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Design and Testing of Plate Supply Devices

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Part I—Design



[Editor's Note: The following is the first of two articles on plate supply devices. Each article is complete in itself, but the second article will be clearer if the first article has previously been read, and if it may be at hand for ready reference when reading the second. The second article will appear in the January issue of the Experimenter.]

I. Design

The manufacture of plate supply devices for radio receiving sets involves many problems of design, production, and testing. It is the aim of this article to acquaint the readers of the Experimenter with some of these problems and with our methods of meeting them.

Design problems are to a great extent affairs of theory and the laboratory, where experimental models are built and tried out to check theory and develop finished design preparatory to production.

Production problems are myriad and never are at an end, but they are of such nature as to be of little interest to readers of this article. Suffice it to say that varied means must be found, and found quickly,

to solve these production worries as soon as they arise, in order to maintain the standard of the finished product as well as sufficient volume of production to meet market demands.

Perhaps testing may be considered a production problem, since it keeps up the standard of the finished article and, paradoxical as it may seem, speeds up production by enabling correction of defects to be made when correction is most easy, i.e., before assembly is entirely completed. If, in reality, the subject of testing is only a problem of production, at least its size and its interest warrant its treatment as a separate field.

Before proceeding to a detailed consideration of design and testing, it will be well to review briefly the more important divisions into which

fall the circuits of plate supply units. Asking the indulgence of those to whom these circuits are familiar, we will briefly, so as not to be tedious, offer to those not conversant with these devices a simple explanation of their schematic operation. Referring to figure 2,

(a) is the actual wiring of a typical plate supply, and (b) is a schematic showing the functions of the corresponding divisions of the circuit (a).

The Transformer both heats the filaments and furnishes stepped-up high-voltage alternately to the plates of

The Rectifier, through which current can pass in only one direction. This current, a pulsating direct current of 120 pulsations per second (for a 60-cycle supply line), passes on to

The Filter. This is a "brute-



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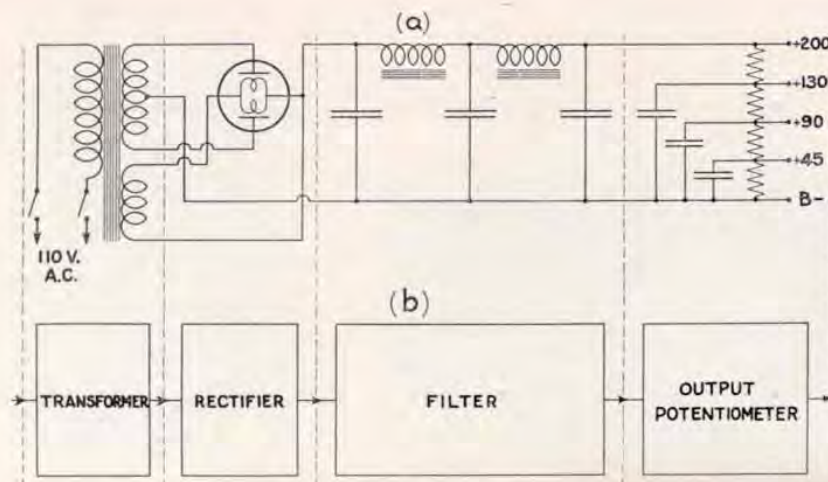


FIG. 2

force" or untuned filter. The pulsating D.C. delivered by the rectifier is equivalent to the sum of an average D. C. and the superposed pulsating ripple or A. C. of a frequency of 120 cycles per second. The D. C. component goes through the filter practically unchanged, being impeded only by the ohmic resistance of the two choke coils. The pulsating ripple, however, is by-passed by each filter condenser and held back by each choke coil in turn until, at the end of the filter, practically no ripple is present in the output, which is impressed across

The Output Potentiometer, which apportions the total voltage in a correct manner to supply various voltages as customarily required by plates of vacuum tubes in receiving sets. This division also contains fixed condensers to by-pass around the resistance of the potentiometer the A. C. energy, either radio or audio, from the receiving set. The plate supply unit is, in effect, a "B" battery of quite high internal resistance, and the by-pass condensers reduce the coupling between tubes operated from the same voltage tap by reducing the effective impedance common to the plate circuits of those tubes.

