Power Pack Manual

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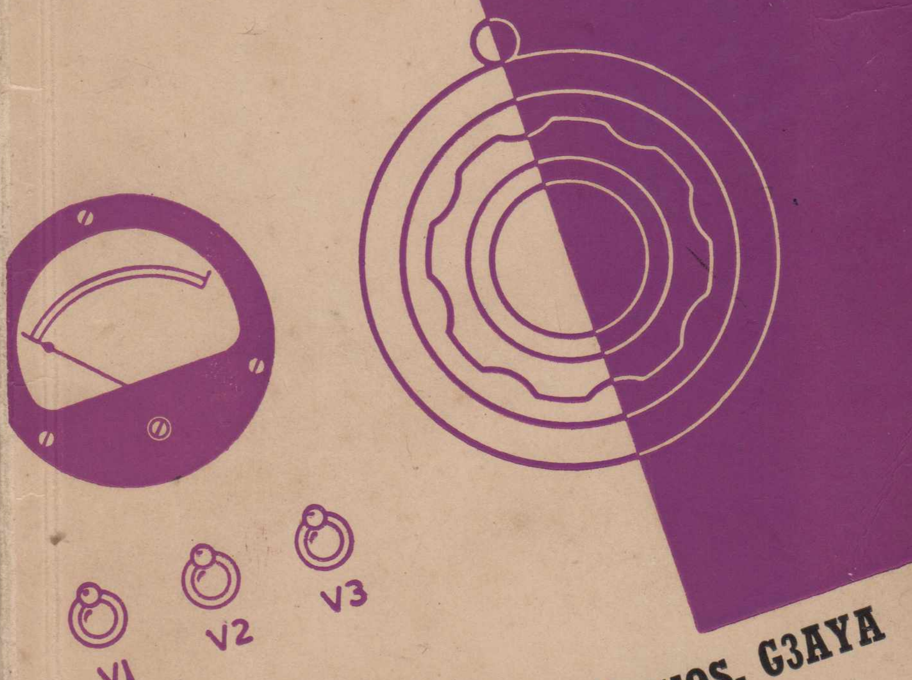

N. Stevens, G3AKA & L. Howes, G3AYA

BERNARDS RADIO MANUALS ★ No. 93

POWER PACK MANUAL

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by

N. STEVENS, G3AKA

and

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with 53 illustrations

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Preface

Every radio constructional enthusiast requires some form of power supply, whether he is an amateur transmitter, a short wave listener, a broadcast band listener, or is interested in test gear: even the users of battery sets need accumulators and dry batteries.

In this work the authors have avoided theoretical aspects, since it was felt that existing textbooks already deal adequately with theory. Apart from the introductory chapters, theory and mathematics have been introduced only when it was considered necessary for clarity.

Nearly fifty different power supply circuits are given with complete details. These circuits and explanations will enable the general principles to be applied in the design of power supplies to suit any contingency, should the published examples not exactly meet requirements.

The authors express the hope that this manual will serve the purpose for which it was intended, namely, to provide a compact source of information for designs and considerations in power supply equipment, from the two valve battery receiver to the 150 watt transmitter and television receiver.

Norman Stevens, G3AKA,
Lionel Howes, G3AYA.

London, 1950.

Contents

WARNING

It should be realised by all users of power supply equipment that in certain circumstances even the low power supply is a potential source of shocks which can be lethal. The reader will not need reminding that many amateurs have met with fatal accidents by their failing to take care. Therefore, it cannot be overstressed that extreme care must be taken by all users of power supply equipment—however small the ratings may be.

POWER PACK MANUAL

CHAPTER 1

RECTIFICATION

Rectification is of vital importance in radio receivers, for without it the transmitted signals of supersonic frequencies could not be rendered audible. We refer, of course, to the rectification of the incoming signals—although more correctly the term should be "demodulation", and the valve which performs this function the "demodulator".

But there is another form of rectification upon which the majority of radio receivers, transmitters and auxilliary gear depend for their operation, namely Power Rectification. This follows the same principle as the demodulator stage in a receiver but differs in that instead of converting the alternating high frequency signals to a uni-directional half-wave DC component it converts the low frequency AC mains to a steady flow of direct current.

For all radio gear a supply of ripple-free direct current is required for application to the various valves. This excludes valve heaters which may be operated from an AC source. The process of converting the AC mains supply to the required DC is called power rectification.

THE DIODE

Let us examine what happens in a typical power rectifier circuit and how the various difficulties are overcome. A typical small power pack (the name given to the group of components which make up the unit) consists of a transformer, a valve, one (or two) chokes and one (two or three) capacitors. The transformer is used to provide the required voltage to operate the valve anodes and to provide a lower voltage to supply the valve heater (and also to provide additional heater supplies for the valves in the equipment to be used). The valve is used for the process of rectification and the chokes and capacitors form the filter system which smooths out the pulsating direct current into current which is suitable for application to valve electrodes.

The simplest rectifier is the diode and Fig. 1 shows this valve in a theoretical circuit arrangement. An alternating voltage is applied to the transformer input, and basic radio theory will show that electrons will flow from the heater to the anode during the half-cycle where a positive potential is applied to the anode. On the second (negative) half-cycle no current will flow since a negative potential is applied to the anode, and the valve ceases to conduct. Current will pass through the load (represented in the diagram by the resistor) only in one direction and then only during the period when the anode is positive in respect to the heater. The resultant output waveform is across A and B shown in the diagram.

FULL-WAVE RECTIFICATION

A more effective and efficient system is that of biphase half-wave rectification in which two diodes are used, or more commonly a twin-diode. This is often referred to as full-wave rectification; but in fact four diodes would be required for this process. However since the more usual nomenclature is "full-wave rectification" we will so refer to it throughout this manual.

Now, by using two diodes a much more practical arrangement becomes possible. By connecting these two diodes in such a way that they each operate on different alternations of the applied voltage we get a resultant waveform that is twice the frequency of that obtained by half-wave rectification, and this makes the subsequent filtering a simpler matter. When the first diode is passing current the second one (having a negative potential on its anode) is idle. On the next half-cycle, since the applied alternating voltages are in a

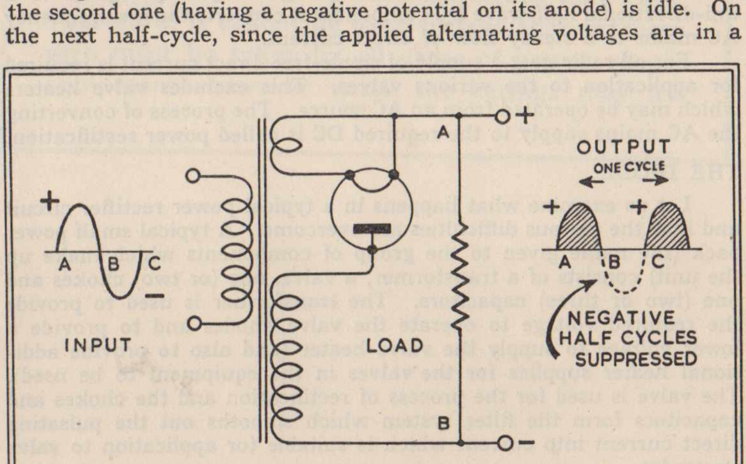

Fig. 1. Theoretical Half-wave rectifier.

reverse direction, the first diode becomes inactive and the second diode begins to pass current. The whole effect is to produce a waveform as shown in Fig. 2A.

THE FILTER

The filter used in conjunction with conventional half-wave or full-wave rectifiers consists essentially of an LC network, that is a mixture of capacitance and inductance. The object of the filter is to remove the ripple which is present at the output of the rectifier. This ripple may be considered as an AC component superimposed on the required DC. From this viewpoint it will be seen that the filter consists of parallel capacitors which short-circuit the AC but leave the DC unhindered, and series inductors which offer high impedance to the AC but readily pass the DC. The efficiency of the filter can be expressed as a per cent. ripple which is the ratio of the ripple (RMS) to the DC value in terms of per cent. With high-grade audio equipment the ripple content should be as low as 0·1%, and with transmitters ('phone) and allied equipment a content of 0·2% can be tolerated. The filter may take one of two forms: condenser input or choke input, depending on the type of apparatus to be fed.

CONDENSER INPUT FILTERS

The effect of introducing a capacitor across the rectifier is shown in Fig. 2B. During the time peak current flows from the diodes the capacitor charges up, and as the output from the rectifier begins to diminish (from point A to B) it will be found that the capacitor is holding a greater voltage than that being supplied from the rectifier. The only path open for the capacitor to discharge this voltage is through the load and as will be seen from the diagram, this has the effect of smoothing the resultant output voltage to some extent. This component is called the Reservoir Capacitor, and the smaller the load current the greater will be the smoothing effect.

The single capacitor does not, however, provide sufficient smoothing for practical needs. Another disadvantage is that a great strain is placed on the rectifier owing to the heavy current being drawn through it. To overcome these difficulties, a low frequency choke is added (see Fig. 2C). The addition of this inductor will provide a greater degree of smoothing as will be seen from the diagram and is obtained by means of the fact that it offers a high impedence to the ripple present in the rectified output. It assists the capacitor to store current between charge periods, and since the discharge from the capacitor is slowed down it receives a further charge before it has completely discharged on the previous half-cycle.

For the removal of the final traces of ripple, however, it is necessary to add a second capacitor as shown in Fig. 2D. A filter such as this is called a single section capacitor input filter, and is

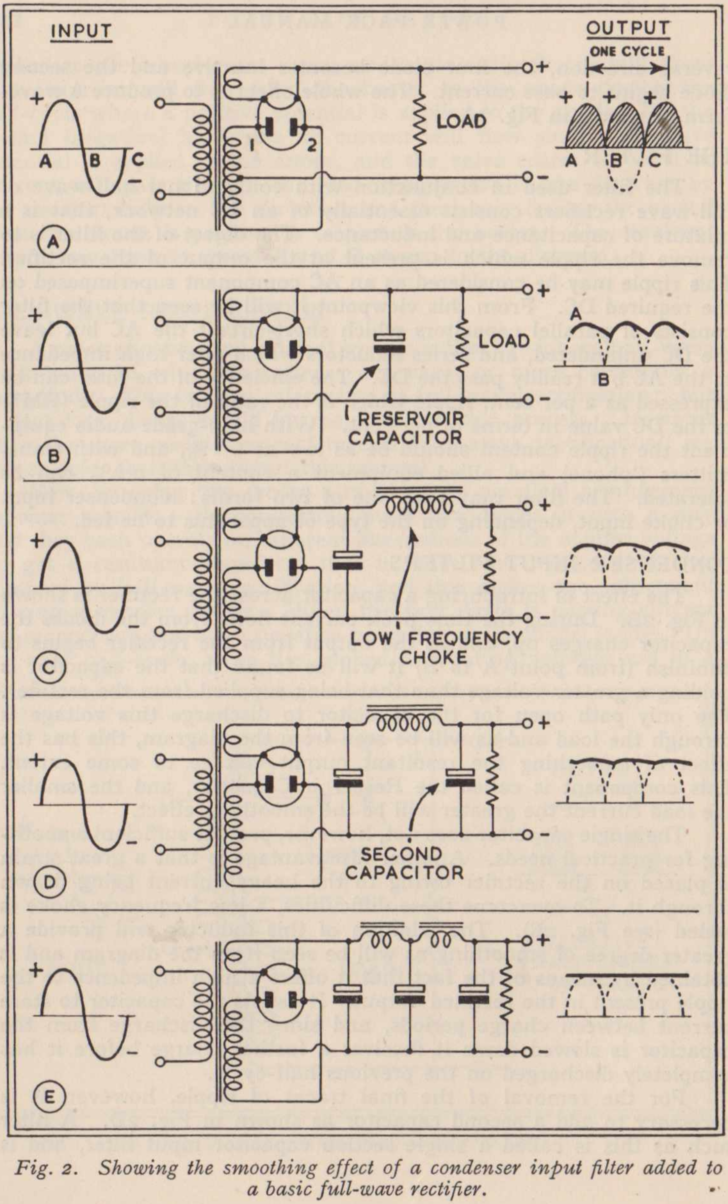

Fig. 2. Showing the smoothing effect of a condenser input filter added to a basic full-wave rectifier.

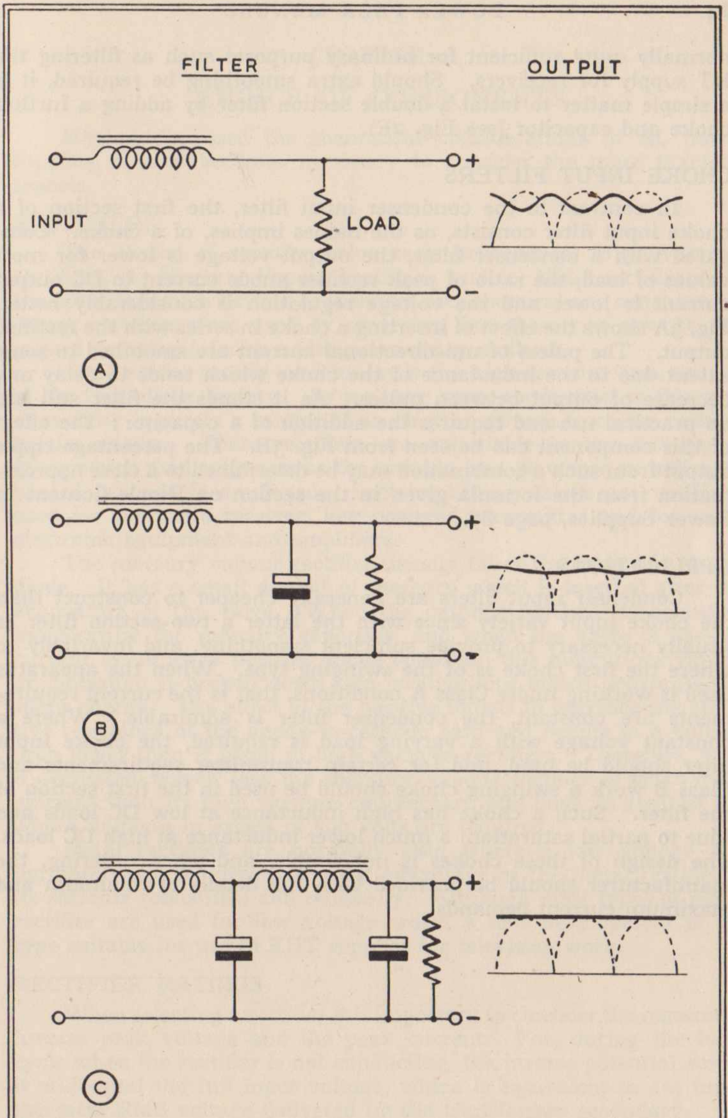

Fig. 3. Choke input filter.

normally quite sufficient for ordinary purposes such as filtering the HT supply for receivers. Should extra smoothing be required, it is a simple matter to instal a double section filter by adding a further choke and capacitor (see Fig. 2E).

CHOKE INPUT FILTERS

In contrast to the condenser input filter, the first section of a choke input filter consists, as the names implies, of a choke. Compared with a condenser filter, the output voltage is lower for most values of load, the ratio of peak rectifier anode current to DC output current is lower and the voltage regulation is considerably better. Fig. 3A shows the effect of inserting a choke in series with the rectified output. The pulses of uni-directional current are smoothed to some extent due to the inductance of the choke which tends to delay any decrease of output between pulses. As it stands the filter still has no practical use and requires the addition of a capacitor: the effect of this component can be seen from Fig. 3B. The percentage ripple output from such a combination may be determined to a close approximation from the formula given in the section on Ripple Content in Power Supplies, page 87.

APPLICATIONS

Condenser input filters are generally cheaper to construct than the choke input variety since with the latter a two-section filter is usually necessary to provide sufficient smoothing, and invariably so where the first choke is of the swinging type. When the apparatus used is working under Class A conditions, that is the current requirements are constant, the condenser filter is admirable. Where a constant voltage with a varying load is required, the choke input filter should be used, and for certain transmitter requirements and Class B work a swinging choke should be used in the first section of the filter. Such a choke has high inductance at low DC loads and (due to partial saturation) a much lower inductance at high DC loads. The design of these chokes is not simple, and when ordering, the manufacturer should be provided with full details of minimum and maximum current demands.

CHAPTER 2

CHOICE OF COMPONENTS

Having discussed the theoretical considerations in AC power supplies, it now becomes necessary to consider the more practical aspects.

RECTIFIERS

The choice of rectifier valve rests between (a) High Vacuum rectifiers, (b) Mercury Vapour rectifiers, and (c) Metal rectifiers. In the early days such devices as mercury-arc, chemical and synchronous rotary rectifiers were used by amateurs, but these can now be dismissed as being inferior under present-day methods.

The rectifier mostly used to-day is the high vacuum type, usually of the twin-diode variety. As we have seen, conduction in this type of rectifier is purely a matter of an electron stream from the cathode to the anodes. These rectifiers are obtainable in two sub-types: (1) in which the heater acts as the cathode, and (2) where an indirectly heated cathode is employed. Such rectifying valves are normally used for the radio receiver, low powered transmitter and for small electronic equipment and amplifiers.

The mercury vapour rectifier usually takes the form of a single diode. It has a small deposit of mercury which is inserted after the evacuation of the valve. When the cathode reached its operating temperature the mercury vaporises, and when the valve is passing current (at times of positive anode potential) this mercurious vapour or ionisation is broken down into positive ions which neutralise the space charge. The effect of the positive ions is to decrease the effective resistance of the anode-to-cathode path and results in a voltage drop lower than is usual in high vacuum rectifiers. Therefore, with a decreased power loss the mercury vapour rectifier is much more efficient than its high vacuum counterpart, and finds its greatest use where voltages in excess of 500 volts are required.

Metal rectifiers are normally used where a low voltage and portability are required. A great advantage of the metal rectifier is its extreme robustness and reliability. Although most types of metal rectifier are used for low voltage work, a new development is the type suitable for use in EHT supplies for television work.

RECTIFIER RATINGS

When selecting a rectifier it is important to consider the maximum inverse peak voltage and the peak current. For, during the half-cycle when the rectifier is not conducting, the inverse potential across it will equal the full input voltage, which is equivalent to 1·4 times the total RMS voltage delivered by the transformer secondary.

Regarding peak current ratings, these will depend to some extent on the type of filter used and the nature of the load—and is based on the flow from the heater. With high vacuum rectifiers an inherent protection against overloading is present owing to the fact that the higher the current, the higher the voltage drop across the tube. An excessive current would result in a greater voltage drop, thus limiting the current flow.

But with mercury vapour rectifiers, the dangers are increased considerably. In these valves, an "arc back" will occur should the critical voltage be exceeded. Such valves should be well ventilated for, as the temperature of the mercury increases, the arc-back voltage will be lower.

Concerning peak inverse voltage in mercury vapour rectifiers, unlike the high vacuum types, the voltage drop remains comparatively constant over considerable changes of current. Therefore, the valve is more critical to overloading. Should an overload occur, no matter how rapid an action, the positive mercurious ions will fly to the cathode with such a velocity as to destroy the coating on the heater. This means a new valve. With vacuum rectifiers a slow constant overload, even if only slight, over a longer time would have a general deleterious effect on the heater coating and, given time, the same effect would occur. It is important, therefore, in high vacuum rectifiers to run them within their operating conditions, and in mercury vapour types it is imperative.

Another point, often overlooked, is that the cathode will certainly lose emission if the heaters are *under-run* and would have the same eventual effect as over-running. Additionally, with mercury vapour rectifiers, it is necessary to apply the heater potential for a specific period prior to applying the load. This will be fully discussed in High Voltage Packs.

CHOKES AND CAPACITORS

The choice of suitable low frequency chokes for filter circuits is relatively simple. For capacitor-input filters a standard low frequency constant-inductance choke is used, normally with an inductance of some 10-30 Henries. For choke-input circuits a "swinging choke" is sometimes used. This type of choke is designed so that its inductance will vary with the value of the current it is passing. Typical values provide a variation between 5-25 Henries.

Capacitors in filter circuits are usually of the dry electrolytic kind, although paper, wet electrolytic or oil filled types are used in some instances. Electrolytics are useful as they are small compared with their capacitance ratings; but for high voltage power units the oil-filled variety is more suitable. In all types of electrolytic capacitor there is a small inherent leakage due to the fact that the dielectric material does not form a perfect insulator. This leakage current is very low—a matter of a few milliamperes—and is higher in wet than in dry electrolytics. However, a voltage overload is more serious when dry electrolytics are used because with wet types an overload simply means an increase in the existing high leakage current. A dry electrolytic with an applied overload would be destroyed.

These components must be kept cool, for the reason that as the temperature rises the breakdown voltage decreases. It is important to see that filter capacitors are of adequate voltage ratings; the initial voltage surge must be taken into consideration and the component's working voltage must give a handsome margin of tolerance. It is of prime importance always to buy capacitors of high quality: it is false economy to use doubtful components in filter circuits, for a breakdown frequently means a damaged rectifier. Electrolytics which have not been used for a time show a marked deterioration in the dielectric film which will in time completely disappear. This film can be, and often is, reformed by applying the working voltage; but it is safer to apply the capacitor across some lower voltage supply for this process. Otherwise not only the capacitor but other power pack components may be seriously damaged. An electrolytic which has been out of action for a few weeks will re-form its film after a few minutes of application across a low voltage source. Finally, care must be taken to connect the capacitors at their correct polarity. This is always marked on the component itself.

RESERVOIR CAPACITORS

When choosing an electrolytic component for use in the reservoir position, one of the most important considerations is the ripple carrying capacity of the condenser. With full-wave circuits, for purposes of calculation, the ripple current can be considered to be equal to the DC load current, and for half-wave circuits twice value of the DC load. Temperature plays a large part in determining the ripple handling capacity of a capacitor and it is most desirable to mount this component in a cool part of the equipment. To give an example, the TCC CE37P will handle a ripple current of 460 m/A's at 30° C. but at 65° C. it falls to 170 m/A's. Generally speaking, plain foil capacitors are preferable to the etched foil variety; should there be any doubt as to the suitability of a given component, the manufacturer should be consulted.

THE TRANSFORMER

The only component not mentioned so far is the Power Transformer. This follows normal form, namely, with step-up or step-down induced voltages and current in direct proportion to the turns ratio. As with other power supply components it is important to see that it is not over-run, for excessive heating in transformers can lead to serious trouble. If the transformer is being operated under suitable conditions it should be hardly warm after hours of continuous operation. The transformer, also, must be operated within its limits to maintain stability in subsequent stages, as a badly regulated supply due to an over-run transformer will ruin the performance of such gear as radio transmitters and audio amplifiers.

The filament supply for the rectifier valve is normally carried on a separate winding on the power transformer; but in some cases (especially where high voltage supplies are concerned) it is often advisable to use a separate transformer to supply to heater voltage. A further heater winding is necessary to supply the heaters of the equipment with which the power unit will be used. Some transformers have several such windings and, where a large number of valves are to be used from the same power pack, this is a great advantage.

