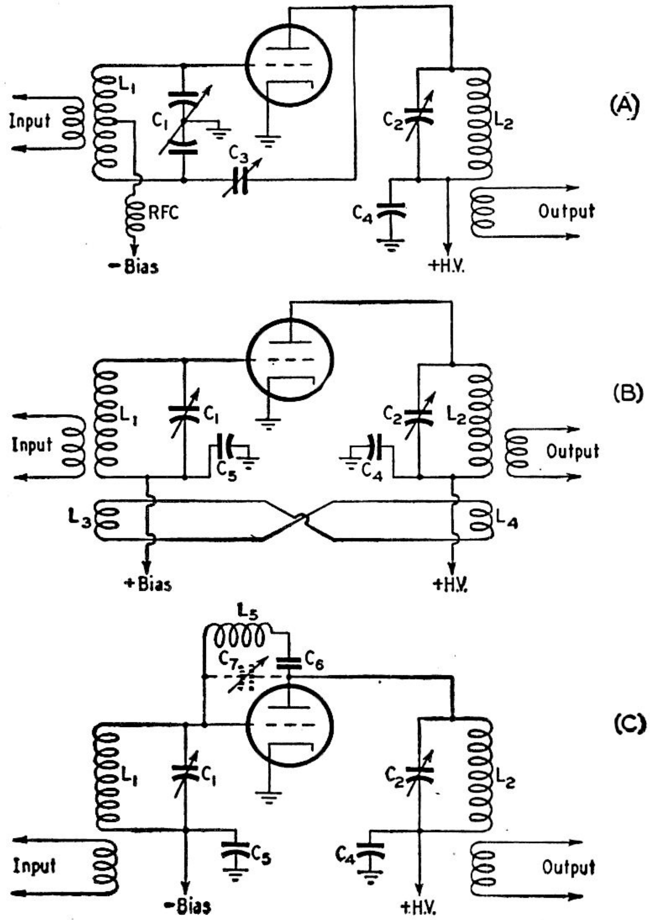


Fig. 6-14 — **Additional, but less commonly-used neutralizing circuits. A — Grid neutralizing. B — Link neutralizing. C — Inductive neutralization.**

L_1C_1, L_2C_2 — Tank circuits tuned to operating frequency.
C_3 — Neutralizing condenser — approximately same capacitance as grid-plate capacitance of tube.
C_4 — Plate by-pass condenser — 0.01-μfd. paper.
C_5 — Grid by-pass condenser — 0.01-μfd. paper.
C_6 — Voltage-blocking condenser — 0.001-μfd. mica.
C_7 — Variable condenser to tune trap circuit to operating frequency with L_5 and grid-plate capacitance of tube.
L_3, L_4 — Neutralizing links — 2 to 10 turns, depending upon frequency.
L_5 — Neutralizing trap coil — to tune to operating frequency with C_7 and grid-plate capacitance of tube.

♦

Inductive Neutralization

The inductive-neutralization arrangement of Fig. 6-14C consists merely of making the plate-grid capacitance of the tube part of a circuit tuned to the frequency at which the amplifier is designed to operate. Since such a circuit presents a high impedance to the flow of current at the frequency to which it is tuned (wavetrap), it prevents voltage feed-back.

All of the circuits of Fig. 6-14 have disadvantages in amateur practice, particularly in respect to the tuning range over which a single adjustment of neutralization will hold.

Frequency Multipliers

● FREQUENCY-MULTIPLYING AMPLIFIERS

Output at a multiple of the frequency at which it is being driven may be obtained from an amplifier stage if the output circuit is tuned to a harmonic of the exciting frequency instead of the fundamental. Thus when the frequency at the grid of the stage is 3.5 Mc., output at 7 Mc. may be obtained by tuning the plate tank circuit to 7 Mc. The circuit otherwise remains the same although some of the values may change. Since the input and output circuits are not tuned to the same frequency, neutralization is not required, unless the stage is to be operated at the fundamental also.

Push-Pull Multiplier

A single-tube amplifier, or an amplifier with tubes in parallel, will deliver output at either even or odd multiples of the frequency at which it is being driven. A push-pull amplifier does not work satisfactorily at even multiples, but very well at odd multiples.

Push-Push Multiplier

A two-tube circuit which works well at even harmonics, but not at the fundamental or odd harmonics, is shown in Fig. 6-15. It is known as the push-push circuit. The grids are connected in push-pull while the plates are connected in parallel.

This arrangement has an advantage in some applications. If the heater of one of the tubes is turned off, making the tube inoperative, its grid-plate capacitance, being the same as that of the remaining tube, serves to neutralize the circuit. Thus provision is made for either straight amplification at the fundamental with a single tube, or doubling frequency with two tubes as desired. Since the efficiency of a frequency doubler as usually operated is much less than that of an amplifier working at the fundamental, the additional tube when doubling helps to maintain a constant output level from the stage, whether operating at the fundamental or at the second harmonic.

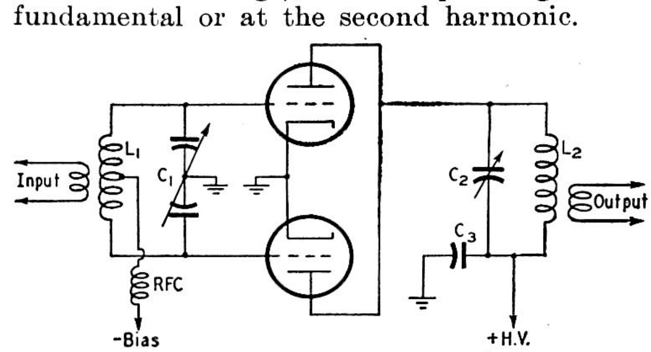


Fig. 6-15 — Circuit of a push-push frequency multiplier for even harmonics. The grid tank circuit, L_1C_1, is tuned to the frequency of the preceding driving stage, while the plate tank circuit, L_2C_2, is tuned to an even multiple of that frequency, usually the second harmonic. C_3 is the plate by-pass capacitor, usually a 0.01-μfd. paper condenser, while *RFC* is a 2.5-mh. r.f. choke.

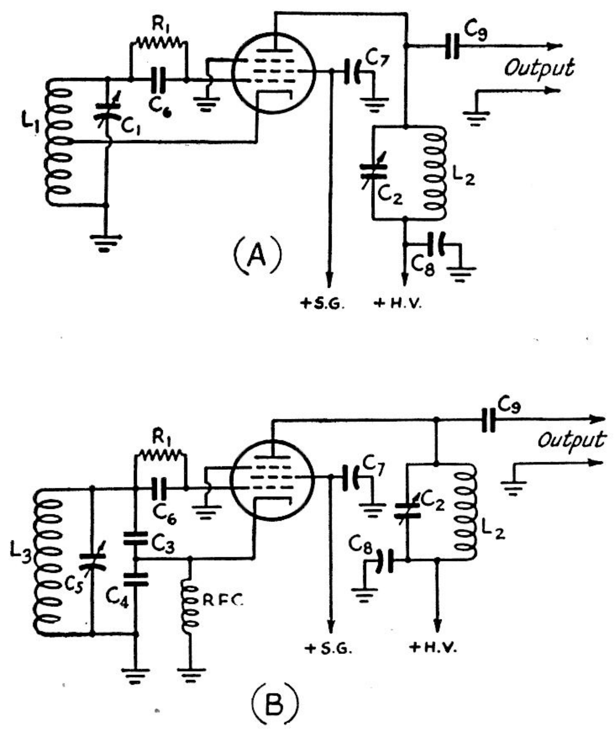


Fig. 6-16 — ECO circuits. A — Hartley. B — Colpitts. Approximate values are as follows:

C_1 — Oscillator tank condenser — for 3.5 Mc.: 500 μμfd. or more total, including any fixed capacitance which may be employed for bandspread purposes.
C_2 — Output tank condenser — 100-μμfd. variable.
C_3 — Tank condenser — 0.003-μfd. mica for 3.5 Mc.
C_4 — Tank condenser — 0.001-μfd. mica for 3.5 Mc.
C_5 — Tuning condenser — 250-μμfd. variable for 3.5 Mc.
C_6 — Grid condenser — 100 μμfd. or less, mica.
C_7 — Screen by-pass condenser — 0.01-μfd. paper.
C_8 — Plate by-pass condenser — 0.01-μfd. paper.
C_9 — Output coupling condenser — 100 μμfd. or less, mica.
R_1 — Grid leak — 50,000 ohms.
L_1 — Oscillator tank coil — 4.3 μhy. tapped approximately one-third from ground end for 3.5 Mc. (with 500 μμfd).
L_2 — Output tank coil — 22 μhy. for 3.5 Mc., 7.5 μhy. for 7 Mc.
L_3 — Oscillator tank coil — 3.3 μhy. for 3.5 Mc. with capacitance values given for C_3, C_4 and C_5.
RFC — Parallel-feed r.f. choke — 2.5 mh.

Multiplications of three and sometimes four or five are used to reach the bands above 28 Mc. from a lower-frequency crystal, but in the majority of lower-frequency transmitters, multiplication in a single stage is limited to a factor of two because of the rapid decline in efficiency as the multiplication factor is increased. Screen-grid tubes make the best frequency multipliers because their high power-sensitivity makes them easier to drive than triodes.

● FREQUENCY-MULTIPLYING OSCILLATORS

Electron-Coupled Oscillators

Several circuits have been devised in which a single screen-grid tube performs the functions of both an oscillator and an amplifier. The ECO circuits of Fig. 6-16 are of this type. The screen serves as the plate of a triode oscillator, while the power is taken from a separate tuned output-plate tank circuit.

In Fig. 6-16A, the oscillator circuit is a Hartley in which the ground point has been shifted from the cathode to the "plate." Fig. 6-16B shows the Colpitts modified in a similar manner. The choke, *RFC,* is required to provide a d.c. path to the cathode without grounding it for r.f. Output at a multiple of the oscillator frequency may be obtained by tuning the output-plate tank circuit to the desired harmonic, although this is seldom done beyond the second harmonic.

In both of these circuits, the oscillator frequency is not entirely independent of tuning or loading in the output plate circuit. The reaction is less, however, when the output-plate circuit is tuned to a harmonic or replaced by an untuned circuit, such as an r.f. choke, as shown in Fig. 6-17. The power output obtainable with the latter arrangement is much lower, however.

Tri-Tet Circuit

Fig. 6-18 shows three crystal-oscillator circuits which operate on principles similar to those of the ECO. Circuits such as these have the additional advantage that they are invariably found to key more reliably than the simple triode or tetrode circuits, and do not incur the considerable loss in efficiency sometimes involved in detuning the plate circuit far to the high-frequency side of resonance for reliable crystal starting under load.

The extent to which the output-plate circuit reacts on the oscillator portion of the circuit, and the output-circuit tuning characteristics, are influenced to a considerable degree by the effectiveness of the screening of the tube selected. Well-screened tubes always are preferable from the standpoints of both isolation and safety to the crystal.

Fig. 6-18A shows the Tri-tet circuit. The oscillator portion is equivalent to that of a triode crystal oscillator, with the screen serving as the "plate" and the ground point being shifted from the cathode to the "plate." Power is taken from a separate output-plate tank circuit. Since the output-plate circuit returns to cathode through the L_1C_1 tank circuit, the plate contributes to the feed-back to a certain

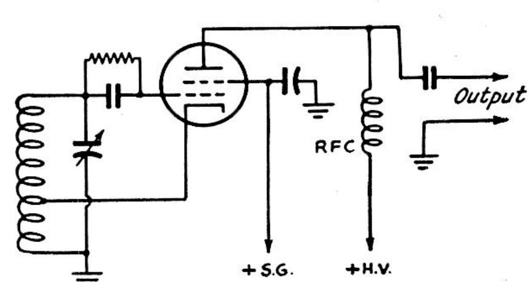


Fig. 6-17 — ECO with an r.f. choke replacing the output tank circuit for the purpose of reducing reaction on the oscillator portion of the circuit.

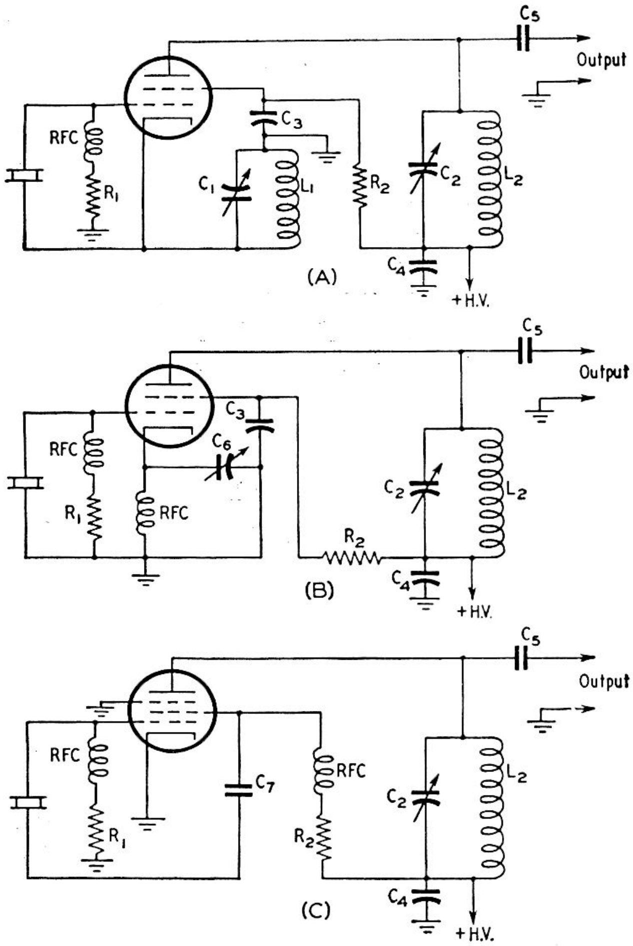


Fig. 6-18 — Crystal-controlled amplifying-oscillator circuits. Approximate values are as follows:

C_1 — Cathode-tank tuning condenser — 100-μμfd. variable.
C_2 — Output-tank tuning condenser — 100-μμfd. variable.
C_3 — Screen by-pass condenser ("plate" grounding) — 0.01-μfd. paper.
C_4 — Plate by-pass condenser — 0.01-μfd. paper.
C_5 — Output coupling condenser — 100 μμfd. or less, mica.
C_6 — Feed-back-control condenser — 100-μμfd. variable.
C_7 — Parallel-feed blocking condenser — 0.001-μfd. mica.
R_1 — Grid leak — 50,000 to 150,000 ohms.
R_2 — Screen voltage-dropping resistor — 25,000 to 100,000 ohms.
L_1C_1 — Tuned to desired harmonic of crystal or well above crystal frequency for fundamental operation (see text).
L_2C_2 — Tuned to desired output frequency.
RFC — Parallel-feed r.f. choke — 2.5 mh.

extent. Therefore, L_1C_1 should always be tuned well to the high-frequency side of the crystal frequency to prevent excessive feedback and consequent unnecessarily-high voltage across the crystal. As with the ECO (Fig. 6-16) and the circuits in Fig. 6-18, harmonic output may be obtained by tuning the output tank circuit, L_2C_2, to the desired multiple of the crystal frequency. In the Tri-tet circuit best harmonic output will be obtained with L_1C_1 also tuned to the desired harmonic.

When operating the Tri-tet circuit at the crystal frequency, L_1C_1 should be tuned no closer to the crystal frequency than is necessary to make the circuit oscillate without output-plate voltage applied. When the oscillator is to be used to obtain output at the fundamental or at harmonics as desired, the cathode tank circuit, L_1C_1, may be tuned to the highest multiple of the crystal frequency at which output is required. While the output at the crystal frequency and lower harmonics under this condition is less than the maximum obtainable with optimum cathode-circuit adjustment, it is usually at least as much as is obtainable at the highest harmonic and therefore the power output from the oscillator is approximately the same on all bands.

With well-screened tubes, such as the 6SK7, 2E25 or 802, the output-plate tuning characteristic is like that shown in Fig. 6-19 at the fundamental as well as at the harmonics and the circuit will continue to oscillate regardless of the tuning of the output circuit. However, with poorly-screened tubes, such as the 6V6, 6F6 or 6L6, the circuit will stop oscillating abruptly when the output circuit is tuned to a frequency lower than the crystal frequency, more in the manner of a simple triode or tetrode oscillator. With well-screened tubes, feed-back is at a minimum when the output circuit is unloaded, the excitation increasing as load is increased. This characteristic is opposite to that of the triode or tetrode crystal oscillator.

Grid-Plate Oscillator

A less widely-used circuit is the grid-plate crystal-oscillator circuit of Fig. 6-18B. The oscillator portion is similar to the triode Pierce with the screen being used as the "plate," and the ground point shifted to the "plate." L_2C_2 is the output-plate circuit. C_6 adds to the "plate"-cathode capacitance for feed-back-adjustment purposes. As in the Tri-tet circuit, the return for the output-plate circuit to cathode is through C_6 which is common to the grid return, and therefore the isolation between oscillator and output circuits is incomplete and the plate contributes to the feed-back. However, with a well-screened tube the oscillator will continue to function regardless of the tuning of the output circuit. This circuit is used principally for its performance at the crystal fundamental, where it is superior

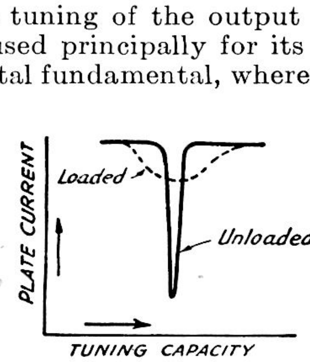


Fig. 6-19 — Plate tuning characteristic for Tri-tet, grid-plate and modified Pierce crystal-oscillator circuits, using well-screened tubes, for loaded (dashed line) and unloaded (solid line) conditions. In this case, the output-plate circuit may be tuned accurately to the minimum plate-current dip for maximum output.

to that of the simple triode or tetrode circuits. Only at odd harmonics is it equal or possibly superior to the Tri-tet circuit.

Modified Pierce

Another version of the Pierce circuit, adaptable to pentodes, is shown in Fig. 6-18C. The oscillator portion of the circuit is the triode Pierce with the cathode grounded and the screen serving as the "plate." In this arrangement the output-plate and grid returns are through independent paths and the suppressor provides screening against capacitance coupling. In theory, at least, this circuit provides better isolation between the oscillator and output portions of the circuit than either of the other two. Pentodes, such as the 6SK7, 6AG7 and 802 are suitable for this circuit.

Interstage Coupling

Of the various systems that have been devised for feeding the output of one stage into the input of another, the inductive-link and capacitive systems are the most widely used in amateur transmitters. The link system is used principally in cases where there must be appreciable physical separation between stages, where balanced and unbalanced circuits are to be coupled, or when minimum circuit capacitance is desired. The capacitive system has the advantages of simplicity, cheapness and compactness, but it does not lend itself so well to the conditions listed above.

● INDUCTIVE SYSTEMS

Link Coupling

The link system, examples of which are shown in Fig. 6-20, consists merely of a two-wire low-impedance line with each end terminated in a coil of a few turns coupled tightly to the low-potential point of the output tank coil of the driver and the input tank coil of the driven stage. This low-potential point occurs at the "ground" end of the tank coil in unbalanced circuits (Fig. 6-20A, B and C) and at the center of the tank coil in balanced arrangements (Fig. 6-20B, C and D).

The coupling between the two stages can be adjusted either by changing the number of turns in the link windings or by changing the coupling between the links and the tank coils. This system does not upset the symmetry of a balanced circuit through the introduction of unbalancing capacitances of the single-ended circuit coupled to it.

♦

Fig. 6-20A shows the link system coupling two unbalanced circuits. This arrangement would be used, for instance, in coupling an oscillator or a screen-grid driver/amplifier to the input of a single-tube stage.

The scheme at B would be suitable for coupling a neutralized or push-pull driver to a single-tube amplifier.

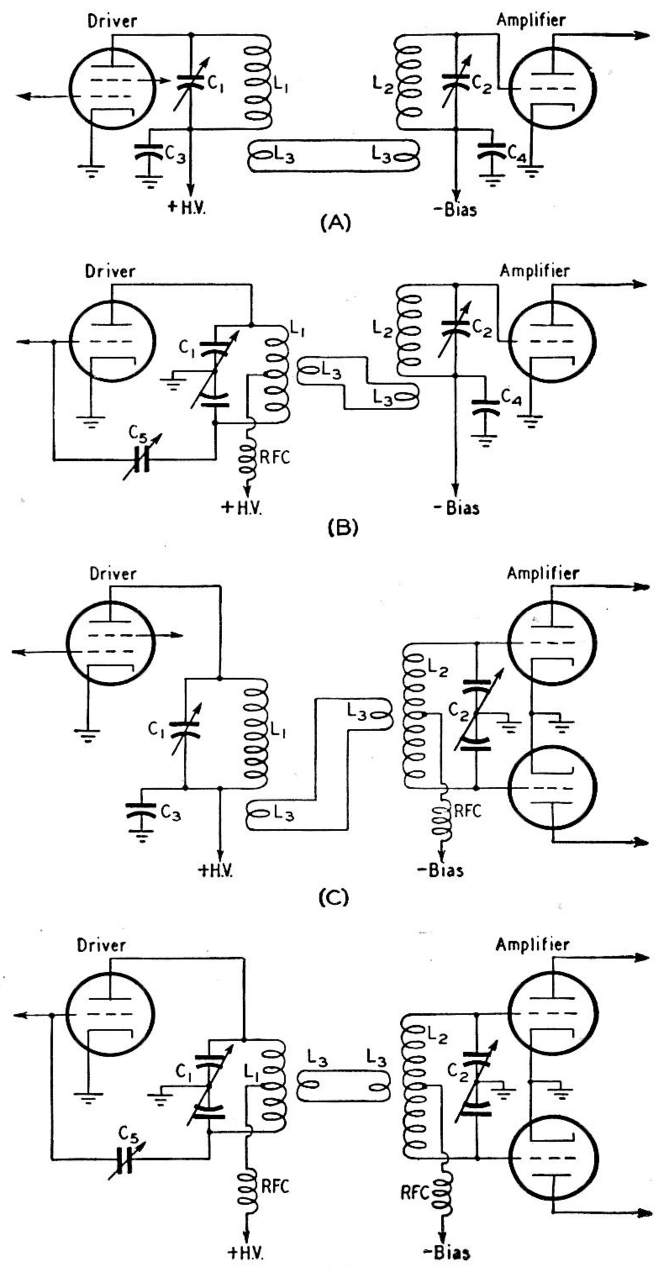


Fig. 6-20 — Link-coupling circuits. A — Unbalanced output to unbalanced input. B — Balanced output to unbalanced input. C — Unbalanced output to balanced input. D — Balanced output to balanced input.

C_1 — Driver-stage plate tank condenser.
C_2 — Driven-stage grid tank condenser.
C_3 — Plate by-pass condenser.
C_4 — Grid by-pass condenser.
C_5 — Neutralizing condenser.
L_1 — Driver output tank coil.
L_2 — Driven-stage input tank coil.
L_3 — Link winding.
L_1C_1 and L_2C_2 are always tuned to the same frequency.
RFC — R.f. choke.

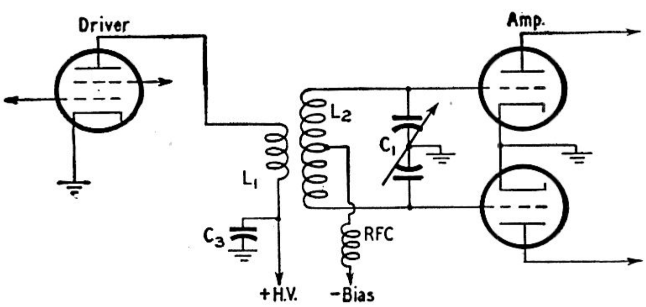


Fig. 6-21 — **Inductive coupling from unbalanced output to balanced input.**

C_1 — Driven-stage grid tank condenser.
C_3 — Plate by-pass condenser.
L_1 — Self-resonant (approximately) output coil.
L_2 — Driven-stage grid tank coil.
***L_1 and L_2* should be coupled tightly.**
RFC — R.f. choke.

Fig. 6-20C shows the method applied in coupling the output of an unneutralized driver to a push-pull amplifier, while D is the circuit to be used in coupling a neutralized or push-pull stage to another push-pull input.

Inductive Coupling

Another system which is used sometimes in coupling between an unbalanced driver and a balanced amplifier is shown in Fig. 6-21. The output coil of the driver stage is designed to resonate, with the driver-tube and circuit capacitances, near the desired operating frequency. The amplifier input tank circuit tunes to the operating frequency and serves to a considerable degree also to tune the output circuit of the driver stage, since the two coils are coupled quite tightly. L_1 should be wound centrally over or inside L_2 and the turns of L_1 adjusted experimentally for optimum power transfer.

● CAPACITIVE COUPLING

In a capacitive coupling system, the output tank circuit of the driver stage serves also as the input tank circuit of the driven stage. Several arrangements for coupling between balanced and unbalanced output and input circuits, depending upon whether series or parallel power feed is desired, are shown in Fig. 6-22. The coupling usually can be adjusted satisfactorily by changes in the value of the coupling capacitance, but sometimes wide differences in impedances of the two circuits to be coupled make it necessary to tap either the plate of the driver or the grid of the

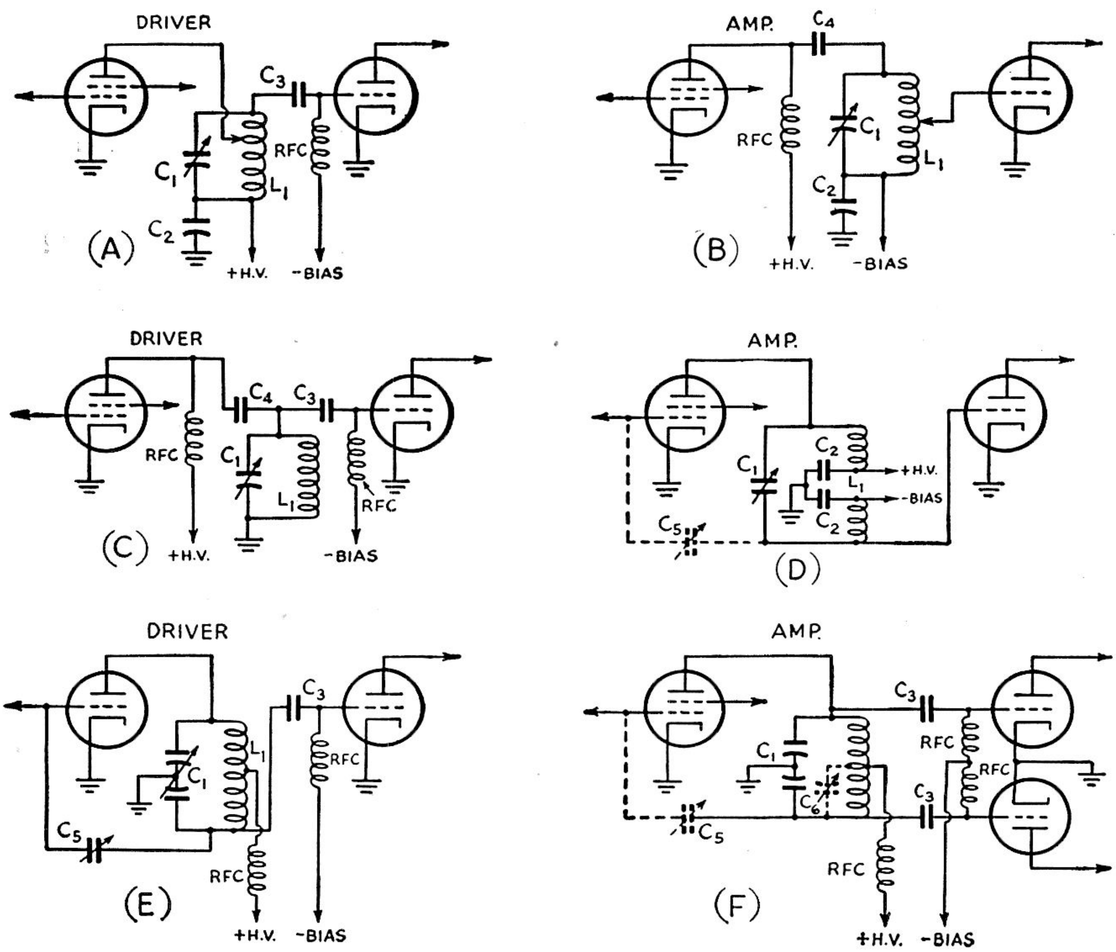


Fig. 6-22 — Examples of capacitive coupling. A — Series plate feed, parallel grid feed. B — Parallel plate feed, series grid feed. C — Parallel feed in both plate and grid. D — Series feed in both plate and grid. E — Balanced output to unbalanced input, series plate feed, parallel grid feed. F — Single tube to push-pull.

C_1 — Tank condenser.
C_2 — By-pass condenser.
C_3 — Coupling condenser.
C_4 — Plate blocking condenser.
C_5 — Neutralizing condenser.
C_6 — Circuit-balancing condenser.
L_1 — Tank coil.
RFC — R.f. choke.

driven tube down on the tank coil, as shown in Fig. 6-22A and B.

With capacitive coupling, the two stages cannot be separated physically any appreciable distance without involving loss in transferred power and the danger of instability because of feed-back which long high-impedance leads may provide. Since both the output capacitance of the driver tube and the input capacitance of the driven tube are lumped across the single tuned circuit, this sometimes makes it difficult, with the high-capacitance of screen-grid tubes, to obtain a tank circuit with a sufficient amount of inductance to provide an efficient circuit for the higher frequencies. Another disadvantage is that it is difficult to preserve circuit balance in coupling from a single-tube stage to a push-pull stage because the circuit tends to become unbalanced by the output capacitance of the driver tube which appears across only one side of the circuit. This does not, however, preclude its use for this purpose, if simplicity in circuit is considered of greater importance, for frequencies below 30 Mc.

The arrangements of Fig. 6-22A and B are most often seen with the plate tap of A and the grid tap of B connected to the top end of the coil, since this connection is satisfactory in the majority of cases. A is used when series driver plate feed is desired; B when series amplifier grid feed is wanted. In the circuit of C, the tank condenser and coil are grounded directly, but parallel power feed is required for both driver plate and amplifier grid.

An arrangement which makes possible series feed to both plate and grid is shown at D. L_1 in D is a single coil, opened at the center for feeding in plate and biasing voltages. Since the by-pass condensers, C_2, are directly in the tank circuit, they should be of good-grade mica and capable of handling the r.f. current circulating through the tank circuit. Because it provides a "double-ended" output circuit, it may be used in a neutralized amplifier stage simply by the addition of neutralizing condenser C_5.

The grid of the driven tube and the plate of the driver tube being connected across opposite halves of the tank circuit helps to distribute stray capacitances more evenly, thereby preserving a better circuit balance. A still better balance can be achieved by using a split-stator condenser at C_1 and a single mica condenser at C_2, grounding the circuit at the split-stator rotor rather than between the two fixed condensers. Excitation may be adjusted, if necessary, by tapping the grid or plate, as may be required, down on the coil. Such a change, however, will necessitate readjustment of neutralization if the tank is used for neutralizing the driver as suggested.

The circuit of Fig. 6-22E is the preferred arrangement for coupling a neutralized driver to a single-tube amplifier in cases where series feed to the grid of the amplifier is not considered important. F shows the same system feeding a push-pull amplifier. If a more accurate balance is desired, a balancing condenser, C_6, can be used to compensate for the driver-tube output capacitance across the other half of the circuit.

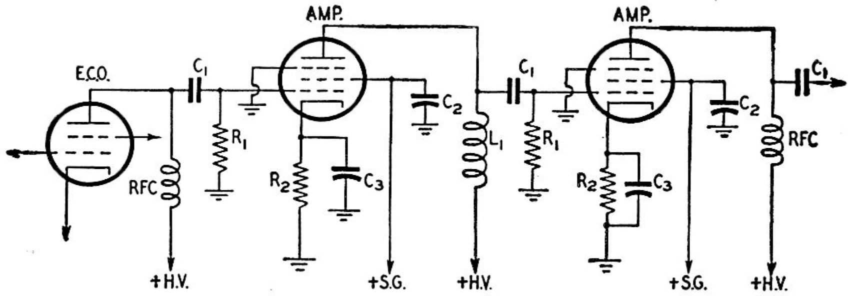


Fig. 6-23 — Diagram showing two isolating-amplifier stages coupled to the output of an ECO.

