resistor should have a resistance of approximately one-fifth of the grid resistor of the following valve. The harmonic distortion given is reduced in all cases as the plate load increases, and therefore on a loudspeaker load the distortion will really be less under average conditions than the values given in the table. This is reversed for a pentode valve, in which case the distortion increases as the load impedance increases. The given values of distortion must therefore be interpreted with a view to the application for which the valves are intended. The method of calculating the operating conditions of Class AB1 amplifiers will be given in a later Bulletin.

INPUT TRANSFORMERS: CLASS AB1 AMPLIFIERS

We have been asked on several occasions whether high impedance input transformers may be used with class AB1 amplifiers. So far as the grid circuit is concerned, a class AB1 amplifier may be treated as being similar to a class A amplifier in that it draws no grid current and no grid power is required to drive it. The only normal limit on the impedance of the grid circuit is the maximum grid resistance permitted for the particular valves used. A step-up ratio transformer having a high impedance secondary is quite satisfactory in all cases of Class A and Class AB1 operation. There are certain cases in which amplifiers are operated under normal conditions as Class AB1 but which may be required to handle occasional peaks running slightly into grid current. In such cases, if the transformer is designed with a step-down ratio, it will be possible to run slightly into grid current without the sudden rise of distortion at grid current point which occurs with a high impedance grid circuit. This arrangement is used in the 30/40 Watt 6L6 amplifier described in the Leaflet on the Radiotron 6L6 and the same method may be used in other cases where it is desired to handle occasional peaks above the limits of class AB1 operation. There is also an advantage in the use of a step-down ratio transformer since it is possible by this means to obtain a better frequency response than with a step-up transformer of similar design. The reason for this is that the primary may have additional turns thereby giving higher inductance and a better response at low frequencies, while the effect of capacities existing in the secondary is very much reduced, thereby assisting in the response to high audio frequencies.

NOTE ON SERIES INVERSE FEEDBACK

A new method of obtaining inverse feedback with resistance coupling which is known as "Series Inverse Feedback" has been described in recent issues of Radiotronics. This method can only be applied when the preceding resistance coupled stage is a pentode valve such as Radiotron 6C6, 1K4 or 1K6. In cases where the preceding valve is a triode this method cannot be applied and it is necessary to use transformer coupling with the lower end of the secondary of the transformer connected to a point in the circuit which will introduce the necessary inverse feedback. We have received a number of requests for applications of series inverse feedback to resistance coupled triode amplifying valves and wish to point out that this application is not practicable.

DIODE DETECTORS NEED HIGH INPUT VOLTAGE

A diode detector (or any other form of detector) always gives serious distortion when operated at a low input voltage. For this reason a set having a manual volume control operating on the R.F. stages always functions best at full volume, and usually gives audible distortion when the volume is reduced. This effect is most pronounced when a high gain audio amplifier is used. A cure is to add a second volume control on the audio side which is best arranged in a similar manner to the volume control of a receiver fitted with A.V.C., that is, as the diode load resistor. Under most conditions the R.F. volume control should be set at maximum and only reduced so as to prevent overloading on very strong local stations, the normal control of volume being effected on the audio side. In the case of superhets. the A.V.C. should be arranged so as to give a peak input voltage to the diode detector of not less than 10 volts on strong stations.

POWER TRANSFORMERS - CURRENT RATING

The current in each half-winding of the secondary of a power transformer is 0.78 times the D.C. current delivered by the rectifier, so that when transformers are ordered, care should be taken to specify the secondary current in terms of the D.C. output. This means that a transformer which is required to give an output of 100 mA. D.C. will need to be wound so as to carry 78 mA. A.C. through each half-winding. The correct voltage should be delivered under conditions of normal full load.

EXPERIMENTERS' SECTION

PLATE MODULATED AMPLIFIER

Method of Calculating Load of Modulator.