In practice it is advisable to ensure adequate ventilation for transformers. No transformer is 100 per cent. efficient; indeed even the best ones can claim only 90 per cent. efficiency. The losses in efficiency materialise as heat which is developed in the core and windings. It must be mentioned that the primary voltage should not be raised above the specified input, otherwise the core will become saturated and serious heating will occur due to the current rising well above the rated figures.

CHAPTER 3

VOLTAGE MULTIPLIERS

A form of rectification frequently used where high voltages are required is the principle of Voltage Doubling. Fig. 4A shows a basic half-wave doubling circuit using two separate half-wave diodes. One of the specially designed twin diodes employing two cathodes could, of course, be used.

The action is as follows: When the anode of V2 is positive, the valve conducts and C1 charges to the peak value of the input voltage less the drop in the valve. At the end of the half-cycle, the polarity reverses and the voltage charge in C1 is added to the input voltage; meanwhile, V1 similarly charges C2. This condenser does not, however, receive the full charge since it commences discharging into the load resistor L as soon as V1 conducts. The output will, therefore, be somewhat less than twice the peak input. With a transformer of 300V (RMS) 100 m/A the output will be some 600V 50 m/A. This circuit has the advantage that one terminal of the input and output

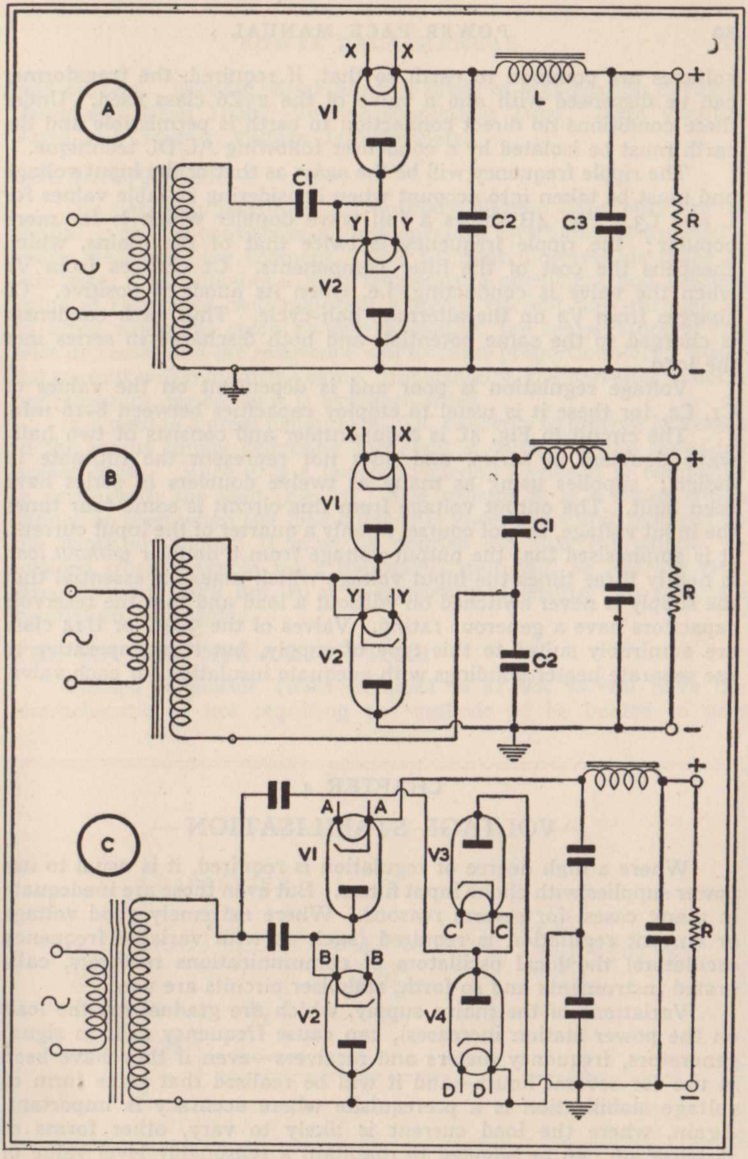

Fig. 4. Voltage multipliers.

voltages are common to earth so that, if required, the transformer can be dispensed with and a valve of the 25Z6 class used. Under these conditions no direct connection to earth is permissible and the earth must be isolated by a condenser following AC/DC technique.

The ripple frequency will be the same as that of the input voltage and must be taken into account when considering suitable values for L and C3. Fig. 4B shows a full wave doubler which is far more popular; the ripple frequency is twice that of the mains, which cheapens the cost of the filter components. C1 charges from V1 when the valve is conducting, i.e. when its anode is positive. C2 charges from V2 on the alternate half-cycle. Thus each condenser is charged to the same potential, and both discharge in series into the load.

Voltage regulation is poor and is dependent on the values of C1, C2, for these it is usual to employ capacities between 8-16 mfd.

The circuit in Fig. 4C is a quadrupler and consists of two half-wave doublers in series, and does not represent the ultimate in design; supplies using as many as twelve doublers in series have been built. The output voltage from this circuit is some four times the input voltage, but, of course, at only a quarter of the input current. It is emphasised that the output voltage from a doubler *without load* is nearly three times the input voltage which makes it essential that the supply is never switched on without a load and that the reservoir capacitors have a generous rating. Valves of the 5Z4G or U14 class are admirably suited to this type of supply, but it is imperative to use separate heater windings with adequate insulation for each valve.

CHAPTER 4

VOLTAGE STABILISATION

Where a high degree of regulation is required, it is usual to use power supplies with choke input filters. But even these are inadequate in many cases, for several reasons. Where extremely good voltage or current regulation is required (such as with variable frequency oscillators) the local oscillators of communications receivers, calibrated instruments and so forth, stabiliser circuits are used.

Variations of the mains supply, which are gradual (as the load on the power station increases), can cause frequency drift in signal generators, frequency meters and receivers—even if they have been in use for several hours—and it will be realised that some form of voltage stabilisation is a prerequisite where accuracy is important. Again, where the load current is likely to vary, other forms of stabilisation can be adopted to maintain a reasonably level value of load current. Broadly, there are five kinds of stabilisation devices: Barretter; Neon Tube; Voltage Regulation Tube; High Vacuum Valve and Constant Voltage Transformers.

THE BARRETTER

The barretter resembles an ordinary electric light bulb and is similar in that it consists of a glass envelope into which is inserted a single electrode—the filament. This filament, however, is made of iron wire, which, having a high temperature coefficient and suitable value of resistance, will maintain a steady current flow through it. In other words, as more voltage is applied, the temperature of the wire increases and the resistance will increase proportionately; hence the current will remain the same. Incidentally, the barretter is not a high vacuum device, as it is hydrogen-filled.

It is used to a great extent in AC/DC receivers to prevent increases in the mains supply delivering too great a voltage to the series-fed heater chain. Since it is a constant current device it is connected in series with the load (Fig. 5). The resistor R is a shunt which should be used when the load current is lower than that required by the barretter, though it must be pointed out that this should be avoided where possible since the stabilisation will be less effective. Barretters run very hot, so it is necessary to ensure that adequate ventilation is provided.

THE VOLTAGE REGULATOR TUBE

Voltage Regulator Tubes (referred to as VR valves) have the characteristic of not requiring the cathode to be heated to pass

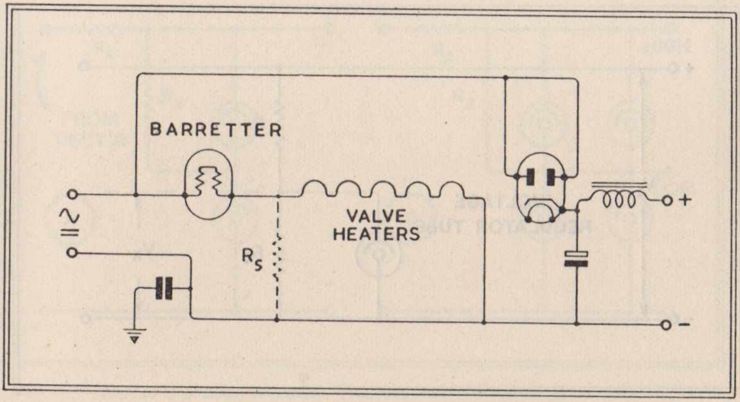

Fig. 5. Basic AC/DC power pack.

current through the tube, hence the name sometimes given to them of "cold cathode tubes". The most commonly used stabilisers of this variety are the VR105/30, VR150/30, and the S130. All these are diodes.

When a certain potential difference is applied across the VR valve electrodes, the gas content in the valve ionises. It is connected to a source of voltage, which must be at least 30 per cent. higher than its operating voltage, via a series resistor. The load is connected in parallel with the valve. The voltage drop across the valve is practically constant for quite moderate variations in current, and the minimum current for stable operation for these types is roughly 5 m/A.

If the maximum current of some 30-40 m/A is exceeded, the life of the valve will be materially shortened.

The series limiting resistor (see Rs in Fig. 6) may be calculated from the following formula:

$$Rs = \frac{1000\ (Vs - Vr)}{I}$$

where Rs = the series limiting resistance in ohms,

Vs = the supply voltage,

Vr = the regulated output voltage (which would be 150 volts in the case of the VR150/30),

I = the maximum permissible tube current (in mA/s).

RL in Fig. 6 represents the load across the regulated supply.

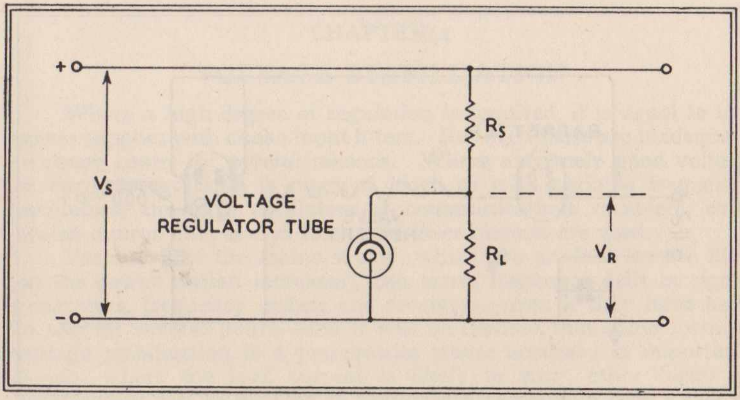

Fig. 6. Stabilising with a V.R. tube.

VR VALVE APPLICATIONS

The VR105/30 or VR150/30 is frequently used for circuits not requiring more than 20 or 30 m/A of stabilised potential. They are readily obtainable on the surplus market at quite low prices. The minimum current (about 5 m/A) for reliable regulation must be taken into account when designing the power supply.

They can be connected in series to stabilise various outputs. For instance, two VR105/30's connected in series will give a stabilised output of 210 volts. Further elaborations can be obtained by various series and series-parallel arrangements; but it is important to note that when in parallel they must be of identical types. If different types are used, the striking and operating voltages will be different, and the results will be quite unsatisfactory. Even when using identical types, some slight variations in performance between the individual tubes may necessitate adjustments. Typical circuits are shown in Fig. 7 A-B, where Rs is the normal series resistor and Rx is a 220 kΩ resistor to ensure even striking.

To determine the correct operating conditions, it is necessary to make some preliminary adjustments. With the load (RL) disconnected, the resistor Rs should be adjusted until a current flow of 30-40 m/A is passing through the stabiliser tube. This initial adjustment is a precautionary measure against damage to the tube during operation.

THE NEON TUBE

The Neon tube is similar in operation to the VR valve previously discussed. They are both DC stabilisers, i.e. both are used on the

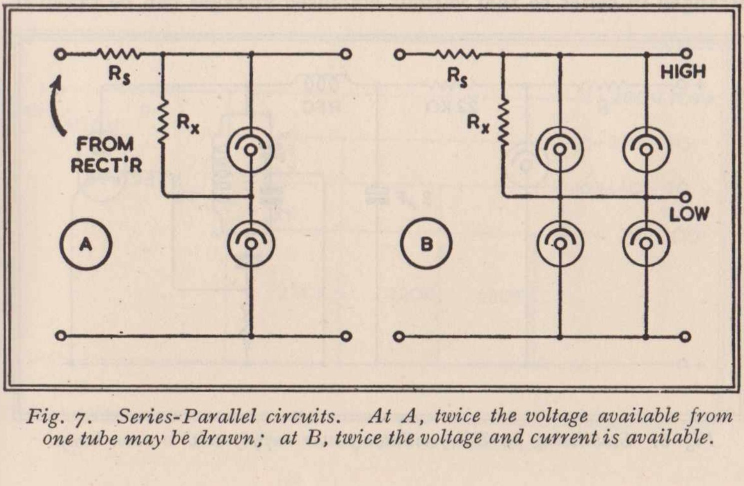

Fig. 7. Series-Parallel circuits. At A, twice the voltage available from one tube may be drawn; at B, twice the voltage and current is available.

rectified side of the power pack. The striking voltage is higher than the operating voltage, and it is recommended that the supply should be 1·5 times the required stabilised voltage. A very useful tube for this class of work is the "Osglim" night-light, a neon tube manufactured by Osram. It is a beehive neon resembling in appearance a standard 60 watt lamp. Before running the tube as a stabiliser it should be aged for about 12 hours on an AC supply. When purchased, these tubes contain a small resistor in the base, which must be removed before the tube is used as a stabiliser. After the resistor has been removed, it will be found convenient to cement the tube into an old valve base. The disc should be connected to the anode pin and the spiral to the cathode. These tubes can be used to stabilise voltages of about 130 to 150 volts and consume some 15 m/A. A suggested circuit using such a tube to stabilise an RF oscillator supply is shown in Fig. 8. The value of R may be calculated as follows:

$$R = \frac{\text{Supply volts} - \text{stabilised volts}}{\text{Neon current} + \text{load current (in Amps)}}$$

If a higher stabilised voltage is required two tubes may be connected in series.

THE STABILOVOLT

This is a special type of voltage stabiliser tube which is finding much favour. It has its greatest application where a number of stabilised voltages are required in the same circuit.

The Stabilovolt is gas-filled and has several discharge gaps arranged in series so that various stabilised voltages can be taken if

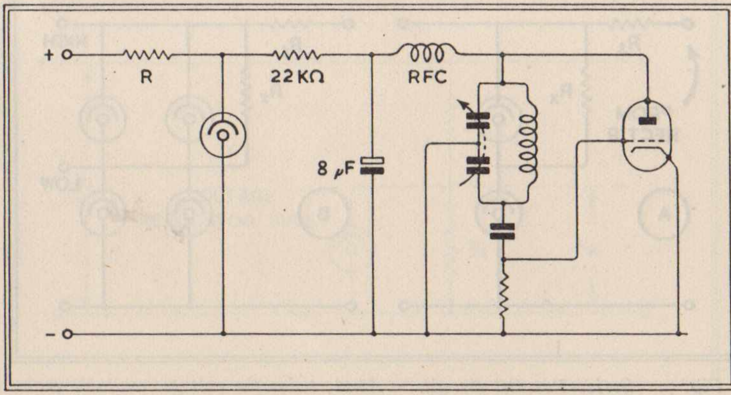

Fig. 8. Stabilising an RF oscillator power supply with a neon lamp.

required. Like its neon and VR counterparts it must be fed from a series resistance for correct operation. Stabilovolts can be joined in series or in parallel if required. Suitable circuits are shown in Figs. 9 and 10.

HIGH VACUUM VALVES

Normal high vacuum valves can be used for stabilising power supplies, and Fig. 11 shows a very satisfactory method. This circuit will give voltage stabilisation within 0·5 per cent. for a load variation of 25 per cent. Also, it will compensate for mains voltage variations, and the whole system is recommended for use where it is necessary to stabilise the potential across lead circuits drawing up to a maximum of 100 m/A.

It will be seen that the first section is a standard full-wave rectifier power pack, which is followed by the stabiliser section. The stabilised potential is achieved through the 6L6G, which acts as an automatic variable series resistor. This is coupled to a DC amplifier a 6J7G or 6C6, which controls the DC bias applied to the 6L6G, effectively controlling the current passing through this valve.

It follows, then, that the 6J7G controls the output voltage. Any output voltage variation affects the anode current of this valve, with the result that the 6J7G anode voltage varies—thus varying the DC bias of the 6L6G.

The 15 KΩ potentiometer controls the grid of the 6J7G and permits the output voltage to be set at either 200 volts at 100 mA or 300 volts at 50 m/A. If higher current is drawn, stabilisation will be less efficient.

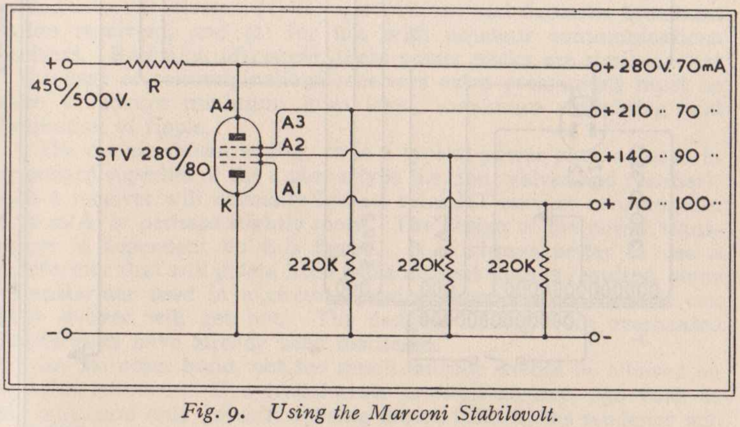

Fig. 9. Using the Marconi Stabilovolt.

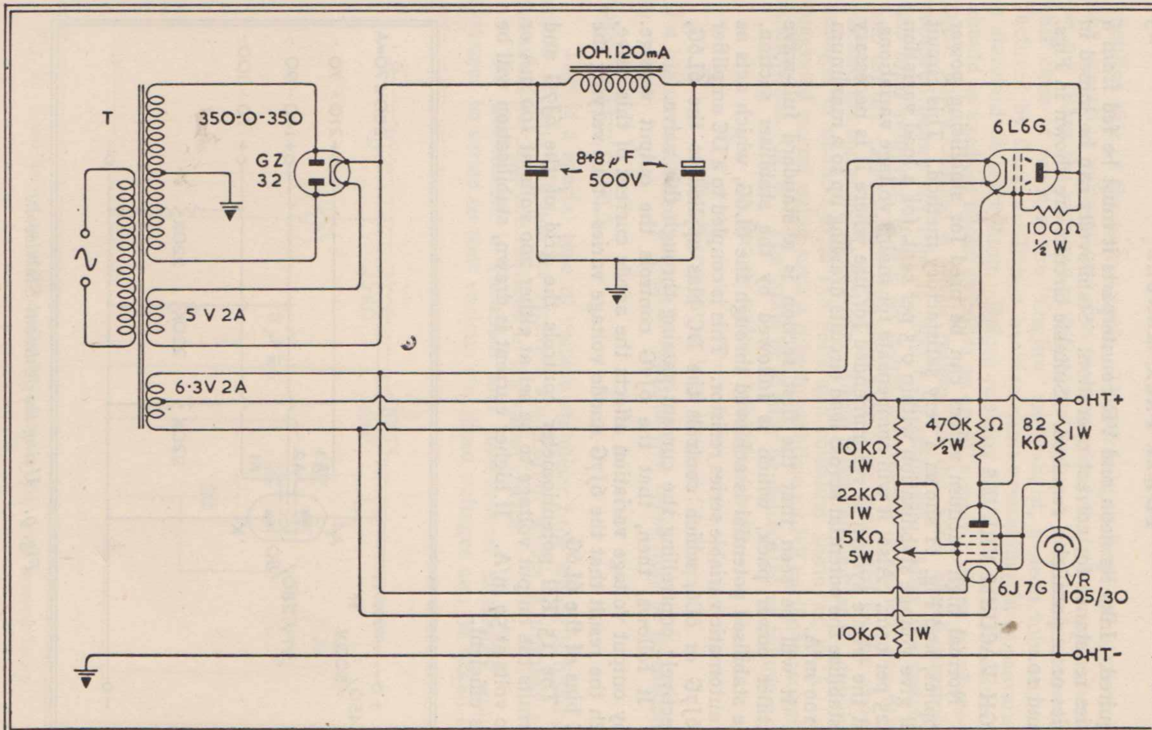

Fig. 11. Regulated supply using hard valves.

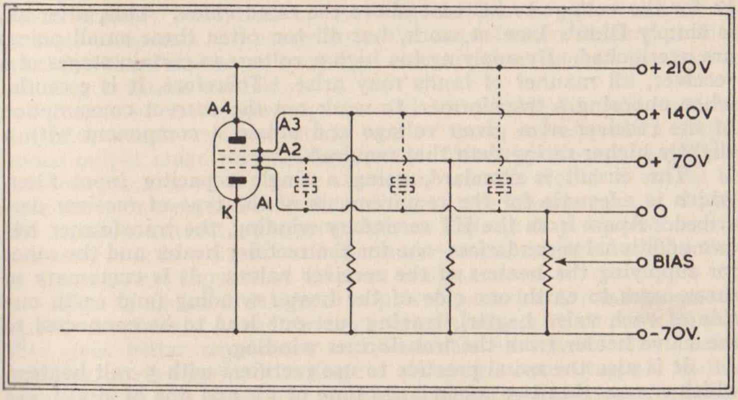

Fig. 10. Alternative Stabilovolt circuit.

CHAPTER 5

POWER SUPPLIES FOR THE AC RECEIVER AND AMPLIFIER

Power supplies for AC operated receivers can be conveniently divided into two classes, (1) for use with normal domestic broadcast station receivers, and (2) for use with amateur communications receivers. Basically, of course, these power packs are similar; but in the case of communications receivers extra precautions must be taken to ensure minimum hum level, maximum smoothing and elimination of ripple.

The circuit shown in Fig. 12 is a typical power pack as used in a standard superhet of the 4 plus 1 type (i.e. four valves and rectifier). Such a receiver will normally have a total HT current consumption of 60 m/A. or perhaps slightly more. The design of the power transformer is dependent on this figure. It is always better to use a transformer that will give a little extra current than is required, since a transformer used in a circuit drawing more current than it can safely deliver will get hot. The dangers arising from overheated transformers have already been discussed.

On the other hand, not too much latitude should be allowed on the other extreme. If a transformer is rated at, say, 250 volts at 100 m/A, and only 50 m/A is being drawn from it, the tendency will be for the voltage to increase above the rated value. This, after all, is simply Ohm's Law at work, but all too often these small points are overlooked. By applying too high a voltage to certain stages of a receiver, all manner of faults may arise. Therefore, it is essential when choosing a transformer, to work out the current consumption of the receiver at a given voltage and obtain a component with a slightly higher rating than that required.

The circuit is standard, using a single capacitor input filter, which is adequate for the requirements of the type of receiver described. Apart from the HT secondary winding, the transformer has two additional secondaries—one for the rectifier heater and the other for supplying the heaters of the receiver valves. It is customary in these cases to earth one side of the heater winding (and earth one side of each valve heater), leaving just one lead to be connected to the valve heater from the transformer winding.