C_1 — Coupling condenser — 100 $\mu\mu$fd. or less, mica.
C_2 — Screen by-pass condenser — 0.01-μfd. paper.
C_3 — Cathode by-pass condenser — 0.01-μfd. paper.
R_1 — Grid leak — 50,000 to 100,000 ohms.
R_2 — Cathode biasing resistor — 200 to 500 ohms.
L_1 — Coupling inductance — see text.
RFC — Plate choke — 2.5-mh.

● ISOLATING AMPLIFIERS

In an unneutralized triode amplifier, changes occurring in the plate circuit, such as alterations in plate voltage, plate-tank tuning or loading, will reflect changes in the effective input capacitance of the tube. When the amplifier is connected to a VFO, these variations will change the frequency of the VFO. Neutralization of a triode amplifier or the substitution of a screen-grid tube will reduce these effects, but will not eliminate them entirely, especially in the case of screen-grid tubes whose electrode voltages are not regulated.

Most of the change takes place when the plate tank circuit is tuned near resonance. Therefore one measure which can be taken to improve isolation is the use of a fixed nonresonant circuit instead of the usual tuned tank in the plate circuit.

The diagram of Fig. 6-23 shows two such stages coupled to a VFO. A nonresonant circuit also is substituted in the plate circuit of the ECO. An r.f. choke is used as the nonresonant circuit in the output of the ECO and in the second amplifier. L_1 in the plate circuit of the first amplifier is a winding that is self-resonant with the tube and circuit capacitances at a frequency near but not in the band of frequencies over which the amplifier is intended to operate. This is to prevent forming a low-frequency t.g.t.p. oscillating circuit which occurs when chokes of approximately the same characteristics are used in both input and output circuits of the amplifier tubes. For the same reason, resistors without chokes are used in the grid circuits.

The power gain of an amplifier of this type is quite small, the purpose being almost entirely that of securing isolation between the VFO and power amplifiers which would react on the frequency of the oscillator if coupled to it directly. Two amplifier stages of this type usually are necessary before a following amplifier can be tuned or keyed without noticeably affecting the oscillator frequency and stability.

Amplifier and Multiplier Tank-Circuit Design

● *L/C* RATIO

Plate Tank Capacitance

Power cannot be readily coupled out of a plate tank circuit if the ratio of inductance to capacitance (*L/C* ratio) is too great. Also, harmonics are more readily generated in a tank circuit in which this ratio is high. On the other hand, a large capacitance and small inductance will cause high currents to circulate in the tank circuit increasing the losses and reducing the efficiency of the amplifier. Unless one of these factors is considered to be of greater importance than the other, a compromise value for the *L/C* ratio usually is selected.

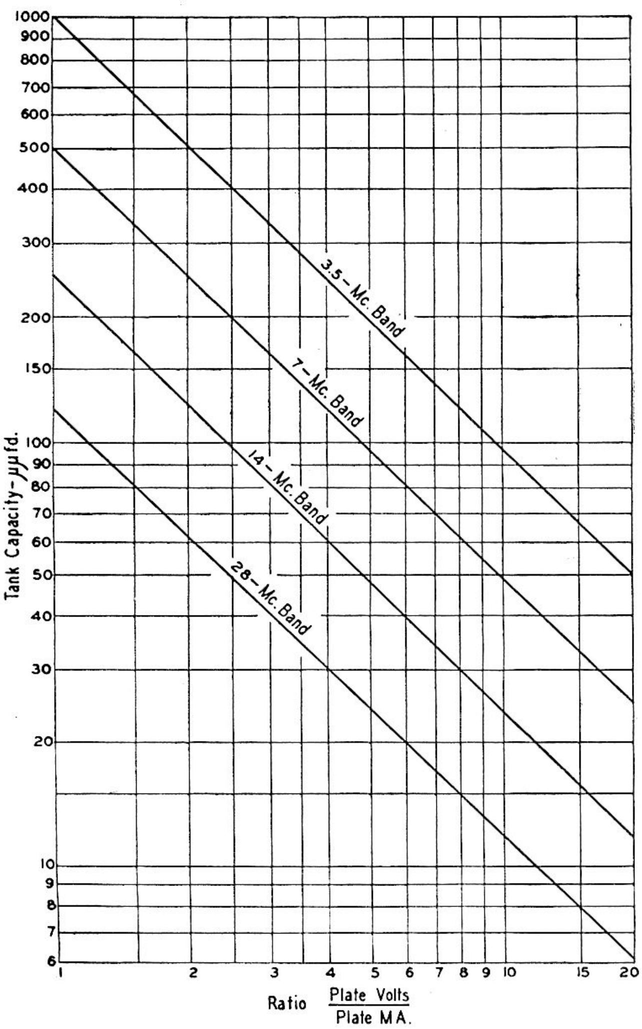


Fig. 6-24 — **Chart showing minimum plate tank capacitances recommended with various ratios of plate voltage to plate current, for the four low-frequency amateur bands. In the circuits F, G and H of Fig. 6-25, the values shown by the graph may be divided by four. In circuits C, D, E, I, J and K, the capacitance of each section of the split-stator condenser may be one-half the value shown by the graph. The full graph values should be used for circuits A and B. These values are based on a circuit *Q* of 12.**

With the conditions under which r.f. power amplifiers in amateur transmitters usually are operated, the *L/C* ratio for the same degree of harmonic suppression and coupling varies in inverse proportion to the ratio of d.c. plate voltage to plate current with the amplifier in operation and loaded. The chart of Fig. 6-24 shows recommended values of tank capacitance for a wide range of plate-voltage/plate-current ratios for each of the low-frequency amateur bands. The values given apply to the type of plate tank circuits shown in Fig. 6-25A and B only. Because the tube is connected across only half of the tank in the remainder of the circuits shown in Fig. 6-25, the total capacitance across the tank coil may be reduced to one-quarter that shown by the graph for the same plate-voltage/plate-current ratio. This means that in circuits in which a split-stator condenser is used, the capacitance of each section of the condenser may be half the value shown in the graph, since the two sections are in series across the coil.

The values shown in Fig. 6-24 are the capacitances which should be in actual use when the circuit is tuned to resonance in the selected band — not the maximum rated capacitance of the tank condenser including tube and circuit capacitances. They should be considered minimum values for satisfactory operation. They can be exceeded 50 to 100 per cent without involving an appreciable loss in circuit efficiency.

Approximately the same *L/C* ratio should be used in the plate tank circuit whether the stage is operating as a straight amplifier or multiplying frequency in order to confine the output to the desired multiple as much as possible.

Plate Tank Coils

The inductance of manufactured coils usually is based upon the highest plate-voltage/plate-current ratio likely to be used at the maximum power level for which the coils are designed, following the logical conclusion that it is easier to cut off turns than to add them. Therefore in the majority of cases, the capacitance shown by Fig. 6-24 will be greater than that for which the coil is designed and turns

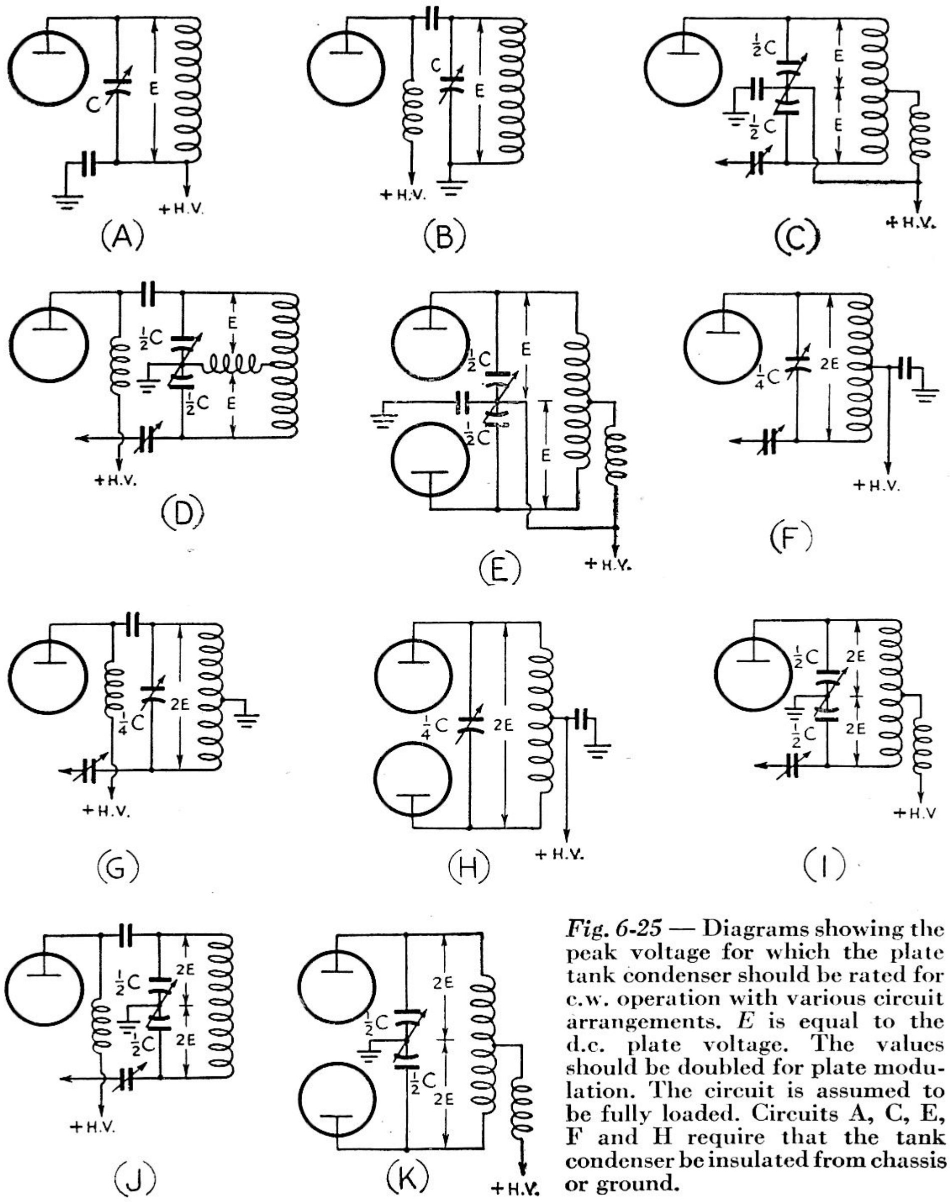


Fig. 6-25 — Diagrams showing the peak voltage for which the plate tank condenser should be rated for c.w. operation with various circuit arrangements. *E* is equal to the d.c. plate voltage. The values should be doubled for plate modulation. The circuit is assumed to be fully loaded. Circuits A, C, E, F and H require that the tank condenser be insulated from chassis or ground.

must be removed to permit the use of the proper value of capacitance. At 28 Mc., and sometimes 14 Mc., the value of capacitance shown by the chart for a high plate-voltage/plate-current ratio will be lower than that attainable in practice with the components available. The design of manufactured coils usually takes this into consideration also and it may be found that values of capacitance greater than those shown in the graph are required to tune these coils to the band.

Manufactured coils are rated according to the plate power input to the tube or tubes when the stage is loaded. Since the circulating tank current is much greater when the amplifier is unloaded, care should be taken to operate the amplifier conservatively when unloaded to prevent damage to the coil from excessive heating.

Plate Tank-Condenser Voltage

In selecting a tank condenser with a spacing between plates sufficient to prevent voltage breakdown, the peak r.f. voltage across the tank circuit without modulation may be taken as equal to the d.c. plate voltage. If the d.c. plate voltage also appears across the tank condenser, this must be added to the peak r.f. voltage, making the total peak voltage twice the d.c. plate voltage. If the amplifier is to be plate-modulated, this last value must be doubled to make it four times the d.c. plate voltage, because both d.c. and r.f. voltages double with 100-per-cent plate modulation. At the higher plate voltages, it is desirable to choose a tank circuit in which the d.c. and modulation voltages do not appear across the tank condenser, to permit the use of a smaller condenser with less plate spacing. Fig. 6-25 shows the peak voltage, in terms of d.c. plate voltage, to be expected across the tank condenser in various circuit arrangements. These peak-voltage values are given assuming that the amplifier is loaded to rated plate current. Without load, the peak r.f. voltage will run much higher. Since a c.w. transmitter may be operated without load while adjustments are being made, although a modulated amplifier never should be operated without load, it is sometimes considered logical to select a condenser for a c.w. transmitter with a peak-voltage rating equal to that required for a 'phone transmitter of the same power. However, if minimum cost and space are considerations, a condenser with half the spacing required for 'phone operation can be used in a c.w. transmitter for the same carrier output, as indicated under Fig. 6-25, if power is reduced temporarily while tuning up without load.

The plate spacing to be used for a given peak voltage will depend upon the design of the variable condenser, influencing factors being the mechanical construction of the unit, the dielectric used and its placement in respect to intense fields, and the condenser-plate shape and degree of polish. Condenser manufacturers usually rate their products in terms of the peak voltage which can be handled between plates.

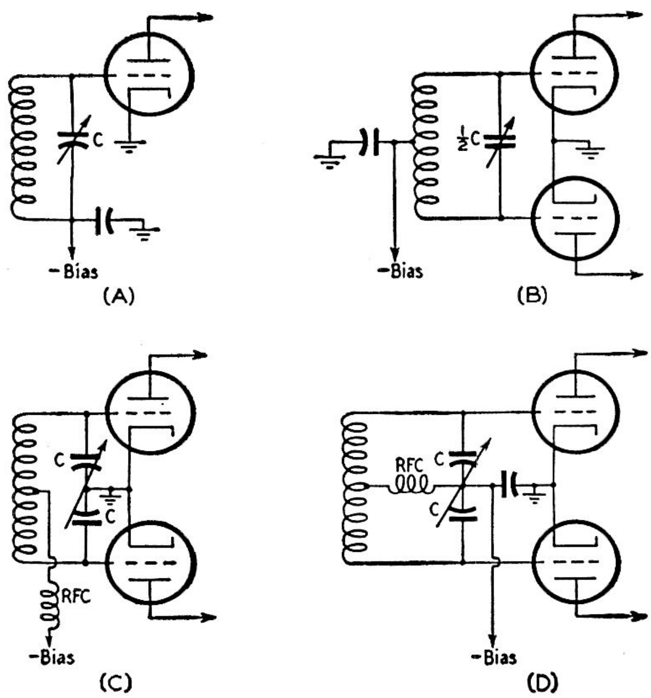


Fig. 6-26 — **Diagrams for determining grid tank-condenser capacitance. *C* should be a minimum of 200 μμfd. for 3.5 Mc., 100 μμfd. for 7 Mc., 50 μμfd. for 14 Mc. and 25 μμfd. for 28 Mc.**

The tank condenser should have a voltage rating approximately equal to the operating bias voltage plus 20 per cent of the plate voltage for circuit A, twice this value for circuit B and each section of the condenser in circuit D, while the biasing voltage must be added to this latter figure in determining the voltage rating of each section of the condenser in circuit C.

Plate-Blocking and By-Pass Condensers

Plate-blocking and by-pass condensers in amplifier stages should have a voltage rating of 25 to 50 per cent above the tube plate-supply voltage if the stage is not modulated or twice this rating if the stage is to be plate-modulated. Paper 0.01-μfd. condensers are satisfactory for use in exciter stages operating at plate voltages of 500 or less. At higher plate voltages mica condensers having a capacitance of 0.001 to 0.002 μfd. with appropriate voltage ratings should be used.

R.F. Chokes

Parallel plate feed provides a considerable measure of protection against serious injury to the operator from accidental contact with high-voltage d.c. in the tank circuit. However, the r.f. choke in this case is called upon to present a high impedance at the operating frequency if serious loss of power in the choke is to be avoided. When a transmitter is designed to operate on all amateur bands from 28 Mc. to 3.5 Mc., loss in r.f. chokes often occurs on one or more of the bands. There is no simple remedy for this difficulty aside from a shift to series plate feed which, of course, nullifies the safety angle. One possible remedy which has not yet been fully developed is the use of different r.f. chokes for each band, the chokes being switched or plugged in along with the tank coil.

● GRID TANK CIRCUITS

The value of capacitance to be used in a grid tank circuit when employing link coupling is not critical so long as the *L/C* ratio is low enough to permit satisfactory coupling to the driver stage. A capacitance of at least 200 μμfd. is recommended for unbalanced grid tank circuits tuned to 3.5 Mc., with the value decreased in proportion as the frequency increases, as given under Fig. 6-26. For unbalanced grid tank circuits, the total condenser capacitance may be cut in half, making the capacitance of each section of a split-stator condenser the same as that of the single condenser used in an unbalanced input grid tank circuit.

Approximate tank-condenser voltage ratings are suggested under Fig. 6-26. Tank coils with a power rating equal to that of the driver plate tank coil should be used in the grid tank circuit.

It is advantageous to operate a link-coupled grid tank circuit of a frequency multiplier with a somewhat higher *L/C* ratio than that used for straight amplification from the consideration of driving efficiency, but the ratio cannot be made too great without encountering coupling difficulties.

Amplifier Operating Factors

● USING TUBE DATA

Transmitting-tube instruction sheets and data tables specify the limitations on various electrode voltages and currents which should be observed to insure normal tube life. Included also are sets of optimum operating conditions which should be followed as closely as possible to obtain rated output with good efficiency.

Filament Voltage

The filament voltage for the indirectly-heated cathode-type tubes found in low-power classifications may vary 10 per cent above or below rating without seriously reducing the life of the tube. But the voltage of the higher-power filament-type tubes should be held closely between the rated voltage as a minimum and 5 per cent above rating as a maximum. Care should be taken to make sure that the plate power drawn from the power line does not cause a drop in filament voltage below the proper value when plate power is applied.

Thoriated-type filaments lose emission when the tube is overloaded appreciably. If the overload has not been too prolonged, emission sometimes may be restored by operating the filament at rated voltage with all other voltages removed for a period of 10 minutes, or at 20 per cent above rated voltage for a few minutes.

Grid Bias

Two values of grid-biasing voltage are of interest in the practical operation of r.f. power amplifiers and frequency multipliers. These are **protective bias** and **operating bias.**

Protective bias must be used with all but "zero-bias"-type tubes to hold the power input to the tube below the rated dissipation value when excitation is removed without removing plate (and screen) voltage. Without excitation, the amplifier delivers no power. Therefore any power input is dissipated in heat which would ruin the tube in a short space of time. This condition exists when the transmitter is keyed ahead of the amplifier, while tuning adjustments are being made, or through failure of a crystal oscillator to function or other accidental failures.

Operating bias is the value of biasing voltage between grid and cathode when the amplifier is being driven and delivering power. The optimum value of biasing voltage for operating under a given set of conditions is listed in tube tables and manuals. Frequency multipliers require a considerably-higher operating bias for most efficient operation.

Protective bias may be any value between that which limits the input to the tube to its rated plate (and screen) dissipation as a minimum, and the operating value as a maximum. It is common practice, however, to set the value at some point between that which is necessary to cut off plate current completely (cut-off value) and the operating value. With fixed plate voltage, the cut-off value for a triode can be determined quite closely by dividing the plate voltage by the amplification factor obtained from the tube data sheet. For screen-grid tubes, the amplification factor of the screen must be used instead. In cases where this is not included in the operating data, the approximate cut-off value may be obtained from an inspection of the plate-current plate-voltage curves which show the plate current for a wide range of plate and biasing voltages.

A factor which must be considered in determining the value of bias which will protect the tube is plate- (and screen-) voltage regulation. If the power-supply regulation is poor, or if the plate or screen is fed from a resistance voltage divider or a voltage-dropping resistor, the electrode voltages will soar as the tube draws less than normal operating current and therefore an increase over the calculated value of cut-off bias will be required to bring the current to zero. This condition is encountered most often in the operation of a screen-grid tube where the screen is not fed from a fixed-voltage source. In such cases, care should be taken to make certain that the proper operating bias is not exceeded under operating conditions when excitation is applied.

Several different systems for obtaining bias are shown in Fig. 6-27. At A, bias is obtained entirely from the voltage drop across the grid leak, R_1, caused by the flow of rectified grid current when the amplifier is being driven. This sytem has the desirable feature that the biasing voltage, being dependent upon the value of grid current, is kept adjusted close to proper operating value automatically over a considerable range of excitation levels. However, when excitation is removed, grid-current flow ceases and the voltage across R_1 falls to zero and there is no bias. Therefore this system provides no protection for the amplifier tube in case excitation fails or is removed.

A battery delivering the required operating bias is used in the arrangement of Fig. 6-27B. Since the biasing voltage still remains when excitation is removed, plate-current flow ceases and the tube is protected. A factor which must be taken into consideration when dry batteries, such as "B" batteries, are used, is the resistance of the batteries. If the internal resistance is high, the resistance will cause an increase, by grid-leak action, in the operating bias above that normally delivered by the batteries. Batteries develop internal resistance with age and should be replaced from time to time. Another factor is that the direction of grid-current flow is such as to reverse the normal direction of current through the battery. This acts to charge the battery. A battery which has been in use for some time, particularly if the grid current under excitation is high, will show a considerably higher-than-rated terminal voltage because of the charging action of the grid current. The terminal voltage of a battery used in transmitter bias service where grid current flows cannot be used as an indication of the condition of the battery. Its internal resistance may be high, even though it shows normal or above-normal terminal voltage. If the grid current in a battery-biased stage falls off after a period of operation and no other reason is obvious, it is probable that the biasing battery should be replaced. The battery life which may be expected in bias service with a given value of grid current will be approximately the same as it would be if that same current were being drawn from the battery.

In Fig. 6-27C, the battery voltage is reduced to the protective value. When excitation is applied, grid-leak action through R_2 supplies the additional biasing voltage necessary to bring the total up to the operating value. This combination of fixed and grid-leak bias is the most popular system, since it combines the safety of protective fixed bias and a measure of automatic adjustment of the operating value through grid-leak action.

In Fig. 6-27D, a power pack is used to supply protective bias. The output of the power pack is connected across the grid resistor which is of the normal grid-leak value for the

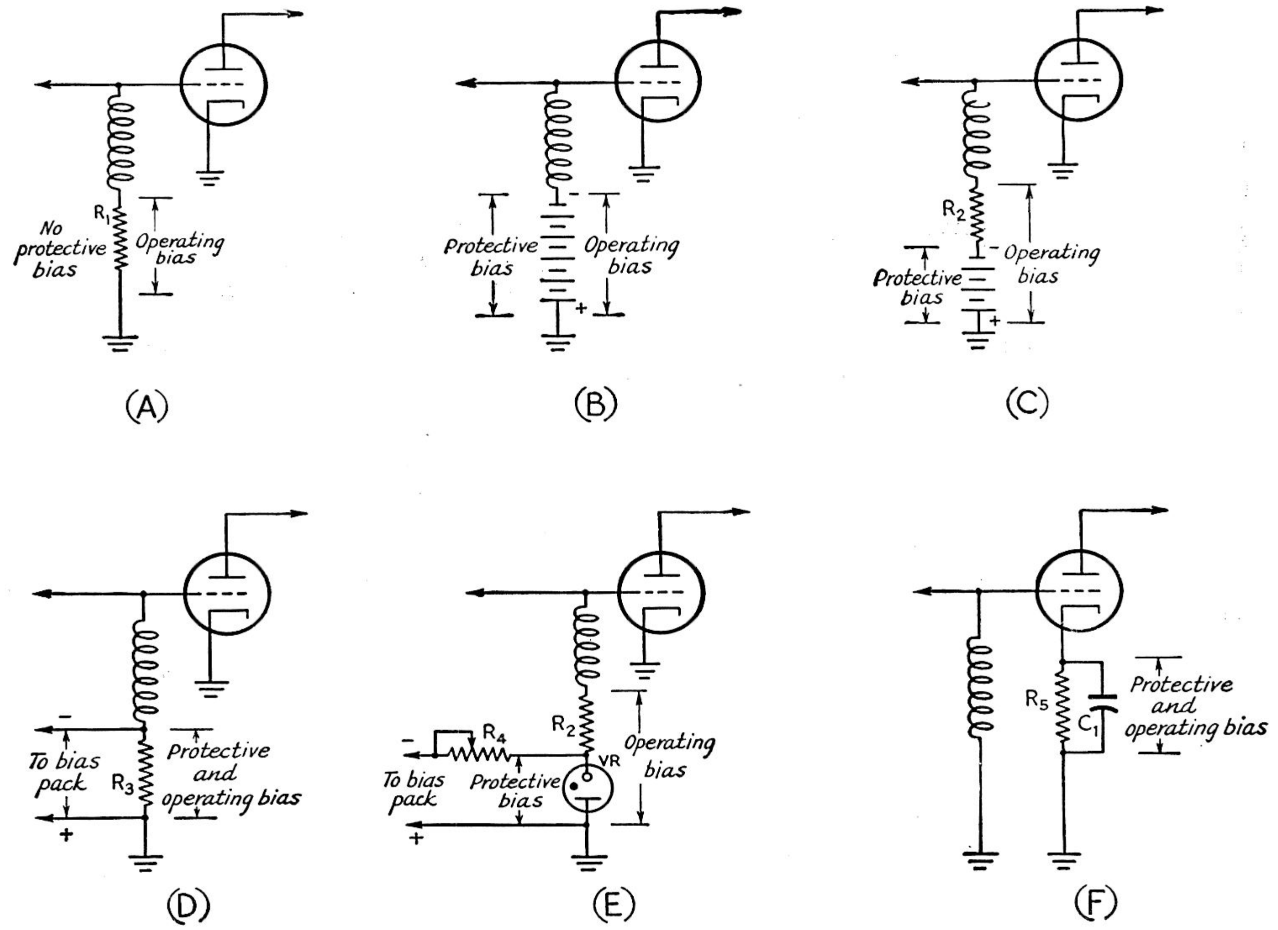


Fig. 6-27 — **Various systems for obtaining protective and operating bias for r.f. amplifiers. A — Grid-leak. B — Battery. C — Combination battery and grid leak. D — Grid leak and adjusted-voltage bias pack. E — Combination grid leak and voltage-regulated pack. F — Cathode bias.**

tube. The peak voltage output of the transformer used in the power pack must not exceed the operating-bias value. A bleeder resistance cannot be used across the output of the pack, nor can the output voltage be reduced by means of a voltage divider or series dropping resistor without affecting the biasing voltage when excitation is applied.

These restrictions on the use of a power pack can be avoided by the addition of a voltage-regulator tube across the output of the pack, as shown in Fig. 6-27E. The voltage across the regulator tube remains constant with or without grid current flowing. By making the voltage-regulator series resistor, R_4, of proper value, the output voltage of the pack may be anything within reason above a minimum of approximately twice the voltage rating of the VR tube. These tubes are available for 75, 90, 105 and 150 volts and each tube will handle up to 30 or 40 ma. of grid current. VR tubes may be used in series to obtain regulated voltages above 150, and in parallel for grid currents above 40 ma. It is usual practice to use a VR tube, or combination of VR tubes in series or series-parallel, with the minimum voltage rating which will give plate-current cut-off, and obtain the additional voltage required to bring the total bias up to the operating value by grid-leak action when excitation is applied, as with battery bias in Fig. 6-27C. The use of VR tubes for this purpose is discussed more fully in Chapter Seven.

A single source of fixed biasing voltage, such as batteries or VR tubes in series, may be used to provide protective bias for more than one amplifier stage, tapping the batteries or connecting to the junction of the tubes in the VR series if lower biasing voltages are required for other stages. In this case, the current flowing through the fixed-bias source is the sum of the individual stages obtaining bias from the source.

In Fig. 6-27F, bias is obtained from the voltage drop across a resistor in the cathode (or filament center-tap) lead. Protective bias is obtained by the voltage drop across R_5 as a result of plate (and screen) current flow. Since plate current must flow to obtain a voltage drop across the resistor, it is obvious that cut-off protective bias cannot be obtained by this system. When excitation is applied, plate (and screen) current increases and the grid current also contributes to the drop across R_5, thereby increasing the bias to the operating value. Since the voltage between plate and cathode is reduced by the amount of the voltage drop across R_5, the supply voltage must be the sum of the plate and operating-bias voltages.

The resistance of R_5 should be adjusted to the value which will give the correct operating bias with rated grid, plate and screen currents flowing with the amplifier loaded to rated input. When excitation is removed, the input to most types of tubes will fall to a value that will prevent damage to the tube, at least for the period of time required to remove plate voltage.

Calculating Bias-Resistor Values

The calculation of the required grid-leak and cathode biasing-resistor values is not difficult. For simple grid-leak bias, as shown in Fig. 6-27A, the resistance is obtained by dividing the required operating-bias voltage by the rated grid current.

Example: Required operating bias = 100 volts.
Rated grid current = 20 ma. = 0.02 amp.

$$\text{Grid-leak resistance} = \frac{100}{0.02} = 5000 \text{ ohms.}$$

If a combination of grid-leak and fixed protective bias is used, the amount of protective bias should be subtracted from the required operating-bias voltage before the calculation is made (except in the case of the arrangement of Fig. 6-27D).

Example: Required operating bias = 150 volts.
Protective bias from battery or VR tube = 90 volts.
150—90 = 60 volts = required bias from grid leak.
Rated grid current = 10 ma. = 0.01 amp.

$$\text{Grid-leak resistance} = \frac{60}{0.01} = 6000 \text{ ohms.}$$

In the case of a cathode biasing resistor, the rated grid, screen and plate currents under load are added together. The required operating voltage is then divided by this total current to obtain the resistance.

Example: Rated grid current = 15 ma. = 0.015 amp.
Rated screen current = 20 ma. = 0.02 amp.
Rated plate current = 200 ma. = 0.2 amp.
Total rated cathode current = 235 ma. = 0.235 amp.
Required operating bias = 150 volts.

$$\text{Cathode resistance} = \frac{150}{0.235} = 638 \text{ ohms.}$$

The power rating of the resistor may be determined from Ohm's Law:

$$P = I^2R$$

Example: In the first example above for grid-leak resistance,
I = 20 ma. = 0.02 amp. $I^2 = 0.0004$
R = 5000 ohms.
P = (0.0004) (5000) = 2 watts.

Example: In the above example for cathode resistor,
I = 235 ma. = 0.235 amp. $I^2 = 0.055$
R = 638
P = (0.055) (638) = 35.1 watts.

Excitation

Excitation, or driving power, is the r.f. power fed to the grid of the amplifier. R.f. power amplifiers in amateur transmitters almost exclusively are operated as Class C amplifiers. A Class C amplifier operates with a relatively high grid-biasing voltage so that plate current flows in pulses over only half or less of the exciting-voltage cycle (operating angle). It is in this manner that the Class C amplifier operates with high plate efficiency.

For efficient operation a triode amplifier requires a driver capable of delivering 15 to 20 per cent as much power as the rated power output of the amplifier. Screen-grid tubes require much less — usually from 5 to 10 per cent of their rated power output, but the power required by the screen is wasted, since it does not contribute directly to the r.f. power output. Because of their higher power sensitivity, screen-grid tubes require more careful isolation between input and output circuits to prevent self-oscillation.

For the same carrier output, a plate-modulated amplifier requires greater driving power, because the average power input and output increase under modulation. Most tubes, however, have lower ratings for plate-modulated service and therefore the driving power will remain about the same with or without modulation for operation of a given tube at maximum modulated or unmodulated ratings.

To cover tank-circuit and coupling losses, a driver capable of supplying several times the driving power listed in the tube data should be used. A frequency multiplier requires two to three times as much driving power as a straight amplifier, more driving power being required as the multiplying factor increases.

Power Output

The figure for power output given in the tube data is the r.f. power which the tube can be expected to deliver to the tank circuit under the conditions specified, at the fundamental frequency. Considerably less power usually can be obtained when multiplying frequency. The lower efficiency of frequency multipliers means that the input must be reduced to prevent exceeding the rated dissipation.

Power Input

Power input for both triodes and screen-grid tubes is the d.c. power input to the plate circuit. It is the product of the d.c. plate voltage and plate current.

Example: Plate voltage = 1250 volts.
Plate current = 150 ma. = 0.15 amp.
Power input = (1250) (0.15) = 187.5 watts.

Plate and Screen Dissipation

All of the d.c. power fed to the plate circuit of an amplifier is not converted into r.f. power. Part of it is wasted in heat within the tube. There is a limit to the amount of power that a tube can dissipate in the form of heat without danger of damage to the tube. This is the maximum rated plate dissipation given in tube data. The power dissipated is the difference between the d.c. power input and the r.f. power output.