With this short resumé of the functions of the various parts of a plate supply unit, we proceed to considerations of the design of a unit having the following desirable general features and characteristics:

1. Pleasing appearance.
2. Convenience of installation.
3. Economy of manufacture as well as economy of space occupied.
4. Safety.
5. Simplicity of operation and installation.
6. Load capacity.

7. Freedom from hum and other extraneous noises.
8. Flexibility or universality of application.
9. Good quality of audio output from receiving set or power unit.
10. Permanence and long life.

These problems have been met in our units as follows:

1. Pleasing appearance has been striven for by making harmonious the general external proportions and mechanical design of the case and by applying to the case a durable finish which will harmonize well with its surroundings.
2. The 110-volt supply cord and the binding posts for external connections have been arranged close together on the rear of the instrument to facilitate connection in the least conspicuous place of the wires leading to the unit. The switch, however, is placed on the end of the case so as to be readily accessible.
3. The case has been made as small as possible consistent with reasonable ease in assembling parts and soldering connections. The sockets, resistance unit and audio transformer are placed in the rear or open compartment, while the remaining parts—condensers, chokes, transformers, etc.—are more easily assembled in less space in the compartments which are later sealed with wax. The final design represents a compromise between the two aims, economy of space and manufacture.
4. Safety has been attained by enclosing and shielding all parts in a well-ventilated metal case which is itself well insulated from the live parts within. Protection from the high voltages of the D. C. output is obtained by the use of bakelite bind-

ing posts, the engraved tops of which cannot be removed. Since these plate supply units cannot supply through their secondary circuits sufficient current to burn out the filaments of even 199 type tubes, should the "B" voltage by accident be applied across the filament terminals, care has been taken to insulate well the primary coil from the secondary coils so that there is no chance for the great primary energy to flow in secondary circuits, to the danger of filaments.

5. Installation involves only the insertion of tubes into the correct sockets, the connection of the supply cord to a 110-volt 60-cycle line, and the connection of the various binding posts to the corresponding terminals on the receiving set. Operation involves only the turning on or off of the 110-volt supply switch. Simplicity of operation is due to the use of a fixed resistance across the whole output of the filter circuit, tapped at the correct points to supply the various "B" voltages commonly used. These resistance taps are so proportioned that the voltage at any tap is, under all normal load conditions, near enough to the nominal voltage for all practical purposes. The elimination of variable voltage controls simplifies enormously the operation of the unit. Also, where tubes with filaments are used, correct voltages are applied to the filaments directly, eliminating filament rheostats that require adjustment. Thus, once installed, the unit may be forgotten, except to be turned off and on, and, nowadays, even that may be accomplished automatically by the use of a control relay (many of which are now on the market) actuated by the filament current from the "A" battery.

6. Load capacity, subject to limitations of rectifier tube ratings, is insured by generous proportions of power transformer coil and core, choke coils and cores, and resistance units.

7. Freedom from hum, even under heavy current drains, demands good choke coils of large current-carrying capacity (i.e., free from magnetic saturation at high currents) and allows no skimping of condenser capacities in the filter circuits. Enlarging the capacity of the last condenser of the filter is most effective in reducing hum in the output. The use of full wave rectification, i.e., rectifying both halves of the alternating current wave, produces better filtering action since the fundamental frequency of the pulsations is 120 instead of 60 cycles, and the higher frequencies are better removed by



the filter. Noises common to variable resistors of the carbon type (the only kind practicable to cover the range necessary if a variable resistor is to be used in a plate supply unit output circuit) are eliminated by use of fixed wire-wound resistances, in which only the best of resistance wires are used.

8. Flexibility of application of the unit demands good regulation of voltage at all voltage taps, i.e., the voltage must vary as little as possible with the current drawn from the unit. Good regulation of the low voltages in the output circuit can not be had unless the total voltage from the filter as applied to the output circuit has itself good regulation. The use of full-wave instead of half-wave rectification and the proper distribution of a sufficient number of microfarads in the filter circuit combine to improve very considerably both the voltage output and the regulation of that voltage. Large capacity of the first filter condenser following the rectifier is most important for obtaining high voltage and good regulation from the filter output. Good regulation of the lower voltages in the output circuit is obtained by properly designing the resistances of the potentiometer across the output so that the variation of the voltage at any tap from no load to a maximum is small, and the voltage is at no time very far different from its nominal value. In general, the smaller the resistance across the output, the better the voltage regulation of the various taps, but there is a happy medium beyond which too large a proportion of the output is diverted through the resistance and too little is available for "B" supply. In general, we have followed the principle of making voltages high rather than low, realizing that the high voltage can easily be cut down by the use of an external resistance in series with the load across any tap which may be high, while there is no remedy whatever if the voltage across any tap is very much too low. With this end in view the output potentiometer has been designed and the high transformer secondary voltages have been made as large as tube ratings will allow.