It is also the usual practice to use rectifiers with 5-volt heaters, which means that two secondaries (one of 5V and one of 6·3V) are required; but it is possible to use a single 6·3V secondary to supply both rectifier and receiver valves. The circuit of Fig. 13 shows an

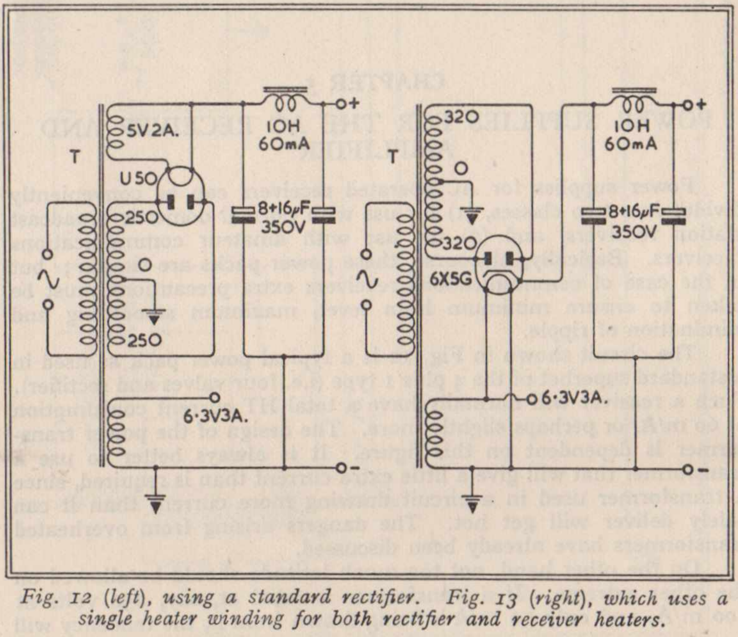

Fig. 12 (left), using a standard rectifier. Fig. 13 (right), which uses a single heater winding for both rectifier and receiver heaters.

example of how this is done, using the 6X5 rectifier. Since the heater-cathode insulation of the 6X5 rectifier is 450 volts, it is possible to operate the heater from the same heater winding as that used for the receiver or amplifier valves. One side of the heater winding is shown earthed.

Either of these power packs will be suitable for low-powered amplifiers, such as those using two or three valves with a single ended output stage (6P25, EL33, etc.). Where push-pull amplifiers are concerned or where more valves are used, it would of course be possible to merely increase the ratings of the transformer to supply the requisite current. However, where high quality reproduction is the aim, as it is with most of the larger amplifiers, the better policy is to use power supplies of different design.

Fig. 14 shows a design of a power pack for a medium power quality amplifier. As will be seen, the filtering is by choke input, as this gives better regulation, and is double sectioned. The heater winding on the power transformer should be centre-tapped, as this arrangement will materially assist in obtaining maximum reduction of hum. Another feature with the same object is the mains RF filter, consisting of two capacitors across the primary winding to

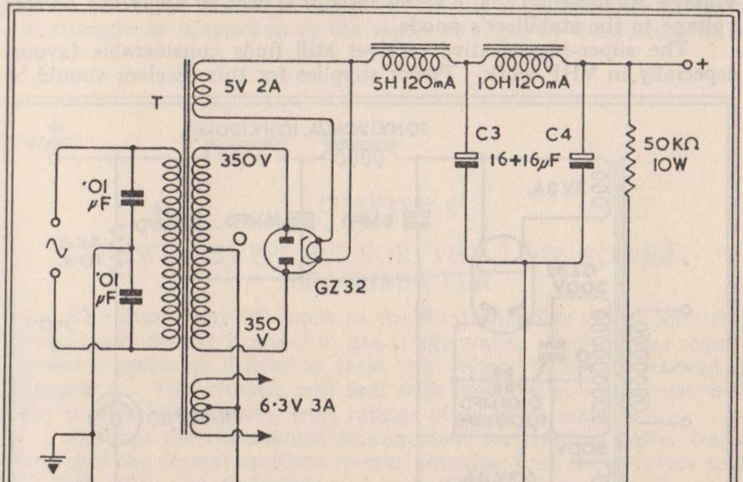

Fig. 14. Power Pack for medium-power amplifiers.

earth. As a final aid to better regulation, a bleeder resistor is placed across the output of the power pack.

The circuit can be adapted to suit various amplifiers by the choice of power transformer, although the values given will be adequate for most amplifiers within the limits of 5 to 10 watts audio output. If directly heated output power triodes are used in the amplifier, further heater windings will be required on the transformer. (High power amplifiers and modulators are dealt with in the section dealing with high voltage power supplies.)

Another instance where a more elaborate power supply is needed is the amateur communications receiver. In these receivers, which must be operated at maximum efficiency, it is necessary to have good smoothing and a stabilised potential to feed the local oscillator to minimise frequency drift. Such a supply is shown in Fig. 15. It incorporates a double section filter with capacitor input, a mains filter, centre-tapped heater supply and, in addition to the main HT output, a low voltage stabilised output for the oscillator anode supply.

The voltage stabiliser tube is the VR150/30, which is in plentiful supply on the surplus market. As its type number indicates, it will supply 150 volts of stabilised HT. It was explained in the chapter on Voltage Stabilisation that a series resistor is used to apply the correct voltage to the stabiliser's anode.

The super-regenerative receiver still finds considerable favour, especially in VHF work. Power supplies for this receiver should be

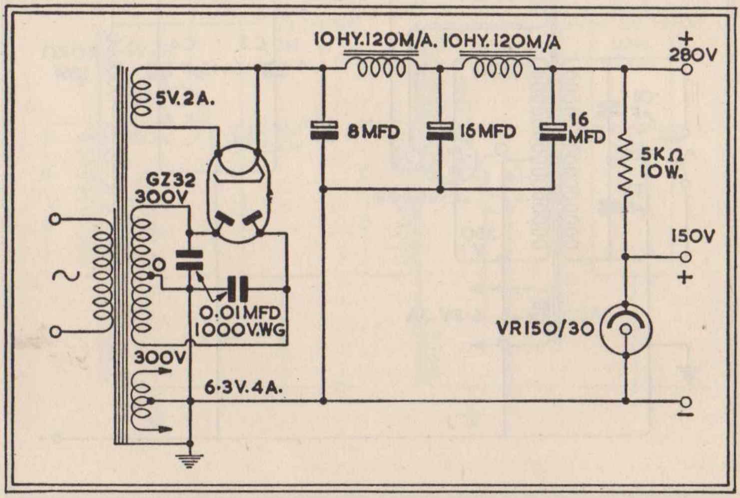

Fig. 15. Communications receiver supply.

carefully chosen for, if a constant voltage is not supplied, an annoying effect best described as tunable hum will sometimes occur. This hum is usually absent when the detector is not oscillating; but will appear as soon as oscillation occurs. No amount of extra filter circuits will cure this trouble, which is caused by RF seeping into the power pack and being modulated. The circuit shown in Fig. 15 can be recommended for such receivers, and others where extremely good regulation is needed.

Incidentally this trouble, often described as "modulation hum", can occur in all types of receiver and there is no hard and fast rule for its elimination. However, in every case the remedy is the insertion of 0·01 mfd. capacitors in certain places in the receiver. It is purely a matter of experiment, but first the capacitor should be tried across each side of the mains input to earth. If this is successful, connect a capacitor to each side of the mains, join them in the centre and take the common connection to earth, as this will take care of any power plug reversal. Another remedy is to connect the capacitors from each side of the rectifier anodes to earth or HT+, or from the rectifier side of the LF choke to earth. Only one of these arrangements is needed and individual instances will require different treatment. In TRF and superhet receivers the modulation hum varies in strength in proportion to the signal strength of the station tuned in.

CHAPTER 6

POWER SUPPLIES FOR THE LOW POWER TRANSMITTER

The maximum DC input to the final amplifier which amateurs in this country are licensed to use is 150 watts. Such inputs require power supplies to deliver at least 750 volts; these are covered in Chapter 7. This chapter will deal with power supplies for use with the smaller transmitters, with ratings of up to 75 watts.

Perhaps the commonest arrangement for the low power transmitter is the crystal oscillator/power amplifier unit using valves such as 6V6 (CO) and 6L6 (PA). A suitable power pack is shown in Fig. 16. It uses a high vacuum rectifier (the 5V4G or G232 is ideal) and employs a standard single section capacitor input filter. A 47K bleeder resistor is included to assist regulation. The main HT line from this unit will give 350 volts to feed the PA anode and the secondary HT line (obtained by dropping the voltage through a

22kr resistor) provides the potential for the PA screen grid and the oscillator anode.

The popular QV05-25 tetrode, which is the equivalent of an 807, finds its place in many amateur amplifier stages and the circuit shown in Fig. 17A gives a power pack designed for use with a three-stage transmitter using a CO/FD/PA arrangement. Typical valves used in such transmitters are the 6V6, KT66 and QV05-25 or 807, in that sequence. The power transformer has a rating of 500-0-500 volts at 250 m/A, and, again, a simple capacitor filter circuit is used. Further regulation is obtained by the bleeder resistors which form the voltage divider network.

The main HT positive line, giving 500 volts, supplies the anode of the PA, and the secondary HT positive line gives the 250 volts required for the PA screen grid, the frequency doubler anode and the crystal oscillator anode and screen-grid.

Amateurs are increasingly using variable frequency oscillators in some form or other, and to maintain the high degree of stability required the anode supply to the valve must be stabilised. Fig. 17B gives the circuit of a power unit designed for a low-powered transmitter using a VFO followed by a PA, or a doubler and PA. As will be seen from the diagram, three separate outputs are provided—one for the PA anode, the second for the PA screen-grid and doubler anode, and the third for the VFO anode. The last is effectively stabilised by the inclusion of a single stabiliser tube. The three output voltages are 350, 250 and 150 respectively.

There is a tendency in amateur transmitting stations to use the VFO as an independent exciter unit. In this way the unit can be used with various frequency doubling and amplifier arrangements

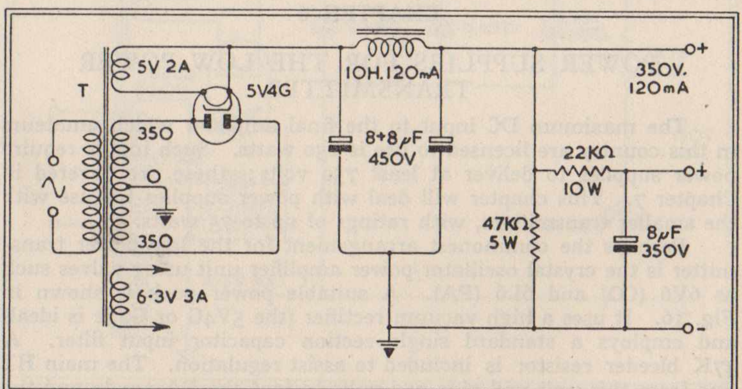

Fig. 16. Low power transmitter power pack.

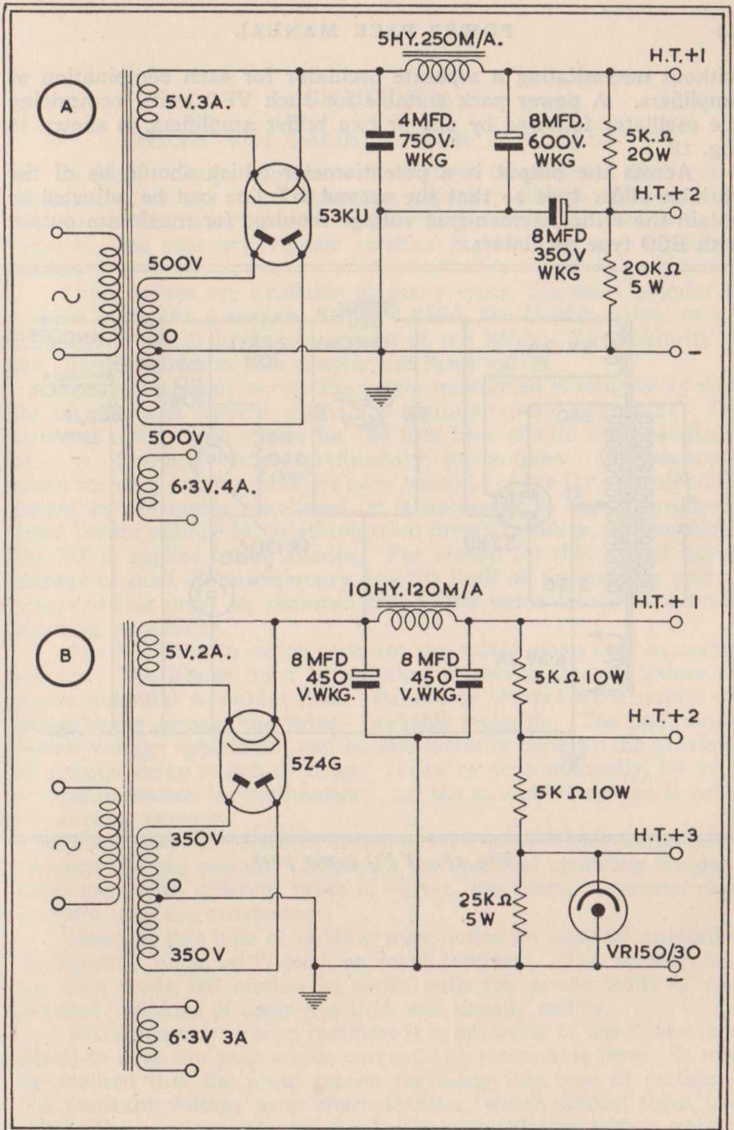

Fig. 17. Alternative packs suitable for three stage transmitters.

without necessitating a separate oscillator for each combination of amplifiers. A power pack suitable for such VFO units, comprising the oscillator followed by one or two buffer amplifiers, is shown in Fig. 18.

Across the output is a potentiometer which should be of the variable slider type so that the second HT line can be adjusted to obtain the critical screen-grid voltage required for maximum output with ECO type oscillators.

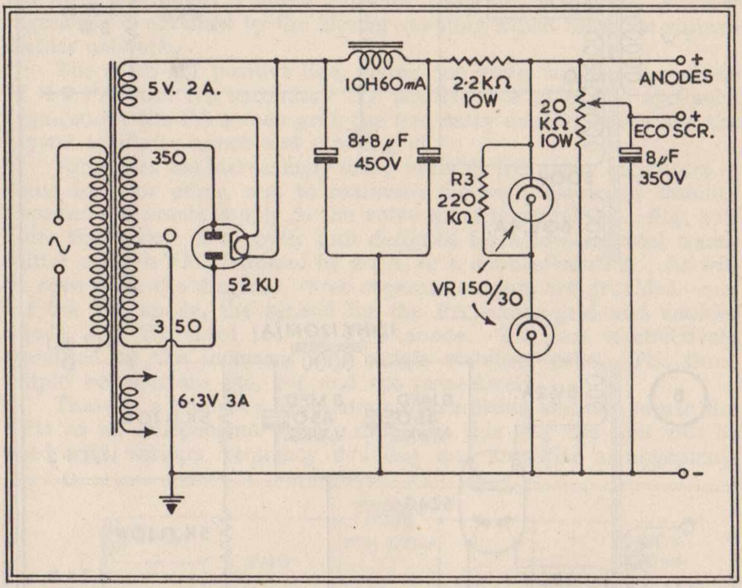

Fig. 18. VFO power pack.

CHAPTER 7

HIGH VOLTAGE POWER SUPPLIES

In high voltage supplies for amateur transmitters there is a tendency nowadays to use mercury vapour rectifiers. Where high voltages at high current with rather better regulation than usual is required, the mercury vapour rectifier is ideal, as was explained earlier.

These valves are available in many types, the most popular at present being the American 866 and 866A, the British GU50, or the RG3-250A, which is the equivalent of the 866A. The majority of the circuits shown in this chapter use these valves.

The voltage drop across the valves mentioned is roughly 15 volts for all values of current within the manufacturers' tolerances. The amateur using these valves for the first time should take particular care in observing certain preliminary precautions. For example, when mercury vapour rectifiers have been out of use for a considerable period or are newly purchased, it is necessary to run them at the rated heater voltage for anything from fifteen to thirty minutes *before* the HT is applied to the anodes. The reason for this is that during storage or shelf life the mercury deposits itself on the cathode and all traces of this must be removed before the valve is operated under working conditions.

Another point to watch concerns the valves when used in normal service. The heater must be switched on 20-30 seconds before the anode potential or output load. Failure to observe these points will undoubtedly damage the valve—probably seriously. The preliminary heater voltage application can be satisfactorily done by the provision of suitable delay switch or relay. It *can* be done manually, by using a separate switch for the heaters ; but the automatic system is better for obvious reasons.

Mercury vapour rectifiers must not be used where extremes in temperature are present. Although the specified operating temperatures vary with different types of valves, the limits of normal room temperatures are satisfactory.

Users of this type of rectifier may notice an unusual amount of background noise or "hash" on local receivers. The remedy is to fit short wave RF chokes in series with the anode leads of each rectifier ; ratings of some 250 m/A will usually suffice.

With mercury vapour rectifiers it is advisable to use choke input filters to keep the peak anode current at a reasonable level. It must be realised that the main reason for using this type of rectifier is the constant voltage drop characteristics, which makes them ideal where the requirements are good voltage regulation with a variable load.

However, a capacitor input filter can be used provided that the maximum tube ratings are not reached, since a pair of 866A's will deliver 1,500 watts of rectified AC at maximum output. This figure is, of course, far in excess of amateur transmitter requirements, where the input to the final stage is limited to 150 watts DC—the power limit.

Fig. 19A shows a high voltage power pack utilising the 866A rectifier. A single section filter is shown, but a further section could be added if more smoothing is considered necessary. The second choke would be a normal LF type rated at a minimum value of 5 Henries at the maximum value of current that will be drawn through it. It should be noted that the DC resistance of the smoothing chokes should be as low as possible, and in the circuits shown in this chapter should not be higher than 100 ohms for each choke. A single section filter will normally provide sufficient smoothing for HT supplies to PA stages and Class B modulator valves in high power amateur transmitters.

The 866A requires a heater voltage of 2·5V, and this is supplied by a heater transformer, which should have a separate switch. Using a 1750-0-1750 V transformer, 1,500 volts DC after the filter will be obtained. It must be stressed that the secondary winding of the heater transformer should be insulated for 5,000V DC. The Mullard RG3-250A can be used in place of the 866A.

Fig. 19B shows a similar power pack, but using the Osram GU50 mercury vapour rectifier. It has some refinements such as additional smoothing, automatic delayed switching, and a mains filter, which consists of the capacitors C1/C2. The GU50 requires a heater supply of 4V.

Fig. 20A shows another high voltage pack, this time using the 816 rectifier, which has a 2·5V heater. A capacitor input filter is used in the circuit and although it gives a higher voltage output the regulation will suffer in some degree. For example, at low values of load current, more than 900 volts will be obtained; but if the current were to be as high as 250 m/A then the voltage would drop to something like 600. This circuit is eminently suitable where comparatively high voltages at a low current are required.

Many amateurs use a pair of 807's in push-pull for their final amplifiers. A power supply designed to cover this arrangement when used in conjunction with a further pair of 807's in a zero-bias modulator, is shown in Fig. 20B. Both the outputs shown (HT+1 and HT+2) will give 750 volts at 500 m/A, one being taken to the PA valves and the other to the modulator valves. The 866A rectifier is used in this design, and with this, and with all the other circuits in this chapter, care must be taken to delay the loading.

A much more ambitious circuit is given in Fig. 21. This unit is suitable in a high-power amateur transmitter where 807's are used

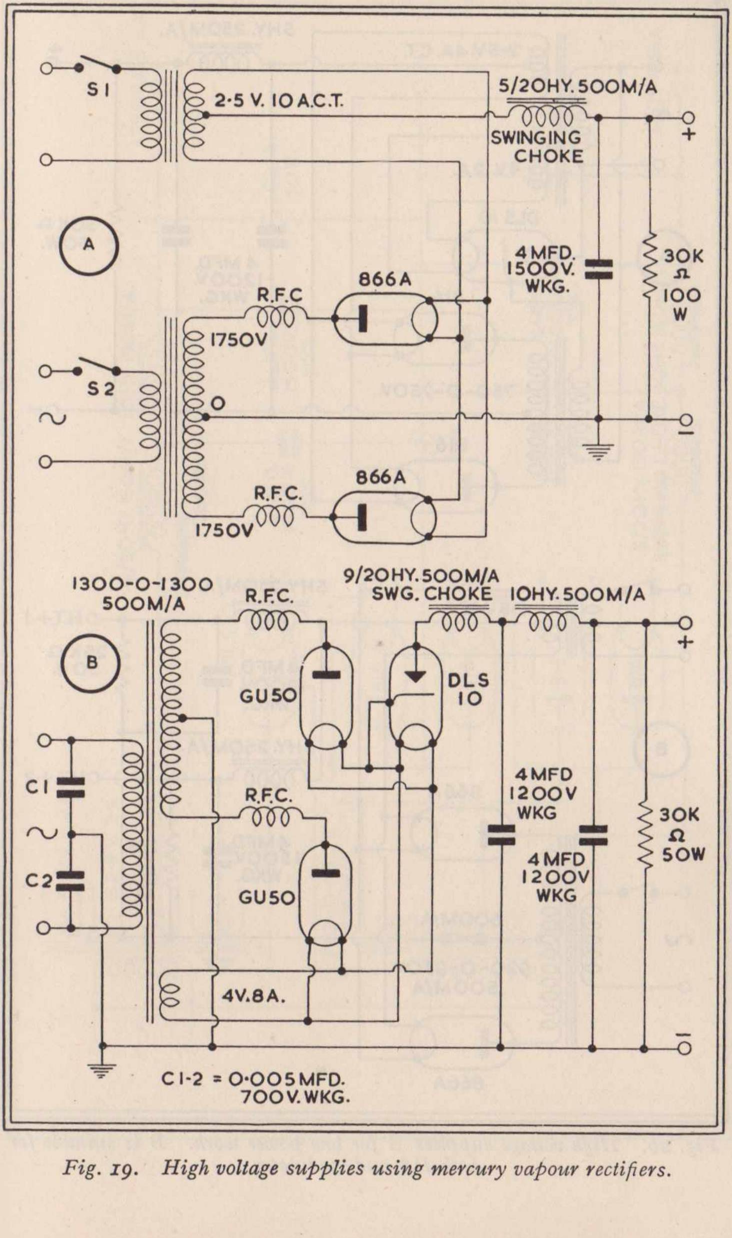

Fig. 19. High voltage supplies using mercury vapour rectifiers.