Since the d.c. power furnished to the screen of a pentode or tetrode does not contribute to the r.f. output, it is entirely dissipated in heat-

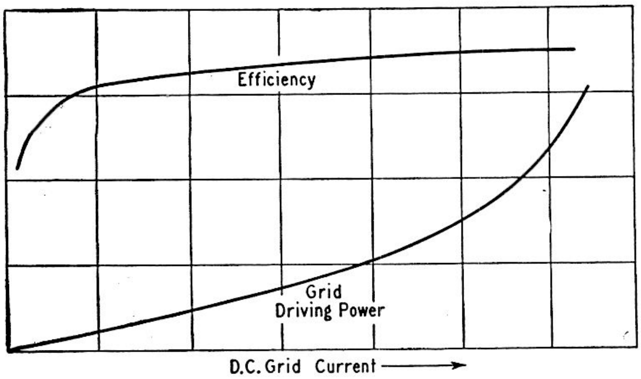


Fig. 6-28 — Curve showing relation between driving power and plate-circuit efficiency of an r.f. power-amplifier stage.

ing the screen, and the maximum-input rating should be carefully observed.

Plate Efficiency

The efficiency of an amplifier is the ratio of r.f. power output to the d.c. power input.

Example: D.c. power input = 175 watts.
R.f. power output = 125 watts.
Dissipation = 175—125 = 50 watts.

$$\text{Efficiency} = \frac{125}{175} = 0.714 = 71.4 \text{ per cent.}$$

The plate efficiency at which an r.f. power amplifier can be operated depends chiefly upon the relative driving power delivered to the input circuit. Fig. 6-28 shows that the driving power must be increased considerably out of proportion to the increase in efficiency at the higher efficiencies. An efficiency of 65 to 75 per cent represents a satisfactory balance between power output and driving power. This figure drops to 20 to 50 per cent for frequency multipliers, the efficiency possible decreasing as the order of multiplication increases. When the tube is operated as a straight amplifier, greater driving power than that necessary for reasonable efficiency is not desirable because it results in increased harmonic output.

Maximum Plate Current and Voltage

All voltage figures given in tube data, unless otherwise specified, refer to the voltage between the electrode mentioned and cathode, or filament center-tap. Included are figures for maximum rated plate voltage and plate current. These are the respective maximum values that should be used under any circumstances. Neither should be exceeded to compensate for a lower-than-rated value of the other in attempting to bring the power input up to permissible level. These maximum values should not be used simultaneously unless it is possible to do so without exceeding the rated plate dissipation. In some cases this cannot be done without higher plate efficiencies than are advisable from the consideration of harmonic output.

Maximum Grid Current

When a Class C amplifier is properly excited, the grid is driven positive over part of the cycle and rectification takes place as it does in a diode. Rectified grid current flows between grid and cathode within the tube and thence through the external d.c. circuit connecting grid and cathode which must always be provided. This external circuit includes the bias source (grid leak or voltage source) and either the grid r.f. choke with parallel feed, or the tank coil in series-feed arrangements. The flow of rectified current causes heat to be developed at the grid. As with the plate, there is a limit to the heat which the grid can dissipate safely. This limit is expressed in terms of maximum d.c. grid current which should not be exceeded in regular operation of the amplifier. Efficient operation usually can be attained with grid current below the maximum rated value.

Interelectrode Capacitances

The value given in tube data for grid-plate capacitance is useful in determining the value of capacitance necessary to neutralize a triode. (See "Neutralized Triode Amplifiers" this chapter.) The input- and output-capacitance values are helpful in arriving at a figure of minimum circuit capacitance, particularly where capacitance coupling is used. (See "Capacitance Coupling" this chapter.)

Adjustment of R. F. Amplifiers

Sets of typical operating conditions are given in all tube-data sheets and these should be followed closely whenever possible. In amateur service, ICAS (intermittent commercial-amateur service) ratings may be used when this set of ratings is given. When the available plate voltage falls between values given in the data, satisfactory performance may be obtained by using intermediate values for the other voltages and currents listed. Fig. 6-29 shows the connections for a voltmeter and milliammeter to obtain desired readings. While cathode metering often is used for reasons of safety to the operator and meter insulation, it is frequently difficult to interpret readings that are the resultant of *three currents,* one of which may be falling while the other two are increasing.

● SCREEN-GRID AMPLIFIER ADJUSTMENT

In setting up a screen-grid amplifier for operation, the necessary provisions for bias should be made first. (See "Grid Bias" this chapter.) The driver stage should then be coupled and excitation applied. The output from the driver should have been checked previously and found to be adequate. When the driver output circuit (and the amplifier grid tank circuit if link coupling is used) is tuned to resonance and properly coupled, a reading of grid current should be obtained. Maximum amplifier grid current should be obtained at the point where the driver plate current dips to minimum.

The value of grid current is influenced by the values of grid-leak resistance and fixed-bias voltage. The grid current will increase with a decrease in grid-leak resistance or fixed biasing voltage. Adequate excitation is indicated only when rated grid current flows when the bias is at the correct operating value with the amplifier loaded.

The coupling to the driver should be adjusted until the grid current is at its maximum rated value or slightly above.

Excitation should then be removed and reduced plate, screen and biasing voltages applied, while a search is made for parasitic oscillations. (See "Parasitic Oscillations" this chapter.) If the screen is fed through a voltage-dropping resistor or voltage divider, plate and screen voltages may be reduced by inserting a 115-volt 50- to 200-watt lamp in series with the primary of the high-voltage transformer, the larger-size lamps being used for higher-power amplifiers. A resistor of 5000 to 10,000 ohms of suitable power rating in series with the high-voltage lead to the amplifier may be used as an alternative, the lower-resistance value being used for higher-power amplifiers.

If the amplifier is entirely stable, no reading of grid current should be obtained at any combination of settings of the input and output tuning condensers without excitation.

The bias may now be increased to its rated value and excitation applied. Readings of screen and plate current should be obtained when excitation is applied. As the plate tank condenser is tuned through its range, the plate current will dip at resonance, while the screen current usually will rise to a peak. The amplifier now may be loaded by coupling it to a following stage, an antenna or a dummy load. As the loading is increased, the plate-current dip at resonance will become less pronounced, indicating that the load is taking power. Each time a change in loading is made, the plate tank circuit should be retuned for the plate-current dip. When the amplifier is partially loaded, the screen and plate voltages may be increased to the full operating value, and the load adjusted to bring the plate current at resonance up to the rated value.

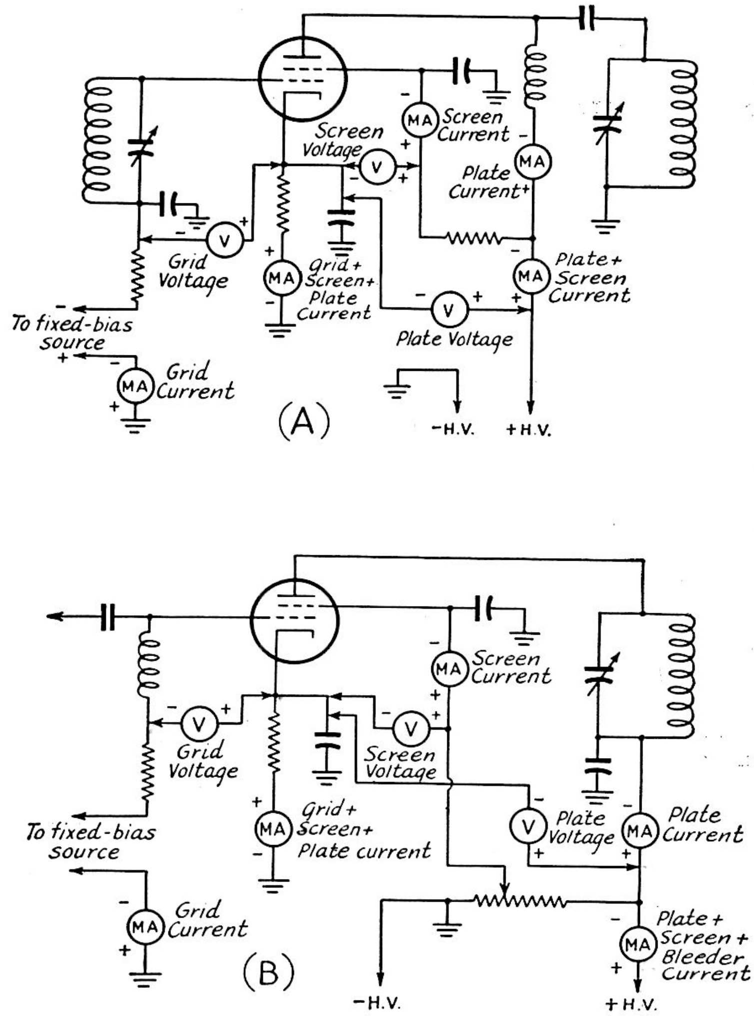


Fig. 6-29 — **Diagrams showing placement of voltmeter and milliammeter to obtain desired measurements. A — Series grid feed, parallel plate feed and series screen voltage-dropping resistor. B — Parallel grid feed, series plate feed and screen voltage divider.**

With the amplifier operating and fully loaded, the coupling to the exciter should be adjusted to give rated grid current and the biasing voltage checked to make sure that it is the correct operating value. The screen voltage also should be checked at this point if it is being fed through a series resistance or voltage divider.

When operating a screen-grid amplifier more excitation than that required to give maximum output at the operating bias specified should not be used, since overexcitation may increase the screen dissipation unnecessarily. If the screen is fed through a series resistor, overdriving may cause the screen current to increase. This increase in current will cause a greater voltage drop across the series resistor and thus the screen voltage may fall considerably below its correct operating value and the output from the amplifier may suffer accordingly.

When a screen-grid amplifier is operating at rated input and loading, the grid current may be the same, above, or below the value obtained before applying screen and plate voltage, depending upon the screen-voltage adjustment. Screen voltage should never be applied without first or simultaneously applying plate voltage and load except for short test periods, since without plate voltage and load, the screen input can run to dangerous proportions.

● ADJUSTMENT OF TRIODE AMPLIFIERS

Triode amplifiers may be adjusted following the procedure outlined previously for screen-grid tubes (ignoring references to the screen, of course), except that the neutralizing adjustment must be made after the bias and excitation have been initially adjusted. When plate voltage and load are applied to triode amplifiers, the grid current can be expected to fall appreciably below the value obtained without plate voltage or load. Excitation should be sufficient to bring the grid current up to rated value with the amplifier operating and loaded at the rated value of operating bias.

Neutralizing Procedure

The procedure in neutralizing is essentially the same for all tubes and circuits. The filament of the tube should be lighted and excitation from the preceding stage fed to the grid circuit. There should be no plate voltage on the amplifier.

The grid-circuit milliammeter makes a good neutralizing indicator. If the circuit is not completely neutralized, tuning of the plate tank circuit through resonance will change the tuning of the grid circuit and affect its loading, causing a change in the rectified d.c. grid current. The setting of the neutralizing condenser which leaves the grid current unaffected as the plate tank is tuned through resonance is the correct one. If the circuit is out of neutralization, the grid current will drop perceptibly as the plate tank is tuned through resonance. As the point of neutralization is approached, by adjusting the neutralizing capacitance in small steps the dip in grid current as the plate condenser is swung through resonance will become less and less pronounced, until, at exact neutralization, there will be no dip at all. Further change of the neutralizing capacitance in the same direction will bring the grid-current dip back. The neutralizing condenser should always be adjusted with an insulated screwdriver to avoid hand-capacitance effects.

Adjustment of the neutralizing condenser may affect the tuning of the grid tank or driver plate tank, so both circuits should be retuned each time a change is made in neutralizing capacitance. In neutralizing a push-pull amplifier the neutralizing condensers should be adjusted together, step by step, keeping their capacitances as equal as possible.

With single-ended circuits having split-stator neutralizing, the behavior of the grid meter will depend somewhat upon the type of tube used. If the tube output capacitance is not great enough to upset the balance, the action of the meter will be the same as in other circuits. With high-capacitance tubes, however, the meter usually will show a gradual rise and fall as the plate tank is tuned through resonance, reaching a maximum right at resonance when the circuit is properly neutralized.

When an amplifier is not neutralized a neon bulb touched to the plate of the amplifier tube or to the plate side of the tuning condenser will glow when the tank circuit is tuned through resonance, providing the driver has sufficient power. The glow will disappear when the amplifier is neutralized. However, touching the neon bulb to such an ungrounded point in the circuit may introduce enough stray capacitance to unbalance the circuit slightly, thus upsetting the neutralizing.

A flashlight bulb connected in series with a single-turn loop of wire 2½ or 3 inches in diameter, with the loop coupled to the tank coil, also will serve as a neutralizing indicator. Capacitive unbalance can be avoided by coupling the loop to the low-potential part of the tank coil.

If a setting of the neutralizing condenser can be found that gives minimum r.f. current in the plate tank circuit without completely eliminating it, there may be magnetic or capacitance coupling between the input and output circuits external to the tube itself. Short leads in neutralizing circuits are highly desirable, and the input and output inductances should be so placed with respect to each other that magnetic coupling is minimized. Usually this requires that the axes of the coils be at right angles to each other. In some cases it may be necessary to shield the input and output circuits from each other. Magnetic coupling can be detected by disconnecting the plate tank from the remainder of the circuit and testing for r.f. in it (by means of the flashlight lamp and loop) as the tank condenser is tuned through resonance. The driver stage must be operating while this is done, of course.

With single-ended amplifiers there are many stray capacitances left uncompensated for in the neutralizing process. With large tubes having relatively high interelectrode capacitances, these commonly-neglected stray capacitances can prevent perfect neutralization. Symmetrical arrangement of a push-pull stage is about the only way to obtain practically perfect balance throughout the amplifier.

The neutralization of tubes with extremely low grid-plate capacitance, such as the 6L6, is often difficult, since it frequently happens that the wiring itself will introduce sufficient capacitance between the right points to "over-neutralize" the grid-plate capacitance. The use of a neutralizing condenser only aggravates the condition. Inductive or link neutralization has been used successfully with such tubes.

Neutralizing Condenser

In most cases the neutralizing voltage will be equal to the r.f. voltage between the plate and grid of the tube, so that for perfect balance the capacitance required in the neutralizing condenser theoretically will be equal to the grid-plate capacitance. If, in the circuits having tapped tank coils, the tap is more than half the total number of turns from the plate end of the coil, the required neutralizing capacitance will increase approximately in proportion to the relative number of turns in the two sections of the coil.

With tubes having grid and plate connections brought out through the bulb, a condenser having at about half scale or less a capacitance equal to the grid-plate capacitance of the tube should be chosen. If the grid and plate leads are brought through a common base the capacitance needed is greater, because the tube socket and its associated wiring add some capacitance to the actual interelement capacitances.

PARASITIC OSCILLATIONS

Parasitic oscillations are oscillations at frequencies other than the operating frequency, which are frequently encountered in the operation of an r.f. power amplifier. Oscillations of this type not only cause the transmission of illegal spurious signals but impair the efficiency of operation. In fact, they can be so severe as to make operation of the stage as an amplifier impossible and may destroy the tube if they are allowed to persist for any appreciable time. Parasitic oscillations may be responsible for erratic tuning characteristics.

Two types are often found to exist either separately or together. The simultaneous use of r.f. chokes in both grid and plate circuits of an amplifier can set up a t.g.t.p. oscillator at low frequencies with the aid of coupling and plate-blocking condensers. A split-stator condenser also can serve to tune the r.f. choke with which it is often associated in either the plate or grid tank circuit. Low-frequency parasitic oscillation sometimes can be detected by listening on a receiver close to the transmitter, when harmonics, usually rough in character, may be heard at regular intervals that are multiples of the fundamental frequency which may lie anywhere between 1500 kc. and 100 kc. or less. On a calibrated receiver, the fundamental frequency can be determined by observing the spacing between adjacent harmonics. The low-frequency parasitic circuit can be eliminated by using series feed in either grid or plate circuit, thus avoiding the necessity for one of the r.f. chokes. In the case of split-stator tank circuits, the grid r.f. choke can be eliminated if a grid leak is used. When a split-stator plate tank is used with an r.f. choke between the rotor of the condenser and the center-tap of the coil, it will be necessary to use series feed in the grid circuit if the stage is capacitance-coupled to the driver, since the plate radio-frequency choke is essential.

V.h.f. parasitic oscillations usually are the result of a t.g.t.p. circuit set up by connecting leads and capacitances shunting them. When screen-grid tubes are used, they usually can be eliminated by inserting a 50-ohm non-inductive resistor at the screen terminal and a v.h.f. choke at the grid, as shown in Fig. 6-30. With triodes, the choke at the grid terminal usually will kill the parasitic, but sometimes a trap circuit tuned to the frequency of the parasitic is necessary, as shown at C. With the circuit oscillating parasitically, the trap condenser should be adjusted with an insulated screwdriver. When the trap is tuned to the parasitic frequency, oscillation will cease. The frequency range over which the condenser will tune can be altered by spreading or squeezing together the turns of the coil.

Amplifiers can be tested for parasitics by lowering plate (and screen) voltage to about half normal operating value and then reducing the fixed bias, if necessary, until the tube draws 50 per cent or so of normal plate current without excitation. The plate tank condenser should be swung through its range for several different settings of the grid tank condenser or, in the case of capacitance coupling, the plate tank condenser of the driver. If a grid-current reading is obtained, oscillation is taking place. The frequency of the oscillation can be determined by means of an absorption-type frequency meter (see Chapter Sixteen).

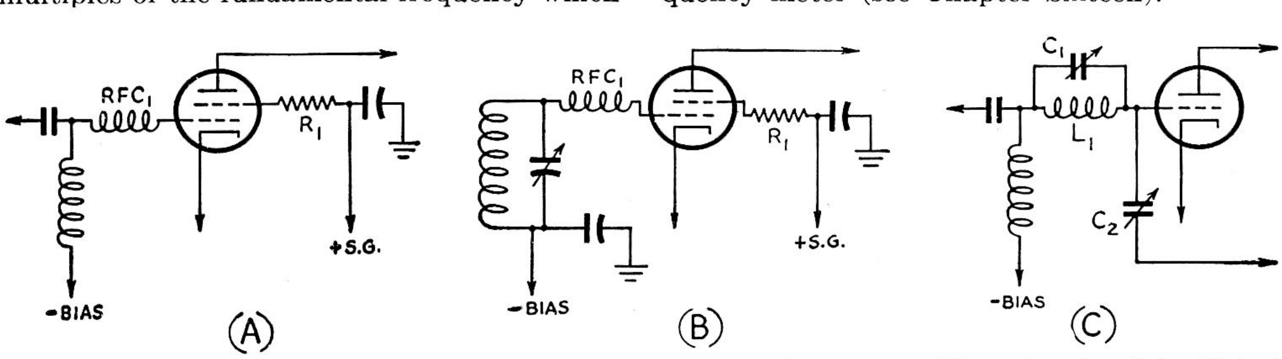


Fig. 6-30 — Methods of suppressing v.h.f. parasitic oscillation in r.f. power amplifiers. A — Parallel grid feed. B — Series grid feed. C — Tuned trap in grid lead. Exact values must be determined experimentally. Approximate values are as follows:

C_1 — 30-μμfd. mica trimmer condenser.
R_1 — 50 ohms, 1 watt, noninductive.
L_1 — 5 turns No. 14, ½-inch diameter, ½ inch long.
RFC_1 — 11 turns No. 20, 5/16-inch diameter, ¾ inch long, wound on 1-watt resistor, 0.1 megohm or more, as a form.

Parasitic oscillation should not be confused with oscillation at or close to the operating frequency caused by insufficient isolation between input and output circuits.

● IMPROPER OPERATION

Inexact neutralization of stray coupling between plate and grid circuits may result in regeneration. This effect is most evident with low excitation, when the amplifier will show a sudden increase in output when the plate tank circuit is tuned slightly to the high-frequency side of resonance. It is accompanied by a pronounced increase in grid current.

Self-oscillation is apt to occur with tubes of high power sensitivity, such as the r.f. pentodes and tetrodes. In event of either regeneration or oscillation, circuit components should be arranged so that those in the plate circuit are well isolated from those of the grid circuit. Plate and grid leads should be made as short as possible and the screen should be by-passed as close to the socket terminal as possible. A cylindrical shield surrounding the lower portion of the tube up to the lower edge of the plate is sometimes required.

"Double resonance," or two tuning spots on the plate-tank condenser, one giving minimum plate current and the other maximum power output, may occur when the tank-circuit capacitance is too low. A similar effect also occurs at times with screen-grid amplifiers when the screen-voltage regulation is poor, as when the screen is supplied through a dropping resistor. The screen voltage decreases with a decrease in plate current, because the screen current increases under the same conditions. Thus the minimum plate-current point causes the screen voltage, and hence the power output, to be less than when a slightly higher plate current is drawn.

A phenomenon known as "grid emission" may occur when the amplifier tube is operated at higher than rated power dissipation on either the plate or grid. It is particularly likely to occur with tubes having oxide-coated cathodes, such as the indirectly-heated types. It is caused by the grid reaching a temperature high enough to cause electron emission. The electrons so emitted are attracted to the plate, further increasing the power input and heating, so that grid emission is characterized by gradually-increasing plate current and heat which eventually will ruin the tube if the power is not removed. Grid emission can be prevented by operating the tube within its ratings.

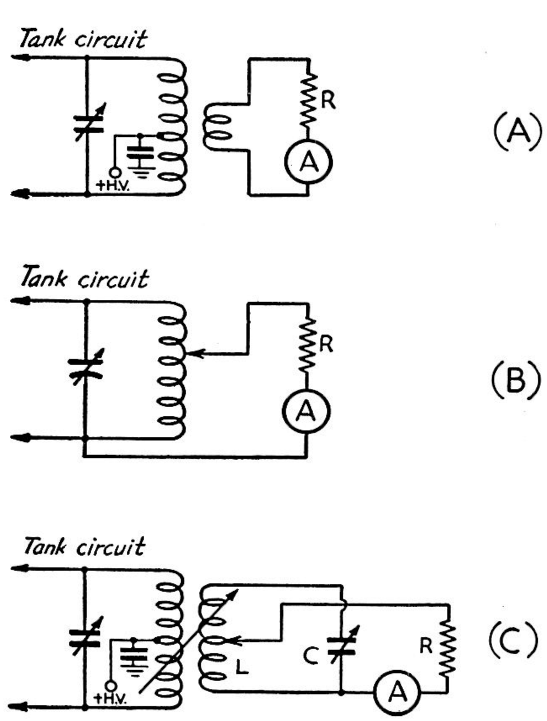


Fig. 6-31 — "Dummy antenna" circuits for checking power output and making adjustments under load without applying power to the actual antenna.

Harmonic Suppression

The most important step in the elimination of harmonic radiation is to use an output tank circuit having a Q of 12 or more. (See "Tank-Circuit Design" this chapter.) Beyond this it is desirable to avoid any considerable amount of overexcitation of a Class C amplifier, since excitation in excess of that required for normal Class C operation further distorts the plate-current pulse and increases the harmonic content in the output of the amplifier even though the proper tank Q is used. If the antenna system in use will accept harmonic frequencies they will be radiated when distortion is present, and consequently the antenna coupling system preferably should be selected with harmonic transfer in mind (see Chapter Ten).

Harmonic content can be reduced to some extent by preventing distortion of the r.f. grid-voltage waveshape. This can be done by using a grid tank circuit with high effective Q. Link coupling between the driver and final amplifier is helpful, since the two tank circuits provide more attenuation than one at the harmonic frequencies. However, the advantages of link coupling in this respect may be nullified unless the Q of the grid tank is high enough to give good voltage regulation, which minimizes harmonic transfer and thus prevents distortion in the grid circuit.

● CHECKING POWER OUTPUT

As a check on the operation of an amplifier, its power output may be measured by the use of a load of known resistance, coupled to the amplifier output as shown in Fig. 6-31. At A a thermoammeter, A, and a noninductive (ordinary wire-wound resistors are not satisfactory) resistance, R, are connected across a coil of a few turns coupled to the amplifier tank coil. The higher the resistance of R, the greater the number of turns required in the coupling coil. A resistor used in this way is generally called a "dummy antenna." The loading may

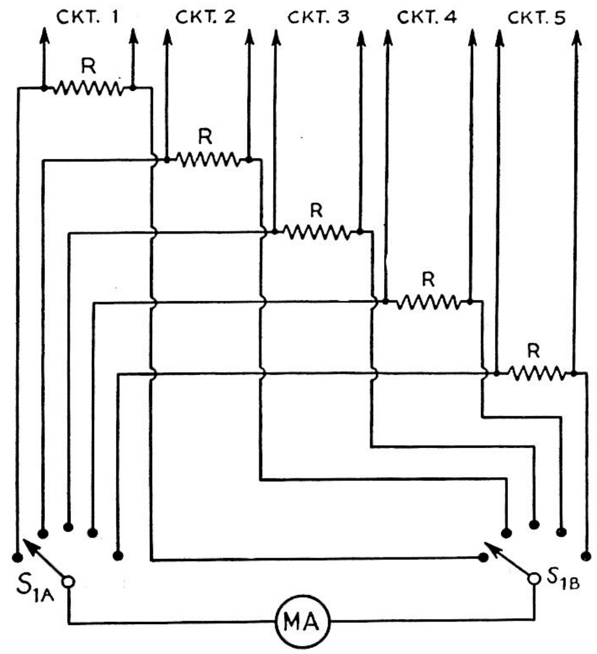


Fig. 6-32 — Method of switching single milliammeter to various circuits with a two-gang switch. The control shaft should be well insulated from the switch contacts, and should be grounded. The resistors, *R*, should have values of resistance ten to twenty times the internal resistance of the meter; 47 ohms will usually be satisfactory. S_1 is a 2-section multiposition rotary switch. Its insulation should be ceramic for high voltages, and a suitable insulating coupling should always be used between shaft and control knob.

readily be adjusted by varying the coupling between the two coils, so that the amplifier draws rated plate current when tuned to resonance. The power output is then calculated from Ohm's Law:

$$P \text{ (watts)} = I^2R$$

where I is the current indicated by the thermoammeter and R is the resistance of the noninductive resistor. Special resistance units are available for this purpose, ranging from 73 to 600 ohms (simulating antenna and transmission-line impedances) at power ratings up to 100 watts. For higher powers, the units may be connected in series-parallel. The meter scale required for any expected value of power output may also be determined from Ohm's Law:

$$I = \sqrt{\frac{P}{R}}$$

Incandescent light bulbs can be used to replace the special resistor and thermoammeter. The lamp should be equipped with a pair of leads, preferably soldered to the terminals on the lamp base. The coupling should be varied until the greatest brilliance is obtained for a given plate input. In using lamps as dummy antennas a size corresponding to the expected power output should be selected, so that the lamp will operate near its normal brilliancy. Then, when the adjustments have been completed, an approximation of the power output can be obtained by comparing the brightness of the lamp with the brightness of one of similar power rating in a 115-volt socket.

The circuit of Fig. 6-31B is for resistors or lamps of relatively high resistance. In using this circuit, care should be taken to avoid accidental contact with the plate tank when the power is on. This danger is avoided by circuit *C*, in which a separate tank circuit, *LC*, tuned to the operating frequency, is coupled to the plate tank circuit. The loading is adjusted by varying the number of turns across which the dummy antenna is connected on *L* and by changing the coupling between the two coils. With push-pull amplifiers, the dummy antenna should be tapped equally on either side of the center of the tank when the circuit of Fig. 6-31B is used.

Meter Switching

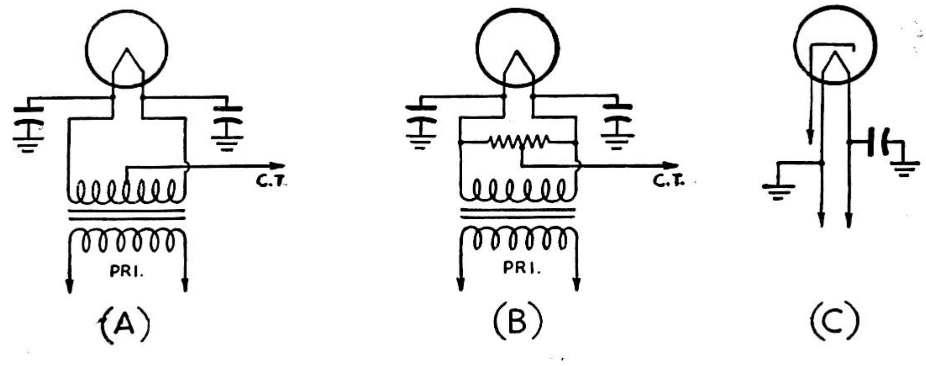
A single milliammeter may be switched to read current in any of several different circuits. The circuit is shown in Fig. 6-32. The resistors, *R*, are connected in the various circuits in place of the milliammeters shown in Fig. 6-29. Since the resistance of *R* is several times the internal resistance of the milliammeter, it will have no practical effect upon the reading of the meter.

When the meter must read currents of widely differing values, a meter with a range sufficiently low to accommodate the lowest values of current to be measured may be selected. In the circuits in which the current will be above the scale of the meter, the resistance of *R* can be adjusted to a lower value which will give the meter reading a multiplying factor. (See Chapter Sixteen.) Care should be taken to observe proper polarity in making the connections between the resistors and the switch.

Filament and Cathode Connections

In the illustrative diagrams shown up to this point, cathodes have been indicated in all

Fig. 6-33 — Filament connections for transmitting tubes. The by-pass condensers usually are 0.01-μfd. paper for frequencies up to 30 Mc. The center-tap resistor may be any low value of 10 to 50 ohms and may be made up of two identical resistors of half value.



tubes for the sake of facilitating the understanding of the circuits and their operating principles. Actually, only the lower-power transmitting tubes have cathodes of this type. In the larger tubes which have no cathodes as such, the filament itself serves as the cathode and the cathode connections shown are actually made to the center-tap of the filament transformer, as shown in Fig. 6-33A or, if the transformer has no center-tap, to the center of a low resistance connected across the filament, as shown at B. Each side of the filament usually is by-passed as shown.

In the case of cathode-type tubes, the heater sometimes is grounded directly as shown in Fig. 6-33C; the other side sometimes is by-passed and sometimes is not, as found necessary to minimize hum.

In the descriptions of apparatus to follow, not only the electrical specifications but also the manufacturer's name and type number have been given for many components. This is for the convenience of the builder who may wish to make an exact copy of some piece of equipment. However, it should be understood that a component of different manufacture, provided it has the same electrical specifications, may be substituted in most cases.

A Simple Single-Tube Transmitter

One of the simplest practical transmitters is shown in the photographs of Figs. 6-34 and 6-36. If the station receiver has a power audio stage which is not required for headphone reception, the tube may be taken from the receiver and used in the transmitter (provided that the tube is a pentode or tetrode as it usually is). A plug inserted in the empty socket in the receiver may be used to obtain power for operating the transmitter.

The circuit is shown in Fig. 6-35. The Tri-tet oscillator circuit is used to permit operation in either the 3.5-Mc. band or the 7-Mc. band with a single 3.5-Mc. crystal. Series plate feed is used and no means of reducing the voltage of the screen below that of the plate is necessary if the supply potential does not exceed 250 to 300 volts.

The cathode circuit is tuned by a fixed mica condenser, C_1, but if necessary, the tuning of this circuit can be changed by changing the dimensions of the coil, L_1.

No provision is included for tuning the antenna system, for the sake of maximum simplicity. This can be done by selecting the proper feeder length and adjusting the size of the antenna coupling coil, L_3.

Construction

To minimize the tools required for the construction of the transmitter the parts are mounted on a simple chassis of wood finished with clear lacquer or shellac. Two 1¾ × 9¾-inch strips of ¼-inch-thick wood are fastened with screws to the two 4½ × 2½ × ¾-inch end pieces, leaving enough separation between the strips for the Amphenol MIP octal sockets used for the crystal and the socket for the tube. Wood screws can be used to mount the sockets, or they can be bolted to the wood strips with 6-32 machine screws. The key of the tube socket should be mounted toward the front of the transmitter for convenience in wiring the plate circuit to the tuning condenser. Because the tuning condenser does not have a long mounting shank, it is necessary to drill a clearance hole for the shank and then dig away — or counterbore — clearance for the nut. The two Fahnestock clips for the antenna are secured under two of the screws used for fastening the wood strips to the right-hand end piece, and the other two clips used for the key leads are held down by machine screws on the left-hand end piece. The r.f.