9. Good quality of audio output and freedom from receiving set oscillation is obtained by placing a sufficiently large by-pass condenser between each "B plus" tap and the "B minus" lead. Large capacity of the last condenser of the filter is important to maintain quality of reproduction. If the capacity is too small, currents of low frequencies in the

power tube, which must be large if they are to actuate the loudspeaker audibly, are liable to modulate the output of the whole unit, thus spoiling the quality. In the power amplifier units it is also found that a by-pass condenser across the biasing resistance of the amplifier tube is necessary in order to achieve best quality of reproduction. In accordance with present accepted practice, the input to the power amplifier tube is through a good audio transformer and the output through an output transformer or speaker filter to remove the D. C. component of the plate current. It has been found also that better results and quality are obtained when the power amplifier has a separate feed circuit across the output in parallel with the output potentiometer. We have also found, as described in the accompanying article on page 4 by Mr. Lamson, that biasing by using the voltage drop across a resistance in the plate circuit gives superior results by compensating somewhat for changes in plate voltage due to different load conditions on the unit.

10. Permanence and long life of the unit mean satisfied owners and a saving of expense to the manufacturer for replacements and repairs. Great care in manufacturing is necessary to prevent failures in service. Non-corrosive fluxes must be used, soldered joints must be firm mechanically and of low electrical resistance, and the whole assembly must be kept clean of bits of metal, solder, or the fine cut-off short ends of stranded lead wires, so that troublesome short circuits may be avoided. Surplus flux must be wiped off of joints to prevent corrosion and appearance of slovenly workmanship. Waxes used for sealing uncased parts must have sufficiently high melting points so as not to melt under the heat developed in continuous service and must not be heated so hot when being melted as to become carbonized or to injure the paper condensers when poured around them. All leads between parts must be well insulated from the case, cores, and each other. Perhaps the most care is required in the selection of the paper condensers since the failure of only one condenser (out of six or eight in a unit) is sufficient to render the whole unit useless. This makes it imperative that condensers having a large factor of safety be employed, and that they be handled carefully to prevent their contamination by moisture or soldering flux, or injury by mechanical abrasion before they are finally hermetically sealed into place.

Simple Method for Increasing Voltage at 45V Tap Where Current Drain is Heavy

Several cases have arisen of sets having an unusually heavy drain—5 to 10 milliamperes—on the 45-volt terminal which were not properly handled by the G. R. power



units. This situation is very easily met by means of a resistance connected as shown in the above diagram. This should have a range of 5,000 to 25,000 ohms. A resistance similarly connected between the highest voltage output (B plus terminal or output transformer) and the 90-volt terminal may be used if this terminal must carry an abnormal load.

A fixed resistance may be substituted for the variable one when the proper value has been ascertained, in order to keep the unit quieter.

On plate supply units having a 130-volt tap, the voltage on the 90-volt tap will be affected less if the variable resistance is connected between the 45- and 130-volt taps.

Correction of Error in November Issue

November Experimenter, Page 4, Column 1, for 500 meters, read 500 kilocycles (600 meters). Column 4, last paragraph should read "To find the turns required for tuning to 60 meters with a 250 MMF condenser, project to, etc."

NOTICE TO RADIO EDITORS

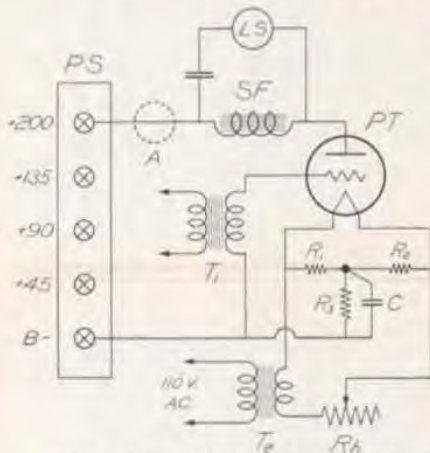
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Biassing the Power Amplifier Tube from the Plate Supply Unit

By HORATIO W. LAMSON, Engineering Department



After the radio fan has banished the need for "B" batteries by the use of some form of plate supply or "B" eliminator he becomes seized, perhaps, with the desire to do away with the "C" batteries, especially those of relatively high voltage required to bias the power tube in the last stage of the audio amplifier. If the plate supply outfit is capable of providing an over-all voltage equal to the normal plate voltage of the tube plus the required grid-bias voltage, this may readily be accomplished, provided a separate source of power is at hand for heating the filament of the power tube.