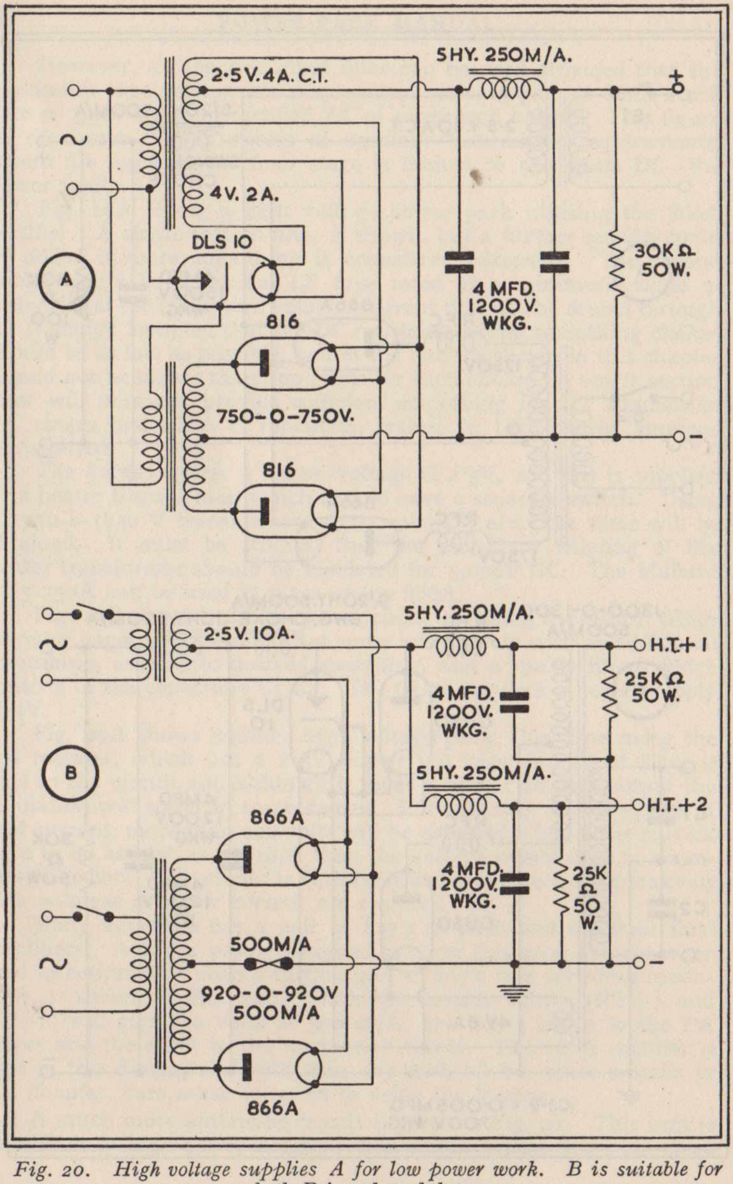

Fig. 20. High voltage supplies A for low power work. B is suitable for both PA and modulator.

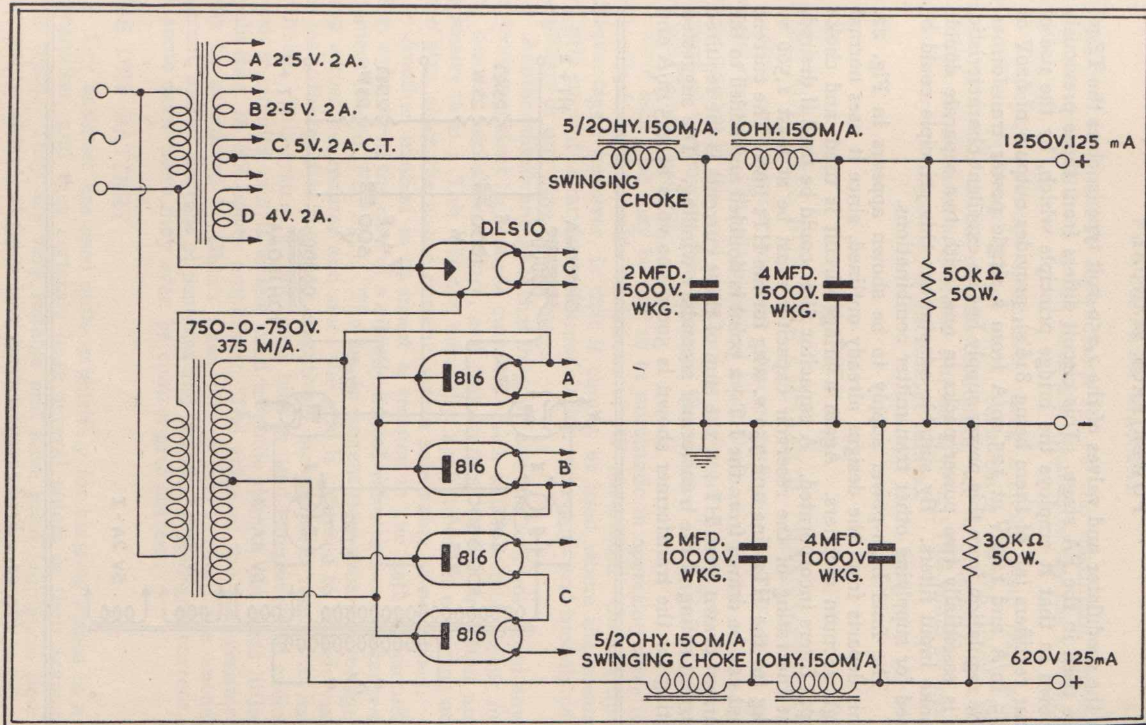

Fig. 21. High voltage Bridge rectifier circuit.

in the modulator and valves of the 1,250-volt type (such as the TZ40) are used in the PA stage. This circuit differs from those previously shown in that it employs the bridge principle which, by the use of four rectifiers (all of them being 816's), provides outputs of 620V at 125 m/A and 1250V at 125 m/A from a single power transformer. The regulation from this power supply has an excellent characteristic. It is essentially two power packs in one, with two separate double choke input filters. By suitable adaptations this principle could be used for supplying other transmitter combinations.

The final high-power supply to be shown appears in Fig. 22. This departs from the designs already outlined, since it uses normal high vacuum rectifiers. Again a bridge circuit is used, and choke input filters incorporated. A capacitor filter could be used if desired, but the rating of the reservoir capacitor must be at least 1,500 v. wkg for the HT2 line and 750 v. wkg for the HT1 line. The current that can be drawn from the HT+2 point is doubled and added to the current drawn from HT+1, the sum of these currents is the required current rating of the transformer secondary winding. The suggested rating for the transformer shown is 500-0-500 volts at 375 m/A and

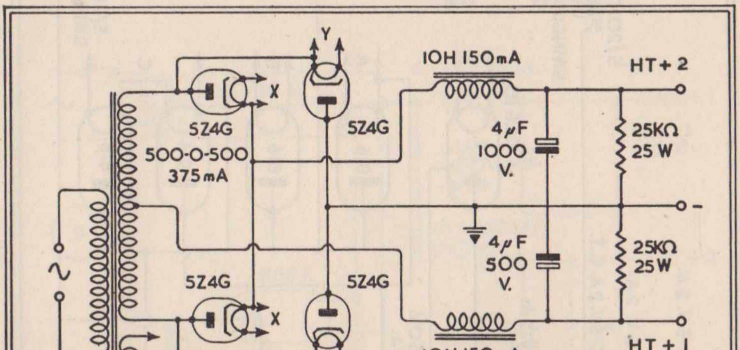

Fig. 22. Bridge rectifier power pack using hard valves.

therefore if 125 m/A is drawn from HT+2 the maximum current obtainable from HT+1 is 125 m/A also (that is to say 125×2+125 equals 375).

The output voltage obtainable, using a choke input filter will be: HT+2 750V and HT+1 375V, each being at 125 m/A. Of course, with this circuit, no delay switching will be necessary.

The 5Z4 rectifier is specified, but the U50 or 5V4G could be used without any modifications to the circuit values.

CHAPTER 8

BIAS SUPPLIES FOR THE AMATEUR TRANSMITTER

Bias voltages for amateur transmitters may be obtained by several methods. The simplest and most obvious is the insertion of a series resistor in the grid circuit of a stage that draws grid current. Because of the current flow through the resistor a negative bias for the grid is obtained (Fig. 23A).

Grid leak bias may be said to be automatic in operation since it will adjust itself to wide variations of RF excitation. One of the disadvantages, however, is that it cannot be used where the mean DC grid current is varying with modulation such as in grid modulated amplifiers or any other linear stage.

Another disadvantage is that the grid leak bias will not afford any protection against high anode currents which will inevitably occur in the case of excitation failure, and transmitting valves are often an expensive item. (This will not, naturally, apply to valves operating at zero bias, since the anode current is at a safe value at zero bias).

Another method is to insert a resistor in the cathode circuit (Fig. 23B), or in the case of a directly heated valve to a centre-tapped filament return (Fig. 23C). The anode current flow causes a voltage drop across the resistor and since the grid is returned to chassis via its leak, the grid is therefore negatively biassed with respect to its cathode. This system of obtaining bias is used extensively in radio receiver circuits, and is widely used in audio design, but finds little application in RF power amplifiers. The value of the bias resistor may be calculated by Ohm's Law, taking into account the anode current, and in the case of pentodes and tetrodes, screen-grid current. In some cases there may even be control grid current.

THE DRY BATTERY

Dry batteries are used quite extensively for biassing stages in a transmitter, and they certainly have several points in their favour (Fig. 23D). They are very reliable and have good regulation (low internal resistance) and provided that the grid current flow is reason-

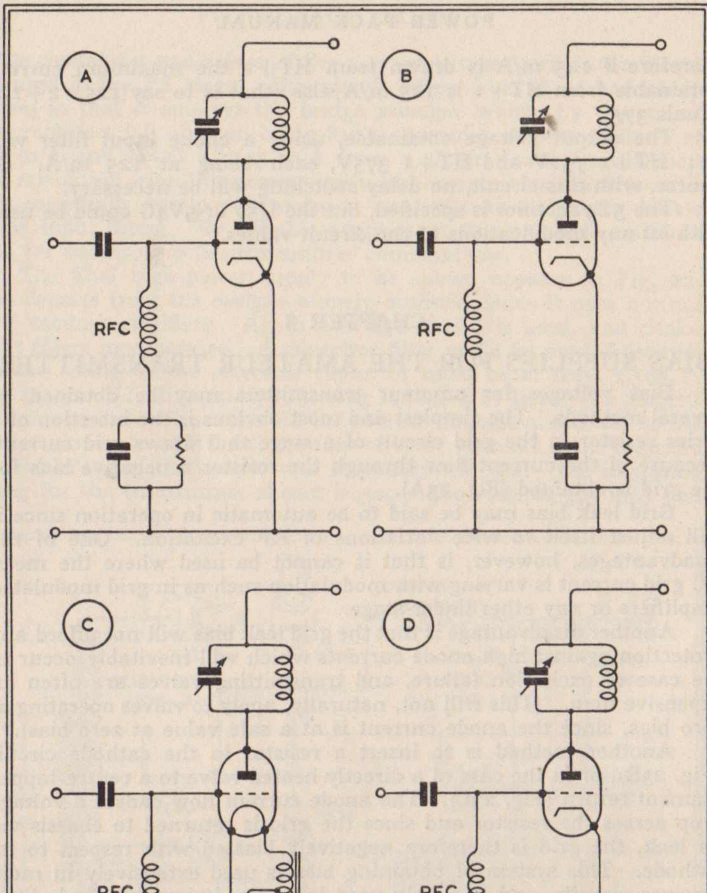

Fig. 23. Methods of obtaining bias.

ably low, will give useful service. If, on the other hand, the grid current is in excess of 10 m/A it will react on the battery cells, tending to charge them, and thus will render the battery useless after a few months' use.

BIAS PACKS

The most satisfactory method of obtaining bias for RF amplifiers is by the use of a mains operated power supply. These can be divided into two types—those built as a separate unit, and those built-in as an integral part of the transmitter. Both types have their advantages, but the built-in method is by far the cheaper. The separate unit, however, scores on account of its versatility; it can be used to supply a variable bias; it can be used on different transmitters; and it can be used for low voltage power supply for other gear if required.

A simple bias pack is shown in Fig. 24. It uses the orthodox full-wave rectifier circuit with a single section capacitor input filter and a bleeder resistor. The choke and second capacitor could theoretically be omitted on the grounds that the filtering requirements are low, the only current drawn from the bias pack being taken by the bleeder. It may, however, be a false economy to omit these components because ripple may be introduced to the control grids of the transmitter valves. Therefore it is wiser to instal a complete filter section in the bias supply.

The regulation characteristics of bias packs can be extremely good provided a low resistance bleeder is used. It must be remembered that the combined grid and bias supply currents flow through the same bleeder resistor so that the bleeder is, in fact, acting much in

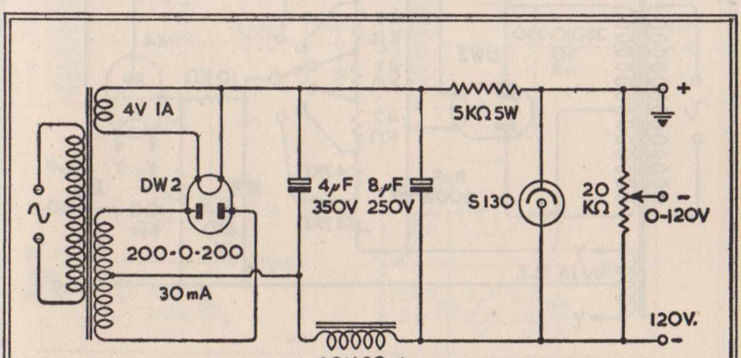

Fig. 24. Simple bias pack.

the same way as a fixed grid leak. The voltage drop caused by the flow of the grid and bias pack currents flowing through the same bleeder will have the effect of adding bias to the grid of the amplifier. Put another way, the actual bias will be higher than the calculated bias, so this extra bias must be allowed for.

For this reason the bleeder current should be many times greater than the grid current; therefore the bleeder should never be of a greater resistance than would normally be required for a grid leak of the amplifier valve concerned. In practice, the resistance of the bleeder is so proportioned that the voltage across the section of it used for supplying bias will be roughly equivalent to the cut-off bias of the valve concerned when no drive is applied. The use of a bleeder affords some protection as a fixed bias arrangement.

Bias packs are used mainly for the RF amplifiers in the final stages of transmitters and, sometimes, for application in Class B audio amplifiers. In either case a stable bias supply is necessary.

HIGH VOLTAGE BIAS PACK

Fig. 25 shows a circuit of a bias pack capable of supplying bias

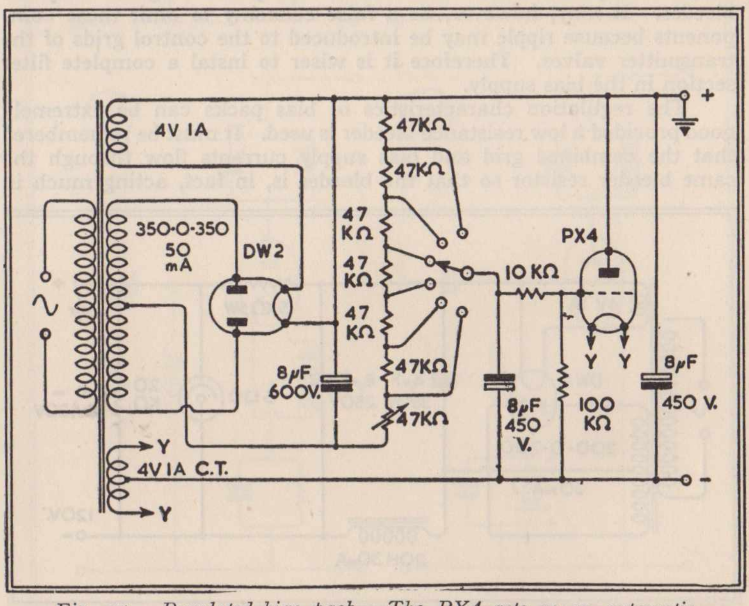

Fig. 25. Regulated bias pack. The PX4 acts as an automatic bleeder resistor.

voltages up to 450V. This design will also allow automatic compensation for grid current flow through the bleeder resistor, and it is recommended in cases where the grid current is high (up to 50 m/A and subject to variation.

A DW2 rectifier is used in a full-wave circuit utilising a capacitor input filter. Half-wave rectification could be used if preferred.

From this bias pack, the output voltage can be varied by means of the selector switch which will give six different outputs, the variable resistor being provided for fine adjustment.

BIAS FROM EXISTING TRANSFORMERS

The circuits of Figs. 26A and B show methods of obtaining the bias from an existing mains transformer as used in the average transmitter. In Fig. 26A the ripple voltage set up across the smoothing choke is fed to a rectifier, smoothed, and bias obtained. The variable resistance allows a variable control of the output bias voltage. A word of warning: this system is not recommended in cases where wide variations of current are drawn from the power transformer.

The output voltage is not particularly high (about 100 volts where a 500-0-500V mains transformer is used) and it will depend

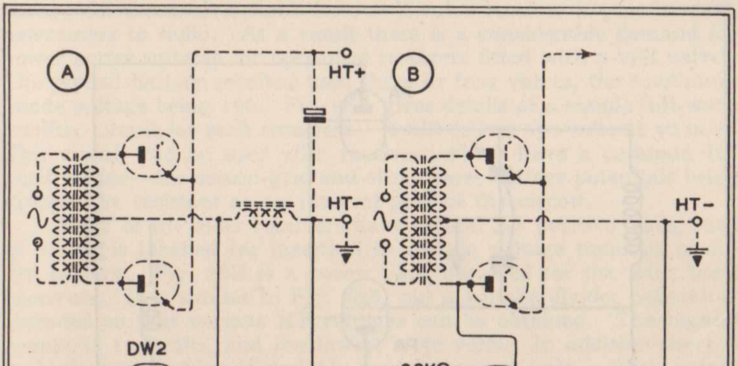

Fig. 26. Obtaining bias from an existing power pack.

to a high degree on L1. The maximum grid current under these conditions should not exceed 5 or 6 m/A.

A more reliable bias supply for heavy duty is that which is depicted in Fig. 26B. This can be used where the grid current is as high as 30 m/A provided a bias voltage not more than 120 volts is required. A rectifier is connected to one end of the mains transformer HT secondary winding and a negative voltage is developed across the reservoir condenser. The bias voltage obtained depends primarily on the transformer secondary voltage.

Using a 350-0-350V transformer, the maximum bias obtained would be 120 volts. However, outputs of from 120-350V could be obtained by interchanging the load resistors.

AUTOMATIC PROTECTION

An interesting circuit is given in Fig. 27 which serves as automatic protection to the transmitter PA valves in the event of excitation failure.

The action is as follows: When the PA grids are being driven from an RF source, the control grid current provides a voltage drop across R2 which biasses the 6L6 to cut-off. Under working conditions

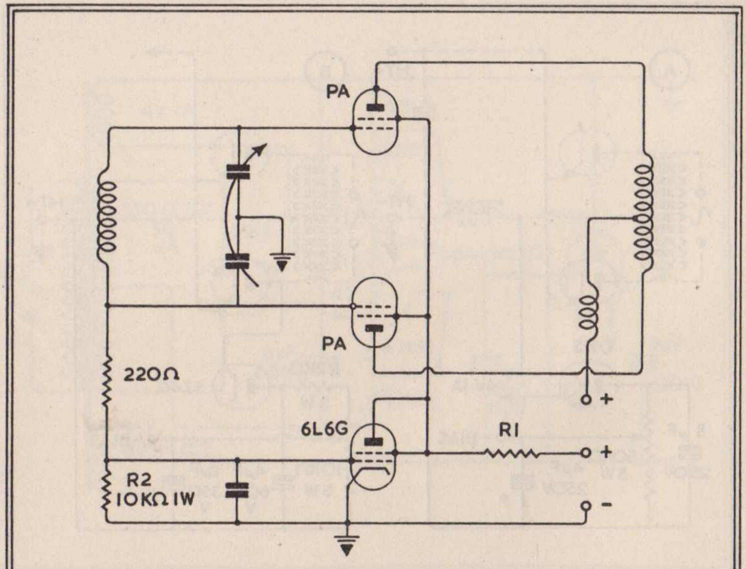

Fig. 27. Automatic PA protection.

the only current passing through R1 is the screen grid current of the PA stage. In the event of excitation failure the negative bias is removed from the 6L6, which conducts heavily, causing a large current to flow through R1. The voltage on the screen-grids of the PA is consequently reduced to a low value, thereby limiting the overall current to a safe value.

CHAPTER 9

BATTERY ELIMINATORS

There are still a large number of battery receivers in use throughout the country. These receivers are based on directly heated valves, usually of the 2-volt filament pattern, and they are in use primarily because supply mains are not available. However, some prefer the battery-driven receiver, and the 2-volt valve receiver is popular with newcomers to radio. As a result there is a considerable demand for power packs suitable for operating receivers fitted with 2-volt valves. The typical battery receiver uses three or four valves, the maximum anode voltage being 150. Fig. 28A gives details of a simple full-wave rectifier circuit for such receivers. It will deliver 150 volts at 30 m/A. This circuit can be used with receivers which have a common HT positive line—the screen-grid and other lower voltage potentials being dropped by resistors as an integral part of the circuit.

Many of the older receivers have several HT positive leads, each of which is labelled for insertion in certain voltage tappings of the dry battery. Fig. 28B is a power pack designed for use with these receivers. It is similar to Fig. 28A, but a voltage divider network is included so that various HT voltages can be obtained. The highest output is 150 volts, and the lowest is 50 volts. In addition there is a third output which is variable between 50-150 volts. Each output is adequately smoothed by separate capacitors.

For simple receivers the circuit shown in 28C is recommended. There are only five components involved in this unit: a transformer (with a single secondary winding); metal rectifier; a smoothing choke and two capacitors. This circuit is eminently suitable for an elementary 2-valve battery receiver.

A comprehensive power supply is shown in Fig. 29, which is an elaboration of Fig. 28B. It provides the same HT positive outputs, but in addition it gives three separate grid bias outputs. The diagram will show that to obtain these negative potentials the HT resistor

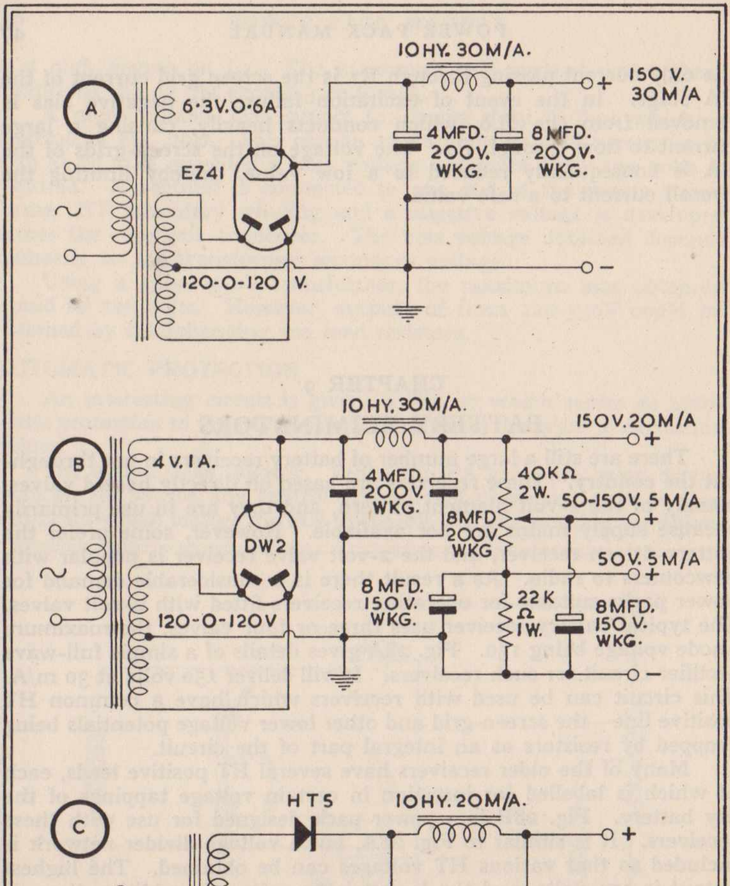

Fig. 28. Simple AC battery eliminators.