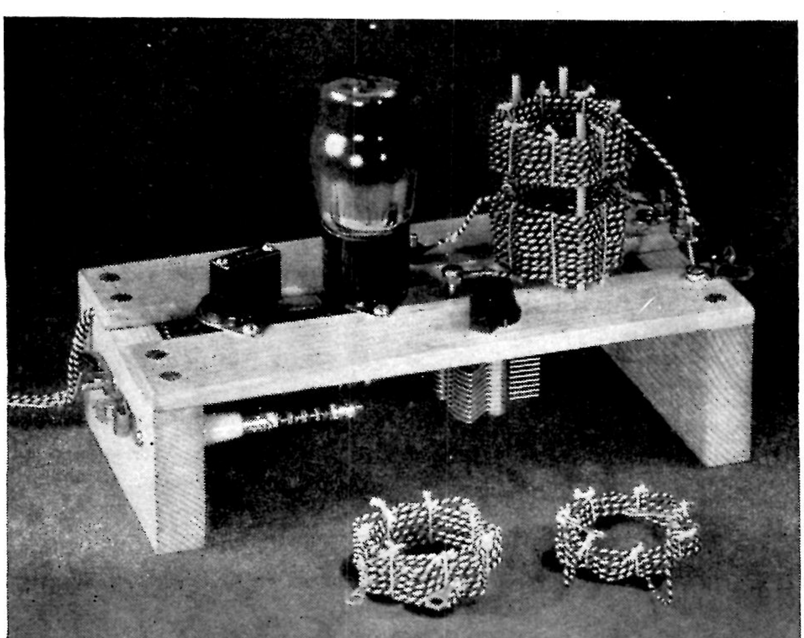


Fig. 6-34 — By using wood for the chassis and simplified construction throughout, this simple oscillator transmitter can be built with very few shop tools. Using a 3.5-Mc. crystal, operation in the 3.5- and 7-Mc. bands is possible by changing the plate and antenna coils. The arrangement is suitable for 6F6, 6V6 or other similar pentodes and tetrodes.

choke is held in place on the left-hand end piece by a machine screw. The four wires used for a power cable are brought out at the rear left under the wood strip — a half-round hole is filed in the end piece to clear the wires.

The plate and antenna coils are held in place on three small sticks set in the top of the chassis — penny suckers are a good source of these sticks. The bottom of the plate coil connects to a brass machine screw soldered to a lug which is sweated to the stator terminal of the tuning condenser, and the screw is built up most of its length by adding nuts or small spacers. The screen end of the coil, the top end of the winding, is fastened to a brass screw that runs through the rear wood strip. The coil ends have lugs soldered to them to facilitate band-changing. The antenna-coil ends similarly fasten to two brass screws supported by short lengths of heavy wire and the wire is sweated to the Fahnestock clips and to the heads of the screws.

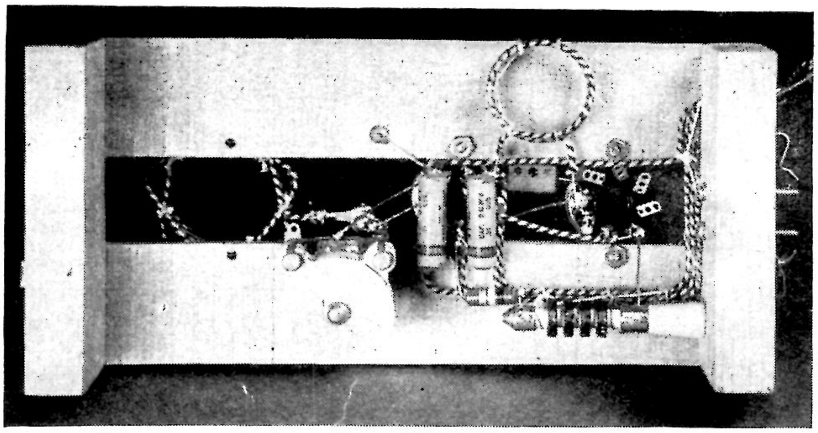


Fig. 6-36 — **Bottom view of the simple single-tube transmitter. The cathode coil is between the tube and crystal sockets. The r.f. choke is to the right, C_4 is at left center with the two by-pass condensers, C_2 and C_3, to the right of it.**

Wiring

The wiring is done with the same wire that is used for the coils, because a single 50-foot roll of No. 18 bell wire, available in any "5 & 10" or hardware store, suffices for the whole rig with some to spare. To insure good electrical connection, the wire is soldered at every connection, which means that the wire is soldered to the heads of the brass machine screws used for the key leads and the screen end of L_2 before the screws are put in place. One key lead, one end of R_1, the outer foil connections on C_2 and C_3, and the lead to Pin 1 of the power plug must be connected to Pin 1 of the tube socket. At the crystal socket, two adjacent pins (e.g., 1 and 8) are bonded together for the grid side of the crystal and the next two pins (e.g., 2 and 3) are bonded together for the cathode side. This permits plugging the crystal into either Pins 8 and 2 or 1 and 3. The connection can be elaborated still further by bonding Pins 4 and 5 with 8 and 1 and tying 6 and 7 to 2 and 3, in which case the crystal can be plugged in any way and it will make the proper connection.

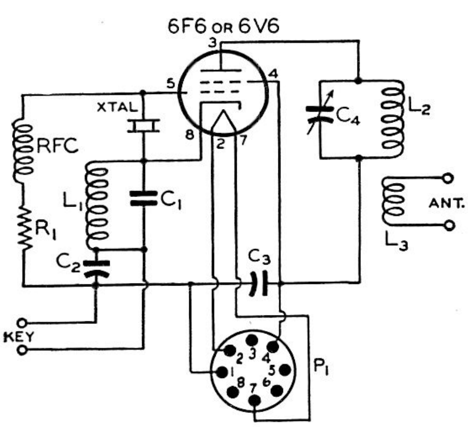


Fig. 6-35 — **Wiring diagram of the inexpensive easy-to-build transmitter.**

C_1 — 470-μμfd. mica.
C_2, C_3 — 0.01-μfd. 600-volt paper.
C_4 — 140-μμfd. variable (Hammarlund SM-140 or Bud MC-1876).
R_1 — 0.1-megohm 1-watt composition.
L_1 — 5 turns No. 18 d.c.c., 1¼-inch inside diameter, close-wound.
L_2 — 3.5 Mc.: 19 turns. 7 Mc.: 12 turns.
L_3 — 13 turns and 6 turns. Requires experiment — see text. See text for L_2 and L_3 winding instructions.
P_1 — See text.
RFC — 2.5-mh. r.f. choke (National R-100U).

The cathode coil, consisting of 5 turns of No. 18 bell wire, is wound on a 1¼-inch diameter form and then removed and tied with string at a number of places. The cathode coil is mounted by its leads only but, being short, they offer adequate support.

The plate and antenna coils are wound by equally spacing seven nails on a 2-inch diameter circle, driving the nails completely through the board used so that the heads are flush against the board. Small spikes can be used, or nails of the "8-penny" size will be satisfactory if a thin board is used. One end of the wire is secured to a nail and the wire is threaded over alternate nails, so that the coil repeats itself every two turns. When the required number of turns has been made, the end of the wire is wrapped around a nail and the coil tied together with string at the seven cross-over points. Soldering lugs are soldered to the ends of the coil for ease in changing bands.

The four wires coming out the side of the chassis that go to the power plug are twisted together slightly and cabled with string to form a neat cable, and the cable plug, P_1, is simply the base from an old tube. If the receiver is to be used as a source of power, the base should be one that will fit the power-output tube in the receiver. Break the tube and chew out the glass from inside the base with a pair of pliers, being careful not to break the bakelite of the base. It will help in making connection to the proper pins if a small drill, slightly larger than the diameter of the No. 18 wire, is run through the pins before the wires are inserted and soldered in place.

Tuning

After checking the wiring, plug in a crystal and connect the 7-Mc. coil in place. Place the audio tube from the receiver in the transmitter and plug in the power cable, and connect a key to the clips on the side of the transmitter. If the receiver has push-pull output, it is probably best to remove both power tubes. Set the tuning condenser, C_4, at about 40 per cent meshed and turn on the power to the receiver. When the tube has had time to warm up — about 30 seconds — close the key and

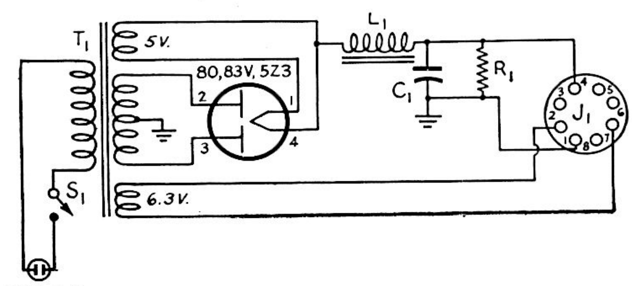


Fig. 6-37 — **Circuit diagram of alternative power supply for the simple single-tube transmitter.**

C_1 — 8-μfd. 450-volt electrolytic.
R_1 — 25,000 ohms, 10 watts.
L_1 — Filter choke — any receiver replacement type, 15 hy. or more, 50 ma. or more.
J_1 — 8-prong tube socket.
S_1 — S.p.s.t. toggle switch.
T_1 — Power transformer — any receiver replacement type, not over 750 volts c.t., 50 ma. or more.

touch a neon bulb to the plate end of L_2. Or a small 10-watt electric lamp can be connected to the antenna posts with the 6-turn antenna coil in place. If C_4 is set properly, the neon bulb will glow or the lamp will light. If this does not happen, try tuning the plate condenser until signs of output become apparent. The transmitter can then be checked on the 3.5-Mc. band by putting in the proper coils — remembering, however, to turn off the receiver and hold the key closed until the power pack of the receiver has been discharged, to avoid getting a shock when touching the coil terminals. The tuning condenser setting will be about 85 per cent meshed on the lower-frequency band.

It will not be possible in most cases to check the keying on the receiver used to furnish power to the transmitter, and it is highly advisable to check the keying in a monitor or another receiver. If the keying is chirpy, the cathode coil, L_1, should be squeezed out of round to reduce its inductance until the keying is better. On the 3.5-Mc. band, best keying will generally be obtained with slightly less capacity at C_4 than the setting for maximum output. In the oscillator shown in the photographs, a slight key click on "break" was reduced almost completely by connecting a 0.1-μfd. 600-volt paper condenser directly across the key. Some crystals key better than others.

Antennas

A 135-foot piece of wire for the antenna can be fed in several ways to give satisfactory results. It can be fed at one end with about 40 feet of open-wire feeders (about 32 feet of Amphenol 300-ohm Twin-Lead) or it can be fed in the center with 100 feet of open-wire feedline (about 80 feet of 300-ohm Twin-Lead). These lengths will enable one to connect the feedline directly to the antenna posts of the transmitter without the necessity for tuning condensers — other lengths may require either series or parallel condensers. Some experiment with the antenna coil may be necessary, but a small flashlight bulb in series with one of the feeders will serve as a good indication of feeder current, and will help in the tune-up process. The lamp need not be shorted during normal operation unless it burns too brightly. A neon bulb will also help in detecting r.f. energy in the transmission line, but it may not always light with this low power.

If room for only a short length of wire is available for the antenna, say 40 or 50 feet, it is best to connect its end to one antenna post and a good ground to the other. Here again some experimentation will be necessary to determine the optimum size of L_3. The diagram of a suitable alternative power supply is shown in Fig. 6-37.

The power can be increased by substituting a 6L6 for a smaller tube and adding a separate power supply to give 350 volts at 100 ma., but it is not advisable to increase the voltage much above this value without keeping the screen voltage down by the addition of a dropping resistor and another by-pass condenser.

An Inexpensive Two-Tube Transmitter

Figs. 6-38, 6-40 and 6-41 show the construction of another simple low-power transmitter capable of about twice the output of that from the simple oscillator transmitter. It is shown complete with power supply in Fig. 6-38. The circuit diagram appears in Fig. 6-39. The arrangement consists of a Pierce crystal oscillator capacitance-coupled to an output stage which may be used either as a straight amplifier at the crystal frequency or as a frequency doubler to deliver output at twice the crystal frequency. This combination has the advantage over a simple oscillator transmitter in that the oscillator is isolated from the effects of tuning and loading. Type 6L6, 6V6 or 6F6 tubes, or their glass equivalents, may be used in either the oscillator or amplifier with only a slight difference in performance at the supplied plate voltage.

By the use of the proper coil at L_1, output may be obtained at 3.5 or 7 Mc. with a 3.5-Mc. crystal or at 7 or 14 Mc. with a 7-Mc. crystal.

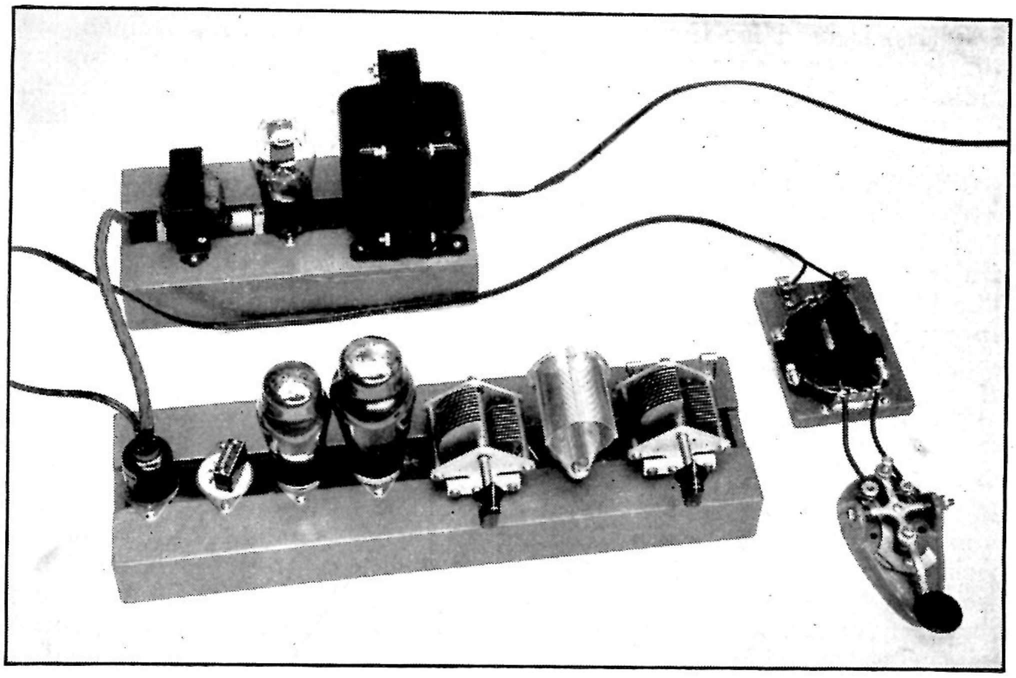


Fig. 6-38 — The complete low-power two-tube transmitter. In the r.f. unit in the foreground, left to right, are the 5-prong socket for the power plug, octal sockets for the crystal, oscillator tube and amplifier tube, and the output tank condensers, C_9 and C_{10}, with the coil L_1 in between.

On the power-supply chassis at the rear are the filter choke, L_2, the Type 80 rectifier tube and the power transformer. The filter condensers, C_{11} and C_{12}, and the bleeder resistor, R_9, are underneath. The key-click filter is to the right.

The amplifier input is not tuned so that neutralization is unnecessary. C_2 provides regeneration; its value should not depart appreciably from that specified. The output tank circuit is in the form of a pi-section filter which makes it possible to use the transmitter with a wide variety of antenna systems.

Parallel plate feed is used in the output stage to remove plate voltage from the tuning condensers and the coil. Plate voltage is reduced for the oscillator by the series resistor, R_8, while screen voltage is obtained from the voltage divider made up of R_2 and R_3. In the amplifier section, the screen voltage is obtained from the second voltage divider consisting of R_6 and R_7. Grid bias for the oscillator is obtained from the grid leak, R_1, alone, while a combination of cathode resistor (R_5) and grid

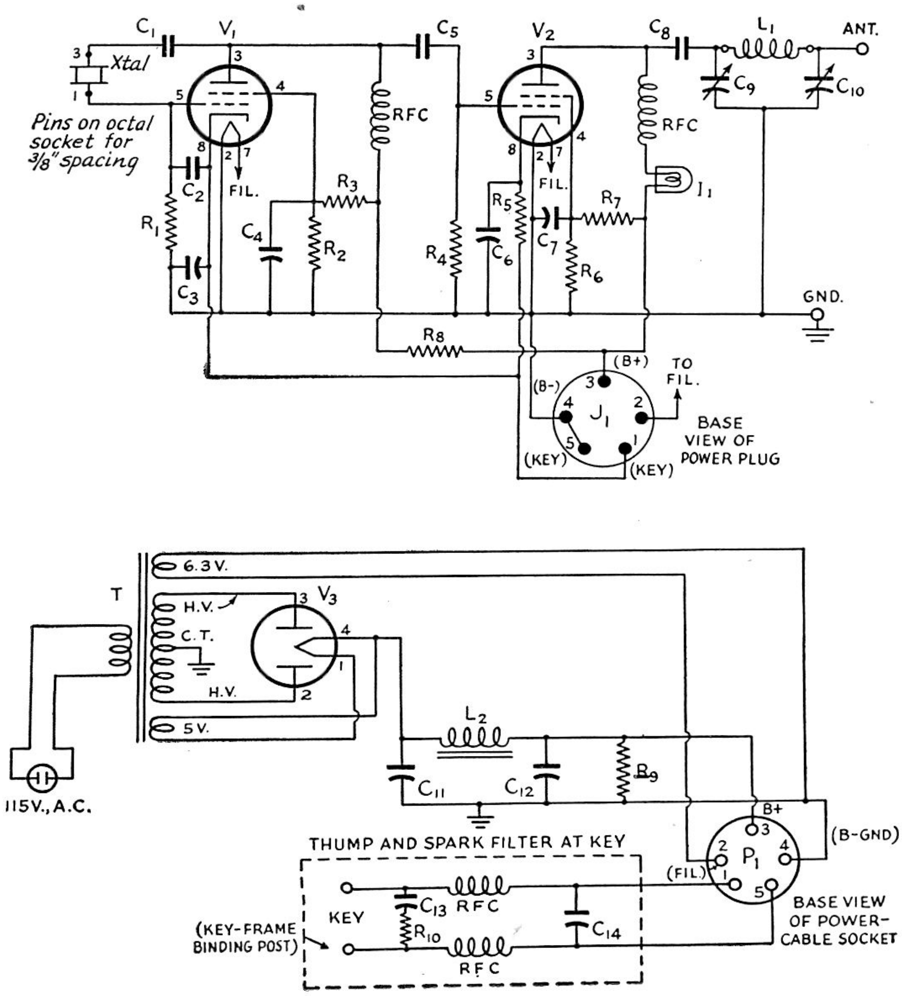


Fig. 6-39 — Circuit diagram of the low-powered two-tube transmitter, power supply and keying filter.

C_1, C_8 — 0.001-μfd. mica.
C_2, C_5 — 100-μμfd. mica.
C_3, C_4, C_6, C_7 — 0.01-μfd. paper.
C_9, C_{10} — 250-μμfd. variable (National TMS 250).
C_{11}, C_{12} — 16-μfd. 475-volt electrolytic.
C_{13} — 1-μfd. 400-volt paper.
C_{14} — 0.5-μfd. 400-volt paper.
R_1, R_3 — 47,000 ohms, 1 watt.
R_2, R_6 — 0.1 megohm, 1 watt.
R_4 — 22,000 ohms, ½ watt.
R_5, R_{10} — 330 ohms, 1 watt.
R_7, R_8 — 15,000 ohms, 2 watts.
R_9 — 20,000 ohms, wire-wound, 10 w.
L_1 — 3.5 Mc.: 32 turns No. 20 d.s.c., 1½-inch diam., close-wound.
— 7 Mc.: 20 turns No. 20 enam., 1½-inch diam., 1½ inches long.
— 14 Mc.: 10 turns No. 18 enam., 1½-inch diam., 1 inch long.
(B & W JEL80, "40" or "20" coils may be substituted.)
L_2 — Filter choke, 10 hy., 130 ma. (Stancor C-2303).
I_1 — 60-ma. dial-lamp assembly.
J_1 — 5-prong chassis-mounting plug.
P_1 — 5-prong female cable plug.
RFC — 2.5-mh. r.f. choke.
T — Power transformer: 350 volts each side of center, 100 ma.; 5 v., 3 amp.; 6.3 v., 4.5 amp. (Stancor P-4080).
V_1, V_2 — 6V6, 6L6, 6F6 or glass equivalents.
V_3 — Type 80 rectifier.

leak (R_4) is used for the amplifier. A 60-ma. dial lamp serves as a resonance indicator in tuning up the transmitter.

Construction

The chassis or frame is made entirely from lattice strip, 1⅝ inches wide and ¼ inch thick. The sketch of Fig. 6-41 shows how the strips are fastened together with 1-inch wire brads. The 1¼-inch spacing between the top strips is appropriate for Millen sockets, but it can be changed to suit sockets of other dimensions, of course.

The completed chassis was given a couple of coats of gray Duco. The sockets are fastened in place by means of small wood screws and are orientated so that most-convenient connections may be made. The power-plug socket has its metal-ring key to the left, the oscillator tube-socket key is to the right, the amplifier tube socket toward the front and the coil socket toward the left.

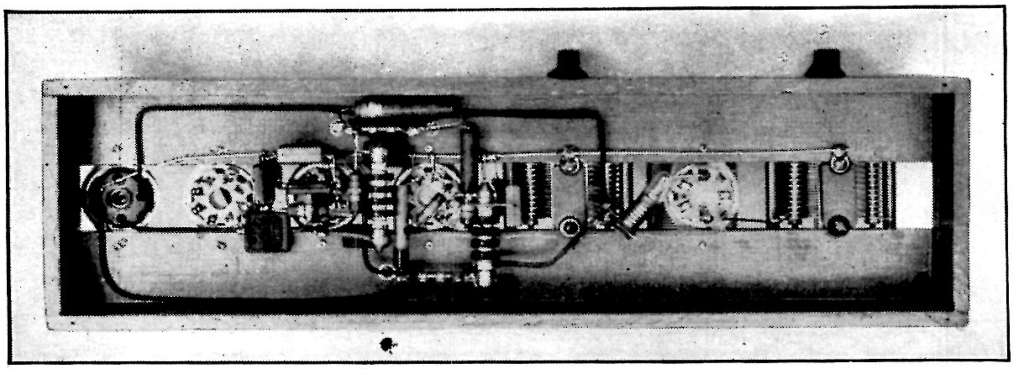


Fig. 6-40 — **Bottom view of the 2-tube low-power transmitter. The by-pass condensers, r.f. chokes and resistors are grouped around the tube sockets. The ground wire mentioned in the text runs along the top edge of the lower chassis strip. The indicator lamp, I_1, is wired in the B+ line just below the amplifier plate r.f. choke. It is placed underneath the chassis where it can be viewed from above through the opening between the chassis strips. The r.f. choke to the right is in the amplifier and the one to the left is in the oscillator circuit.**

All wiring is done underneath. The ground wire is a piece of No. 14 bare wire which runs the length of the chassis from the No. 4 prong on the power-supply socket to the rotor of C_{10}. To this wire all ground connections shown in the diagram are made. Connections to by-pass condensers and r.f. chokes should be as short as possible, the by-pass condensers being connected to the nearest point on the ground wire. A pair of fiber lug strips provides anchorage for resistors and r.f. chokes. "Hot" r.f. leads (those from the plates and control grids of the tubes and the connections between the tuning condensers and the coil) should be short and direct instead of going around right-angle bends. The output terminals are Fahnestock clips fastened to the two sides of C_{10}.

Homemade coils may be constructed by winding them, according to the dimensions given under Fig. 6-39, on Hammarlund 1½-inch diameter 5-prong coil forms. Those shown in the photograph are the B & W JEL series.

Inexpensive components are used in the power supply. The transformer is a broadcast-receiver replacement type as are the filter components. The chassis is similar to that used for the transmitter, the only difference being in the length — 9½ inches instead of 15½ inches. The filter condensers, and the bleeder resistor, R_9, are placed underneath.

The key-click filter is a separate unit assembled on a small piece of ¼-inch wood. The connecting leads and the leads to the key should be short if the filter is to be effective. The side of the filter connected to power-plug Pin 5 should be connected to the frame of the key.

Adjustment

The transmitter should first be tuned up without the antenna connected. It should be remembered that only the second harmonic of crystals between 3500 and 3650 kc. and between 7000 and 7200 kc. are useful in the higher-frequency amateur bands. With a suitable crystal and coil plugged in, the power supply may be plugged in and the key closed after allowing time for the heaters of the tubes to come up to temperature. The indicator lamp should glow brightly when the key is closed. Setting C_{10} at about half capacitance, C_9 should be adjusted as I_1 is watched for a dip in illumination. If this dip cannot be found anywhere within the range of C_9, another setting of C_{10} should be tried. As soon as the dip has been found, the antenna may be connected, and the tuning process repeated as before. With the antenna connected the dip at resonance will not be so pronounced. In fact, when the amplifier is loaded properly, the dip should be just noticeable — just enough to indicate that the output circuit is tuned to resonance. The proper loading point may be found by adjusting C_{10} at several fixed settings and rotating C_9 through its range for each setting of C_{10}. As the proper point is approached, the capacitance of C_{10} should be adjusted in smaller steps. In most cases the loading will increase as the capacitance setting of C_{10} is decreased. Near maximum loading, the adjustment is fairly critical. With antennas of certain dimensions, it may be necessary to short-circuit a few turns on L_1 to obtain maximum loading in the 3.5-Mc. band.

While the best antenna within the limits of cost and space should be used, the output circuit provides means of feeding power into a wire of random length; it is not necessary that

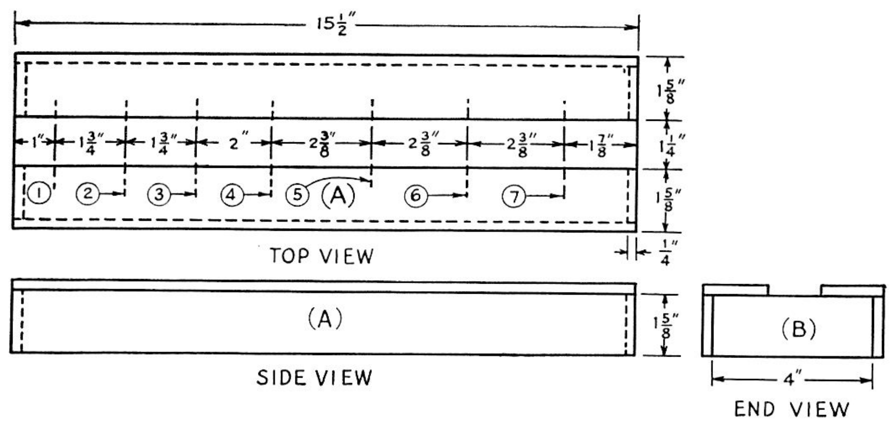


Fig. 6-41 — Sketch showing the important dimensions of the chassis for the simple two-tube transmitter. The center lines are numbered as follows: 1 — power plug, 2 — crystal socket, 3 — oscillator-tube socket, 4 — amplifier-tube socket, 5 — tuning condenser, C_9, 6 — coil socket, 7 — condenser C_{10}.

its length be a multiple of a half-wavelength. With the power supply described, an output of about 10 watts should be possible at the crystal fundamental; and 5 or 6 watts when the output stage is used as a frequency doubler. If a milliammeter is connected in series with the key, it should show a reading of about 20 ma. with the amplifier tuned to resonance and unloaded at the crystal fundamental, and about 40 ma. when doubling. Loaded, the plate current should run between 70 and 80 ma. With a power-supply voltage of 350, the oscillator plate voltage should be 170, the oscillator screen voltage 90, and the amplifier screen voltage 220, with the amplifier loaded and tuned to resonance.

A Self-Contained 60-Watt Transmitter for Three Bands

The diagram of Fig. 6-43 shows the circuit of a simple two-stage transmitter. The finished unit, shown in Fig. 6-42, is enclosed in a cabinet, complete with power supply and antenna tuner.

A 6V6GT Tri-tet oscillator drives an 807 output stage directly with simple capacitive coupling. Any one of ten crystals may be selected from the front of the panel by the crystal switch, S_1. A pair of terminals also is provided at the rear for VFO connection. Bands are changed by means of a system of plug-in coils.

The oscillator circuit operates with either 3.5- or 7-Mc. crystals. In either case, oscillator output may be obtained at the crystal fundamental frequency or its second harmonic. While the output stage may be used as a frequency doubler with fair efficiency, this sort of operation is not recommended unless the unit is to be used as an exciter for a following amplifier.

Parallel plate feed is used in both stages to permit mounting the tuning condensers, C_2 and C_3, directly on the metal chassis without insulation. The v.h.f. choke RFC_2 and the screen

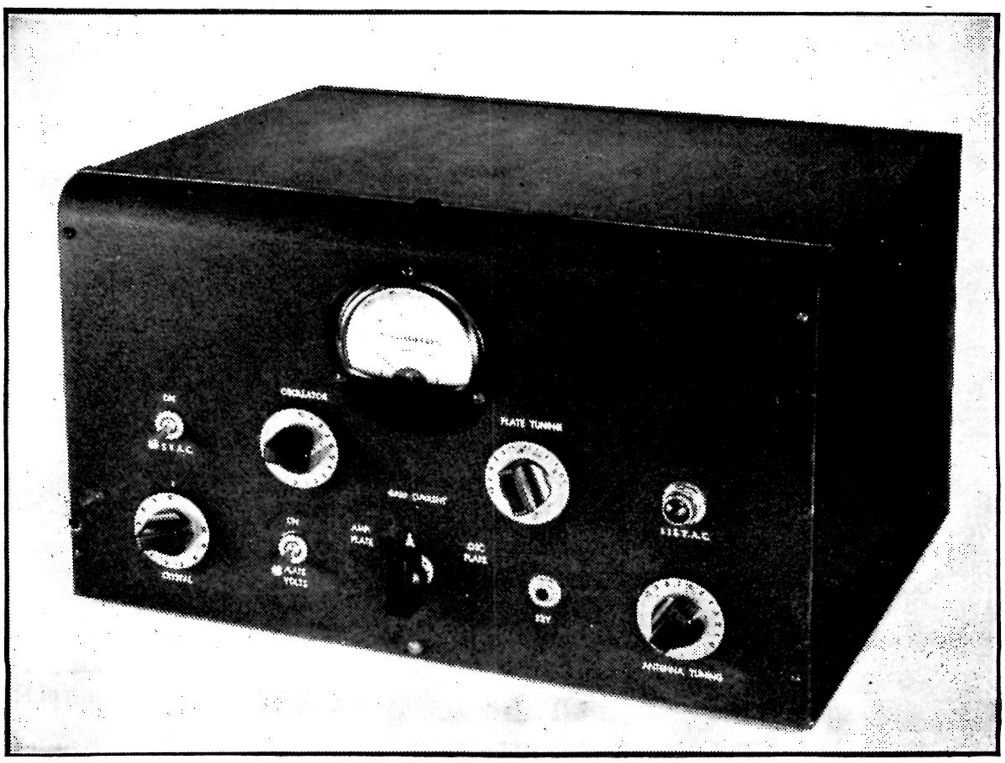


Fig. 6-42 — A two-stage 60-watt transmitter for three bands. To either side of the milliammeter are the oscillator and amplifier plate-tuning controls. Along the bottom are the crystal switch, the plate-voltage switch, the meter switch, the key jack and the antenna tuning control.