A Class C R.F. amplifier presents to the modulator a load approximately equal to a pure resistance. The value of the resistance may be found by dividing the D.C. plate voltage by the D.C. plate current in amperes. If two R.F. amplifiers are used in push-pull, the load on the modulator is equal to the plate voltage divided by the total current in amperes to both valves.

Correction.

Two errors occurred in the leaflet "Radiotron Circuits for Experimenters." We would ask you to make the following corrections.

The screen dropping resistor for the 807 in Circuits 3 and 5 should read 5,000 ohms instead of 50,000 ohms.

The link shown between primary and secondary of the modulation transformer in Circuit 3 should be omitted.

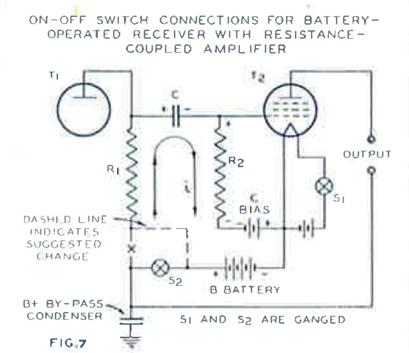


Fig. 7

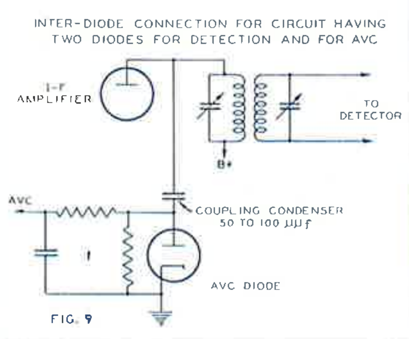


Fig. 9

R.C.A. APPLICATION NOTE

GRID BLOCKING IN BATTERY RECEIVERS

Many battery-operated receivers employ a dual off-on switch in order to control filament and B-supply voltages simultaneously. Such receivers may block when this dual switch is opened and closed rapidly. The reason for the blocking can be seen from the a-f portion of a receiver circuit, shown in fig. 7.

When the ganged switches (S_1 and S_2) have been closed for some time, the temperature of the filament is normal and the circuit is in operating condition. When S_1 and S_2 are opened, the temperature of the filament decreases and condenser C discharges almost immediately. Now, when S_1 and S_2 are closed before the temperature of the filament reaches a very low value, the charging current from the B-battery through circuit R_1, C, R_2 causes the grid of the tube to become positive by an amount equal to the voltage drop across R_2, and the temperature of the filament starts to increase. Thus, due to the heating lag of the filament, it is possible for the grid to be highly positive while the temperature of the filament is less than normal. The grid may emit secondary electrons under such conditions. This secondary-emission current flows in the same direction as the charging current (i); thus, the positive potential

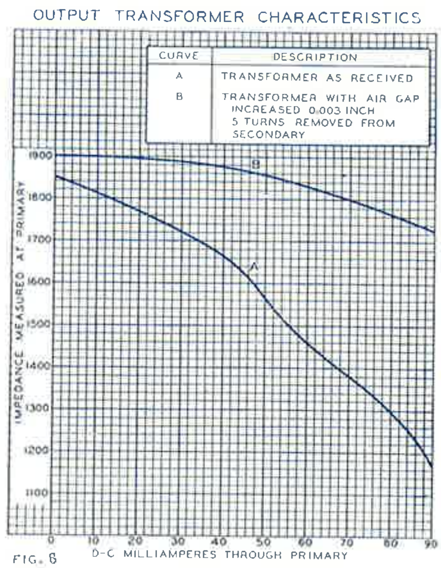


Fig. 8

R.C.A. APPLICATION NOTE

of the grid increases to a high value. The transconductance and, hence, the output of the valve is low under these conditions. Normal operation can be restored by turning the receiver off long enough for the filament to cool to a low temperature and then turning it on again.