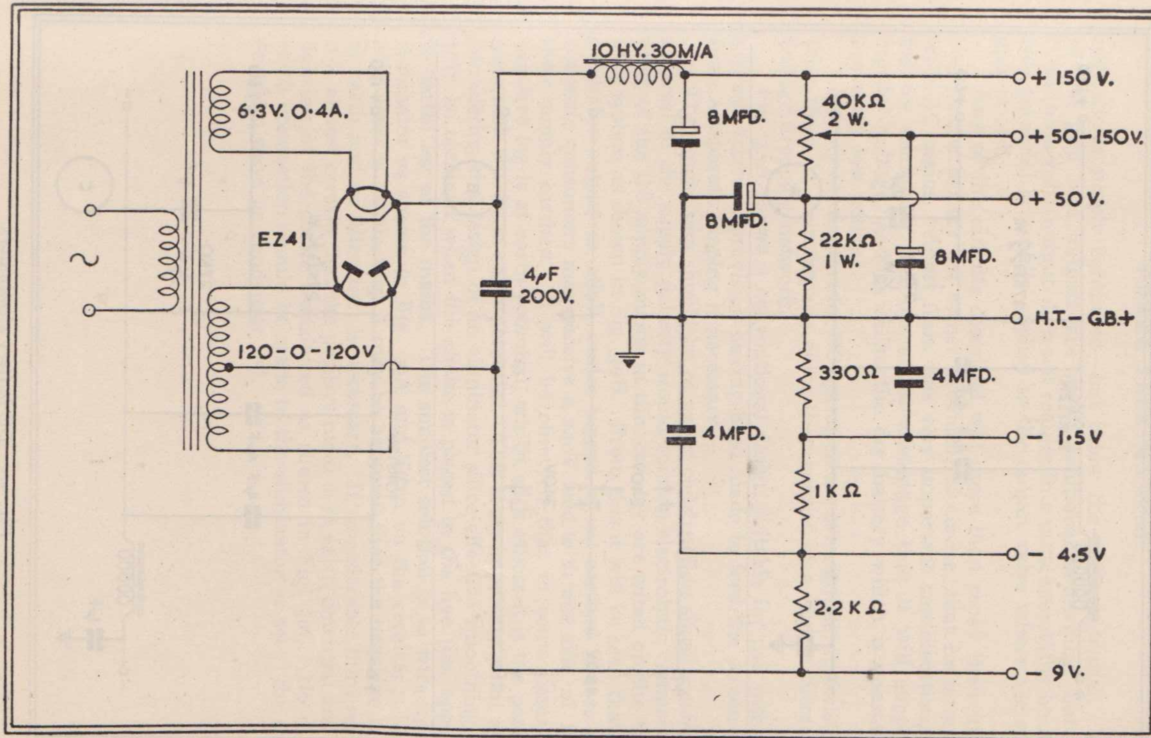

Fig. 29. AC battery eliminator including a bias supply.

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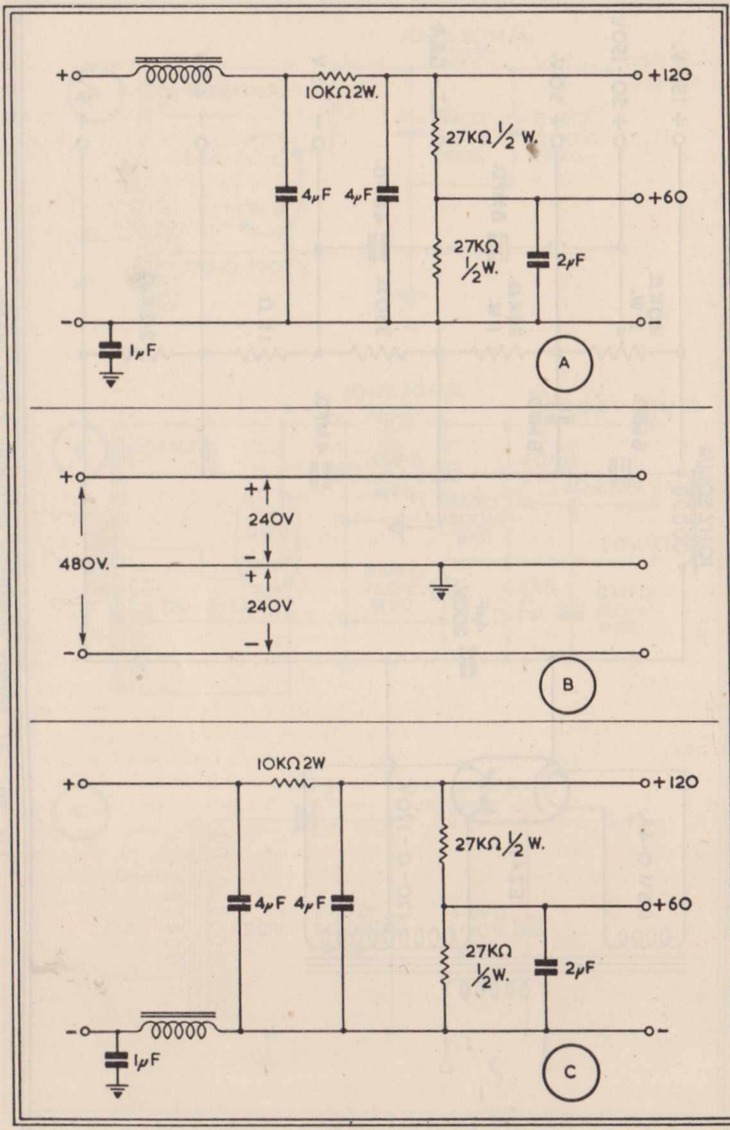


Fig. 30. DC battery eliminators.

network is simply continued—but below the earth potential. Two of the grid bias outputs are given additional smoothing, but the third (nine-volt) output does not require this extra smoothing because this potential is usually applied to the output valve where the stage gain is low.

Any of the circuits described will more than repay their initial cost to the battery set owner provided, of course, that he is served with AC mains. Apart from this very important consideration, the battery eliminator has the added advantage that it will supply a regular voltage, and is unlike the dry battery which is constantly becoming less active.

Battery eliminators for DC operation are even simpler to construct than their AC counterparts since they consist of a simple filter and voltage dropping network.

Fig. 30A shows a conventional design suitable for use with the average receiver, provision having been made to feed the screen-grid from a separate tapping if necessary.

The condensers should be of paper construction since accidental reversal of the supply polarity would ruin an electrolytic component. Most of the DC supply mains in this country are wired on the three wire system as shown in Fig. 30B. From this it will be seen that the generator output is 480V centre tapped by an earthed line so that domestic consumers may receive a 240V feed with one side of their their supply earthed. It will be observed that in some cases the negative leg is at earth potential, whilst with others it is the positive leg which will be at earth potential. This is an important point when considering the design of an eliminator since effective smoothing can only be obtained when the choke is placed in the live (i.e. opposite to earth) leg of the mains. The simplest solution is to wire up the eliminator as shown in Fig. 30A and listen on the receiver; if the hum level is satisfactory it may be assumed that the negative leg is at earth and no alteration is necessary. If considerable hum results it is almost certain that the positive main is at earth potential and the position of the choke transferred as shown in Fig. 30C. No direct earth connection should be made to the eliminator or set; the earth should always be condenser fed.

CHAPTER 10

TRICKLE CHARGERS

Should the owner of a battery receiver build a battery eliminator to take care of the HT and GB voltages, the question of the accumulator for supplying the filaments remains, and it will still need to be regularly recharged. But the trickle charger will enable the accumulator to be kept in a fully charged condition at home. Fig. 31A shows the circuit of a simple trickle charger suitable for the 2-volt accumulator. It is simple enough, consisting of a transformer and a bridge rectifier. The output from this unit will be approximately 2 volts at 0·5 amp.

A more elaborate circuit is given in Fig. 31B. This charger will accommodate three to six accumulators at the same time, according to the position of the selector switch.

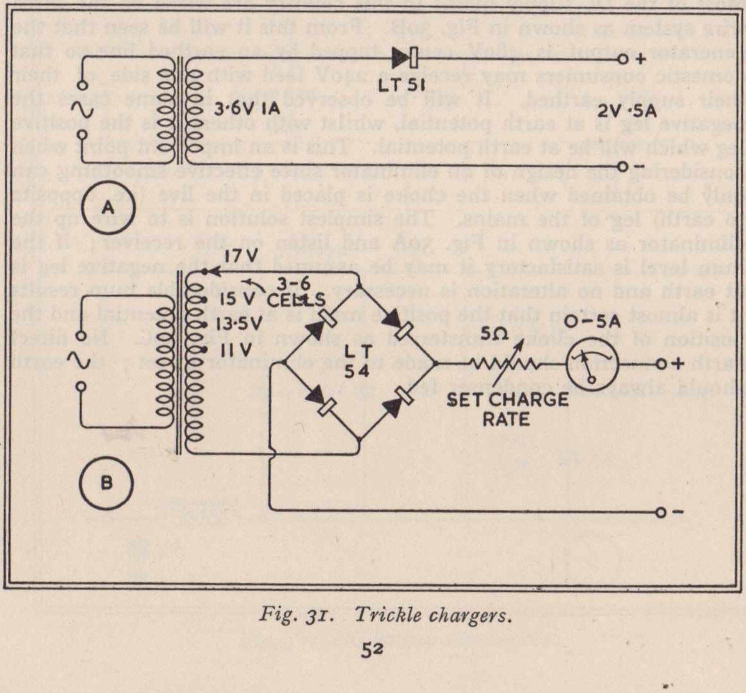


Fig. 31. Trickle chargers.

THE ACCUMULATOR

If the accumulator is to be charged in the home, it is desirable that something be known of its characteristics. Too few realise that the lead-acid variety of accumulator in general use requires constant and careful attention if good service is expected.

When using a trickle charger the maker's instructions regarding the rate of charge should be strictly followed. A typical accumulator as used for a 3- or 4-valve receiver will be of a 40 Ampere-hour rating. This means that the accumulator will deliver a current of 1 Amp for 40 hours, 0·5 Amp for 80 hours, and so forth. Of course, it is possible to draw 2 Amps for 20 hours, but it must be pointed out that it is not advisable to take too great an advantage in the upwards current direction because heavy discharge currents will tend to distort the plates and so shorten the useful life of the cell. This also applies conversely for charging at too heavy a current will have the same effect. With some chargers it will be necessary to regulate the charging current to a safe value and the use of a variable series resistor and ammeter of suitable range is recommended.

The condition of the accumulator can be checked by noting the colouration of the plates, but this check is not wholly reliable. Under charged conditions, the positive plate will be a chocolate brown colour and the negative plate a slate grey. When the cell is discharged, both the plates will appear greyish-white.

Sulphuric acid of the correct Specific Gravity should be used, and though this will vary slightly in different cells it is normally 1·280. The SG can be measured by a hydrometer, and when it falls to 1·150 the cell requires recharging.

The easiest way to check an accumulator is to measure the terminal voltage while the receiver is switched on. Should the reading be 1·8 volts or less, an immediate recharge is indicated. (Some accumulators have an automatic indicator which shows the condition of the cell.)

CARE OF ACCUMULATORS

To ensure a long and trouble-free life from an accumulator there are several rules which must be observed. The most important one is to charge at regular intervals, but not to overcharge. An accumulator which is to stand idle for a lengthy period must be kept in a charged condition to avoid a deterioration of the plates. There is a brown coloured sediment which appears at the bottom of the cell, which is formed by the disintegration of the active material on the plates. This sediment is quite normal, but it should not be allowed to become excessive as it may reach the plates and short-circuit, or partially short-circuit, the cell and damage the plates, probably permanently.

Terminals should be kept smeared with vaseline or similar agent to prevent corrosion, which in extreme cases has been known to eat away most of the terminal. It appears as a green crystalline deposit and should be removed immediately by filing off the corrosion and giving the terminals a thorough brushing with hot soda water. Corrosion is often the cause of crackling sounds and erratic performance in a receiver, so it is desirable that the terminals be kept clean.

Another point is to make sure that the electrolyte (the solution of sulphuric acid and distilled water) does not fall below the level indicated on the outside of the accumulator.

A common cause of trouble is sulphation of the plates, which is a coating of lead sulphate. This is a real danger signal and should be treated immediately, as the capacity of the cell may be completely ruined. Whenever sulphation takes place, the cell will be damaged and cannot be completely reconstituted. This is often the result of leaving the cell in an uncharged condition for a long period.

It is desirable that an accumulator should be refilled about once a year with a new electrolyte. Although this can be done at home, it is advisable that it should be undertaken professionally.

CELL CAPACITY

What capacity cell does the battery receiver need? Roughly, small receivers with one or two valves can be run from a 20 Amp-hour cell, but it is both advisable and more economical to use a 40 Amp-hour cell where the number of valves is three or more. If an accumulator of insufficient rating is used it will need frequent recharging and will be overloaded.

If any of the danger signs appear or if any doubts arise (such as the question of correct specific gravity), the accumulator should be taken to a charging station and competent advice sought.

COMBINATION PACK

To conclude this chapter, a combined multi-purpose battery receiver power supply and trickle charger is described (see Fig. 32). This versatile power pack has a number of HT and GB outputs suitable for adaption to the majority of receivers. Following a full-wave rectifier and smoothing circuit, three HT outputs are provided, 150 volts, 100-150 volts variable and 60 volts. The grid bias outputs are −1·5 volts and −4·5 volts. The trickle charger can be switched on during periods when the receiver is not in use.

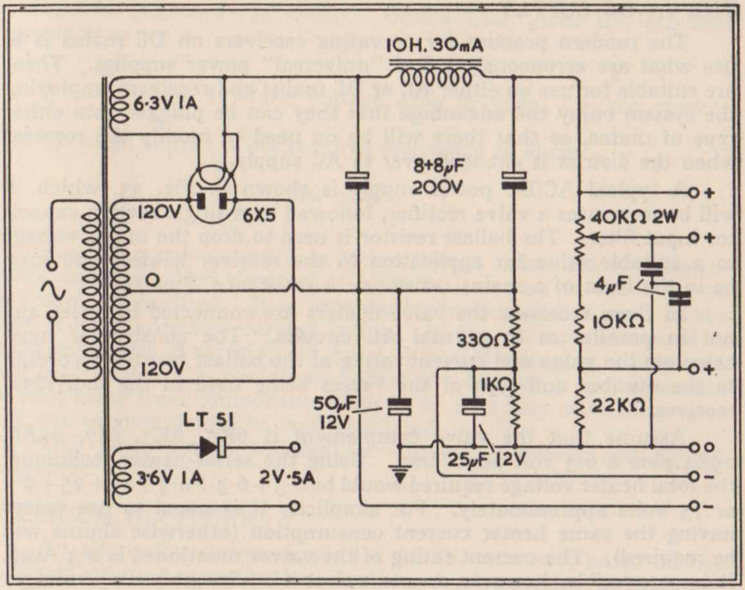


Fig. 32. Comprehensive battery eliminator.

CHAPTER 11

AC/DC POWER SUPPLIES

Those who are served with DC mains are at a considerable disadvantage, particularly where high voltages for transmitter circuits are required. Where high voltages are required, the problem can be overcome by the installation of rotary converters, generators and other electro-mechanical devices. This chapter, however, will be restricted to power supplies for receivers.

THE AC/DC SUPPLY

The modern practice for operating receivers on DC mains is to use what are erroneously called "universal" power supplies. These are suitable for use on either AC or DC mains and receivers employing the system enjoy the advantage that they can be plugged into either type of mains, so that there will be no need to modify the receiver when the district is changed over to AC supply.

A typical AC/DC power supply is shown in Fig. 33, which, it will be seen, uses a valve rectifier, followed by a single section capacitor input filter. The ballast resistor is used to drop the mains voltage to a suitable value for application to the receiver heaters and may be in the form of a mains resistor or a resistance "line cord".

In these receivers the valve heaters are connected in series and not in parallel as in normal AC circuits. The constructor must calculate the value and current rating of the ballast resistor according to the number and type of the valves being used in the individual receiver.

Assume that the valve complement is 6K7, 6K7, 6J7, 25A6, 25Z4 plus a 6·3 volt pilot lamp. Using the series-heater technique, the total heater voltage required would be 6·3 + 6·3 + 6·3 + 25 + 25 + 6·3 or 75 volts approximately. For simplicity it is usual to use valves having the same heater current consumption (otherwise shunts will be required). The current rating of the valves mentioned is 0·3 Amp. It is permissible, however, to use valves of different heater voltages since the amount of current flowing is the relevant factor.

Assuming the mains supply to be 230V, a voltage drop of 155

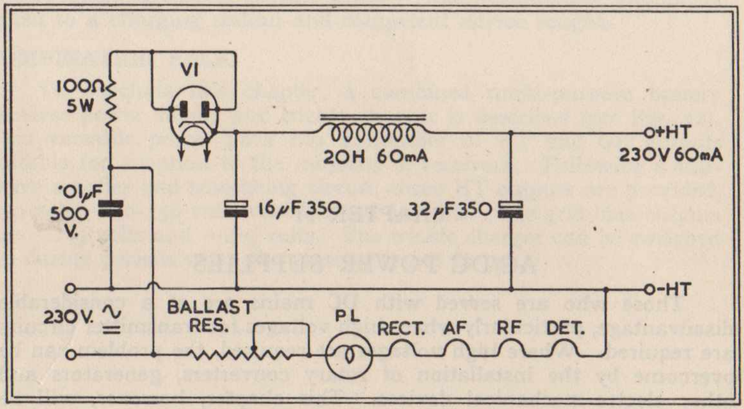


Fig. 33. Half-wave AC/DC power pack.

is required (i.e. 230 − 75 volts). Ohm's Law gives the required resistance as:

$$R = \frac{E}{I}$$ where E = the voltage drop in volts, I = the current flow in amps and R = the required resistance in ohms.

$$\therefore \frac{155}{0{\cdot}3} = 516 \text{ ohms}$$

From this calculation it is shown that a ballast resistor (sometimes called a mains dropper) or suitable line cord to the value of 516 ohms is required. It is important when using line cord to see that it is of adequate current rating; in the example discussed it must be capable of carrying 0·3 Amp. Either the dropper or line-cord will become warm in operation, so that if a dropper is used it should be kept away from components likely to be adversely affected by heat and the cabinet should be well ventilated.

This pack is also suitable for superhet receivers and AC/DC amplifiers.

SELENIUM RECTIFIERS

An alternative power supply for AC/DC receivers, based on the previous example, may be had by the use of an oxide or selenium rectifier. Such a circuit is shown in Fig. 34. It is simplicity itself—and what is more, is extremely robust (with less likelihood of breakdown than with a rectifier valve) and slightly less expensive.

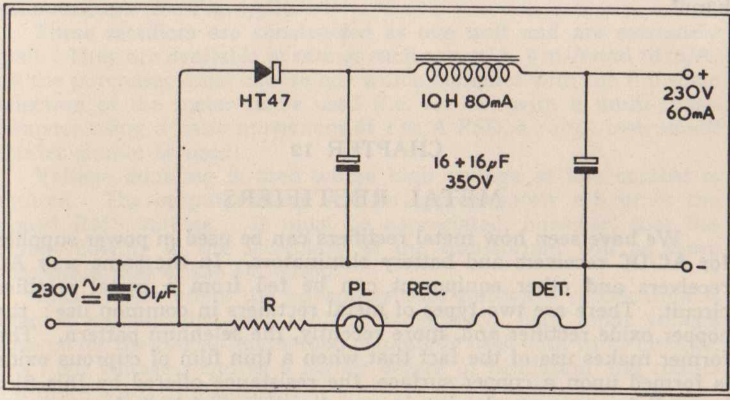


Fig. 34. Alternative design using a metal rectifier.

However, should this type of rectifier be used, the dropping resistor value must be re-calculated, allowing an extra 25 volts drop, as the metal rectifier has no heater to feed. The heater voltage total is now only 50, which leaves 230 – 50 or 180 volts to drop. Again using Ohm's Law we get $\frac{180}{0 \cdot 3} = 600$ ohms.

PRECAUTIONS

In all circuits supplied from an AC/DC power pack, it is advisable to wire up the series heaters so that the detector valve is at the earthy end of the chain. In a simple superhet receiver that is being wired up, the heater chain would be wired in the following order: From the mains dropper to Rectifier, Output, IF, FC, 2nd Det. The pilot lamp, if used, is usually the first in the heater chain; the detector the last. With amplifiers the early stages should be at the earthy end.

When these circuits are used with AC mains, the power plug may be connected either way round, but with DC mains the set will work only when the positive side of the mains is connected to the rectifier anode. So that if, after the normal initial warming up period, there is no sign of life, the mains plug should be reversed.

It is important to isolate the receiver chassis from earth by the use of a 0·01 mfd capacitor. It must be remembered that the aerial should be isolated by a capacitor (of about 0·0005 mfd) as a further precaution. This capacitor must be of a rating sufficient to withstand the mains voltage. Finally, when using "live chassis" circuits, take precautions to see that other metal objects (such as control knob grub-screws) are not likely to come into contact with the operator's hands.

CHAPTER 12

METAL RECTIFIERS

We have seen how metal rectifiers can be used in power supplies for AC/DC receivers and battery eliminators. In the same way AC receivers and other equipment can be fed from a metal rectifier circuit. There are two types of metal rectifiers in common use: the copper oxide rectifier and, more recently, the selenium pattern. The former makes use of the fact that when a thin film of cuprous oxide is formed upon a copper surface, the resistance offered by this film is small for currents flowing in one direction and high for currents flowing in the opposite direction. The rectifying action is very stable, and the only perceptible effect, after some thousands of working hours, is a slight increase in resistance in the forward or conducting direction. With selenium rectifiers the necessary rectifying action is obtained when a properly processed selenium film is formed on a metal surface such as iron. These rectifiers have characteristics similar to the copper oxide pattern with respect to stability and long life.

In the conducting direction, however, the resistance is less, so that the efficiency and current carrying capacity for a given physical size is greater. No attempt should be made to measure the reverse resistance of these rectifiers with a high pressure insulation tester such as a "Megger" as this will probably lead to serious damage to the rectifier, if not destruction. An ohmmeter is also useless, as an entirely erroneous result will be obtained.