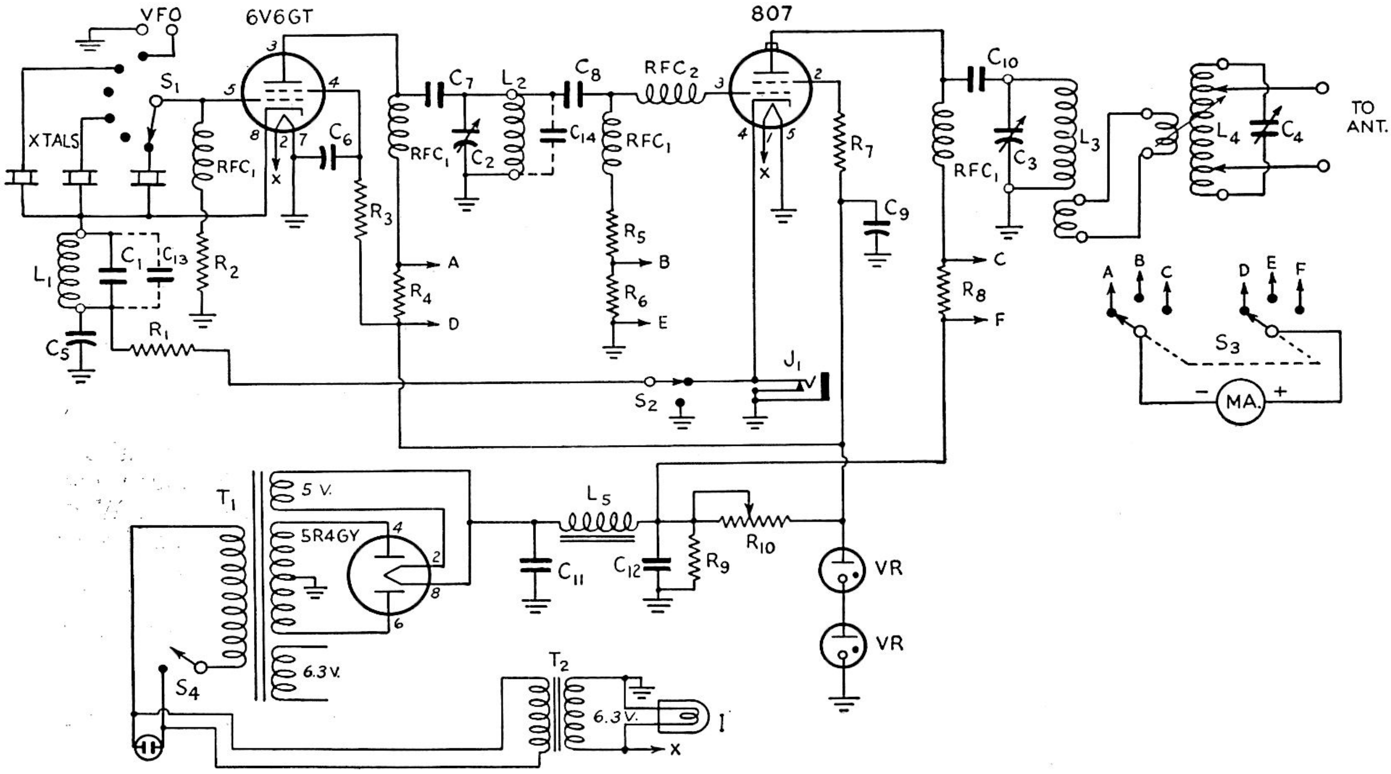


Fig. 6-43 — Circuit diagram of the 3-band 60-watt transmitter.

C_1, C_8 — 100-μμfd. mica.
C_{13} — 100-μμfd. mica (see text).
C_2 — 50-μμfd. variable (National ST-50).
C_{14} — 22-μμfd. mica (see text).
C_3, C_4 — 150-μμfd. variable (National ST-150).
C_5, C_6, C_9 — 0.01-μfd. paper.
C_7, C_{10} — 0.001-μfd. mica.
C_{11}, C_{12} — 4-μfd. 1000-volt paper.
R_1 — 220 ohms, 1 watt.
R_2 — 47,000 ohms, ½ watt.
R_3 — 40,000 ohms, 5 watts.
R_4 — 100-ma. meter shunt (see text).
R_5 — 15,000 ohms, 1 watt.
R_6 — 47 ohms, ½ watt.
R_7 — 47 ohms, 1 watt.
R_8 — 200-ma. meter shunt (see text).
R_9 — 50,000 ohms, 25 watts.
R_{10} — 10,000 ohms, 25 watts (adjustable).
L_1 — Oscillator cathode coil:
- 1A (3.5-Mc. crystals) — 14 turns No. 22 d.c.c., 1-inch diam., ⅞ inch long. 100-μμfd. mica, C_{13}, connected in parallel.
- 1B (7-Mc. crystals) — 10 turns No. 22 d.c.c., 1-inch diam., ⅞ inch long.

L_2 — Oscillator plate coil:
- 2A (3.5 Mc.) — 80 turns No. 26 d.s.c., ½-inch diam., close-wound, C_{14} connected in parallel.
- 2B (7 Mc.) — 40 turns No. 24 d.c.c., ½-inch diam., close-wound.
- 2C — (14 Mc.) 25 turns No. 18 d.c.c., ½-inch diam., 1⅜ inches long.

L_3 — Amplifier plate coil:
- 3A (3.5 Mc.) — 24 turns 1½-inch diam., 1⅜ inches long (B & W JEL80 with 16 turns removed). 3-turn link.
- 3B (7 Mc.) — 18 turns 1½-inch diam., 1¾ inches long (B & W JEL40). 2-turn link.
- 3C (14 Mc.) — 12 turns 1½-inch diam., 2 inches long (B & W JEL20). 2-turn link.

L_4 — Antenna coil:
- 4A (3.5 Mc.) — 30 turns 1¾-inch diam., 2 inches long, 3-turn variable link at center (B & W JVL80 with 5 turns removed from each end).
- 4B (7 Mc.) — 24 turns 1¾-inch diam., 2⅜ inches long, 3-turn link at center (B & W JVL40).
- 4C (14 Mc.) — 14 turns 1¾-inch diam., 2¼ inches long, 3-turn link at center (B & W JVL20).

L_5 — 6-henry 175-ma. filter choke.
I — 6.3-volt signal-lamp assembly.
J_1 — Closed-circuit jack.
MA — 0–10 ma. meter.
RFC_1 — 2.5-mh. r.f. choke.
RFC_2 — 11 turns No. 20, 5⁄16-inch diam., ¾ inch long.
S_1 — 11-point tap switch, ceramic insulation.
S_2 — S.p.d.t. toggle.
S_3 — Double-gang 3-position rotary switch.
S_4 — S.p.s.t. toggle.
T_1 — 600 volts each side of center, 200 ma.; 5 volts, 3 amp. (UTC S-41).
T_2 — 6.3 volts, 3 amp. (UTC S-55).
VR — Voltage-regulator tubes — VR-150 and VR-105 types in series to give 255 volts.

resistor, R_7, are necessary to suppress h.f. parasitic oscillations.

The s.p.d.t. toggle switch, S_2, makes it possible either to key both stages simultaneously for break-in work on the lower frequencies, or the output stage alone at 14-Mc. frequencies where oscillator keying chirp may become noticeable. The unit includes a link-coupled antenna tuner, L_4C_4.

The self-contained power supply is built around an inexpensive multiwinding transformer, T_1. The separate filament transformer, T_2, makes it possible to cut off the plate voltage without turning off the heaters of the tubes. A condenser-input filter is used to boost the output voltage to 600 under load. Voltage for the plate of the oscillator and the screen of the 807 is kept from soaring when the key is open by a pair of voltage-regulator tubes. This operating voltage of 255 is dropped to 150 volts for the screen of the 6V6GT by the series resistor, R_3.

The milliammeter may be switched to read oscillator plate current and 807 grid or plate current by the double-gang switch, S_3, which connects the meter across the shunting resistors, R_4, R_6 and R_8. R_4 and R_8 are adjusted to multiply the 10-ma. basic meter-scale reading by 10 and 20, making the full-scale reading 100 and 200 ma. respectively when checking plate currents, while the resistance of R_6 is sufficiently high to have negligible effect upon the meter reading when measuring the grid current of the amplifier.

Construction

Reference should be made to the photographs of Figs. 6-42 through 6-47 for constructional details. The transmitter is built on a 10 × 14 × 3-inch chassis which fits a standard 9 × 15 × 10¾-inch cabinet. The r.f. section occupies the front half of the chassis, while the power-supply components are lined up at the rear.

All tube and coil sockets are submounted. The cathode coil, L_1, requires a 4-prong socket; octals are needed for the 6V6GT, the oscillator plate coil, L_2, the rectifier and the two VR tubes; L_3 and L_4 require 5-prong sockets.

The oscillator and amplifier groups are separated by a small baffle shield cut from sheet aluminum. It is 4 inches high and 5 inches long and has a cut-out in front for the meter. It is spaced 8 inches in from the right-hand end of the chassis. The line of ten Millen crystal sockets is placed as close to the left-hand edge of the chassis as possible. Each of these requires two clearance holes and a mounting-screw hole between.

Alongside the crystal row are the 6V6GT oscillator tube and its cathode coil, L_1, followed by the plate coil, L_2, and the oscillator tuning condenser, C_2. The latter is mounted directly on the chassis 4⅝ inches from the left-hand edge. The oscillator grid and plate chokes are mounted underneath.

On the other side of the baffle shield are the 807 with its plate-circuit choke and blocking condenser, C_{10}, the output tank condenser and coil, C_3 and L_3, and the antenna-coupler coil, L_4. The antenna tuning condenser, C_4, is mounted under the chassis. The socket for the 807 is spaced as far below the chassis level as possible, without protruding from the bottom, by means of brackets cut from strip metal. The purpose of this is to provide a shield between the input and output sections of the tube. A 1⅞-inch hole is required to clear the tube envelope. C_3 is mounted directly on the chassis with its shaft 4⅝ inches from the right-hand end of the chassis to balance the shaft of the oscillator plate-tank condenser.

The antenna tuning condenser, C_4, must be insulated from the chassis. This is done by means of an aluminum angle bracket and a pair of polystyrene feed-through buttons. The condenser is placed so that its shaft comes 1⅝ inches from the end of the chassis to balance the shaft of the crystal switch at the opposite end. The antenna coil is mounted at right angles to L_3.

The meter switch, S_3, is mounted at the center between the front edge of the chassis and the bottom part of the 807. The key jack and power switch, S_4, are spaced equally to either side of the center of the front edge of the chassis.

The power-supply components are placed as close as possible to the rear edge of the chassis, with the transformer T_1 at the left followed by the rectifier and voltage-regulator tubes, the input condenser, C_{11}, the filter choke, L_5, and the output condenser. A large cut-out is required for the transformer terminals and if filter condensers of the type shown are used, holes for the terminals must be provided in addition to the mounting-screw holes. The leads to the filter choke are fed down through a grommet-lined hole next to the choke. The key switch, S_2, and the antenna terminals are mounted in the rear edge of the chassis where the power cord also enters.

Underneath the chassis, the power wiring was done first, keeping it bunched and close to the chassis wherever possible. The separate filament transformer, T_2, is fastened to the left-hand end of the chassis. By-pass condensers and r.f. chokes should be placed close to the tube terminals to which they connect. The by-pass condensers should be grounded to the chassis at the nearest available point. The coupling and blocking condensers, C_7, C_8 and C_{10}, should be well spaced from the chassis. The same applies to all r.f. wiring, which should also be kept short and direct between points of connection. The length of leads to resistors is not important. In some cases it may be convenient to use fiber lug strips as anchorages or supports for small resistors and r.f. chokes.

The meter shunts, R_4, R_6 and R_8, are

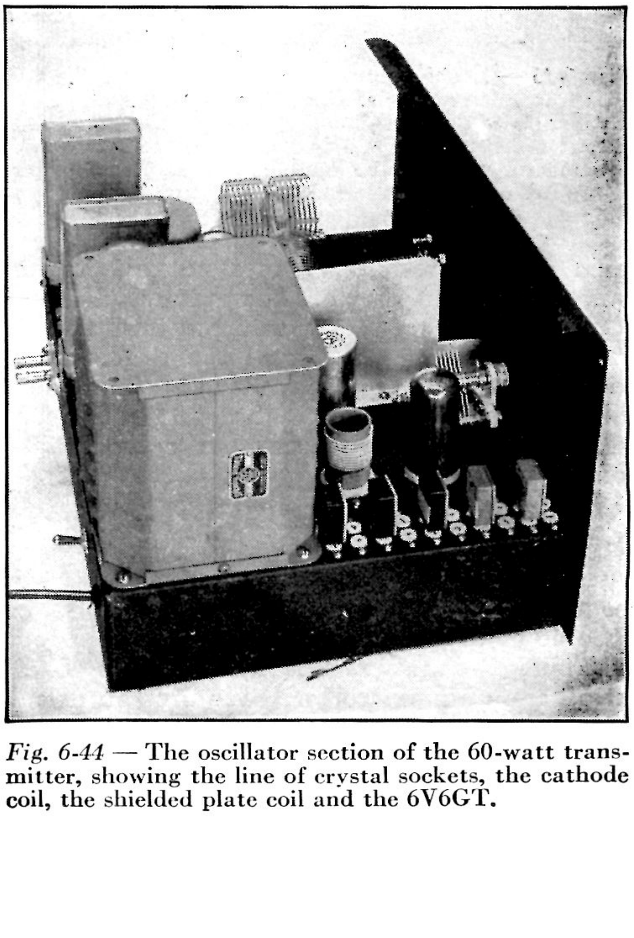


Fig. 6-44 — The oscillator section of the 60-watt transmitter, showing the line of crystal sockets, the cathode coil, the shielded plate coil and the 6V6GT.

mounted directly on the meter switch. R_4 and R_8 are made from No. 30 magnet wire. Approximately 7 feet will be required for R_8 and 14 feet for R_4. Before the meter is mounted in the panel, it should be connected in series with a 3-volt battery and a variable resistance of about 500 ohms. A resistor with a slider will serve the purpose if no other is available. The resistance should be adjusted until the meter reads full scale. When the shunting wire, cut to a length of two or three feet more than that required is connected across the meter terminals, the reading will drop. The length of the wire should be adjusted, bit by bit, until the reading drops to 1 ma. for R_4 and to ½ ma. for R_8. The wire then may be wound on a small form for compactness. A ½-watt

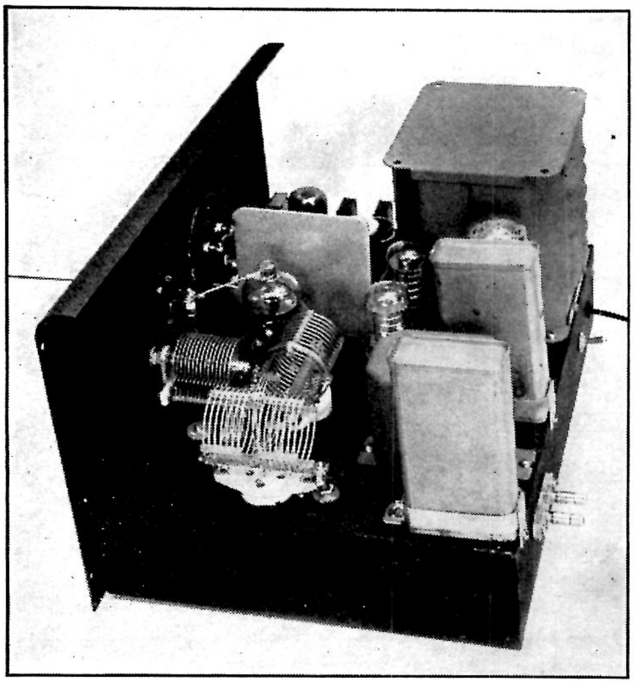


Fig. 6-45 — **Looking into the amplifier end of the 60-watt transmitter chassis. The 807 socket is spaced below the chassis to provide shielding between the input and output sections. The coil in the foreground is in the antenna tuner, while the one behind it is the amplifier plate tank coil.**

resistor of 100 ohms or more makes a good form and its resistance does not affect the calibration of the shunt to any practical degree.

The link line between the output tank circuit and the antenna tuner, and the connections between the latter and the antenna terminals at the rear, should be made with rigid wire spaced well away from the chassis and surrounding components.

Coils

The output and antenna tank coils, L_3 and L_4, are of the B & W JEL and JVL series respectively.

Some of these require pruning, as indicated in Table 6-I to provide the correct L/C ratio. The antenna coil, L_4, requires an extra pair of contacts for the tap leads. Since a center-tap is not required, it may be cut free from the base pin so that this pin may be used

TABLE 6-I
Coils for 60-Watt Rig

Xtal f.	*Output f.*	L_1	L_2	L_3	L_4
3.5 Mc.	3.5 Mc.	1A	2A	3A	4A
3.5 Mc.	7 Mc.	1A	2B	3B	4B
7 Mc.	7 Mc.	1B	2B	3B	4B
7 Mc.	14 Mc.	1B	2C	3C	4C

for one of the tap contacts. The other tap contact is provided by drilling out the tubular rivet at one of the ends of the coil-supporting base strip and substituting a banana plug as shown in Fig. 6-46. A jack for this plug then is mounted in the chassis close to the coil socket by drilling out a pair of polystyrene button-type feed-through insulators to fit the jack and setting them in the chassis.

The two cathode coils for L_1 are wound on Millen 4-prong 1-inch forms. The one to be used with 3.5-Mc. crystals requires a 100-$\mu\mu$fd. mica condenser, C_{13}, connected across it in addition to C_1. This condenser is mounted inside the form so that it is connected in the circuit along with the coil when the latter is plugged in.

The oscillator plate coils are wound on Millen octal-base shielded plug-in forms. If the forms are of the type with iron-core slugs, these should be removed. The 3.5-Mc. coil requires an extra padding condenser, C_{14}, of 22 $\mu\mu$fd. This may be a mica condenser soldered across the winding as shown in the photograph of Fig. 6-46.

Adjustment

Since the tuning of the cathode tank circuit is fixed, only three circuits, including the antenna circuit, need adjustment. The coil table shows which coils should be plugged in to obtain output depending upon the crystal frequency and the output frequency desired. For initial testing it is well to use a combination giving output in the 3.5- or 7-Mc. band. Before turning on the power supply, a key connected to a plug should be inserted in the key jack and the key switch, S_2, should be thrown to the amplifier-keying side. This will permit the oscillator to operate alone. When the power plug is inserted, the heaters of the tubes should warm up. The VR tubes should glow as soon as the power switch, S_4, is

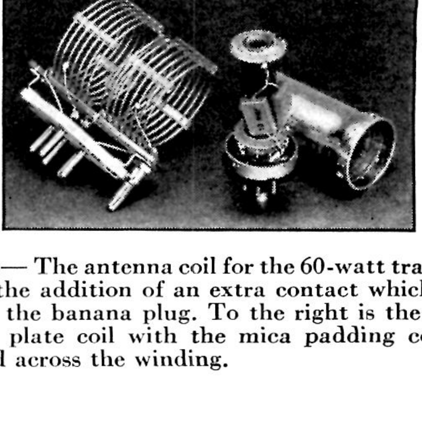


Fig. 6-46 — **The antenna coil for the 60-watt transmitter requires the addition of an extra contact which is provided by the banana plug. To the right is the 3.5-Mc. oscillator plate coil with the mica padding condenser connected across the winding.**

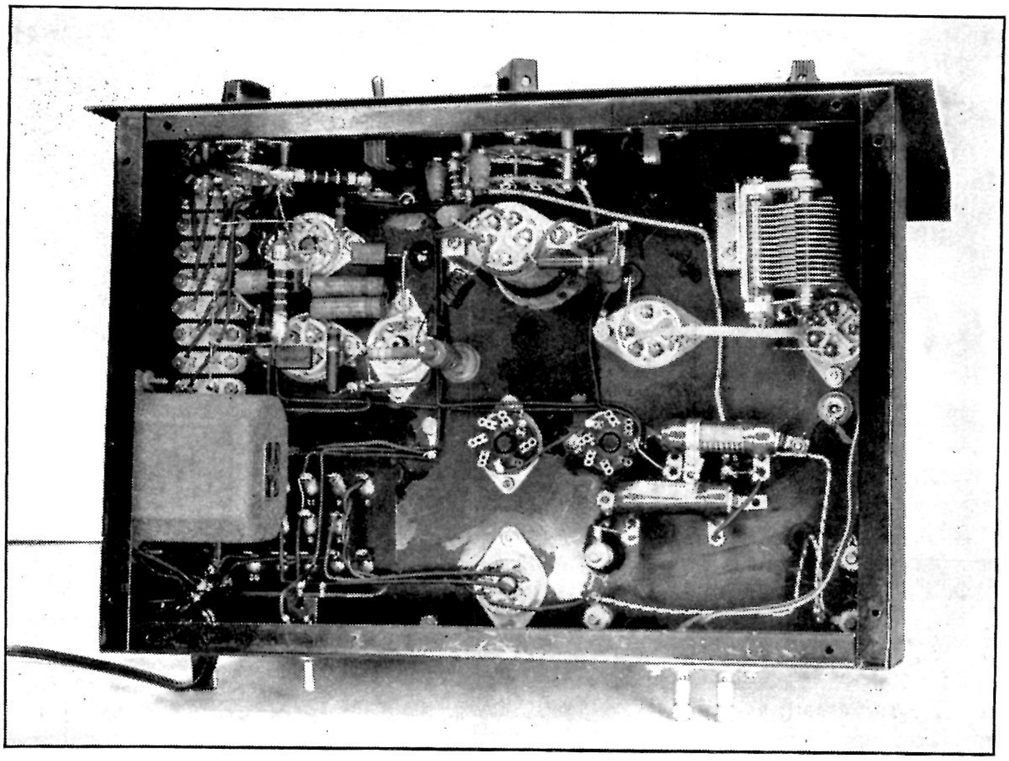


Fig. 6-47 — Bottom view of the 60-watt transmitter, showing the mounting of the 807 socket at the upper center and the location of by-pass condensers, resistors and r.f. chokes. The separate filament transformer is fastened to the left-hand edge of the chassis. The antenna tuning condenser is in the upper right-hand corner, supported on an aluminum angle bracket which is insulated from the chassis by polystyrene buttons.

closed. If they do not, the resistance of R_{10} should be reduced until they do.

With the high voltage applied and the meter switched to the first position for oscillator plate current, the meter should read between 35 and 50 ma. As C_2 is adjusted, a point will be found where the plate current dips to a minimum (between 10 ma. and 30 ma. depending upon the frequency), rising on either side. If L_2 has been made close to specifications, this resonance point should be found with about 60 per cent of maximum capacitance in use at C_2 for 3500 kc., 70 per cent for 7000 kc. and 30 per cent for 14,000 kc. If the plate circuit is tuned to a harmonic of the crystal frequency, the increase in current either side of the minimum should be smooth. However, if the plate circuit is tuned to the crystal frequency, the plate current may jump suddenly to a high value when it is tuned to the high-capacitance side of the minimum plate-current point. This indicates that the circuit has stopped oscillating. C_2 should be set sufficiently to the low-capacitance side of the minimum to insure reliable starting of the oscillator when the power is switched on or when the amplifier is keyed.

When VFO input is used, the cathode tank circuit should be shorted out. Otherwise the adjustment is the same except that the oscillator plate circuit may be tuned for maximum amplifier grid current at the fundamental as well as at the harmonic.

The amplifier should be tuned up first with the antenna coil out of its socket. With the meter switched to the second position where it reads amplifier grid current, a reading of 3 to 9 ma. should be obtained when the key is closed. If no grid-current reading is obtained, it is probable that the oscillator stopped when the key was closed. In this case, the tuning of the oscillator should be readjusted. In this instance, at least, it has been found that best keying is obtained when the oscillator plate circuit is detuned to the low-capacity side of resonance to a point where the oscillator plate current remains constant with the key open and closed. This refers only to amplifier keying when the oscillator plate circuit is tuned to the crystal fundamental, of course. Readings of 5 to 10 ma. or more should be obtained in all cases. The key should not be held closed for periods longer than necessary to obtain the reading, until the amplifier plate circuit is tuned to resonance.

With the meter switch thrown to the last position, where it reads amplifier plate current, a reading of 100 ma. or more should be obtained. As C_3 is turned through its range the plate current should dip to a minimum of between 10 and 15 ma. With the L_3 coils altered as indicated in the coil table, resonance should occur at approximately 90 per cent for 3500 kc., 30 per cent for 7 Mc. and 15 per cent for 14 Mc.

The antenna should now be connected to the antenna terminals and the antenna coil plugged in. The adjustable link of the antenna coupler should be swung about halfway out and the taps should be placed on the outside turns of L_4. With the key closed, C_4 should be swung through its range. At some point the amplifier plate current should increase to a maximum, decreasing on either side. Leaving C_4 at the point where maximum plate current is obtained, C_3 should be readjusted for a minimum point which, of course, will be higher than the unloaded minimum obtained before. The adjustments of C_3 and C_4 should be juggled around until a point is reached where any change in C_3 will cause an increase in plate current, while any adjustment of C_4 will cause a decrease in plate current. If the plate current at this point is less than the maximum rated plate current for the tube, the link coupling should be closed up. If it is greater than 100 ma., the coupling should be reduced. If it is found that the link adjustment is insufficient to bring the plate current to the desired value, the taps should be moved in a turn at a time, keeping them always equidistant from the ends of the coil. The tap adjustments as well as any change in the position of the link may affect the tuning of the amplifier plate circuit, so it should be retuned to obtain minimum plate current as a final adjustment. This minimum should, of course, be the rated plate current of 100 ma. when the amplifier is fully loaded. The dip in plate current at resonance naturally will be very slight when the amplifier is operating under full load.

A 150-Watt Transmitter with Plug-In Stages

Figs. 6-48 through 6-55 show a complete 150-watt transmitter with its associated power supply, antenna coupler and control system. In this unit, coverage of all amateur bands from 3.5 to 28 Mc. is accomplished by means of plug-in exciter stages instead of utilizing either bandswitching or plug-in coils. The arrangement permits multiplying frequency from 3.5- and 7-Mc. crystals to the 28-Mc. band, yet provides a ready means of disposing of the unneeded doubler stages when working at low frequencies. This type of construction permits the constructor to build, and operate, a stage at a time, as his finances and time permit. Even the oscillator unit may be used as a low-power transmitter while the doubler and amplifier stages are being built.

The complete tube line-up (for 28-Mc. operation) consists of a 6AG7 crystal oscillator-doubler, doubler stages for the 14- and 28-Mc. bands using 6V6s, and two 807s in parallel as the final amplifier. The oscillator and the two doubler stages are built as separate units, each in a 4 × 4 × 2-inch utility box. These boxes plug into sockets on the main r.f. chassis. The position into which a given box is plugged depends upon the output frequency desired, as shown in Fig. 6-50. For 3.5- and 7-Mc. operation, the oscillator box is plugged into the position that drives the 807s directly, and the doubler units are not used. For 14-Mc. operation, the oscillator box is moved back one position, and the 14-Mc. doubler stage is plugged into the socket nearest the 807s. For 28-Mc. operation the oscillator and both the 14- and 28-Mc. doublers are used.

Each plug-in stage has a 60-ma. pilot lamp mounted on it as a resonance indicator, and each has terminals brought out from a link to permit coupling to an antenna tuner if low-power operation is desired before the final amplifier is built. Provisions are made for keying the cathode circuit of any stage of the transmitter.

The general construction of the transmitter is shown in Figs. 6-48 and 6-53. Two main chassis are used, one held above the other by angle brackets. The power supply and control

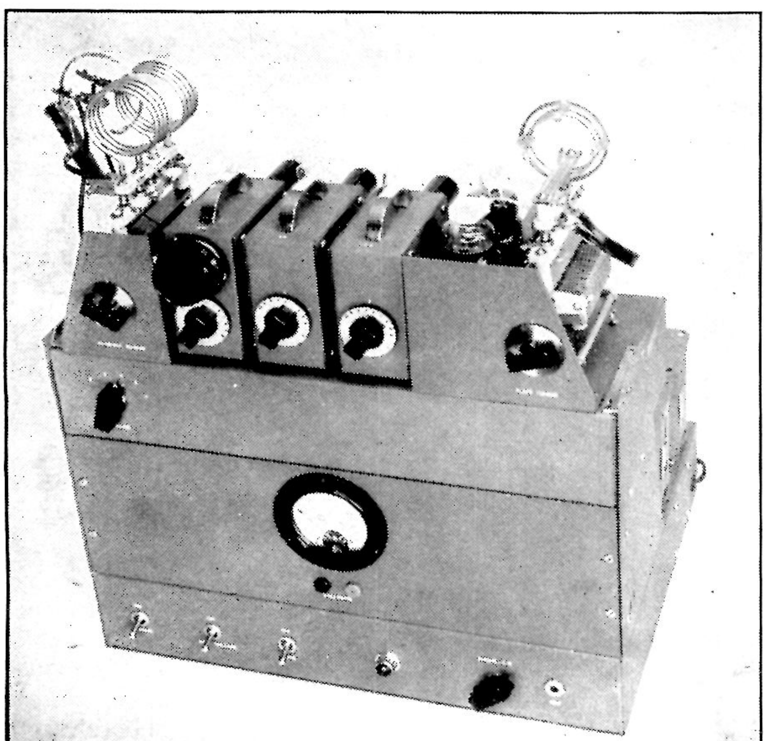


Fig. 6-48 — A compact 150-watt transmitter using plug-in stages. This unit, using 807s in parallel for the final amplifier, is for table-top use. Three separate plug-in units, shown in the center of the upper chassis, are used for the low-power exciter stages. In this view, the units are in the positions required for 28-Mc output. A built-in antenna tuner is at the upper left, and the tank circuits for the 807s at the right. The meter switch is at the left in the upper chassis and the voltmeter pin jacks below the meter. The toggle switches, from left to right, are S_2, S_3 and S_1 in Fig. 6-51. The knob at the right is the 'phone-c.w. switch, S_4, and the jack is for the key.

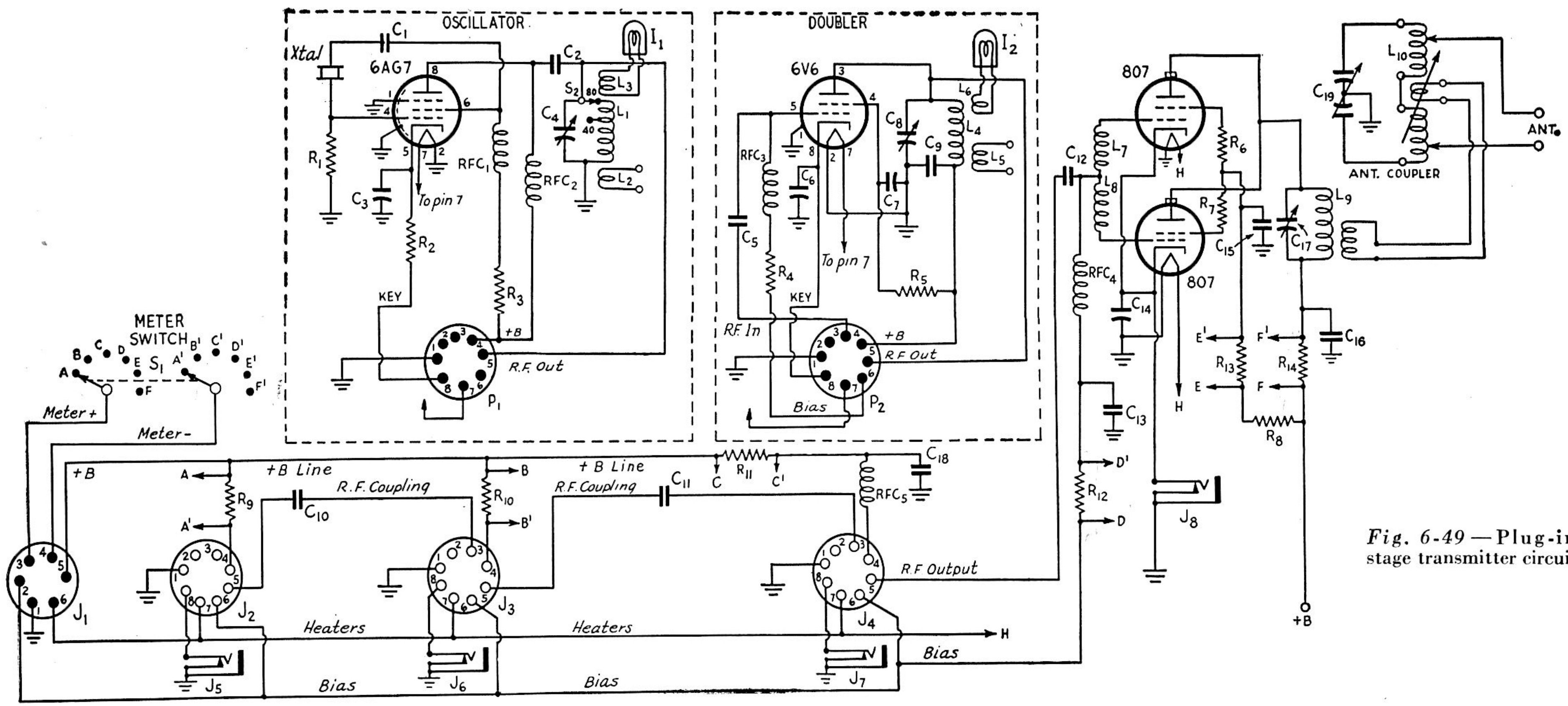


Fig. 6-49 — Plug-in-stage transmitter circuit.