Two methods may be used to eliminate this undesirable blocking. The lead to R_1 may be broken at x, Fig. 7, and R_1 connected directly to B+, as shown by the dashed line. With this connection, the B-battery is connected to T_1 through R_1 at all times; hence, no charging current flows through C when S_2 is closed.

A second method of eliminating the trouble is to delay the closing of S_2 until the temperature of the filament is high enough to avoid secondary emission from the grid.

This secondary-emission effect is not peculiar to the output stage or to a particular valve type; it may occur in any resistance-coupled-amplifier stage.

OUTPUT TRANSFORMER

Measurements on a number of output transformers designed for a-c/d-c receivers indicate that an appreciable improvement in performance may be obtained by increasing the length of the air gap. The improvement obtained in one case is shown by the curves of Fig. 8. The proper load for the transformer was connected to the secondary; the total impedance across the primary terminals was measured at 420 cycles for different values of direct current through the primary with normal field current. The total impedance should have been approximately 2,000 ohms for a direct current of 50 milliamperes through the primary; the measured value was found to be 1,560 ohms.

The variation in impedance with current is more important than the absolute value of the impedance. When the load impedance of a single-valve amplifier varies with current, the output is distorted; this distortion cannot be minimised by an adjustment of the bias or of the load impedance.

The impedance characteristic shown by curve A of Fig. 8 was corrected to that of curve B by an increase of 0.003 inch in the length of the air gap. A few turns were removed from the secondary in order to raise the impedance to a higher value. The important result, however, is the reduced change in impedance with current, because distortion is introduced by a load impedance which varies throughout the signal cycle.

CONVERTER VALVES

Difficulty is often experienced in lining up the oscillator and signal circuits of a pentagrid converter due to coupling between oscillator and signal sections of the valve. This difficulty is most noticeable at the high-frequency end of the high-frequency band. It has been found that a resistor of approximately 50 ohms connected in series with the signal grid (No. 4) and the tuned circuit reduces lining-up difficulties.

SEPARATE AVC DIODE CIRCUIT

When separate diodes are used for detection and avc, and the i-f transformer is connected through a condenser to the diode, it is desirable to employ a condenser of 50 to 100 $\mu\mu$f. Values of coupling condensers greater than 100 $\mu\mu$f cause an appreciable decrease in output voltage at the higher audio frequencies.

The avc diode loads the i-f transformer to which it connects (Fig. 9). Increasing the value of the coupling condenser increases the loading; for a given value of coupling condenser, the loading increases with modulation frequency. A 50 to 100 $\mu\mu$f coupling condenser is suitable for most purposes. In one instance, a decrease in the value of this condenser from 250 $\mu\mu$f to 50$\mu\mu$f doubled the voltage output at 5000 cycles. This change in output does not include the attenuation at 5000 cycles due to the selectivity of the i-f transformer.

OSCILLATION

Difficulties due to oscillation in the output stage may be experienced when the transconductance of the output valve is high. In the case of the 25L6, 6L6, 6L6G, or 6V6G, it may be necessary to shunt the bias resistor with a small mica condenser (approximately 0.001 μf) in order to prevent oscillation; the usual electrolytic by-pass condenser is also used across the bias resistor when degeneration is not desired.

Another aid in suppressing oscillation is to ground the shell of each all-metal valve with a short, heavy wire. When the impedance in series with the shell is appreciable, spurious oscillations at high frequencies may occur. This type of oscillation may be detected by an oscillograph or by measuring the screen current; the screen current will be appreciably higher than normal when the valve oscillates.

The following suggestions have been effective in suppressing oscillation in push-pull output stages using glass-type valves. (1) Connect a 500-ohm resistor in series with the control grid of each output valve; each resistor should be mounted as close as possible to the grid terminal of the socket to which it connects. (2) Mount each plate by-pass condenser as close as possible to the plate terminal of the socket to which it connects. The purpose of the suppressor resistor and the plate by-pass condenser may not be served when they connect to a valve through comparatively long leads.