The rectifying action is essentially the same as that of the valve rectifier, i.e. a waveform of uni-directional pulses are obtained. To obtain a comparatively pure DC output such as required by an amplifier or a receiver it is essential that smoothing filters be added. A single metal rectifier can be used with a mains transformer to obtain half-wave rectification as described in Chapter 9; but with AC receivers it is usual and more economical to use a voltage-doubling circuit which gives full-wave rectification. Both the bridge circuit and the voltage doubler give full-wave rectification and these systems are shown in Fig. 35A-B-C-D. The bridge circuit is usually found where currents of 0·5 Amp. and upwards are required such as energising low voltage field windings on loudspeakers. Another application of this circuit is the instrument rectifier for use with moving coil milliammeters (see Fig. 35D).

These rectifiers are constructed as one unit and are extremely small. They are available in ratings such as 1 m/A, 5 m/A and 10 m/A, and the purchaser must choose one which complies with the full scale deflection of the meter to be used (i.e. for use with a multi-range testmeter using a basic movement of 1 m/A FSD, a 1 m/A instrument rectifier should be used).

Voltage doubling is used where high voltage at low current is required. The output voltage will be approximately 2·8 times the applied RMS voltage. It must be appreciated, however, that the current flowing in the secondary of the transformer will be some three times that of the DC output.

This system offers the advantage that full-wave rectification is obtained without the need for the dangerously high input voltage required for the centre-top method commonly used with valve circuits. This high voltage requires a higher degree of insulation and results in a more costly transformer.

Should more current at a given voltage be required it is possible to connect metal rectifiers of similar pattern in parallel. Fig. 36A-B shows how this applies to voltage doubler and bridge circuits. The voltage doubler arrangement will give twice the current at the original voltage, but extreme care should be taken to ensure that the current rating is not exceeded because if one rectifier fails the full load will be taken by the other, and so the unit may be ruined. Another point to note is that the capacities of the two capacitors should be increased by 50 per cent. when used in this manner.

With bridge rectifiers, paralleling will give 1·6 times the current output of one unit at the same output voltage as given by one rectifier.

Similarly, metal rectifiers may be connected in series. These circuits (see Fig. 36C) will give twice the voltage obtained from a single voltage doubler circuit at approximately the same current as for a normal doubler circuit. The working voltages of the reservoir capacitors must be doubled; but half the normal capacitances will be sufficient. The transformer must, of course, be capable of giving twice the input voltage than is necessary for a single voltage doubler circuit.

When connecting bridge rectifiers in series (Fig. 36D) two

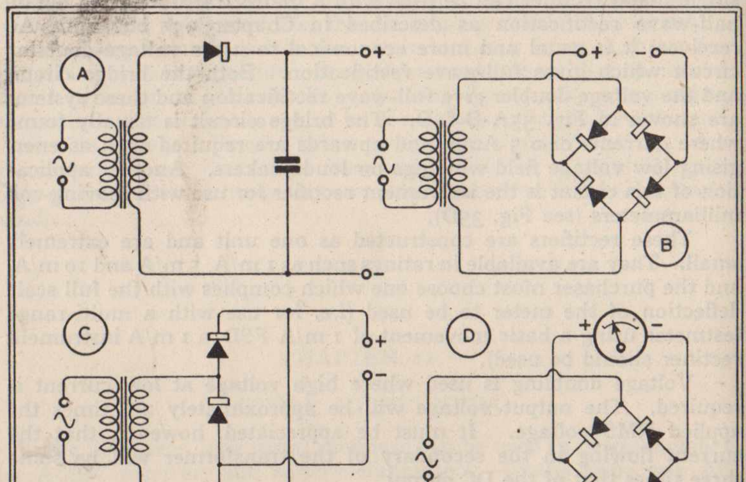


Fig. 35. Metal rectifier systems. A, Half-wave; B and D, Bridge; C, Full-wave doubler.

separate transformers (or, if possible, a single transformer with two identical secondary windings) is used. The rectifiers are series connected at the output side (if this were made on the input side the secondaries would be short-circuited). A single reservoir capacitor is used. In this way, an output voltage of twice that of a single bridge rectifier is obtained.

When designing power supplies utilising metal rectifiers, it is most important to see that the value of reservoirs capacitance specified by the manufacturer is not exceeded. If the quoted value is exceeded, excessive peak current will flow and the rectifier may be damaged.

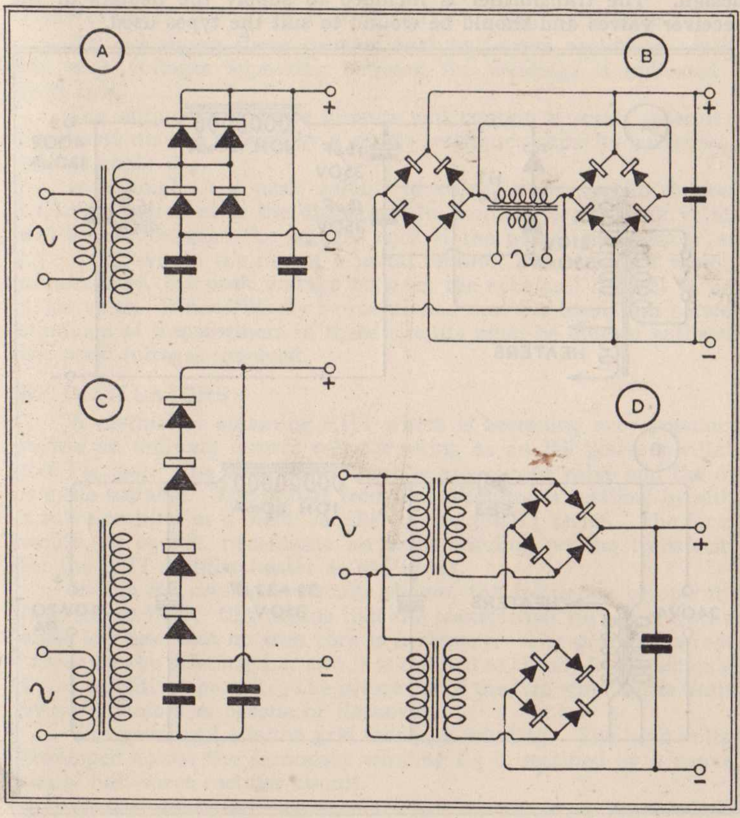


Fig. 36. Series-parallel methods.

A power supply using a Westingham HT.44 is shown in Fig. 37A. With the values shown it is suitable for use with a medium sized audio amplifier. An alternative output of 400V at 75 m/A is available from this circuit which makes it suitable for equipment with a lower HT current requirement. To obtain this, the reservoir capacitors should be reduced to an 8 mfd each and the transformer secondary rating may be reduced to 210V 150 m/A.

A simple half-wave pack is shown at Fig. 37B; it is suitable for feeding small receivers and amplifiers. The rectifier is of the selenium pattern, a Brimar SB.3 followed by a filter of conventional design. The transformer is included to supply the heaters of the receiver valves and should be wound to suit the types used.

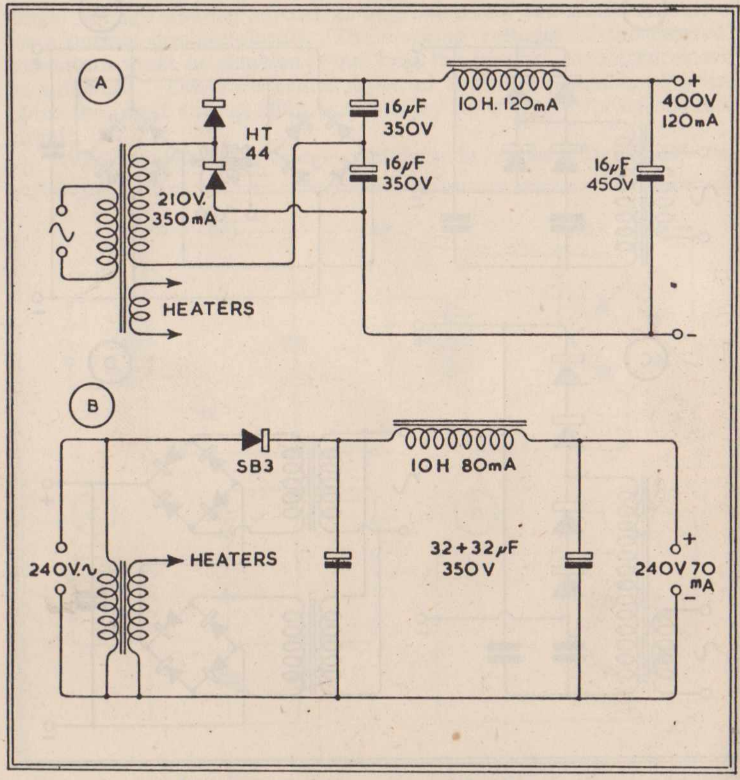


Fig. 37. Practical metal rectifier designs.

CHAPTER 13

EHT SUPPLIES

There are several ways of obtaining the high voltage low curren supplies necessary for the operation of cathode ray tubes in television and oscilloscope circuits. They have their own merits and demerits, and this chapter will deal with these different EHT systems and their aspects.

HALF-WAVE CIRCUITS USING MAINS TRANSFORMERS

Fig. 38 shows three conventional half-wave rectifier circuits : the peak voltages appearing between the windings is indicated in each case.

The output from these circuits will contain a small amount of ripple and may be filtered by a simple resistance-capacitance network (see example D).

In example A a peak voltage of 10,000 volts appears between L1/L2 as indicated in the diagram. In example B this peak voltage will appear between the earthed core of the power transformer and L3. In C, where the use of a metal rectifier makes an LT winding unnecessary, the peak voltage between the core and L5 will be only 5,000 volts. It need hardly be mentioned that the insulation between windings of transformers in these circuits must be able to withstand the peak voltages involved.

RF OSCILLATORS

A method of obtaining EHT which is becoming very popular is to use an ordinary output valve working as an RF power oscillator (see Fig. 39). The valve can almost be any output valve and the 6V6 is quite suitable. The output from the oscillator is rectified by either a valve rectifier or a metal rectifier of the 36EHT series. The former would, of course, necessitate an extra winding on the transformer for the EHT rectifier heater as in Fig. 41.

In the RF oscillator circuits shown, the frequency of operation is about 50 kc/s ; this means that the transformer turns-per-volt are quite low and that no iron core is necessary. The primary is represented by the winding L2, and it is coupled as closely to the secondary L3 as conditions permit. The proximity of the two windings is limited by such factors as corona or flashover.

The winding L4 is the grid feedback winding. The high voltage developed across the secondary winding L3 is rectified by a conventional half-wave rectifier circuit.

If the intending constructor has access to a wave-winding machine there is no reason why the RF transformer should not be

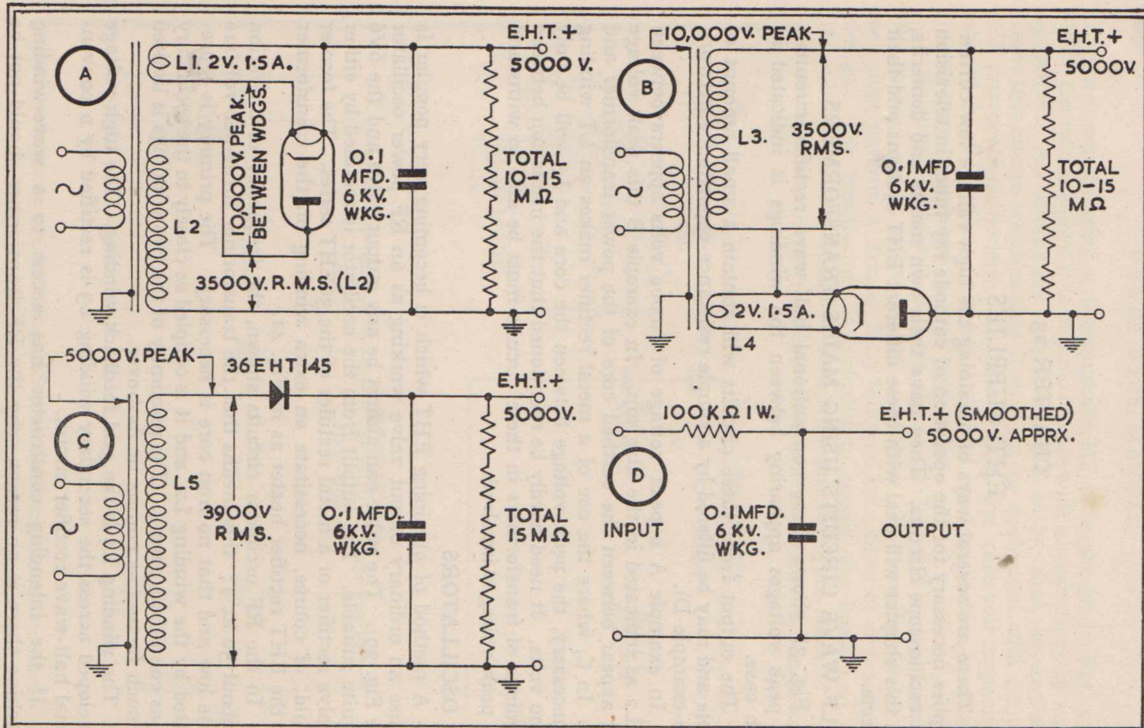


Fig. 38. 50 c.p.s. EHT supplies.

home constructed. Fig. 40 gives the general dimensions of the windings and formers, the coil data being as follows:

Two coils are used, one 1 in. diameter and 4 in. long; the other $\frac{3}{4}$ in. diameter and 4 in. long. The 1 in. diameter former should preferably be of high dielectric strength (glass is suitable) to prevent breakdown. The smaller former may be of bakelite or similar material. L2, the smaller coil, is inserted into the larger former (which carries L3 and L4 windings) and fixed in position. Litz wire is recommended (150/41) for winding L2.

The individual windings should be carried out to the following specification:

L2 Litz wire (150/41), 200 turns close wound (preferably in two layers—each layer insulated with one layer of empire cloth). Completed coil covered by two layers of empire cloth.

L3 38 swg DSC pi-wound in five pi's of 1,000 turns each.

L4 38 swg DSC, 80 turns, pi-wound. Must be wound in same direction as L3.

The grid coil, if connected one way round, will determine one frequency, and if connected the opposite way will give a different frequency. The *lower* of the two frequencies should be used.

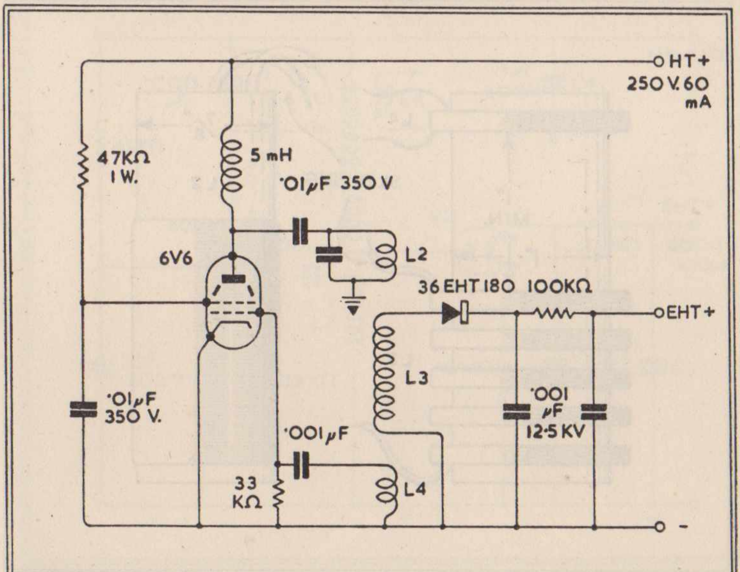


Fig. 39. RF EHT supply using a metal rectifier.

The two leads enclosed in sleeving on L3 should be kept separated from each other and take the shortest possible path (one to the chassis and the other to the metal rectifier). All components should be mounted as close to the RF transformer as possible. Maximum load current should not exceed 250 μA for reasonable regulation. Output Characteristics (approx.):

7,000 volts at 50 μA
6,000 volts at 150 μA
5,000 volts at 250 μA

The RF power supply must be completely screened or it may cause severe interference with local receivers. A shielding box made of brass or copper will give the most effective screening.

COMMERCIAL TRANSFORMER

Fig. 41 is an RF oscillator supply using a commercial transformer marketed by Hazlehurst Designs Ltd. A hard vacuum valve rectifier is used, but a metal rectifier could, of course, be used instead and connected as shown in the circuit (Fig. 39). Choice of oscillator valve

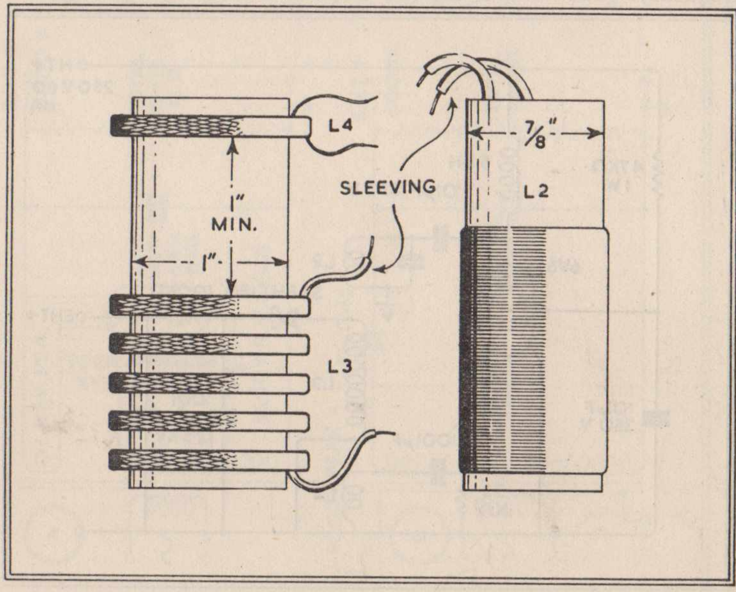


Fig. 40. Oscillator coil dimensions.

is quite wide, and such valves as 6V6, PEN45 and EL33 are all perfectly suitable for this purpose. The transformer is made up of the tuned primary (L1), the high voltage secondary (L3) and the grid feedback winding (L2). The other winding (L4) supplies the heater of V2 (the requirements being very small), so that the heater voltage can be taken from the RF transformer without any detrimental effect to its performance. Coil connections are shown in Fig. 42.

Concerning the heater supply to the EY51 HT rectifier, it is suggested that the valve be firstly connected to a known source of 6·3 volts, noting the colour of the heater glow, because the voltage output of L4 may vary somewhat, depending on various circuit and component variations. If an excess voltage is obtained, the L4 winding may be moved away from L1/L3; conversely a low voltage output can be corrected by moving the coils together.

The Hazlehurst RF transformer has a variable iron dust core, and this can be used to give a fine adjustment control of the voltage output of L4.

In the majority of cases the smoothing components R and C will be found unnecessary and can be omitted.

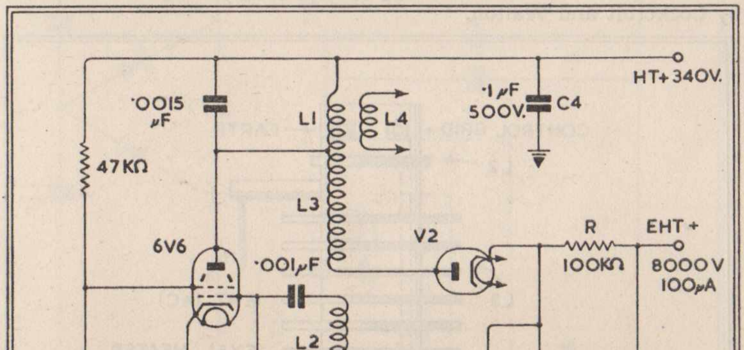


Fig. 41. RF EHT unit with Hazlehurst coil. V2 is an EY51, R12 or SU61.

Since the whole coil operates at a high potential, care should be taken to keep the assembly mounted well clear from earthed objects, otherwise flashover or corona discharge may take place. No metal filings should be allowed to adhere to the coil. The screening and chassis must be of non-magnetic material such as brass or copper.

Typical performance figures for this type of oscillator are:

DC EHT Output ...	8000	7000	6000	5000
HT supply voltage ...	340	325	300	280
Oscillator Anode current	40	37	35	32

With a 6V6 the load current in all instances is 250 μA.

Regulation is 2 per cent. for all outputs quoted. For a television circuit, where the only current drain is the picture tube beam current of approx. 80 μA, the EHT voltage will be correspondingly higher.

VOLTAGE MULTIPLYING

It is possible to obtain DC voltages of almost any value, suitable for cathode ray tubes where a high voltage at low current is required by using an ordinary 350-0-350V power transformer in conjunction with metal rectifiers. This voltage multiplying principle was devised by Cockcroft and Walton.

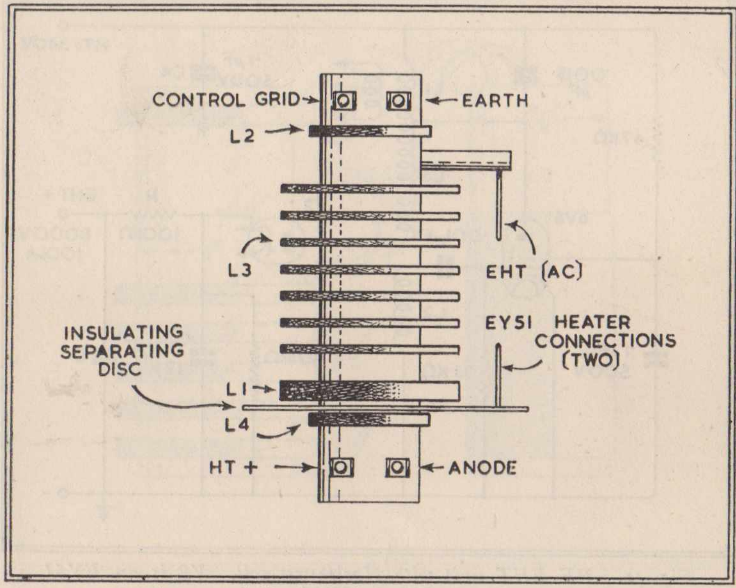


Fig. 42. Coil connections to the Hazlehurst coil.