C_1, C_{13} — 0.0015-μfd. mica.
C_2 — 0.001-μfd. mica.
C_3, C_6, C_7, C_{14} — 0.01-μfd. paper.
C_4 — 100-μμfd. receiving-type variable (Millen 19100).
C_5 — 14 Mc. — 100-μμfd. mica; 28 Mc. — 22-μμfd. mica.
C_8 — 14 Mc. — 50-μμfd. variable (Millen 19050).
28 Mc. — Same with 2 rotor plates removed.
C_9 — 0.0047-μfd. mica.
C_{10}, C_{11}, C_{12} — 100-μμfd. mica.
C_{15} — 0.001-μfd. 1000-volt mica.
C_{16} — 0.001-μfd. 2500-volt mica.
C_{17} — 250-μμfd. 1500-volt variable (National TMK-250).
C_{18} — 0.0022-μfd. mica.
C_{19} — 100-μμfd.-per-section dual transmitting variable, 1500 volts peak (National TMK-100D).

R_1 — 47,000 ohms, ½ watt.
R_2 — 330 ohms, 1 watt.
R_3, R_5 — 22,000 ohms, 1 watt.
R_4 — 2200 ohms, ½ watt.
R_6, R_7 — 68 ohms, ½ watt.
R_8 — 30,000 ohms, 20 watts.
R_9 to R_{13} — 100 ohms, ½ watt.
R_{14} — Meter shunt, see text.
L_1 — 27 turns No. 22 d.s.c., tapped 17 turns from ground end, close-wound on ¾-inch diam. form.
L_2 — 2 turns No. 20 enam. inside L_1.
L_3 — 1 turn at ground end of L_1.
L_4 — 14 Mc. — 10 turns No. 22 d.s.c. 1 inch long, ¾-in. diam. (form National PRF-2).
28 Mc. — 4½ turns No. 22 d.s.c. 1 inch long, ¾-inch diam. (form National PRF-2).
L_5 — Similar to L_2.

L_6 — Similar to L_3.
L_7, L_8 — 18 turns No. 20 d.s.c. close-wound on a 1-watt resistor of any high value.
L_9 — B & W BEL series. 3.5 Mc. — 40 BEL; 7 Mc. — 20 BEL; 14 Mc. — 10 BEL; 28 Mc. — 10 BEL with 3 turns removed.
L_{10} — B & W BVL series, no alterations.
I_1, I_2 — 60-ma. pilot lamp.
J_1 — 6-contact male connector (Amphenol 86-CP6).
J_2, J_3, J_4 — Ceramic octal sockets (Millen).
J_5 to J_8 — Closed-circuit 'phone jack.
P_1, P_2 — Low-loss octal plug (Amphenol 86-CP8T).
RFC_1 to RFC_5 — 2.5-mh. choke (Millen 34102).
S_1 — 2-section 6-position ceramic rotary switch (Centralab 2511).
S_2 — Single-pole 2-position ceramic rotary switch (Centralab 2501).

circuits occupy the lower chassis, while all of the r.f. circuits, including the built-in antenna tuner, are in the upper chassis. The entire r.f. unit is removable, permitting the power supply and control circuits to be used with other transmitters of the same chassis size and similar power requirements if desired. All connections between the two chassis are made by a 6-wire cable, a high-voltage lead and a keying lead as shown in Fig. 6-51.

R.F. Circuits

In the oscillator, the screen grid of the 6AG7 is used as the anode of a triode Pierce circuit, with electron coupling to an output plate circuit that can be tuned to either the 3.5- or 7-Mc. bands. A tapped coil, L_1 in Fig.

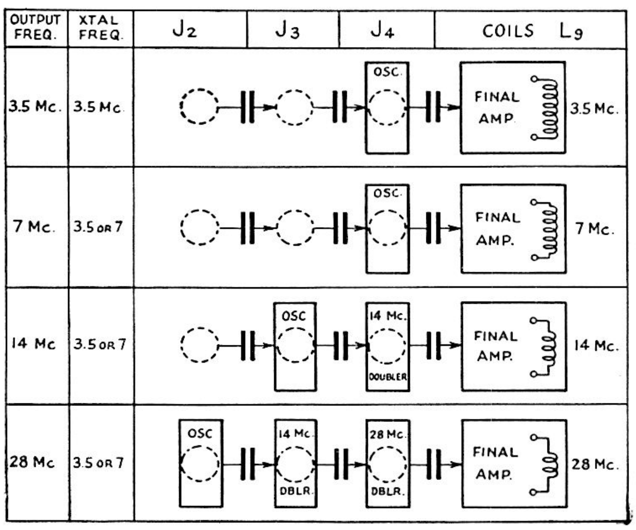


Fig. 6-50— Operating chart for the plug-in-stage transmitter. This chart illustrates the band-changing system used with the various plug-in units used to drive the final amplifier. The columns headed J_2, J_3 and J_4 represent the *position* in Fig. 6-49 a given unit should be plugged in to produce output in a given band. This position is the same for either 3.5- or 7-Mc. crystals. For output at 7-Mc. and higher, the bandswitch in the oscillator unit must be set to the 7-Mc. position.

6-49, and a ceramic bandswitch, S_2, permit this range to be covered. This type of oscillator lends itself nicely to the needs of this transmitter, since output at 7 Mc. may be obtained with either 3.5- or 7-Mc. crystals with no circuit changes other than switching the plate coil. The output of the oscillator, whether operating at the crystal fundamental or doubling frequency from 3.5 to 7 Mc., is sufficient to drive the 807s with some to spare.

The interstage coupling capacitances are adjusted to give optimum drive regardless of whether the oscillator is feeding the 807 grids or the grid of one of the doubler stages. This is accomplished by a series coupling condenser C_5 inside the doubler boxes in addition to the 100-$\mu\mu$fd. interstage coupling condensers, C_{10}, C_{11} and C_{12}. Operating bias for the doublers is obtained from the grid leak, R_4, in addition to a fixed bias of 90 volts which is applied to all stages to assure plate-current cut-off, in the doublers, and protection for the 807s if oscillator keying is to be used.

Plug-in coils are used in the plate circuit of the final amplifier. This stage operates as a straight amplifier on all bands. Series feed is used for maximum efficiency. The full plate potential is thus exposed at the tuning condenser and the plate coil, necessitating extreme caution in turning off plate voltage whenever the coils are being changed. Resistors R_6 and R_7 and chokes L_7 and L_8 prevent high-frequency parasitic oscillations. A screen voltage-dropping resistor, R_8, is used to permit plate-and-screen modulation of the final-amplifier stage.

Coupling to the antenna is accomplished by means of a balanced tank circuit, C_{19}-L_{10}, link-coupled to the final amplifier. The feedline to the antenna is connected to the antenna coil by adjustable taps to permit almost any line impedance to be matched.

Power Supply

In the power-supply circuits, shown in Fig. 6-51, 350 volts at 200 ma. and the regulated fixed bias voltage are obtained from one transformer, while either 750 or 600 volts is obtained from another which has a tapped secondary. A ceramic switch, S_4, selects the proper taps. In c.w. operation the 807s can be used with 750 volts on their plates, but for 'phone operation, the switch selects taps that reduce this voltage to 600. T_3 supplies the 816 filaments while the other, T_4, provides filament voltage for the 5U4G, the 6X5 and the r.f. tubes.

The control circuits use three toggle switches, S_1, S_2 and S_3, in a series arrangement so that filament voltage must be turned on first, followed in sequence by the 350- and 750-volt power supplies. Thus, once all tuning-up operations have been concluded, S_2 is used as the transmit/stand-by switch. An a.c. outlet, J_1, is wired across the primary of the high-voltage transformer so that primary voltage may also be applied to external equipment, such as a modulator supply or an antenna change-over relay, whenever S_2 and S_3 are closed.

A key jack, J_2, is provided on the power chassis as an operating convenience, eliminating the need for long keying leads running behind the r.f. chassis to the various key jacks. It simply provides an extension from the jacks in the r.f. section.

The meter, MA_1, is mounted on the power-supply chassis so that it, too, may be used with another transmitter. Pin jacks are provided for the connection of an external voltmeter so that both current and voltage measurements may be made simultaneously. The switch shifts the voltmeter from stage to stage along with the milliammeter.

R.F.-Chassis Construction

In Fig. 6-48 the layout of the entire assembly is shown. On the 17 × 7 × 3-inch r.f. chassis,

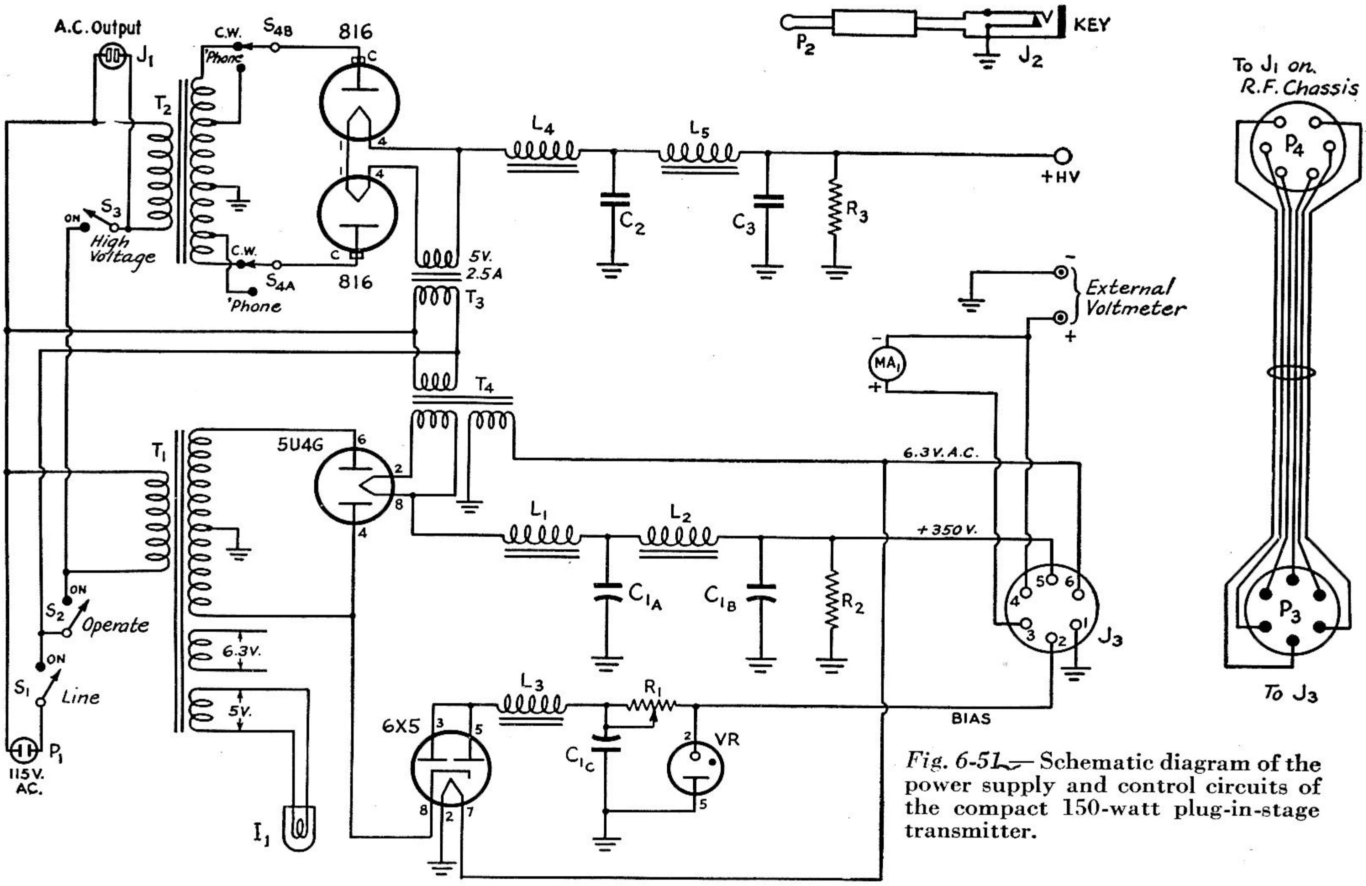


Fig. 6-51—Schematic diagram of the power supply and control circuits of the compact 150-watt plug-in-stage transmitter.

C_1 — 3-section 8-μfd. 450-volt electrolytic (Mallory RM-265).
C_2, C_3 — 4-μfd. 1000-volt oil-filled.
R_1 — 10,000 ohms, 5 watts, adjustable.
R_2 — 20,000 ohms, 25 watts.
R_3 — 50,000 ohms, 50 watts.
L_1 — 5–20-hy. 200-ma. swinging choke, 130 ohms (Thordarson T-19C35).
L_2 — 12-hy. 200-ma. smoothing choke, 130 ohms (Thordarson T-19C42).
L_3 — 8-hy. 40-ma. filter choke, 530 ohms (Thordarson T-13C26).
L_4 — 5–25-hy. 225-ma. swinging choke, 120 ohms (UTC S-32).
L_5 — 15-hy. 225-ma. smoothing choke, 120 ohms (UTC S-31).
I_1 — 6.3-volt pilot-lamp assembly.
J_1 — Female a.c. receptacle (Amphenol 61F1).
J_2 — Closed-circuit jack.
J_3 — 6-prong socket (Amphenol 78RS6).
MA_1 — 0–100-ma. d.c. milliammeter, 3-inch.
P_1 — Male a.c. line plug.
P_2 — 'Phone plug.
P_3 — Male cable connector, 6-contact (Amphenol 86-PM6).
P_4 — Female cable connector, 6-contact (Amphenol 78-PF6).
S_1, S_2, S_3 — S.p.s.t. toggle switch.
S_4 — 2-section 2-position ceramic rotary switch (Mallory 162C).
T_1 — Replacement-type power transformer. 389-0-389 v. a.c., 200 ma. (Thordarson T-92R21).
T_2 — Power transformer, 900/750-0-750/900 v. a.c., 200 ma. (UTC S-45).
T_3 — Filament transformer, 5 volts, 5 amp. (Thordarson T-19F83).
T_4 — Dual filament transformer, 5 volts, 6 amp., 6.3 volts, 5 amp. (UTC S-67).
VR — VR-90 voltage-regulator tube.

the antenna coupler is at the left, then the oscillator box, followed in sequence by the two doubler boxes and the final amplifier. The bottom view of the r.f. chassis, Fig. 6-52, shows the location of the ceramic octal sockets for the plug-in stages, the interstage coupling condensers, C_{10}, C_{11} and C_{12}, and the components grouped around the sockets of the 807s. A meter switch, S_1, appears at the upper left, and the 6-prong chassis plug, J_1, used to terminate the 6-wire cable that connects the low-voltage supply and the meter circuit to the r.f. chassis is at the lower left. The keying jacks, J_5, J_6, J_7 and J_8, are on the rear side of the r.f. chassis, and the high-voltage terminal is at the lower right.

In placing the ceramic sockets for the plug-in units, care should be taken to line up the terminals in such manner that the plug-in boxes will be square to the chassis edges when they are in place. A little care and forethought are all that are necessary, bearing in mind that the octal plugs on the bottom of the plug-in boxes must also be aligned with these sockets.

In wiring the r.f. chassis the metering resistors, R_9, R_{10}, R_{11}, R_{12}, R_{13} and R_{14}, are mounted on S_1. R_{14}, used to multiply the scale reading of the meter by four when the switch is set to read amplifier plate current, is wound with No. 30 d.s.c. wire on a ½-watt resistor of any high value that happens to be handy. Care should be taken to keep lead inductance low in the screen and cathode circuits of the 807 stage. Heavy, short leads are used to tie the paralleled circuit elements together, and both cathode and screen by-pass condensers, C_{14} and C_{15}, are returned to a common ground point.

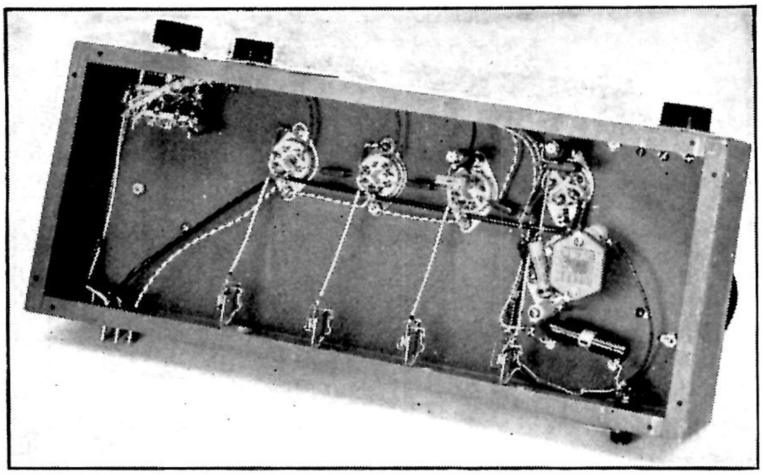


Fig. 6-52 — Bottom view of the r.f. chassis of the plug-in-stage transmitter. The octal sockets for the plug-in units are ranged along the center of the chassis. The components of the 807 stage are at the right. The meter switch is at the upper left, and the power connections and key jacks are on the rear chassis edge.

A ⅜-inch ceramic feed-through bushing brings the high voltage up through the chassis from the plate by-pass condenser and the safety terminal. The plate leads of the 807s are made of flexible shield braid, and run from the tubes to the coil jack-bar. External shielding of the 807s is not required, the shielding afforded by the box-type construction used for the driver stages being sufficient.

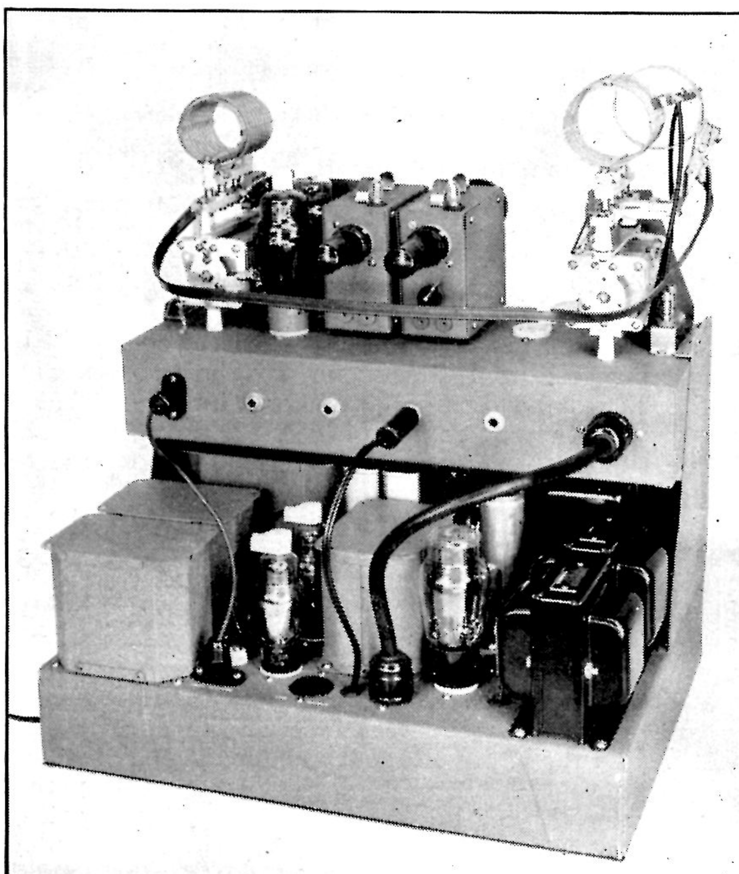
The tuning condenser for the 807 plates is raised above the chassis on National GS-10 stand-off insulators to bring the coil mounting, which is bolted to the top of the condenser frame, up to the level of the 807 plate caps. The condenser rotor shaft is fitted with an insulated coupling to insulate it from the steel panel and the control dial. The antenna condenser, C_{19}, is similarly insulated from both chassis and panel.

Connection from the link winding on the amplifier tank coil to the swinging link of antenna coil, L_{10}, is made through a length of 300-ohm Twin-Lead, held in place by special stand-off insulators made for this type of line by Amphenol. A bracket-mounted antenna terminal (National FWH) is mounted on the chassis just below the swinging link. Flexible leads made of No. 14 stranded copper wire cased in spaghetti tubing connect this terminal to spring-type clips used to tap the antenna feeders across the required number of turns of the antenna-coupler coil.

Fig. 6-53 — Rear view of the plug-in-stage transmitter. In this view the units are set up for 14-Mc. output. Connections between the two chassis are shown, with the high-voltage lead at the left, the keying lead in the center, and the 6-wire power cable on the right.

Oscillator and Doubler Units

The arrangement of the parts in the 4 × 4 × 2-inch oscillator and doubler boxes is shown in Figs. 6-54 and 6-55 respectively. Only one of the doubler boxes is shown in the photograph as well as in the schematic diagram because the two are identical in appearance and parts placement. A 5-prong ceramic socket is mounted on the front of the oscillator box just above the tuning dial to hold a Dekaxtal multiple-crystal unit. This device provides the additional feature of crystal switching. A standard crystal socket may be substituted if desired, of course. The bandswitch, S_2, is mounted on the rear of the box, just below the tube socket. The coil form is mounted on the rear bearing bracket of the condenser. The coil itself has three windings, the tapped



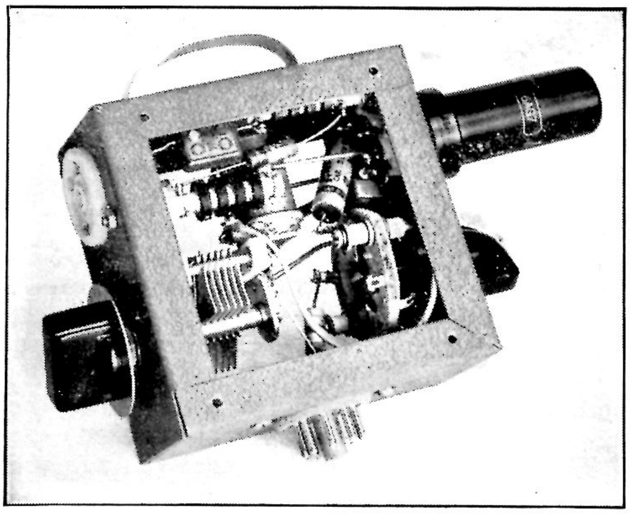


Fig. 6-54 — Interior view of the plug-in oscillator unit used with the compact 150-watt transmitter (side plates removed). The crystal socket is at the upper left, above the plate tuning dial. The plate coil is mounted on the rear bearing bracket of the tuning condenser. The r.f. chokes extend out from the front and rear walls, and the plate-blocking and cathode by-pass condensers are mounted at the tube socket. The bandswitch is mounted on the rear wall of the box, below the tube.

tank coil, L_1, and two adjustable link windings, L_2 and L_3, for coupling to the pilot-lamp resonance indicator and to an antenna tuner. The insulated tip jacks used for the antenna-link terminals are at the rear below the switch knob.

Twin-Lead (75-ohm) is used as the link line to the indicator lamp socket and to the tip jacks. The indicator lamp is mounted in a Drake Type 317H socket and is insulated from the box by a grommet which also serves to hold the assembly in place.

The Millen Type 34102 r.f. chokes are mounted from opposite sides of the oscillator box through the holes drilled for mounting the tube socket and the crystal socket. Some care is required in placing these parts to assure clearance between the r.f. chokes and the oscillator coil form.

Construction of the doublers is similar to that of the oscillator, but is simplified by the fact that fewer components are required. The series coupling condenser, C_5, and the bias resistor, R_4, are mounted vertically right at the octal plug. The r.f. choke is mounted vertically through one of the holes used to mount the plug.

As indicated below Fig. 6-49, there are minor differences, in addition to the coil specifications, in the circuit values used in the 14- and 28-Mc. doublers.

More than ordinary care should be taken to make clean, firm, soldered connections to the octal plugs used to connect the oscillator and the doublers to the r.f. chassis. These joints are subject to considerable wear and tear, and should be as solid as possible. The pins of the plugs should be scrubbed clean with alcohol after the soldered joint is made to remove all traces of flux or rosin. No. 14 bare tinned wire is used for r.f. leads wherever possible.

Building the Power Supply

The arrangement of the parts on the 17 × 13 × 3-inch power-supply chassis can be seen in Fig. 6-53. The two power transformers are placed along the front edge of the chassis, each set in about an inch from the side to provide room for the angle brackets used to support the r.f. chassis. The filter chokes are immediately behind their respective transformers. The dual filament transformer used for the 5U4G low-voltage rectifier, the 6X5 bias rectifier, and the tubes in the r.f. chassis are mounted near the center of the chassis, behind the filter condensers, and between the two 816s and the 5U4G. Space for the high-voltage safety terminal, the a.c. power outlet, the keying lead, and the 6-terminal low-voltage output socket is left at the rear of the chassis, keeping the back of the chassis clear so that it may be placed against a wall if the unit is used on the operating desk. The 5-volt transformer for the 816 filaments and the small filter choke used in the bias circuit are mounted beneath the chassis. If a 2.5-volt 5-amp. filament transformer is available, it may be substituted if the 816 filaments are connected in parallel instead of in series as shown in the circuit diagram. The voltage regulator is placed just in front of the 3-section filter condenser. The 6X5 bias rectifier is behind the 5U4G.

Supports made from 5 × ½ × ¾-inch blocks of hard wood bolted to the inside of the upright angle brackets carry the weight of the r.f. chassis. Small aluminum angle strips are also bolted to the brackets above the r.f. chassis so that they, with the blocks mentioned above, form a channel into which the r.f. chassis slides like a drawer. This permits

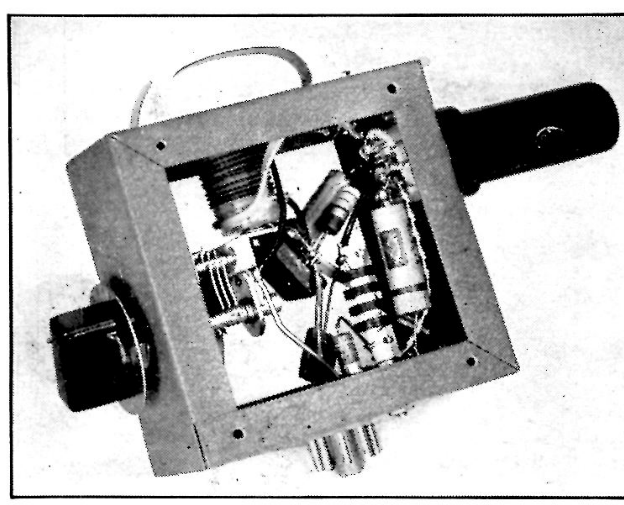


Fig. 6-55 — Interior view of one of the plug-in doubler units used with the compact 150-watt transmitter. The screen and the cathode by-pass condensers run from the tube sockets to ground points. A two-terminal tie-point supports one end of the screen dropping resistor and the plate-blocking condenser. The grid condenser and the bias resistor are mounted vertically from the octal plug. The indicator lamp protrudes from the top.

the r.f. chassis to be removed without unbolting the side brackets, and prevents it from being lifted off the supporting blocks when the plug-in boxes are pulled out of their sockets.

Adjustment Procedure

Reference should be made to Fig. 6-50 in setting up the exciter stages to obtain output in the desired band.

The oscillator plate-and-screen current should run between 20 and 30 ma., depending upon whether or not the oscillator is doubling frequency. The dip in current at resonance will be slight when the oscillator is coupled to one of the following stages. The resonance-indicator lamp or the grid current to the final-amplifier stage will be more reliable indicators of maximum oscillator power output.

The 14-Mc. doubler combined screen-and-plate current also should run between 20 and 30 ma. when loaded, while the reading for the 28-Mc. doubler should run 40 to 50 ma.

With the final amplifier loaded to the rated plate current of 200 ma., the grid current should be adjusted to 8 ma., detuning the oscillator plate-tank circuit if necessary to reduce the grid current to this value. More than adequate drive to the final amplifier increases screen dissipation and actually decreases power output. The doubler circuits should not be detuned because of the danger of exceeding the dissipation rating of the doubler tubes.

The adjustment of antenna tuning and coupling is discussed in Chapter Ten.

A Three-Stage 250-Watt Transmitter

The three-stage transmitter illustrated in Figs. 6-56 through 6-60 uses a single Hytron 5514 in the output stage. A 6AG7 in a modified Pierce circuit is the crystal oscillator, which can deliver output at the second harmonic as well as the fundamental frequency of the crystal. It drives a pair of 6L6s arranged to operate as either a push-push doubler or a neutralized single-tube amplifier. Capacitance coupling and plug-in coils are used throughout to simplify the circuit and reduce the cost.

Circuit Details

Referring to the circuit diagram of Fig. 6-57, a combination of fixed and grid-leak bias is used in all stages to provide tube protection in case of failure of the crystal to function. The full 400 volts of the low-voltage plate supply is used for the plate of the oscillator, but the voltage-dropping resistor, R_3, reduces this voltage considerably for the screen of the 6AG7. A split-stator condenser, C_4, is used to provide a balanced input circuit for the push-push stage. C_{18} is used to compensate for the output capacitance of the 6AG7 which is connected across the other half of the circuit.

Since a push-push stage cannot be used for straight-through amplification, one of the 6L6s is made inoperative when the stage is not doubling by turning off its filament by means of S_1. An incidental convenience of this arrangement is that the plate-grid capacitance of the inoperative tube serves as the neutralizing capacitance for the remaining active tube. A split-stator tank condenser, C_9, is used in the plate circuit of the doubler stage to help in minimizing stray circuit capacitances.

Because both tubes are not always in operation simultaneously, separate screen voltage-dropping resistors, R_5 and R_6, are used.

Series plate feed is used in the final amplifier and the circuit is so arranged that the d.c. plate voltage appears between both sides of the tank condenser, C_{14}, and ground, but not between stators and rotors, thus reducing the required condenser-plate spacing. The tank condenser specified has an insulated frame and shaft. Condensers of other types will require good d.c. insulation from both the chassis and the control dial. The output circuit is equipped with links for coupling to the antenna system.

A closed-circuit jack is provided in the cathode circuit in each stage so that any stage may be keyed as desired. These jacks also may

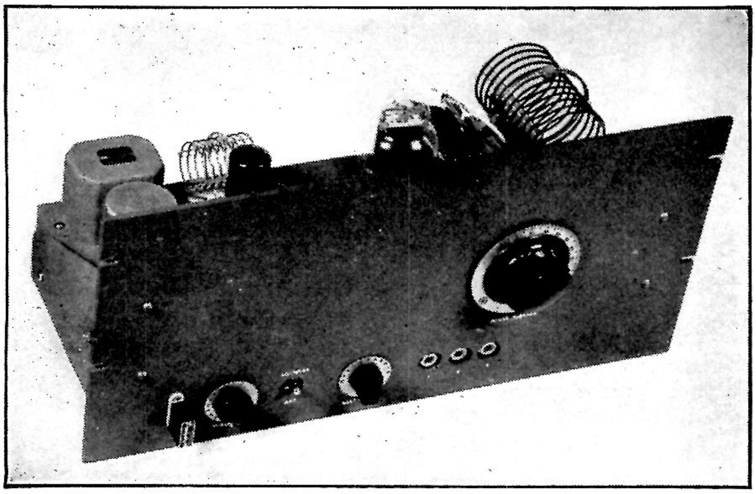


Fig. 6-56 — Front panel view of the 250-watt transmitter. The crystal plugs into a ceramic socket at the lower left. Next in line is the oscillator tuning dial. The toggle switch changes the 6L6 stage from a push-push doubler to a neutralized amplifier. The tuning knob for the 6L6 plate circuit is in the center, followed by the three key jacks. The large dial is connected to the amplifier tuning condenser by an insulated shaft.