The circuits and equipment for doing this are indicated schematically in the figure. PS represents the terminal panel of a typical plate supply unit. PT is the power tube in question, for which T1 is the customary input transformer. SF is a speaker-filter in the plate circuit of the tube to keep the direct current from passing through the loud-speaker LS. This filter may consist, perhaps, of a thirty henry choke used in conjunction with a 2 MF condenser, or it may be replaced by an output transformer which will serve the same purpose.

An ordinary bell ringing transformer, T2, connected to the A. C. house mains, may be employed to heat the filament of the tube, using a suitable rheostat, Rh, to control the filament voltage. In this way no storage battery is required for the power tube, which makes it possible to add a stage of power amplification directly to a radio set employing only dry cell tubes.

Directly across the filament terminals are connected two resistances in series, R1 and R2. These may be from thirty to fifty ohms each. Their exact value within this range is immaterial but it is essential that they be closely equal to each other so that their center point is "equally distant" from the tube filament terminals. Between this center point and the B- terminal of the plate supply a third resistance, R3, is connected. This is known as the "biasing resistance" and it should be directly shunted with a condenser "C" of 1 MF capacity.

Examination of the figure will show that the plate emission current of the tube is obliged to pass through the resistance R3, and that the location of the grid return is such that the grid will be biased negatively with respect to the center of the filament, by a voltage very closely equal to the IR drop of the plate current through the resistance R3. In other words, the tube is biased by its own plate current. This is advantageous in that any change in plate voltage is compensated by a proportional variation in grid bias, thus maintaining automatically the correct relation between the two.

The by-pass condenser C is desirable to reduce the A. C. coupling between the grid and plate circuits of the tube, due to the resistance R3, which is common to both circuits.

The value of the biasing resistance depends, of course, upon the tube used and the voltage available at the plate supply terminals. By inserting a milliammeter at A the bias may be computed as described above or it may be measured directly by means of a high resistance voltmeter connected across the terminals of R3. If desired, this resistance may be an adjustable unit having an operating range of 500 to 5,000 ohms.

In general, it is not advisable to attempt to bias any but the last audio tube in this manner. Other tubes requiring a biasing battery should be provided with dry cell units. These tubes rarely require more than a few volts, which may conveniently and economically be supplied by small-sized flash light cells which, since they supply no current, will last throughout their normal shelf life.

A "Rock-Bottom" Standard



The importance of keeping all radio stations exactly on their assigned wavelengths has become vital. With the great number of stations operating at present, there is no vacant space between their assigned waves, and if a station is off its assigned wave it is interfering with another. The resultant effect is most unpleasant, as any of us can testify.

To help in the relief of this acute situation, the General Radio Company has designed an instrument known as a Piezo Electric Oscillator, the operation of which depends on a plate cut from a quartz crystal.

It has been discovered that when a plate, cut and ground from a piece of quartz crystal, is properly connected in a vacuum tube circuit, the quartz absolutely controls the oscillating frequency of the circuit. The quartz can be ground to any frequency (wavelength) desired, and is as unchanging as the rock from which it was cut.

The instrument shown above is a commercial adaptation of this principle. It consists of a quartz plate, and the necessary tube circuit, mounted in a cabinet. By means of this instrument, with a plate ground to the wavelength at which the station operates, its wavelength may be kept very constant, checking it frequently against the standard. A number of the larger broadcast stations are using this system to keep from straying over the fence of their frequency channel. A few stations have gone further and are using the quartz plate to control their transmitter directly.

The adoption of quartz standards promises much for the elimination of interference due to stations being off their wavelength. The older types of wavemeters were easily thrown out of adjustments by temperature changes and sometimes the calibration was affected by the treatment received in shipment. The quartz plate standard eliminates both of these difficulties.