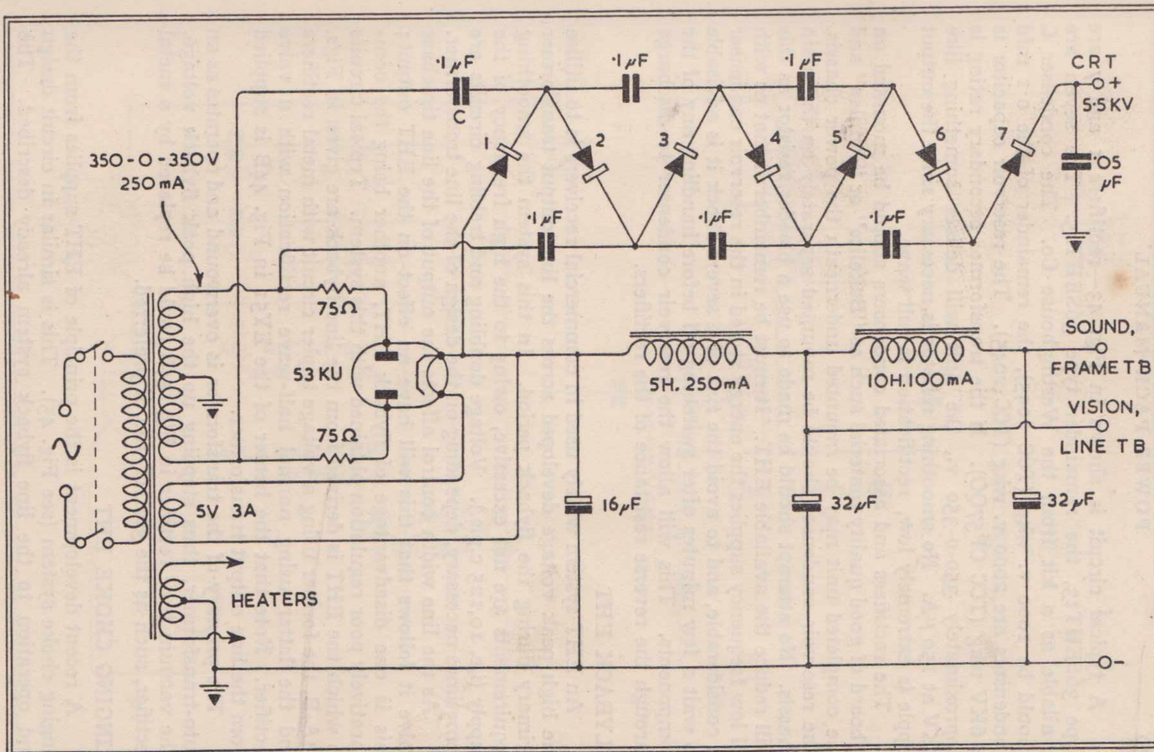


Fig. 43. Combined television power pack.

A typical circuit is shown in Fig. 43—rectifiers 1 and 7 are type 36SEHT13, the remainder type 36SEHT25. The seven are available as a kit from the Westinghouse Co. The condenser C should be 1000 v. wkg (TCC 1045), the remainder of the 0·1 mfd condensers are 2000 v. wkg (TCC 2045). The reservoir capacitor is a 6KV wkg (TCC CP57QO). If the transformer secondary rating is approximately 350-0-350 v., the unit will deliver something like 5KV at 150 μA. No smoothing resistor is necessary since the output ripple is extremely low, rectification is full wave.

The rectifiers and associated condensers should be mounted on a board of good quality material such as "Bakelite" or "Panilex" and the completed unit may be mounted underneath the power chassis. The reservoir condenser should be mounted separately on the main chassis. No attempt should be made to use a bleeder resistor as this will reduce the available EHT. It must be remembered that as with all low frequency supplies the energy stored in the reservoir condenser is considerable, and to avoid the risk of a severe shock it is advisable to wait a few minutes after switching off before handling any of the components. This will allow the reservoir condenser to discharge through the reverse resistance of the rectifiers.

FLYBACK EHT

An EHT system widely used in commercial receivers is to utilise the high peak voltage developed across the line output transformer primary during the flyback period. In this system the smoothing requirements are not excessive, owing to the high frequency of the supply (i.e. 10,125 c.p.s.). Voltage doubling and trebling circuits are sometimes necessary, depending on the design of the line transformer.

As the line width control affects the output of the line timebase valve it follows that this will have an effect on the EHT output; this is one disadvantage of flyback EHT, another being the comparatively poor regulation obtained with this system. Typical circuits in which the EHT is derived from the line flyback are given in Figs. 44A-B, the former using a voltage tripler circuit with metal rectifiers and the latter using normal half-wave rectification with a valve rectifier. Note that the heater of the EY51 in Fig. 44B is supplied from the line output transformer.

The primary of the transformer is overwound and operates as an auto-transformer, thus stepping up the high peak flyback voltage. The vacuum tube rectifier in Fig. 44B could be replaced by a metal rectifier, such as the 36EHT-100, if preferred.

RINGING CHOKE EHT

A recent development is the principle of EHT supplies from the ringing choke system (see Fig. 45). This is similar in circuit design and operation to the line flyback system already described. The

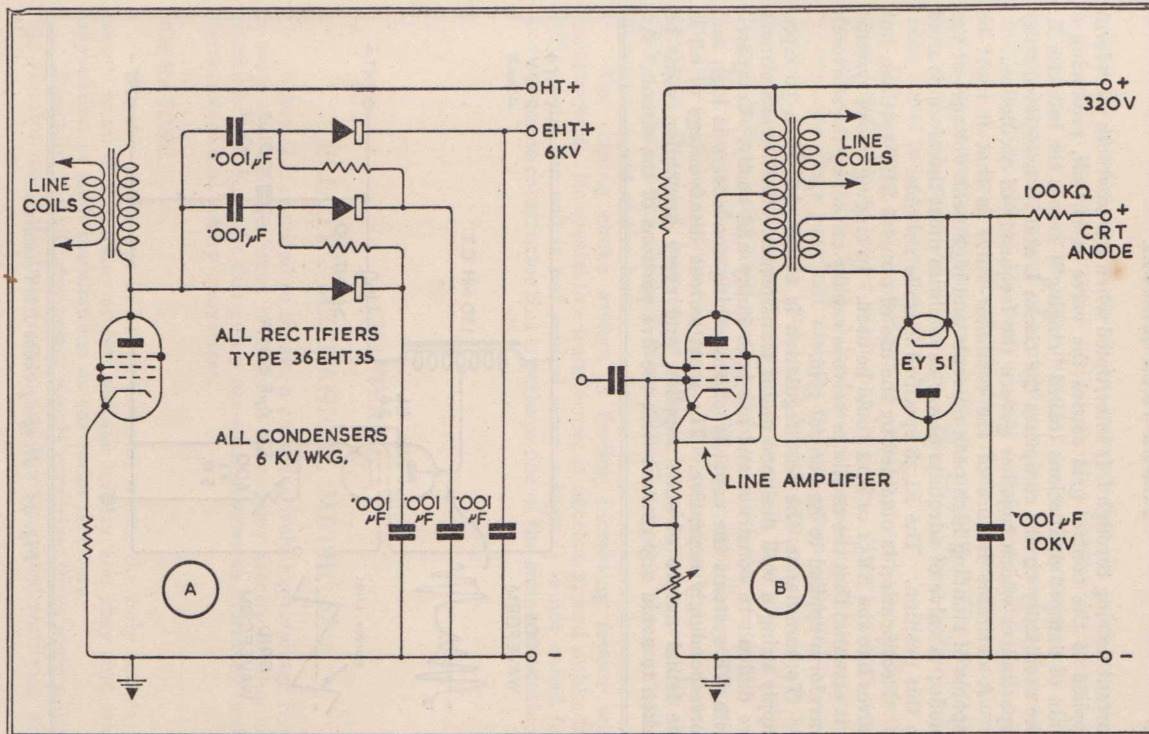


Fig. 44. Flyback EHT systems.

current flowing through L is interrupted when the sawtooth waveform applied to the control grid causes the valve to cut-off, producing a train of damped oscillations (called "ringing") across the inductor L. The oscillatory circuit comprises the choke L and its associated stray capacitances which together govern the frequency of oscillation.

A desirable feature of the oscillator valve is that it must be capable of standing high peak currents and high peak voltages at the anode; a valve of adequate power capabilities must therefore be used in this position. The EL38 specified is quite suitable.

Rectification is obtained by the use of a metal EHT rectifier, but valves like the EY51 or R12 could be used. In ringing choke systems it is essential that the oscillator valve is rapidly cut off by the sawtooth waveform applied to its control grid.

To summarise, the best regulation is obtained from a 50 c.p.s. supply using a well designed mains transformer. Such transformers are difficult to construct and are both bulky and costly. Compared with RF systems the capacity of smoothing condensers is high and correspondingly expensive. The most serious disadvantage of all is the lethal nature of such supplies, and every precaution must be taken to avoid any contact with the live portions of the circuit. An

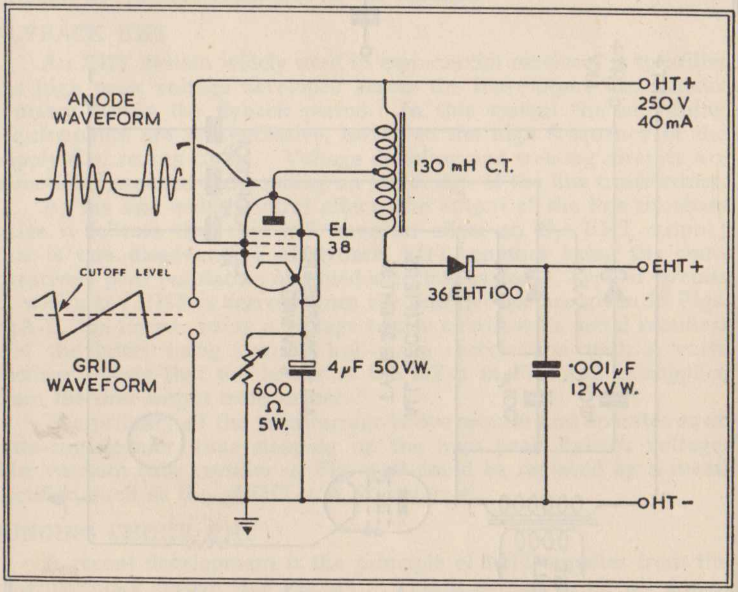


Fig. 45. Ringing choke EHT system.

adequate bleeder chain MUST be incorporated in such supplies, OTHERWISE THE CAPACITORS WILL RETAIN SUFFICIENT CHARGE TO KILL EVEN DAYS AFTER THE UNIT HAS BEEN SWITCHED OFF. The bleeder chain can consist of a number of 2·7 MΩ resistors in series; single high resistance bleeders are not satisfactory since they tend to develop an open circuit after a short time. A number of resistors available on the market are unsuitable for use with EHT: they burn out after a short period of service. The Erie 2-watt pattern have been found to be very satisfactory.

RF systems are inexpensive to construct and give sufficiently good regulation to cover most requirements. The heart of these systems is, of course, the coil, and unless a good quality component is used the stage may not always oscillate when switched on. In common with the ringing choke and flyback systems, this supply has the major advantage over the 50 c.p.s. supply in that it is not lethal, though quite a nasty burn can result from accidental contact.

The successful operation of the flyback system is dependent on the line output transformer design. Such components are not easily obtained. Provided, however, a suitable transformer is available the system provides the cheapest form of EHT supply; the regulation, however, is not of the best.

The ringing choke system is finding increasing favour with constructors. No special line transformer is necessary, and unlike the RF supply, the coil is not critical since a high Q is not called for. For the home constructor this is perhaps one of the simplest solutions.

CHAPTER 14

ELECTRO-MECHANICAL METHODS

When it is required to obtain a comparatively high voltage from a very low voltage input it is usual to employ electro-mechanical methods. Included in this group are such devices as vibratory units, dynamotors and rotary converters.

VIBRATORS

Vibrator packs are in heavy demand where the only source of power is an accumulator or low voltage battery and they find wide application in such installations as car radio receivers.

Basically, the vibrator power supply comprises three main units: the vibrator itself, the transformer, and the associated rectifying and smoothing circuits. There are two types of vibrator—the synchronous and the non-synchronous (Fig. 46).

The synchronous vibrator is self-rectifying and so it is not necessary to provide rectification by a valve or other means. The non-synchronous types are not self-rectifying and separate rectification is necessary; needless to say these are cheaper than the synchronous pattern; but where a compact design is important the self-rectifying type is definitely to be preferred.

The transformers in these units are usually of special design; but it is possible to use a standard power transformer, as used in the ordinary radio receiver, and the circuit shown in Fig. 47 explains how this can be done. The two heater windings are seriesed and operate as the primary, the original primary being ignored.

OPERATION

The operation of a vibrator unit is simple. When DC is applied to the vibrator unit the contacts vibrate in a manner similar to a bell buzzer and interrupts the DC flow. This interrupted direct current, which has a square wave-form, flows via the primary of the transformer, first in one direction and then in the other. It induces an alternating voltage in the secondary, the actual value of which will depend on the usual transformer factors.

Rectification in the conventional manner is carried out by the 6X5G, and the output is subjected to standard single-section capacitor input filtering. Hash, or vibrator noise, is often predominent, and so it is necessary to include additional filtering by the use of RF chokes and filter capacitors in both primary and secondary circuits.

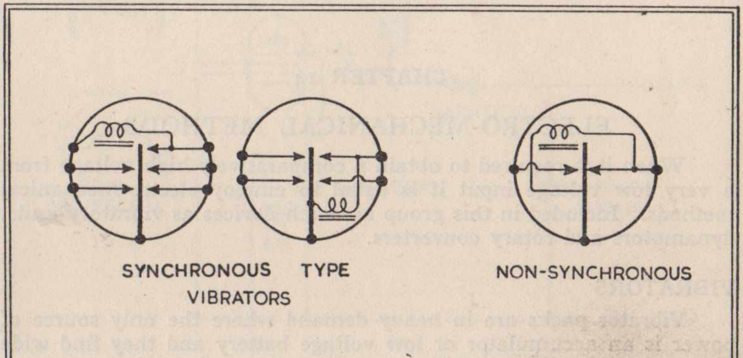


Fig. 46. Internal connections of standard vibrators.

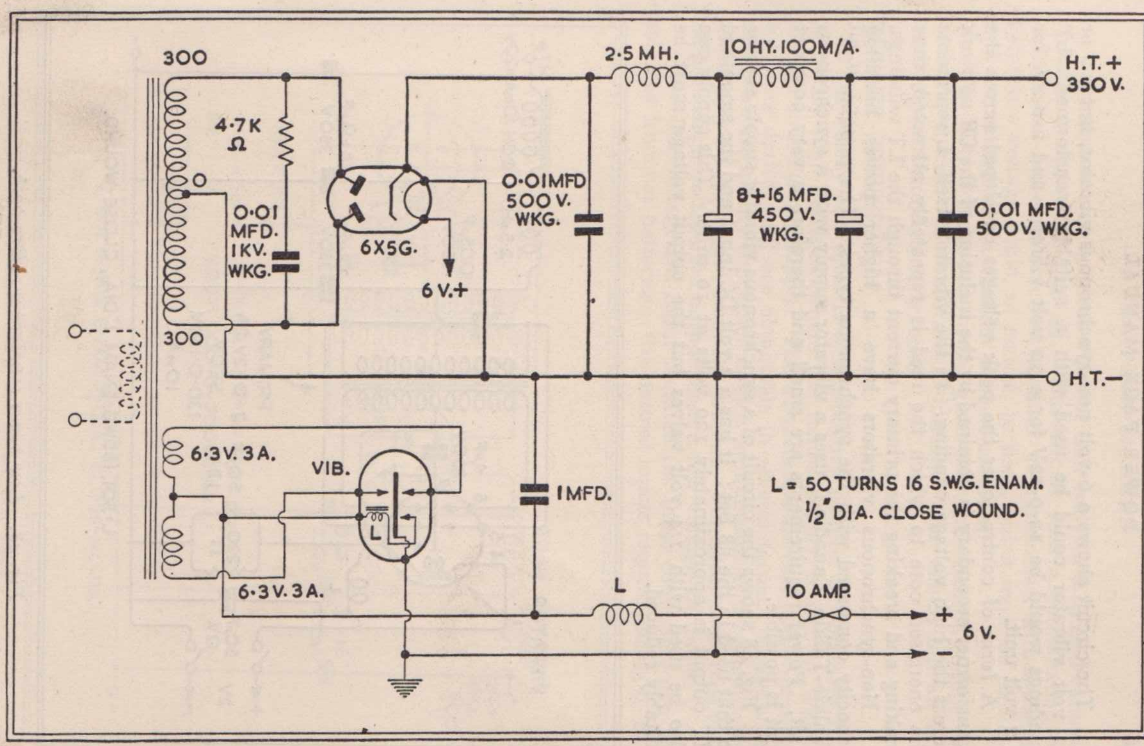


Fig. 47. Non-synchronous vibro-pack.

The circuit shows a 6-volt non-synchronous vibrator, but a 2 or 12 volt vibrator could be used with a suitable transformer. LT windings would be 12-0-12V for a 12 volt vibrator and 2-0-2V for a 2 volt unit.

A form of control over the peak voltages developed across the transformer secondary is obtained by the inclusion of the CR network across the high voltage winding. In the vibrator itself, L represents the energised core to which the reed is repeatedly attracted, thus making and breaking the primary current through the LT windings.

Non-synchronous vibrators have a higher power handling capacity compared with the synchronous types. The popular "58" Walkie-Talkie (Canadian) uses a vibrator supply with a synchronous unit. Power requirements are small and therefore a very compact unit is possible.

Fig. 48 shows the circuit of a synchronous vibrator supply similar to that used in the 58 Set; it has a 2 volt DC input and the smoothed HT output is approximately 120 volts at 10 m/A. This supply can also be used with 1·4 volt valves but the output voltage must be suitably reduced.

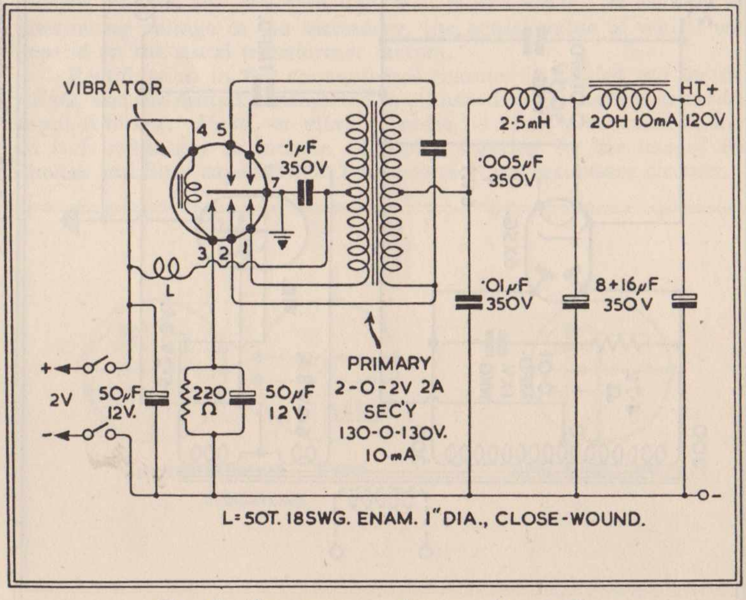


Fig. 48. Low power synchronous vibro-pack.

A standard synchronous vibrator unit with an OZ4 cold cathode rectifier is shown in Fig. 49. This circuit uses a combination of mechanical and electronic rectification. A transformer with a higher secondary voltage could, of course, be used, but it must be ensured that the ratings of the rectifier are not exceeded.

The output from this circuit gives twice the output voltage (at half the current) of conventional circuits. The centre tap on the transformer secondary is ignored.

ROTARY CONVERTERS

The rotary converter is a satisfactory method of obtaining the necessary high voltages, where the mains supply is DC, or where there is no electricity supply. These converters are essentially rotating armature devices and are obtainable in several forms. Those with which we are mostly concerned have a commutator arrangement and will supply an AC output from DC sources. The dynamotor type will supply a high voltage DC output from a low voltage DC input.

The low voltage DC input required for these converters can be obtained from car batteries; the normal inputs required being 6, 12,

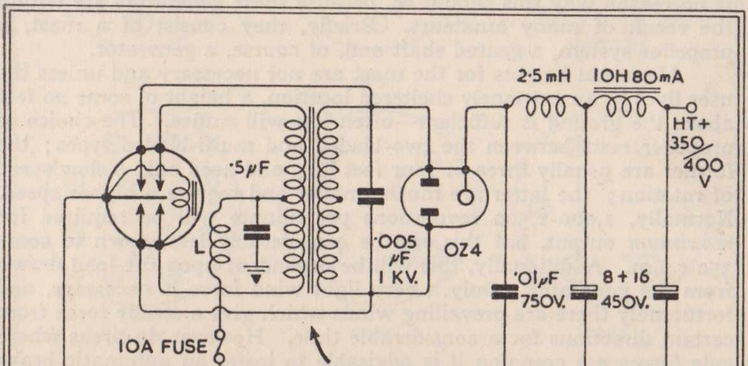


Fig. 49. Standard synchronous vibro pack.

24 or 32 volts. Outputs of as high as 1,000 volts DC can be obtained from these converters, though the average AC output on the DC-AC converters is 230V at 50 c.p.s. Suitable converters are to be found at reasonable prices in most stores dealing in Government surplus radio gear.

The regulation characteristic of these converters is quite good over reasonable load variations, but on the earlier models the efficiency was not as good as with modern types.

When using rotary converters precautions must be taken to avoid interference with radio equipment. It is necessary to insert series chokes in the high voltage leads to filter the high frequency currents caused by sparking between the commutator segments and the brushes. Commutator ripple must be eliminated, and this is usually done by additional filtering in the form of series inductors of high value and shunt capacitors.

WIND GENERATORS

Although wind generators are used widely in other parts of the world, they are not encountered to any extent in this country. There is no reason why this should be, because these generators are within the reach of many amateurs. Briefly, they consist of a mast, a propellor system, a geared shaft and, of course, a generator.

Abnormal heights for the mast are not necessary and unless the user lives in an extremely sheltered location, a height of some 20 feet above the ground is sufficient—often less will suffice. The choice of propeller rests between the two-bladed and multi-bladed types; the former are usually three or four feet long and need only a slow speed of rotation; the latter are much smaller and require a higher speed. Normally, 1,000-1,500 revolutions per minute will be required for *maximum* output, but this can be considerably less, down to some 350 r.p.m. Additionally, this will be dependent upon the load drawn from the generator. Only a very light wind force is necessary, and fortunately there are prevailing winds which give a steady force from certain directions for a considerable time. However, in areas where gale forces are common it is advisable to instal an automatic brake to protect the whole installation.

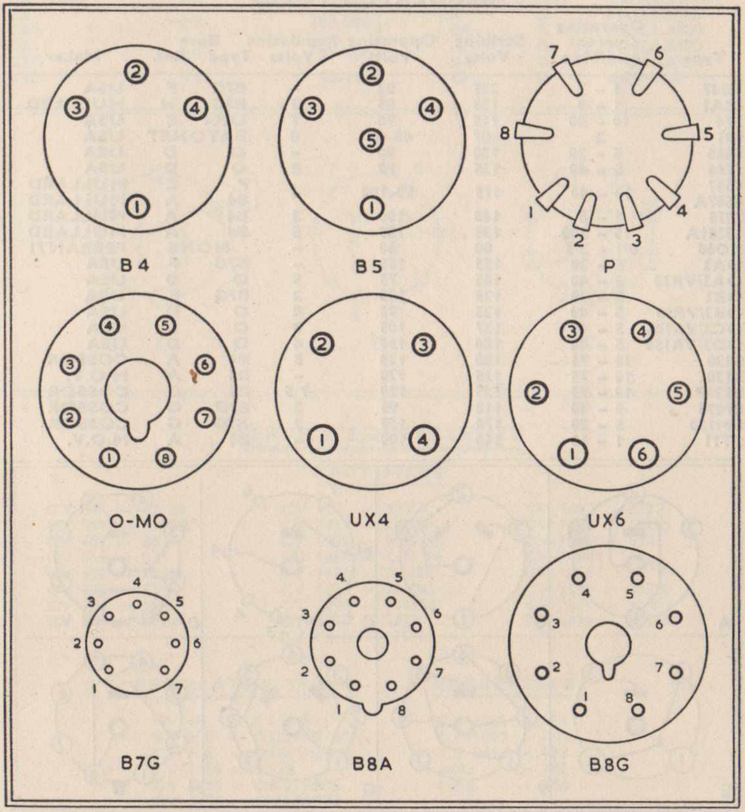
A tailpiece, which should be mounted at right angles to and directly behind the propeller, will ensure that it will take up the direction of the prevailing wind at all times.