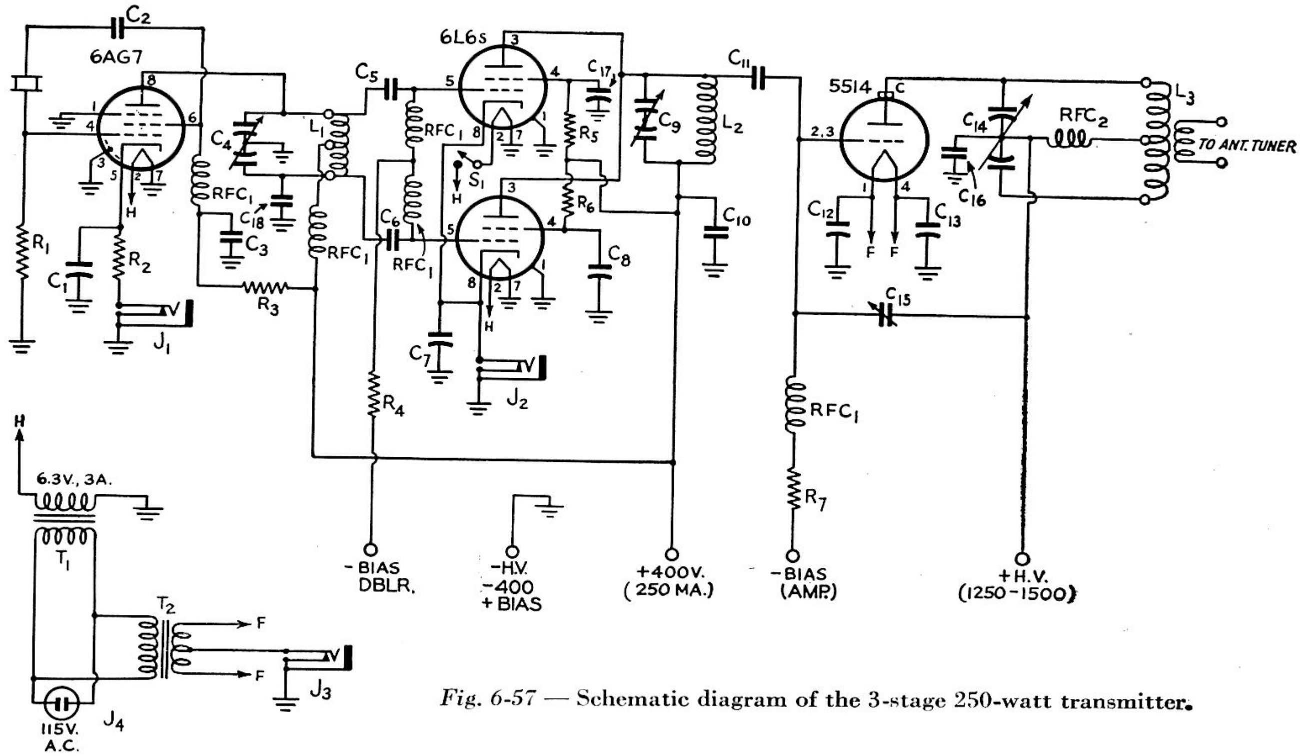


Fig. 6-57 — Schematic diagram of the 3-stage 250-watt transmitter.

C_1, C_7, C_8, C_{12}, C_{13}, C_{17} — 0.01-μfd. paper.
C_2, C_3 — 0.0047-μfd. mica.
C_4 — 140-μμfd.-per-section dual variable (Hammarlund HFD-140).
C_5, C_6 — 47-μμfd. mica.
C_9 — 100-μμfd.-per-section dual variable (Cardwell EU-100-AD).
C_{10} — 0.001-μfd. mica.
C_{11} — 47-μμfd. 1000-volt mica.
C_{14} — 100-μμfd.-per-section transmitting variable (Hammarlund HFBD-100-E).
C_{15} — Neutralizing condenser (National STN).
C_{16} — 0.001-μfd. 5000-volt mica.
C_{18} — 7.5-μμfd. ceramic (two 15-μμfd. Erie Ceramicons in series).
R_1 — 47,000 ohms, ½ watt.
R_2 — 330 ohms, ½ watt.
R_3 — 68,000 ohms, 1 watt.
R_4 — 4700 ohms, 1 watt.
R_5, R_6 — 25,000 ohms, 5 watts.
R_7 — Bias resistor (see text).
L_1 — 3.5 and 7 Mc. — 44 turns No. 22 d.s.c., close-wound, 1-inch diam., center-tapped.
— 7 and 14 Mc. — 20 turns No. 22 d.s.c., 1 inch diam., 1⅛ inches long, center-tapped.
Above coils wound on Millen Type 45000 forms.
L_2 — 3.5 Mc. — B & W 80 JCL with 12 turns removed.
— 7 Mc. — B & W 20 JCL.
— 14 Mc. — B & W 10 JCL.
— 28 Mc. — Bud OCL-5.
(The above coils are supplied with center links. These link windings are unused, but need not be removed.)
L_3 — B & W TL series.
— 3.5 Mc. — 80 TL; one turn added each side.
— 7 Mc. — 40 TL.
— 14 Mc. — 20 TL.
— 28 Mc. — 10 TL.
J_1, J_2, J_3 — Closed-circuit jack.
J_4 — 115-v. a.c. male plug.
RFC_1 — 2.5-mh. 100-ma. r.f. choke.
RFC_2 — Transmitting r.f. choke (Millen 34140).
S_1 — S.p.s.t. toggle switch.
T_1 — Filament transformer, 6.3 volts, 3 amp.
T_2 — Filament transformer, 7.5 volts, 4 amp. (UTC S-59).

be used for checking cathode currents by means of a meter on a plug.

A 6.3-volt transformer for the tubes in the exciter stages and a 7.5-volt transformer for the 5514 are included on the chassis.

Construction

The transmitter is built on an 8 × 17 × 3-inch chassis with a standard 10¾-inch rack panel. In Fig. 6-58, the exciter stages occupy the right-hand side of the chassis while the output-stage components are grouped to the left. In line, from front to back along the right-hand edge are the 6AG7, a removable shield can which covers L_1, and the 7.5-volt filament transformer, T_2. Immediately to the left are the 6L6s and their plate tank coil, L_2.

The neutralizing condenser for the 5514, C_{15}, is mounted on small stand-off insulators in front of the tube. The lead between C_{15} and the grid terminal of the tube passes through a clearance hole in the chassis. The plate tank condenser, C_{14}, is elevated on ½-inch cone insulators to bring its terminals closer to those of the tank coil at the left. The by-pass condenser, C_{16}, is fastened between the rear rotor terminal and the chassis. RFC_2 is to the left of the tank coil.

In the bottom view of Fig. 6-59, the oscillator tank condenser, C_4, is mounted between the two rows of sockets on metal spacers to bring its shaft level with that of the doubler tank condenser, C_9, which is mounted on small stand-off insulators to the right. The 6.3-volt filament transformer, T_1, is fastened to the rear edge of the chassis and the three jacks are set in a row in the opposite front edge.

The circuit diagram of a suitable power supply for operating the 5514 at maximum ratings is shown in Fig. 6-60.

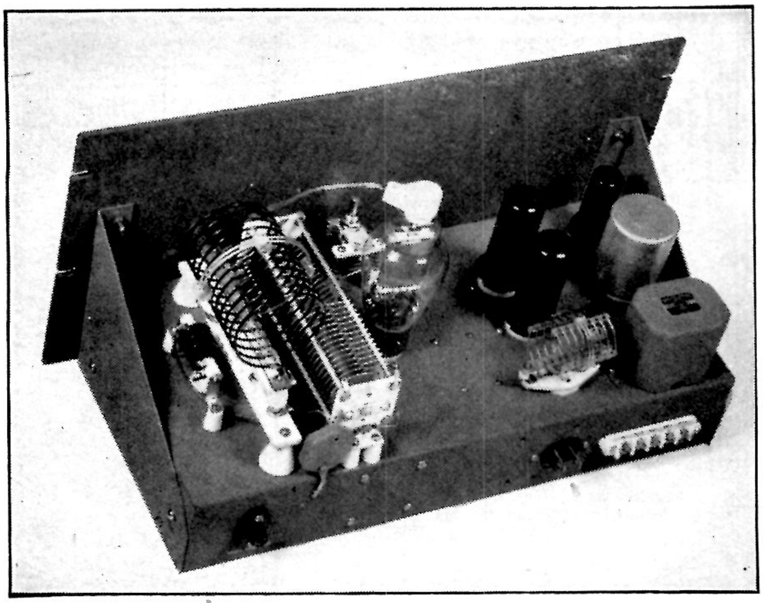


Fig. 6-58 — Chassis layout of the 3-stage 250-watt transmitter. Along the rear edge are the safety terminal for the high-voltage connection, 115-v. a.c. plug for the filament transformers and a terminal strip for bias and low-voltage connections.

Tuning Characteristics and Circuit Adjustment

The oscillator should function regardless of the tuning of the plate tank circuit. If the plate coils, L_1, are made closely to the dimensions given, it should be possible to tune to both 3.5 and 7 Mc. with one coil and to 7 and 14 Mc. with the other. The plate-current dip indicating resonance in the output circuit will not be pronounced, so it must be watched for carefully. When the complete transmitter is in operation, the grid current to the final amplifier will be the best indicator of maximum oscillator and buffer-doubler output. With a 400-volt supply, the oscillator screen voltage should be about 180 and the cathode current approximately 18 ma., whether or not the oscillator stage is doubling frequency.

The buffer-doubler should show a cathode current of about 200 ma. with both tubes operating as doublers or 100 ma. with only the single tube in operation as a buffer amplifier. In this stage also, the dip in cathode current at resonance is slight. Grid current to the 6L6s under load should be about 5 ma. per tube. If the difference in grid currents to the two tubes is more than 1 ma., the value of the balancing condenser, C_{18}, should be changed until balanced grid current is obtained.

With fixed bias applied, a final-amplifier grid current of 100 ma. or more should be obtained before plate voltage is applied to the 5514. Before neutralization, tuning the amplifier plate tank circuit through resonance should cause a wide deflection in grid current. Starting at minimum capacitance, the neutralizing condenser should be adjusted, bit by bit, until the dip in grid current is brought to a barely noticeable minimum or eliminated altogether. Increasing the capacitance of the neutralizing condenser beyond this point should result in an increase in the grid-current dip again. The correct adjustment is the one that produces least change in grid current as the amplifier plate tank circuit is tuned through resonance.

With the amplifier neutralized, plate voltage may be applied and the amplifier coupled to an antenna system and loaded as described in Chapter Ten. For maximum c.w. ratings, the plate voltage should not exceed 1500 volts and the plate current 175 ma., with R_7 500 ohms. Similar ratings with 100-per-cent plate modulation are 1250 volts and 142 ma., with R_7 150 ohms. Under load, the grid current will be less than without load. The excitation should be adjusted to obtain the rated value of 60 ma. under actual operating conditions with load.

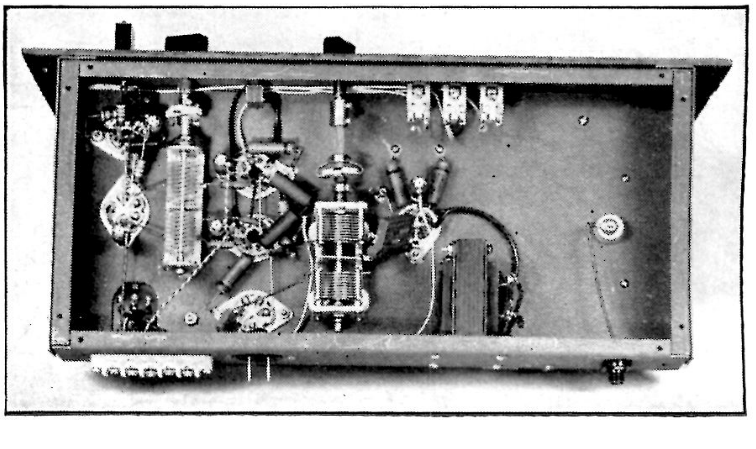


Fig. 6-59 — Bottom view of the 3-stage 250-watt transmitter.

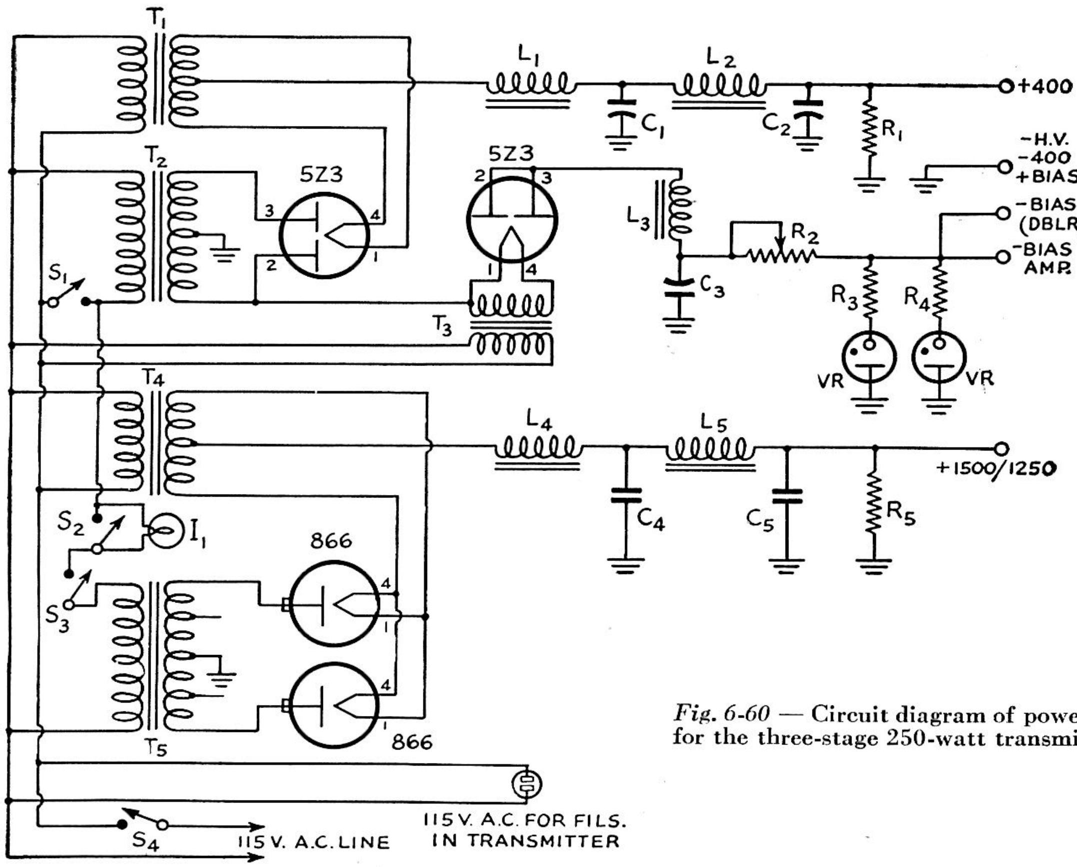


Fig. 6-60 — Circuit diagram of power supply for the three-stage 250-watt transmitter.

C_1, C_2, C_3 — 8-μfd. 600-volt-wkg. electrolytic.
C_4, C_5 — 4-μfd. 2000-volt oil-filled.
R_1 — 25,000 ohms, 25 watts.
R_2 — 30,000 ohms, 10 watts, with slider.
R_3, R_4 — 47 ohms, 1 watt.
R_5 — 25,000 ohms, 150 watts.
L_1 — 5/25-hy. 225-ma. swinging choke.
L_2 — 20-hy. 225-ma. smoothing choke.
L_3 — 30-hy. 75-ma. filter choke.
L_4 — 5/25-hy. 175-ma. swinging choke.
L_5 — 10-hy. 175-ma. smoothing choke.
I_1 — 150-watt 115-volt lamp.
S_1, S_3, S_4 — 10-amp. toggle switch.
S_2 — 5-amp. toggle switch.
T_1, T_3 — 5-volt 3-amp. filament transformer.
T_2 — 400-v. d.c. 225-ma. plate transformer.
T_4 — 2.5-volt 10-amp. filament transformer, 10,000-volt insulation.
T_5 — 1500/1250-v. d.c. 175-ma.-or-more plate transformer.
VR — VR-75 voltage-regulator tube.

S_4 turns on all filaments in power supply and transmitter and sets up circuit so that S_1 will turn on 400-volt supply. S_1 also sets up the circuit so that S_3 will turn on high-voltage supply. When S_2 is open, the lamp I_1 is inserted in series with the primary of T_5 to reduce voltage during adjustment. In operation of the transmitter, S_1 serves as the stand-by switch. R_2 should be adjusted so that the VR tubes barely ignite with the transmitter not operating.

A Two-Stage High-Power Transmitter

The photographs of Figs. 6-61, 6-63 and 6-64 show a two-stage transmitter capable of handling a power input of 900 watts on c.w. or 675 watts on 'phone. The circuit diagram is shown in Fig. 6-62. It is a simple arrangement in which a 6L6 Tri-tet crystal oscillator drives an Eimac 4-250A in the output stage, either at the crystal fundamental or at the second harmonic so that the transmitter will cover two bands with a single crystal of proper frequency without doubling in the output stage. Through the use of plug-in coils and a selection of crystals, the transmitter may be used in all bands between 3.5 and 28 Mc. inclusive.

Any one of four crystals may be selected by means of S_1, although more crystal positions may be added. R_4, R_5 and R_6 are metering resistors across which the milliammeter is switched to read combined oscillator screen-and-plate current, amplifier grid current or amplifier cathode current. R_5 has sufficient resistance to have no practical effect upon the meter reading, but the other shunts which are made from copper wire are adjusted to give a meter-scale multiplication of 10, making the full-scale reading 500 ma. The diagram shows both stages keyed simultaneously. If amplifier keying only is desired, R_1 should be connected to ground instead of to the key terminal.

Construction

The transmitter is built on a 10 × 17 × 3-inch chassis with a 10½-inch standard rack panel. The mechanical arrangement shown in the photographs should be followed as closely as possible, since upon the placement of parts may depend the stability of the amplifier. The oscillator-circuit components are grouped at the left-hand end of the chassis. The Millen crystal sockets are lined up with their centers

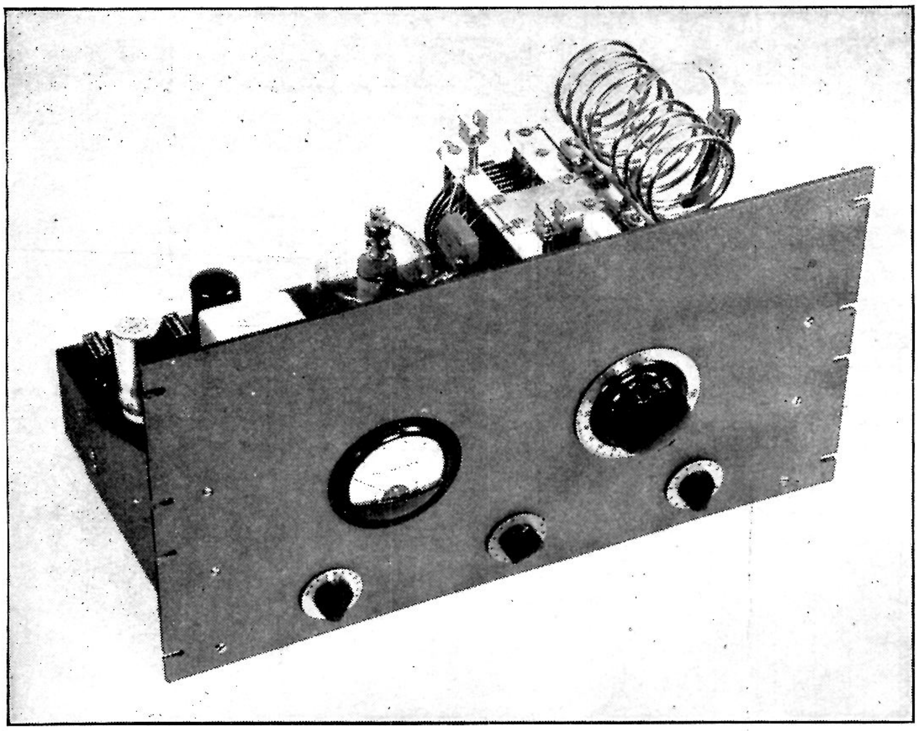


Fig. 6-61 — Front view of the 4-250A transmitter. Along the bottom of the panel, from left to right, are the controls for the oscillator tuning condenser, the crystal switch and the metering switch. The large dial is for the output tank condenser.

1½ inches in from the rear edge of the chassis in the left-hand corner. The sockets for the 6L6 and the plug-in cathode coil, L_1, are in line with their centers, 3½ inches from the back edge of the chassis, while the oscillator plate coil is in line with the 6L6, 6 inches from the rear edge of the chassis and 3½ inches from the left-hand end. The crystal switch is placed near the 6L6

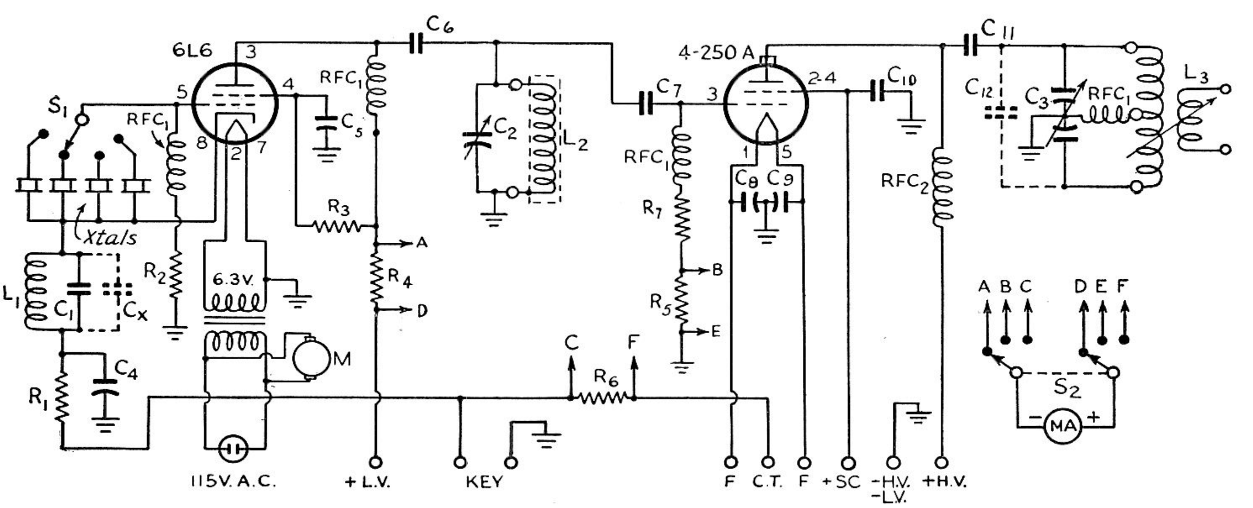


Fig. 6-62 — Circuit diagram of the two-stage high-power transmitter.

C_1 — 100-μμfd. mica.
C_2 — 100-μμfd. variable (National ST-100).
C_3 — 50-μμfd.-per-section 0.171-inch-plate-spacing variable (Millen 14050).
C_4, C_5, C_8, C_9 — 0.01-μfd. paper.
C_6 — 0.0015-μfd. mica.
C_7 — 100-μμfd. mica, 5000 volts.
C_{10} — 0.001-μfd. mica, 5000 volts.
C_{11} — 0.001-μfd. mica, 10,000 volts.
C_{12} — Vacuum-type padding capacitor, 25 μμfd., 16,000 volts (GE GL-122).
C_X — 100-μμfd. mica (for 3.5-Mc. crystals only).
R_1 — 220 ohms, 1 watt.
R_2 — 47,000 ohms, ½ watt.
R_3 — 5,000 ohms, 10 watts.
R_4, R_6 — 58 inches No. 22 copper wire wound on small-diam. form.
R_5 — 47 ohms, ½ watt.
R_7 — 5000 ohms, 25 watts.
L_1 — 3.5-Mc. crystals: 22 turns No. 22 d.s.c., ½-inch diam., close-wound. C_X connected across full winding.
— 7-Mc. crystals: 12 turns No. 22 d.s.c., ½-inch diam., close-wound.
— 14-Mc. crystals: 6 turns No. 20 d.s.c., ½-inch diam., ⅝ inch long.
L_2 — 3.5 Mc.: 40 turns No. 22 d.s.c., 1-inch diam., close-wound.
— 7 Mc.: 20 turns No. 22 d.s.c., 1-inch diam., close-wound.
— 14 Mc.: 9 turns No. 22 d.s.c., 1-inch diam., ¾ inch long.
— 28 Mc.: 5 turns No. 20 enam., ⅝-inch diam., ⅜ inch long (on Millen Type 45500 threaded ceramic form).
L_3 — B & W TVH-series coils.
M — Fan motor (Barber-Colman Type d Yab 569-1 with Type Yab 355-2 2½-inch fan; Rockford, Ill.).
MA — 0-50 milliammeter.
RFC_1 — 2.5-mh. r.f. choke.
RFC_2 — Hammarlund CH-500 r.f. choke.
S_1 — 4-position ceramic tap switch.
S_2 — Double-gang 3-position switch.

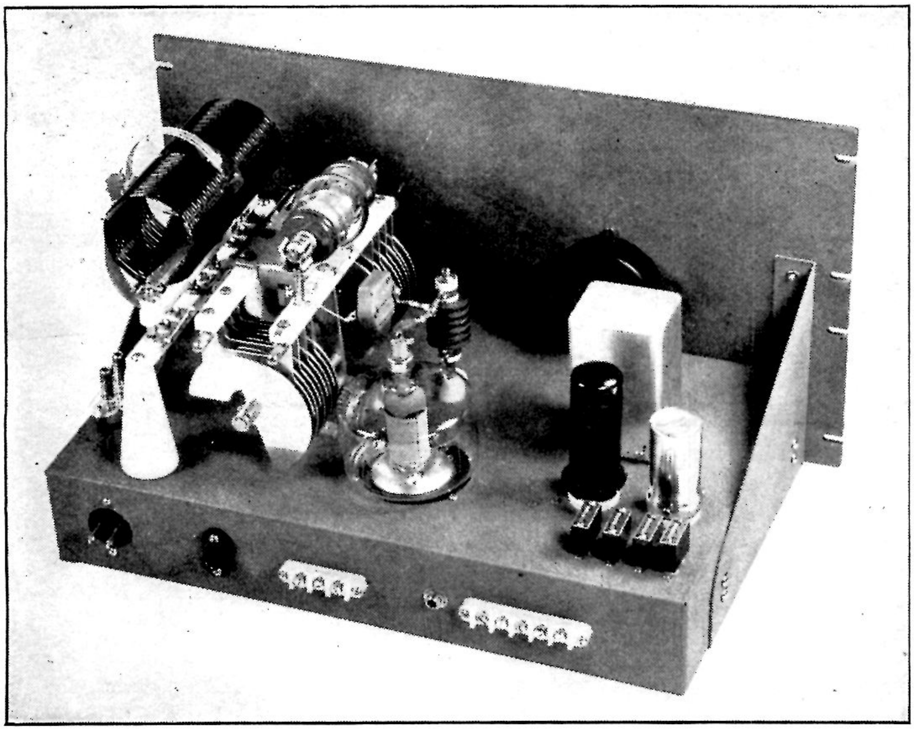


Fig. 6-63— Rear view of the two-stage high-power transmitter, showing the vacuum-type padding condenser in place on top of the tank condenser.

socket and set at an angle with respect to the edges of the chassis. It is controlled by a knob at the center by means of a long ¼-inch shaft, which runs diagonally across the chassis, and a Millen 39005 all-metal flexible shaft coupling of the "universal-joint" type.

The socket for the 4-250A is centered 7¾ inches from the left-hand end of the chassis and 3 inches from the rear edge. It is spaced 1⅛ inches below the chassis on metal pillars so that the base of the tube is shielded from the plate. A spring contact is fastened to the socket so that the metal ring around the base of the tube will be grounded when the tube is inserted in the socket. The 4-250A requires a small amount of forced-air cooling. This is supplied by a small fan, *M*, Fig. 6-62, directed at the base of the tube. A bottom plate should be used on the chassis so that the air will be forced up around the envelope of the tube. The amplifier plate-tank condenser is placed with its shaft 5¼ inches in from the right-hand edge of the chassis, while the coil-base assembly is elevated on 3-inch cone insulators centered 2½ inches from the edge. The clips for the padding condenser, C_{12}, required for the 3.5- and 7-Mc. bands, are mounted on top of the condenser on 1-inch tubular spacers. A pair of long 6-32 mounting screws, passing through the spacers, serve to make the connection between the stators of C_3 and the terminals of C_{12}. The Hammarlund CH-500 r.f. choke, RFC_2, is mounted alongside the tank condenser, near the center, with the plate-blocking condenser, C_{11}, fastened to the top.

Plate voltage is fed from a Millen safety terminal in the rear edge of the chassis to the bottom end of the r.f. choke through a Millen 32101 steatite bushing. The hole for the safety terminal should have a clearance of about 1⁄16

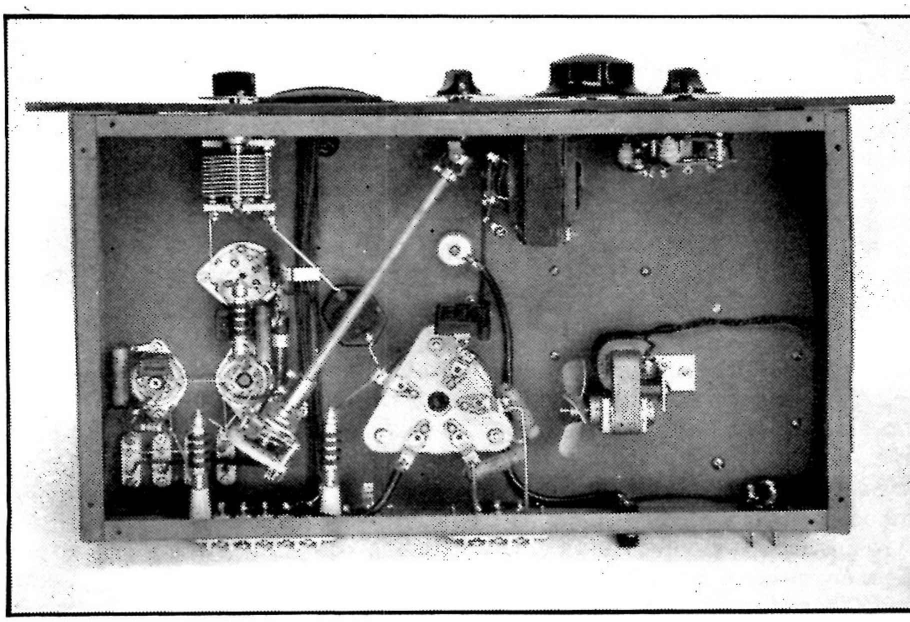


Fig. 6-64 — Bottom view showing the arrangement of parts under the chassis. Mounted off the rear edge of the chassis are the oscillator (left) and amplifier (right) grid chokes. The oscillator plate choke is above. The condenser under the crystal-switch control shaft is the coupling condenser, C_7. The oscillator tuning condenser, C_2, the 6.3-volt filament transformer and the metering switch are along the front edge of the chassis. The ventilating fan is to the right of the tube socket.

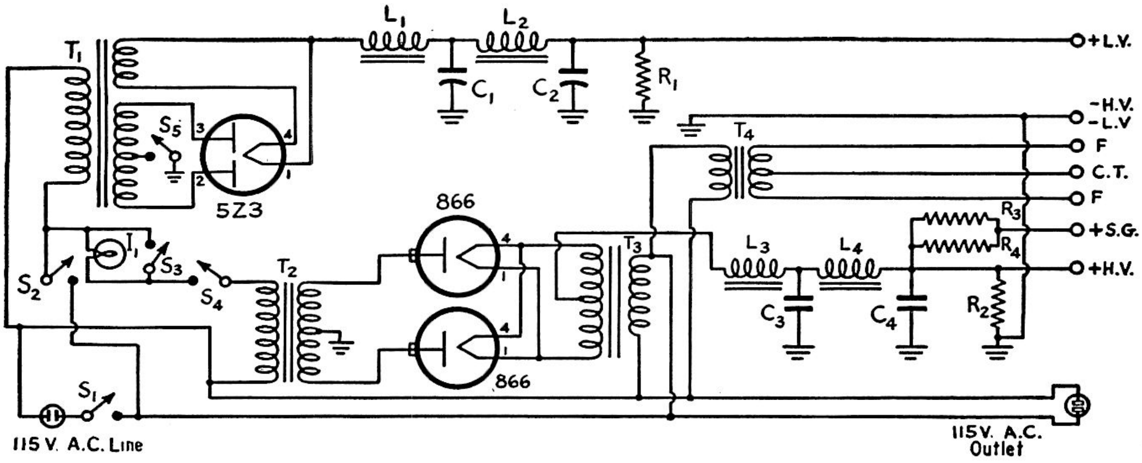


Fig. 6-65 — Diagram of power supply suitable for use with the two-stage high-power transmitter.