CHAPTER 15

SUGGESTED RECTIFIERS AND REGULATORS

The following tables are not intended to be a complete reference to existing types. The purpose of this chapter is to provide a reference to the more popular types of rectifier, regulator tube and barretter. Constructors and engineers who require comprehensive data on all types are referred to the *International Radio Tube Encyclopædia* (Bernards (Publishers) Ltd.), which lists nearly 2,000 different rectifiers and regulators.

Below is a pictorial representation of valve bases shown in this chapter.



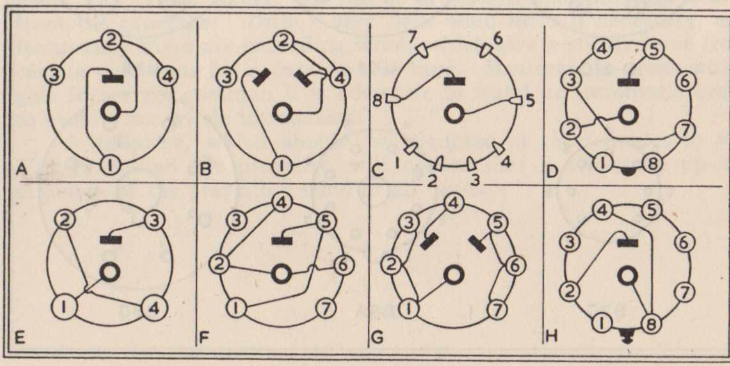
Abbreviations used in this chapter:

HW	*Half-wave*	RMS	*Root mean square*
FW	*Full-wave*	Min	*Minimum*
HW-M	*Half-wave Mercury*	Max	*Maximum*
FW-M	*Full-wave Mercury*	I-m/A	*Current in milli-amperes*
VD	*Voltage doubler*	USA	*Valves of American origin*
V	*Volts*		
I/A	*Current in amperes*	MOV	*Marconi-Osram valve*

All valve schematics and bases shown are viewed looking at the pins of the valve.

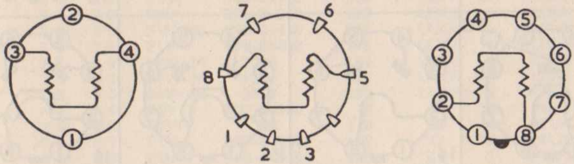
REGULATOR TUBES

Type	Operating Current Min/Max	Striking Volts	Operating Volts	Regulation Volts	Base Type	Base Ref.	Maker
1B47	1 – 2	225	82	–	B7G	F	USA
85A1	1 – 8	125	85	2	B8G	H	MULLARD
874	10 – 50	115	90	7	UX4	E	USA
991	2	87	48–67	8	BAYONET		USA
1265	5 – 30	130	90	–	O	D	USA
1266	5 – 40	125	90	8	O	D	USA
4687	10 – 40	115	80–100	4	P	C	MULLARD
4687A	10 – 40	115	80–100	4	B4	A	MULLARD
7475	1 – 8	140	100	3	B4	A	MULLARD
13201A	15 – 200	135	100	5	B4	A	MULLARD
KD60	0·1 – 2·5	80	60	–	NONE		FERRANTI
OA2	5 – 30	155	150	–	B7G	F	USA
OA3/VR75	5 – 40	105	75	5	O	D	USA
OB2	5 – 30	125	108	2	B7G	F	USA
OB3/VR90	5 – 40	125	90	8	O	D	USA
OC3/VR105	5 – 40	127	105	2	O	D	USA
OD3/VR150	5 – 40	180	150	4	O	D	USA
S130	10 – 75	180	120	5	B4	A	COSSOR
S130	10 – 75	135	120	–	B4	A	M.O.V.
S130P	10 – 75	135	120	7·5	B4	B	COSSOR
SM95	5 – 20	110	95	3	B7G	G	COSSOR
SM150	5 – 20	170	150	3	B7G	G	COSSOR
ST11	1 – 10	140	100	–	B4	A	M.O.V.



BARRETTERS

Type	Stabilised I/A	Voltage Drop	Base Type	Base Ref.	Maker
150 A4	0·2	100–200	B4	A	ATLAS
150 AC			P	B	ATLAS
161	0·16	100–200	Edison Screw		M.O.V.
202	0·2	120–200	B4	A	M.O.V.
301	0·3	138–221	Edison Screw		M.O.V.
302	0·3	112–195	Edison Screw		M.O.V.
303	0·3	86–129	Edison Screw		M.O.V.
304	0·3	95–165	Edison Screw		M.O.V.
BR 201	0·2	100–200	B4	A	TUNGSRAM
BR 201S			P	B	TUNGSRAM
BR 202	0·2	40–100	B4	A	TUNGSRAM
BR 202S			P	B	TUNGSRAM
BR 3000E	3·0	10–40	Edison Screw		TUNGSRAM
C1	0·2	100–200	P	B	MULLARD
C1C			B4	A	MULLARD
C2	0·2	35–100	P	B	MULLARD
C2C			B4	A	MULLARD
D15	0·15	90–140	O	C	BRIMAR



A B C

SERVICE EQUIVALENTS

RECTIFIERS

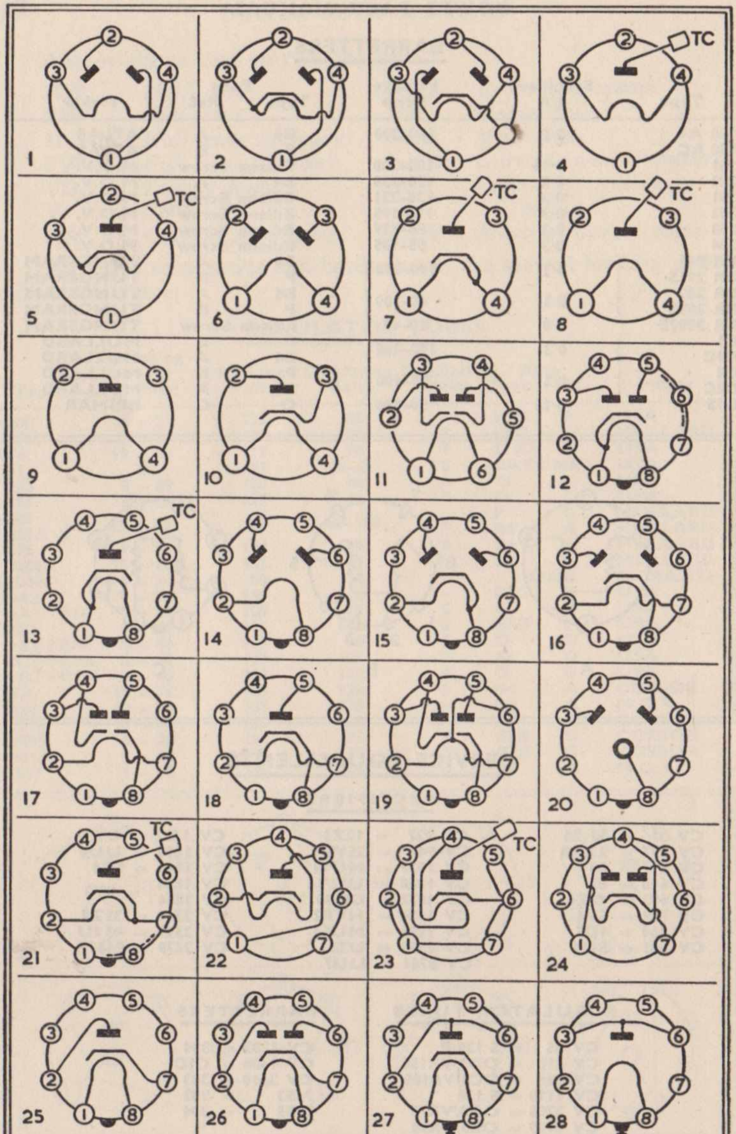
CV 31 = U 20
CV 597 = 2X2A
CV 617 = 80
CV 618 = 83
CV 692 = OZ4
CV 729 = 5V4
CV 764 = 1D5
CV 841 = 5U4
CV 927 = 12Z3
CV 942 = 25Y5
CV 1039 = MU14
CV 1064 = U12/14
CV 1072 = GU50
CV 1134 = HVR2
CV 1296 = MU14
CV 1356 = U22
CV 3761 = UU7
CV 1402 = CY31
CV 1413 = UU6
CV 1846 = 5T4
CV 1854, CV 1856 = 5Y3
CV 2500 = 35Z4
CV 2529 = 45 IU
CV 2679 = 866JR

REGULATOR TUBES

CV 45 = S 130 P
CV 216 = OD3/VR150
CV 686 = OC3/VR105
CV 1110 = S 130
CV 3798 = OA3/VR75
CV 3799 = OB3/VR90

BARRETTERS

CV 1202 = 304
CV 1400 = C1C
CV 2610 = 303
NS3 = 202
NS5 = 304


1
2
3
4
TC
5
TC
6
7
TC
8
TC
9
10
11
12
13
TC
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TC
22
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TC
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27
28

VALVE RECTIFIERS

Type	Heater V	Heater I/A	Class	Anode Volts RMS	Max. I-m/A	Base Type	Base Ref.	Maker
1D5	40·0	0·2	HW	250	100	B5	3	BRIMAR
2X2/A	2·5	1·75	HW	450	7·5	UX4	7	USA
5T4	5·0	3·0	FW	450–0–450	225	O	14	USA
5U4G	5·0	3·0	FW	450–0–450	250	O	14	USA
5V4G	5·0	2·0	FW	400–0–400	175	O	15	USA
5Y3G	5·0	2·0	FW	350–0–350	120	O	14	USA
5Z3	5·0	3·0	FW	450–0–450	225	UX4	6	USA
5Z4G	5·0	2·0	FW	350–0–350	120	O	15	USA
6X4	6·3	0·6	FW	325–0–325	70	B7G	24	USA
6X5GT	6·3	0·6	FW	325–0–325	70	O	16	USA
12Z3	12·6	0·3	HW	235	55	UX4	10	USA
25Y5	25·0	0·3	HW	2X235	2X75	UX6	11	USA
25Z5	25·0	0·3	HW	2X235	2X75	UX6	11	USA
25Z6	25·0	0·3	HW	2X235	2X75	O	17	USA
35Z4	35·0	0·15	HW	235	100	O	18	USA
35Z6	35·0	0·3	VD	125	110	O	17	USA
40SUA	40·0	0·2	HW	250	75	B5	3	COSSOR
431U	4·0	2·5	FW	500–0–500	150	B4	2	COSSOR
451U	4·0	3·5	FW	500–0–500	250	B4	2	COSSOR
52KU	5·0	2·0	FW	500–0–500	150	O	15	COSSOR
53KU	5·0	2·8	FW	500–0–500	250	O	15	COSSOR
54KU	5·0	2·0	FW	300–0–300	300	O	15	COSSOR
80	5·0	2·0	FW	350–0–350	125	UX4	6	USA
83	5·0	3·0	FW-M	450–0–450	225	UX4	6	USA
83–V	5·0	2·0	FW	400–0–400	175	UX4	6	USA
816	2·5	2·0	HW-M	7000	125	UX4	8	USA
866 JR	2·5	3·0	HW-M	1250	125	UX4	9	USA
866/A	2·5	5·0	HW-M	3500	250	UX4	8	USA
AZ31	4·0	1·0	FW	500–0–500	70	O	14	MULLARD
CY31	20·0	0·2	HW	250	120	O	18	MULLARD
CY32	30·0	0·2	FW	250–0–250	120	O	17	MULLARD
DW4/500	4·0	2·0	FW	500–0–500	120	B4	1	MULLARD
EY51	6·3	0·08	HW	7000	1·0	B2G*	—	MULLARD
EY91	6·3	0·42	HW	250	75	B7G	22	MULLARD
EZ35	6·3	0·6	FW	325	70	O	16	MULLARD
FW4/500	4·0	3·0	FW	500–0–500	250	B4	1	MULLARD
FW4/800	4·0	3·0	FW	850–0–850	125	B4	1	MULLARD
GU50	4·0	3·0	FW-M	1500	500	B4	4	M.O.V.
GZ32	5·0	2·0	FW	500	250	O	15	MULLARD
HVR2	4·0	0·65	HW	6000	3	B4	5	MULLARD
HVR2A	2·0	1·5	HW	6000	3	B4	5	MULLARD
IW4/350	4·0	2·5	FW	350–0–350	125	B4	2	MULLARD
IW4/500	4·0	2·4	FW	500–0–500	120	B4	2	MULLARD
MU14	4·0	2·5	FW	500–0–500	120	B4	2	M.O.V.
OM1	30·0	0·2	HW	250	120	O	18	COSSOR
OZ4	—	—	FW	300	75	O	20	USA
PY31	17·0	0·3	HW	250	125	O	18	MULLARD
PZ30	52·0	0·3	FW	250	240	O	19	MULLARD
R3	4·0	2·5	FW	500–0–500	120	B4	2	BRIMAR
R10	4·0	0·5	HW	5500	5	B7G	23	BRIMAR
RV120/500	4·0	2·5	FW	500–0–500	120	B4	1	TUNGSRAM
RV200/600	4·0	2·8	FW	600–0–600	120	B4	1	TUNGSRAM
SU2150	2·0	1·15	HW	8000	2	B4	5	COSSOR
U12/14	4·0	2·5	FW	500–0–500	120	B4	1	M.O.V.
U33	2·0	1·0	HW	6300	3	B4	4	M.O.V.
U84	4·0	1·0	HW	250–0–250	75	B8G	28	M.O.V.
U18/20	4·0	3·75	FW	850–0–850	125	B4	1	M.O.V.
U20	4·0	3·75	FW	850–0–850	125	B4	1	M.O.V.
U22	2·0	2·0	HW	4500	5	MO	13	MAZDA
U24	2·0	0·15	HW	7800	0·5	O	21	MAZDA
U50	5·0	2·0	HW	400–0–400	110	O	14	M.O.V.

* Wire ends.

—continued overleaf

VALVE RECTIFIERS—*continued*

Type	Heater V	Heater I/A	Class	Anode Volts RMS	Max. I-m/A	Base Type	Base Ref.	Maker
U52	5·0	3·0	FW	500–0–500	250	O	14	M.O.V.
U78	6·3	0·7	FW	350–0–350	75	B7G	24	M.O.V.
U201	20·0	0·2	HW	250	90	O	18	MAZDA
U404	40·0	0·1	HW	250	90	B8A	25	MAZDA
UU5	4·0	2·3	FW	500–0–500	120	B4	2	MAZDA
UU6	4·0	1·4	FW	350–0–350	120	MO	12	MAZDA
UU7	4·0	2·3	FW	350–0–350	180	MO	12	MAZDA
UU8	4·0	2·8	FW	350–0–350	250	MO	12	MAZDA
UU9	6·3	0·63	FW	350–0–350	90	B8A	26	MAZDA
UY21	50·0	0·1	HW	250	140	B8G	27	MULLARD
UY41	31·0	0·1	HW	250	90	B8A	25	MULLARD
V30	30·0	0·2	HW	275	120	B5	3	TUNGSRAM

CHAPTER 16

MISCELLANEOUS DATA

FUSES

Fuses have not been shown, in the majority of circuits given, which does not imply that the authors consider these components unnecessary—much to the contrary.

Fuses are necessary to protect the equipment against breakdowns (such as capacitors) which would cause an extremely heavy current to flow and damage—or completely ruin—other components, particularly the rectifier. There is no excuse for neglecting to use fuses, for they are simple to fit and cost but a few pence.

Fuses in power supplies can be fitted in the primary windings of the power transformer, one in each side of the mains input. Ordinary copper wire is often used for fuses, but is not to be recommended for ordinary radio equipment. Cartridge fuses are the most popular and are very reliable: they are obtainable in ratings from 60 m/A to 25 A.

To secure adequate protection for the rectifier and associated components, the fuse is best fitted in series with the power transformer centre tap, i.e. between the centre tap and earth. In some circuits this is not possible, and in such cases the fuse can be fitted in the HT positive or HT negative line. The value of a fuse should be equal to the maximum current of the transformer secondary. An alternative to the cartridge fuse is the ordinary torch bulb, where the fusing current is between the ranges of approx. 0·15—0·6 Amp.

FUSING VALUES

(*For copper wire*)

DIAMETER (inches)	FUSING CURRENT (Amperes)	NEAREST SWG
0·0044	3	41
0·0053	4	39
0·0062	5	38
0·0098	10	33
0·0129	15	30
0·0156	20	28
0·0181	25	26
0·0205	30	25
0·0227	35	24
0·0248	40	23
0·0288	50	22
0·0325	60	21
0·0360	70	20
0·0394	80	19

COLOUR CODE USED FOR BRITISH MAINS TRANSFORMER LEADS

Primary Winding

Start of Winding	Black.
10 Volts	Black and Green
210 Volts	Black and Yellow
230 Volts	Black and Red
250 Volts	Black and Brown.

Secondary Winding

H.T. Winding: Red and Red with centre tap coded Red and Yellow.

Rectifier Heater: Green and Green with centre tap coded Green and Yellow.

Valve Heaters: (1) Brown and Brown with centre tap coded Brown and Yellow.

Valve Heaters: (2) Blue and Blue with centre tap coded Blue and Yellow.

The Electrostatic Screen between Primary and Secondary is usually brought out by a bare wire. It will be noted that all centre taps are coded in two colours, one of which is always Yellow.

Mains Transformers designed for half-wave circuits are not normally fitted with a centre tap on the H.T. secondary winding. The coding of the leads for this winding is then Red and Red and Yellow.

COLOUR CODE USED FOR AMERICAN MAINS TRANSFORMER LEADS

Primary Winding

Start of winding	Black
1st Tap	Black
2nd Tap	Black and Yellow
Finish of winding	Black and Red.

Secondary Winding

H.T. Winding: Red and Red with centre tap coded Red and Yellow.

Rectifier Heater: Yellow and Yellow with centre tap coded Yellow and Blue.

Valve Heaters: (1) Green and Green with centre tap coded Green and Yellow.

Valve Heaters: (2) Brown and Brown with centre tap coded Brown and Yellow.

The coding of the Primary winding is no indication of the voltage for which the transformer is designed.

RIPPLE CONTENT IN POWER SUPPLIES

Normal smoothing circuits are most conveniently considered in three sections:

(1) The input filter which may be either (a) Condenser input, or (b) Choke input.

(2) Additional choke condenser (LC) filter sections.

(3) Additional resistance condenser (RC) filter sections.

The formulae given are simplified in order to make the calculations easy and rapid: the answers obtained are, however, sufficiently accurate for all normal purposes. In the case of the input filter they give the ratio of the ripple voltage to the rectified D.C. output voltage; in the case of the following filters they give the ratio of the ripple voltage at the output of the filter to that at the input. Split the circuit into sections to determine the ripple after smoothing in a power supply. Determine the proportion of ripple after the first section; secondly, determine the further reduction due to any subsequent sections. From these the final ripple figure can be obtained. For example, consider a conventional circuit consisting of a reservoir condenser followed by a choke and condenser. The ripple voltage after the input condenser or first section might be, say, 1/10th of the D.C. output voltage, and since the choke condenser filter following will reduce this ripple appreciably, the final ripple is likely to be 1/200th of the D.C. voltage or $\frac{1}{2}\%$.

1. The reservoir condenser alone represents the first section of a condenser input filter; but with choke input, both the choke and the condenser following it must be considered as the first section.

(*a*) With condenser input the ratio of the ripple voltage to the D.C. output voltage is equal to $\dfrac{10^6 \times \sqrt{2}}{\omega C R_L}$ or expressed as a percentage is equal to $\dfrac{10^8 \times \sqrt{2}}{\omega C R_L}\%$

(b) With choke input the ratio of the ripple voltage to the D.C. output voltage is equal to $\dfrac{8 \times 10^5}{\omega^2 CL}$ or as a percentage $\dfrac{8 \times 10^7}{\omega^2 CL}\%$

2. Additional choke condenser filter sections. The ratio of the output ripple voltage to the input ripple voltage is equal to $\dfrac{10^6}{\omega^2 CL - 1}$ or as a percentage $\dfrac{10^8}{\omega^2 CL - 1}\%$.

3. Additional resistance condenser filter sections are usually included for decoupling purposes; but also contribute to the smoothing. The ratio of output to input ripple voltage is equal to $\frac{10^6}{\omega CR}$ or as a percentage $\frac{10^8}{\omega CR}\%$. This formula is sufficiently accurate provided the value of CR exceeds 5,000; for lower values of CR serious errors are introduced.

In the preceding formulae:

ω	equals	$2\pi f$.
C	,,	Capacity in microfarads.
L	,,	Inductance in henries.
R	,,	Resistance in ohms.
R_L	,,	Load resistance in ohms.
π	,,	3.14159 . . . . .
f	,,	Ripple frequency (with 50 cycle mains the ripple frequency is 100 cycles in full-wave circuits and 50 cycles in half-wave circuits.)

The load resistance is found by dividing the D.C. output voltage by the D.C. output current in amperes.

The majority of A.C. supplies in this country are 50 c.p.s. and the formulae are further simplified below for use with full and half-wave circuits at this frequency.

CONDENSER INPUT. Full-wave Half-wave

$$\frac{\text{Ripple voltage RMS.}}{\text{D.C. output voltage.}} = \frac{\sqrt{2} \times 10^6}{\omega CR_L} = \frac{2200}{CR_L} \text{ or } \frac{4400}{CR_L}$$

CHOKE INPUT.

$$\frac{\text{Ripple voltage RMS.}}{\text{D.C. output voltage}} = \frac{8 \times 10^5}{\omega^2 CL} = \frac{2}{CL} \text{ or } \frac{4}{CL}$$

CHOKE CONDENSER FILTER.

$$\frac{\text{Output ripple voltage}}{\text{Input ripple voltage}} = \frac{10^6}{\omega^2 CL - 1} = \frac{10}{4CL-1} \text{ or } \frac{10}{CL-1}$$

RESISTANCE CONDENSER FILTER

$$\frac{\text{Ouput ripple voltage}}{\text{Input ripple voltage}} = \frac{10^6}{\omega CR} = \frac{10^6}{630\,CR} \text{ or } \frac{10^6}{315\,CR}$$