C_1, C_2 — 8-μfd. 600-volt-wkg. electrolytic.
C_3 — 2-μfd. 3000-volt oil-filled.
C_4 — 4-μfd. 3000-volt oil-filled.
R_1 — 20,000 ohms, 25 watts.
R_2 — 50,000 ohms, 200 watts.
R_3, R_4 — 50,000 ohms, 160 watts.
L_1, L_2 — 20-hy. 100-ma. filter choke.
L_3 — 5/25-hy. 300-ma. swinging choke.
L_4 — 20-hy. 300-ma. smoothing choke.
I_1 — 200-watt 115-volt lamp.
S_1, S_2, S_4 — 10-amp. toggle switch.
S_3 — 5-amp. toggle switch.
S_5 — Ceramic rotary switch, single section, 2 positions.
T_1 — Power transformer — 400 v. d.c., 100 ma. or more; 5 v., 3 amp.
T_2 — Plate transformer — 2500 to 3000 volts d.c., 300 ma. or more.
T_3 — 2.5-volt 10-amp. filament transformer, 10,000-volt insulation.
T_4 — 5-volt 15-amp. filament transformer.

S_1 turns on all filaments in power supply except 5Z3; also those in the transmitter and sets up circuit for S_2. S_2 turns on low-voltage supply and sets up circuit for S_4 which turns on high-voltage supply. Since the oscillator in the transmitter is keyed, it is not necessary to turn off the low-voltage supply for stand-by. S_5 may be used in case it is not desired to turn off the 5Z3 filament while changing bands, etc. When S_3 is open, I_1 is in series with the high-voltage transformer primary to reduce voltage for adjustments.

inch around the part which goes through the chassis, to decrease the danger of a voltage breakdown at this point. The link output terminals are in the right rear corner, insulated from the chassis on a National FWG polystyrene terminal strip.

Underneath, at the amplifier end of the chassis, are the metering switch, S_2, and the 6.3-volt filament transformer.

On the panel, the milliammeter is placed to balance the amplifier tuning dial, the meter-switch knob to balance that of the oscillator tuning condenser, while the crystal switch is at the center, near the bottom edge. Along the rear edge of the chassis, from right to left, as viewed from the rear, are a terminal strip for making connections to the oscillator supply and to the external screen-voltage dropping resistor, the key jack, filament terminals for the 4-250A including a center-tap connection, a safety terminal for the high-voltage connection, and a male plug for the 115-volt line to the 6.3-volt filament transformer and the fan motor.

The cathode coils, L_1, are wound on Millen octal-base shielded forms without tuning slugs. A change in cathode coils is required only with a change in the band in which the *crystal* lies. The coil for use with 3.5-Mc. crystals requires an additional 100-$\mu\mu$fd. mica condenser, C_X, connected across the winding as shown by the dotted lines in Fig. 6-62. This condenser is placed inside the plug-in shield along with the 3.5-Mc. coil. The 100-$\mu\mu$fd. capacitor, C_1, which is connected permanently in the circuit, is sufficient for use with 7- and 14-Mc. crystals. Since larger coils are desirable for the plate circuit of the oscillator, the coils for L_2 are wound on 1-inch diameter forms enclosed in National Type PB-10 plug-in shield cans. The shield should be grounded to the chassis through one of the available pins in the base.

External connections to the unit are indicated in Fig. 6-62. Keying of the oscillator alone is not recommended because of the effects of soaring screen voltage, which makes it impossible to cut off plate and screen currents in this unit without exceeding the normal operating bias. For this reason, it is highly advisable to use an overload relay in the plate-supply circuit of the amplifier, to protect the tube in case the oscillator fails to function. The circuit diagram of a suitable power supply for this transmitter is shown in Fig. 6-65.

Adjustment

After the proper coils for the desired band have been plugged in and the crystal switch turned to select the proper crystal, the key may be closed with the low-voltage supply turned on, but with the high-voltage supply turned off. The combined oscillator plate-and-screen current at resonance should be between 35 and 75 ma., depending upon the crystal frequency and whether or not the oscillator is doubling frequency. If the oscillator is operating at the crystal fundamental frequency, oscillation will cease abruptly when the plate tank circuit is tuned to the high-capacitance side of resonance. For reliable operation this circuit should be tuned slightly to the low-capacitance side. When doubling frequency this characteristic disappears so that the plate circuit may be tuned to exact resonance where maximum output should occur.

Tuning the oscillator plate circuit to resonance should result in a grid-current reading when the meter is switched to the second meter-switch position. The reading will vary between 30 and 35 ma. to 50 ma. or more, depending upon the frequency and whether the oscillator is doubling frequency or working "straight through." The potential of the high-voltage supply should be reduced during preliminary adjustments. If no other means of reducing the voltage is available a 200-watt 115-volt lamp may be connected in series with the primary winding of the high-voltage transformer. The plate circuit of the amplifier should be tuned to resonance first with the antenna link swung out to the minimum-coupling position. The output tank circuit of the amplifier may be coupled through the link coil, either directly to a properly-terminated low-impedance transmission line, or through an antenna tuner to any type of antenna system. With the antenna system connected and the link swung in for maximum coupling, the plate current should increase when the antenna system is tuned through resonance. Every adjustment of the coupling or tuning of the antenna system should always be followed by a readjustment of the tuning of the amplifier tank circuit for resonance. As the loading is increased the plate current at resonance will increase. The loading may be carried up to the point where the plate current (cathode current, minus grid and screen currents) is 300 ma. at 3000 volts.

An Enclosed 1-Kw. Transmitter

Figs. 6-66, 6-68, 6-69 and 6-71 show different views of an enclosed three-stage transmitter which will handle an input of 1 kw., with c.w. operation on all bands from 3.5 or 7 Mc. to 28 Mc. using either 3.5- or 7-Mc. crystals. Push-pull 813s are used in the final amplifier.

Circuits

Fig. 6-67 shows the circuit of the exciter. A pair of 807s are used in an arrangement that permits either of the two stages to be used as a Tri-tet oscillator. The second stage may be operated also as a frequency doubler.

The arrangement shown has a number of advantages. The two 807 stages need not be operated at the same frequency for output on any band, thereby avoiding stabilization difficulties sometimes encountered with tubes of this type when operating as straight amplifiers. It provides for oscillator keying for break-in work at 3.5 and 7 Mc. and amplifier keying for 14 and 28 Mc. where chirp with oscillator keying might become objectionable. Shielding problems are reduced because the first 807

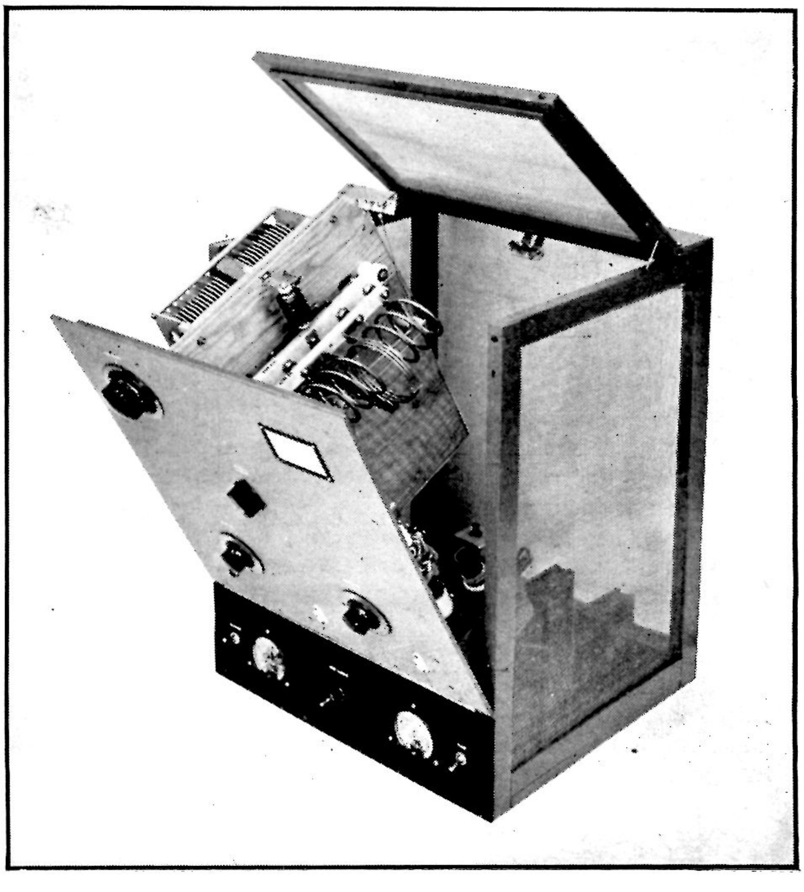


Fig. 6-66 — A three-stage 3.5–30-Mc. kilowatt transmitter using push-pull 813s. Measuring 18 inches wide, 24 inches high, and 16 inches deep, it fits readily on most operating tables. The hinged front panel drops down for coil changing. Interlock switches combined with complete enclosure ensure against accidental contact with any high-voltage circuits when the power is on.

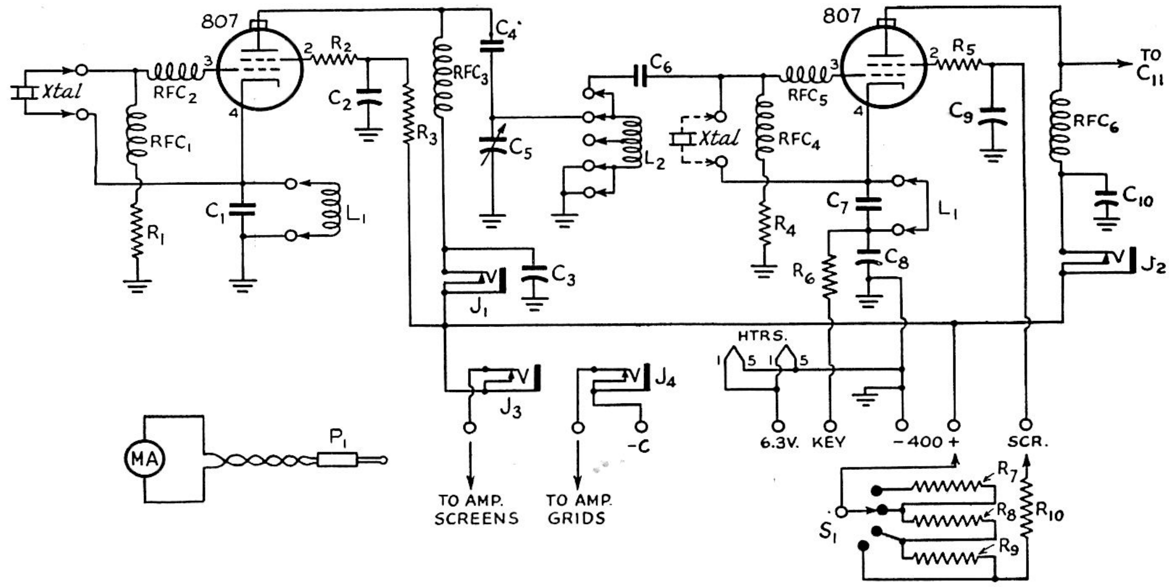


Fig. 6-67 — Circuit diagram of the exciter section of the enclosed 1-kw. transmitter.

C_1, C_7 — 150-μμfd. mica.
C_2, C_3, C_9, C_{10} — 0.01-μfd. paper, 600 volts.
C_4 — 470-μμfd. mica, 1000 volts.
C_5 — 50-μμfd. variable (National ST-50).
C_6 — 100-μμfd. mica, 1000 volts.
C_8 — 0.0047-μfd. mica.
R_1 — 0.33 megohm, 1 watt.
R_2, R_5 — 50 to 100 ohms, ½-watt carbon.
R_6 — 330 ohms, 1 watt.
R_3 — 25,000 ohms, 10 watts.
R_4, R_7 — 47,000 ohms, 1 watt.
R_{10} — 10,000 ohms, 1 watt.
R_8, R_9 — 22,000 ohms, 1 watt.
L_1 — Tri-tet cathode coil; for 3.5-Mc. crystals, 13 turns No. 22 d.s.c., close-wound, diameter 1 inch, shunted by extra 75-μμfd. mica condenser inserted inside form. For 7-Mc. crystals: 3 turns No. 22 d.s.c., close-wound on 1-inch diameter form. (Cathode coils wound on Millen No. 45004 forms.)
L_2 — Plate coil; for 3.5 Mc., 36 turns No. 22 d.s.c., close-wound; 7 Mc., 16 turns No. 18 bare, length 2 inches; 14 Mc., 8 turns No. 18 bare, length 2 inches; 28 Mc., 4 turns No. 18 bare, length 1 inch. All coils wound on 1⅞-inch diameter forms (Millen No. 44001) and tapped at center.
J_1, J_2, J_3, J_4 — Closed-circuit jack.
MA — 0–200 d.c. milliammeter.
P_1 — Insulated plug.
RFC_1, RFC_3, RFC_4, RFC_6 — 2.5-mh. r.f. choke.
RFC_2, RFC_5 — Parasitic chokes; 18 turns No. 20 d.c.c. on ¼-inch diameter form (a high-value 1-watt resistor is suitable as a form).
S_1 — 4-position single-pole rotary switch.

never is called upon to operate at the same frequency as either of the two following stages. A single set of coils suffices for both stages of the exciter.

When both 807 stages are in use, the crystal and cathode coils are plugged into the first stage, while a jumper closes the cathode circuit of the second stage. When the second 807 is used as an oscillator, crystal and cathode coil are transferred to the second stage and removal of the coil in the plate circuit of the first stage breaks the connection between the two stages.

Parallel plate and grid feed is used in both exciter stages, while the screens are fed through series voltage-dropping resistors. The value of the resistor for the screen of the second tube may be varied in steps by S_1 and this provides a means of adjusting the excitation to the final amplifier. Jacks are provided for shifting a milliammeter from one circuit to another to obtain readings of plate current in either exciter stage or grid or screen current to the final amplifier. RFC_2, RFC_5, R_2 and R_5 are inserted to prevent v.h.f. parasitic oscillation. The key is in the cathode of the second 807 stage.

The circuit of the push-pull 813 final amplifier is shown in Fig. 6-70. Series feed is used in both grid and plate circuits. Although the 813 is a screened tube, experience has shown that neutralization is necessary to prevent self-oscillation. A single set of coils suffices for L_2 in both the amplifier section and the exciter section. Variable-link output is provided for coupling to the antenna system.

Construction

The r.f.-circuit components are assembled on a panel of ¼-inch crackle-finished tempered Presdwood, 18 inches wide and 19 inches high, backed with copper screening. The panel is hinged at the bottom so that it may be tipped outward, as shown in Fig. 6-66, for changing plug-in coils, etc. Suspended from the back of the panel is a vertical partition of ⅝-inch plywood, 13¼ inches wide and 18 inches high. This partition also is covered on both sides with copper screening from the bottom edge up to within 6 inches of the top. The lower edge of the partition comes ⅝ inch above the lower edge of the panel and is placed 11¼ inches from the right-hand edge of the panel as viewed from the front. A strip of ⅝-inch plywood 1¼ inches wide runs across the top of the panel, as shown in Fig. 6-71, and a similar strip ⅝ inch wide runs across the bottom of the panel, flush with the lower edge. The bottom strip provides a means of fastening the hinge to the panel.

Thin strips of wood along the vertical edges of the panel serve to hold the copper screening in place, while a metal strip is used to bind the edges of the partition.

The portion of the r.f. circuit shown in Fig. 6-67 is built as a subassembly on a 5 × 10 × 3-inch chassis, fastened to the panel in the lower left-hand corner and braced by the partition, as shown in Figs. 6-68 and 6-69. As viewed from the rear, the first 807 is placed near the left-hand edge of the chassis with its cathode-coil socket behind. The tuning condenser, C_5, is placed between the 807 and the first-stage tank coil, 4 inches from the outside end of the chassis. The socket for the cathode coil for the second 807 is in the rear corner to the right. The socket for the second 807 is set in the right-hand edge of the chassis and a clearance hole for the base of the tube is cut in the partition so that the tube protrudes horizontally as shown in Fig. 6-69. The two crystal sockets are fastened to the front edge of this chassis and protrude through holes cut in the panel.

In the rear edge of the chassis are the four meter jacks and strips bearing the terminals indicated in Fig. 6-67.

The 813s and their input-circuit components are made up as another subassembly on a 5½ × 9½ × 1½-inch chassis which is fastened centrally on the partition with its bottom edge 3½ inches up from the bottom edge of the partition, as shown in Fig. 6-71. The two tube sockets are submounted as close as possible to the ends of the chassis with their centers 2½ inches in from the outside edge. Underneath, as shown in Fig. 6-69, the coil socket is centered on the tube sockets and the tank condenser, C_{13}, is to the left. It is placed so that its dial will balance the dial of C_5 on the panel. The strips which form the neutralizing condensers are mounted on feed-through insulators set in the chassis about 1⅛ inches from the bases of the tubes. A ceramic strip set in the rear edge of the chassis bears the power-supply terminals indicated in Fig. 6-70.

The plate tank condenser for the 813s is fastened to the partition above the screening, the wood serving to insulate the frame and rotors from ground as required. The output tank-coil jack-bar is mounted on short stand-off insulators on the opposite side of the partition, with its center 4 inches below the top edge of the partition.

The link control shaft is coupled to a knob centered on the panel by means of a pair of Millen universal-joint-type shaft couplings. Leads from the link terminals are brought to the upper rear corner of the partition where they connect to a pair of banana plugs which slide into jacks connected to feed-through insulators set in the back of the enclosure. These serve as the output terminals.

Below the main panel is a smaller panel 5¼ inches high which is used for the control switches and meters.

Plenty of room is available within the enclosure to the rear of the panel assembly for filament transformers and the additional terminals, indicated in Fig. 6-72, which serve as junctions between the external and internal power leads. One of the two interlock switches is of the push-button type. This is mounted on an aluminum bracket fastened to the floor

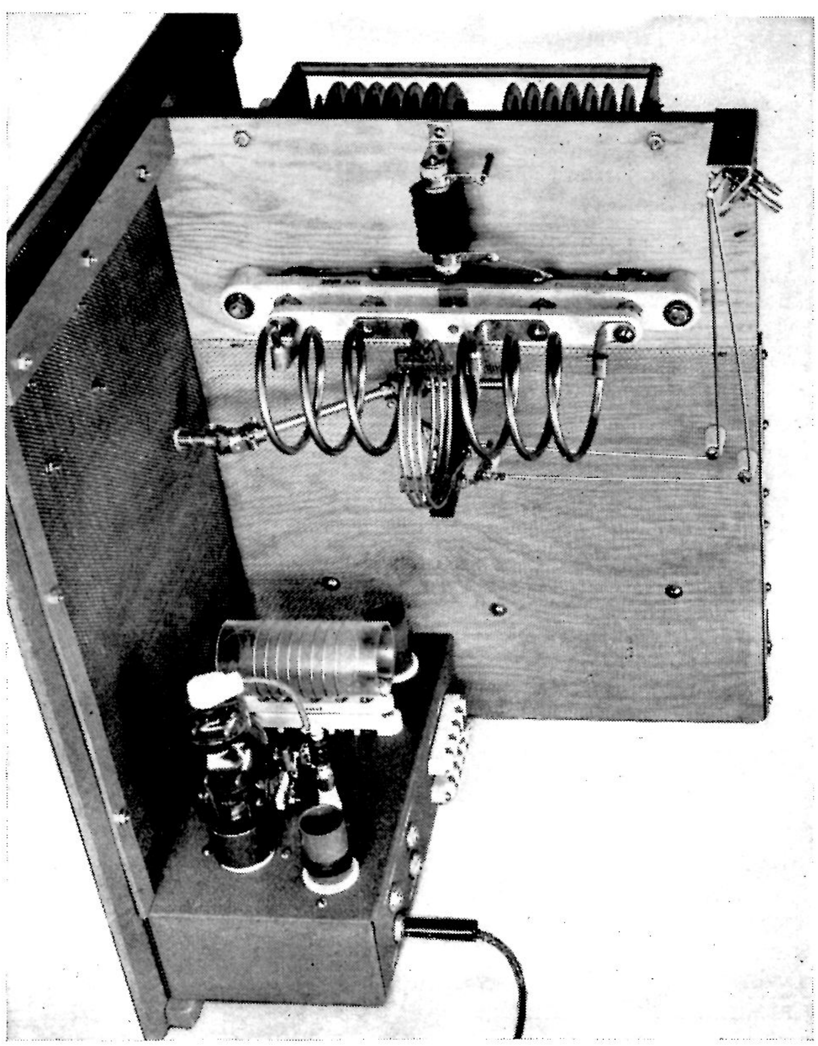


Fig. 6-68 — The exciter unit of the enclosed 1-kw. transmitter is mounted between the vertical partition and the panel, and serves as additional support for both. This view shows the first 807 with its Tri-tet cathode coil in the foreground. The plate tuning condenser is partly concealed by the tube, and to its right is the plate choke. The small bakelite coil form behind the plate coil is the jumper for the second-tube cathode circuit; when the latter tube is used as the oscillator a Tri-tet cathode coil goes in this socket.

The final tank-coil assembly and plate choke are at the top. The banana plugs at the right automatically engage a pair of jacks on the rear of the case when the panel is in position, providing connection to the antenna binding posts.

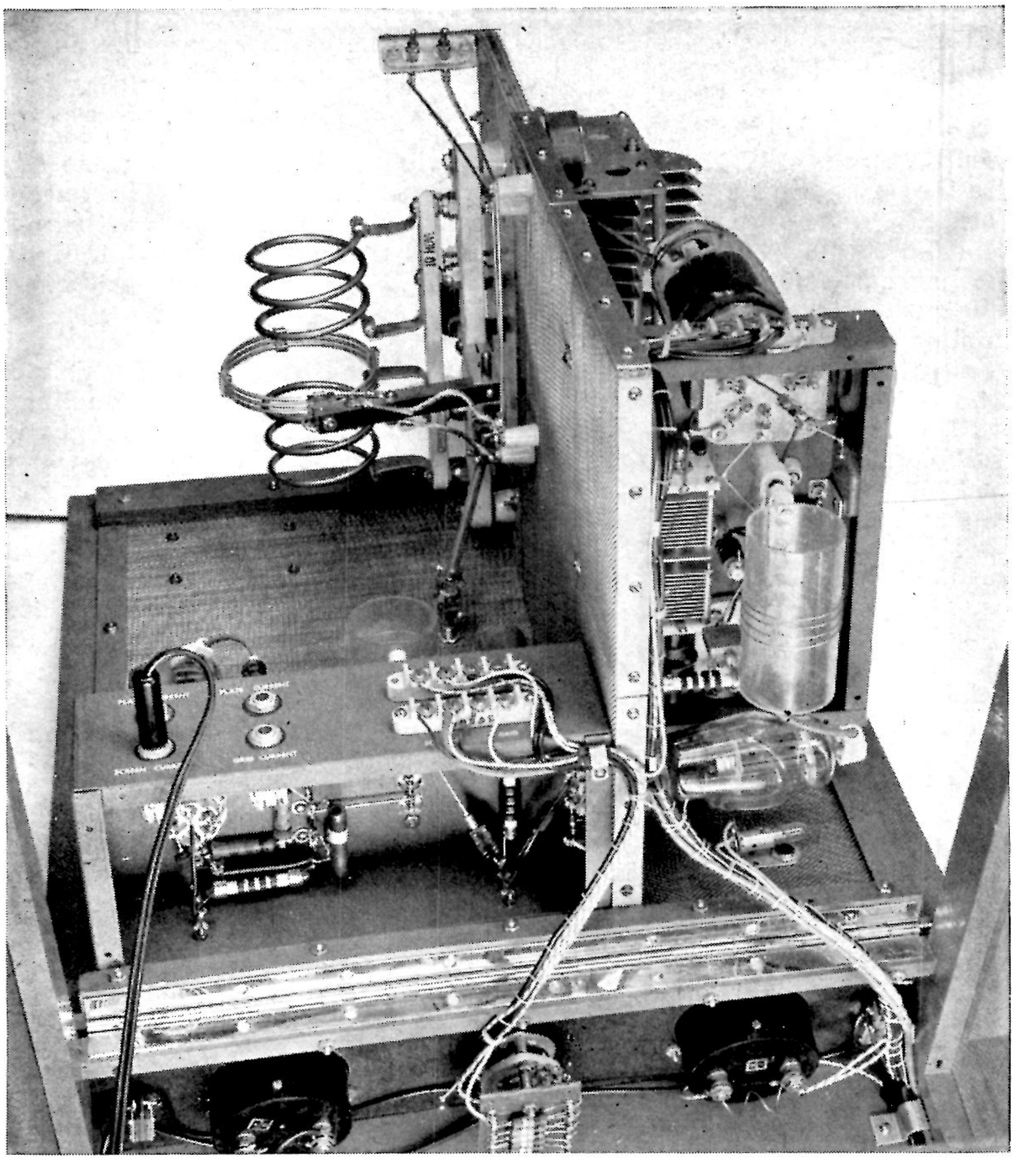


Fig. 6-69 — View from the back of the enclosed 1-kw. transmitter with the front panel dropped down. The second 807 projects through the partition to bring its plate near the tuned circuit that feeds the amplifier grids. The 807 plate choke, visible just below the amplifier grid-tuning condenser, is supported by a feed-through insulator mounted on the end of the exciter chassis. The four metering jacks are accessible only when the case and interlock switches are open, providing for safety.

of the enclosure so that the rear end of the lower edge of the partition closes the switch when the panel is hinged back into place. The circuit is broken as soon as the panel is tipped forward. The second interlock is fastened to the side of the enclosure where it is operated by the top lid.

The frame of the enclosure is made up of 1¼-inch strips cut from ⅝-inch plywood. It is 18 inches wide, 24½ inches high and 16 inches deep overall, and has a solid bottom of the same plywood material. The copper screening is tacked over the outside of the panels formed by the framework and the edges of the screening are covered with thin strips of wood. The woodwork is finished off in gray enamel.

Power Supply

The diagram of a suitable power supply for operating the 813s at maximum rated input is shown in Fig. 6-73. At current tube prices, however, the 813s are an economical proposition for operation at considerably less than maximum ratings if power-supply considerations make this desirable.

Adjustment

Since there is only a maximum of three tuned circuits to adjust, tuning the transmitter for any desired output frequency is a relatively simple job. Undesired harmonic responses, always to be found in a multiband rig, are quite readily identifiable as such, so there is little danger of tuning up on the wrong harmonic if a little care is used in watching the dial readings. For reasons given previously, the design does not provide for operating the first 807 out-

TABLE 6-II

Comb.	*Xtal f*	*Output f*	*1st 807 Plate*	*2nd 807 Plate*
A	3.5	3.5	—	3.5
B	3.5	7	—	7
C	7	7	—	7
D	3.5	7	3.5	7
E	3.5	14	7	14
F	7	14	7	14
G	3.5	28	14	28
H	7	28	14	28

put at the same frequency as that of the final amplifier and this sort of operation should not be attempted, even if the constructor is willing to make the extra coils, since the simplified construction does not provide the necessary shielding between the input and output circuits of the final amplifier.

The accompanying Table 6-II shows the correct coils to be used in the 807 tank circuits, depending upon the crystal frequency and the desired output frequency. Combinations A, B and C, for 3.5- and 7-Mc. output, permit break-in operation in these two bands, since in each of these cases the keyed stage (the second 807) is operating as the oscillator. In the remainder of the combinations, the keyed stage operates as a frequency multiplier, the first 807 becoming the oscillator, which runs continuously.

Table 6-III gives the approximate dial settings for resonance in the three tank circuits. Variations in wiring or coil dimensions will, of course, alter these readings, but they may be used as a guide. The last column to the right shows the dial setting where undesired crystal-harmonic responses may be expected in the multiplier circuit, the harmonics being identified.

It is advisable initially to choose one of the first three combinations from Table 6-II — one that requires the use of only two stages. With the proper coils and crystal plugged in (be sure to plug the crystal in the right socket!), the low-voltage and bias supplies may be turned on and the key closed. At some point within the range of the 807 tank condenser the plate current should dip to a minimum, rising on either side. If the tank circuit is tuned to the crystal frequency (3.5 Mc. with a 3.5-Mc. crystal or 7 Mc. with a 7-Mc. crystal) the crystal will usually stop oscillating entirely, as indicated by a sudden increase in plate current to a high value when the tank circuit is tuned to the high-capacitance side of the dip in plate current. The best tuning adjustment under these circumstances is a bit to the low-capacitance side of the dip. When the oscillator tank circuit is tuned to a harmonic of the crystal frequency, the circuit normally will continue to oscillate regardless of the setting of the tank condenser. Tuning is then merely a matter of adjusting the tank circuit to resonance as indicated by the plate-current dip or by maximum final-amplifier grid current. Tuning the tank circuit to resonance should result in a reading of grid current to the final amplifier. The oscillator tank circuit can then be adjusted to a point that will give maximum amplifier grid current consistent with reliable keying. During the adjustment the key should not be held closed longer than is absolutely necessary, since the amplifier screen current will run to a considerably higher-than-normal value without plate voltage and load.

TABLE 6-III

Comb.	*1st 807*	*2nd 807*	*Final Amp.*	*Undesired Harm., 2nd 807*
A	—	75	45	None
B	—	15	25	3rd–90
C	—	15	25	None
D	50	15	25	3rd–90
E	60	20	75	5th–60/6th–85
F	60	20	75	3rd–90
G	70	80	85	6th–20/7th–53
H	70	80	85	3rd–23

Neutralizing

The amplifier should be neutralized at this point. At the start the aluminum strips (shown in Fig. 6-71) should be exactly alike — about ½ inch by 3 inches, with the centers of the feed-through insulators on which they are mounted 1⅛ inches from the tube bases. The

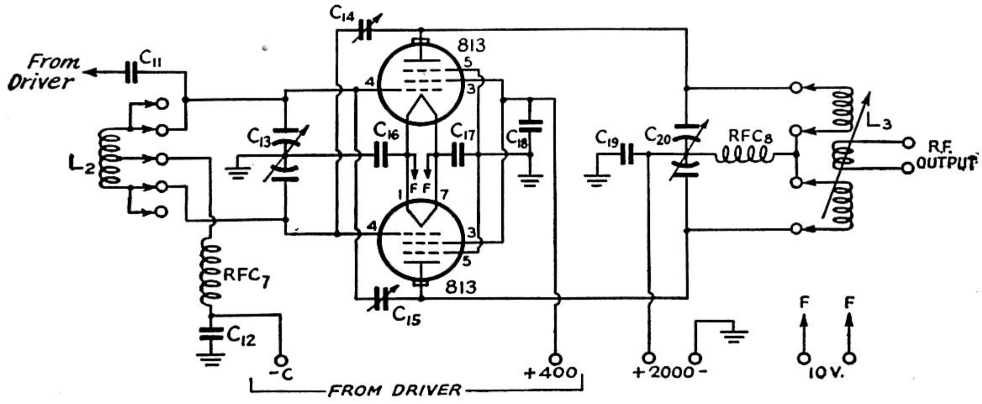


Fig. 6-70 — **Circuit of the final amplifier in the enclosed 1-kw. transmitter.**

C_{11} — 470-μμfd. mica, 1000 volts.
C_{12}, C_{16}, C_{17} — 0.0047-μfd. mica.
C_{13} — 100-μμfd.-per-section variable (Cardwell ER-100-AD).
C_{14}, C_{15} — Neutralizing condensers; see text.
C_{18} — 0.001-μfd. mica, 1000 volts.
C_{19} — 0.001-μfd. mica, 5000 volts working.
C_{20} — 100-μμfd.-per-section variable (National TMA-100DA).
L_2 — Same as L_2 in Fig. 6-67.
L_3 — Amplifier plate tank coils, Barker & Williamson HDVL series with following modifications:
— 3.5 Mc.: 9 turns shorted out at each outer end.
— 7 Mc.: 2 turns shorted out at each outer end.
— 14 Mc.: 1 turn shorted out at each outer end.
— 28 Mc.: No modification.
RFC_7 — 2.5-mh. r.f. choke.
RFC_8 — 2.5-mh. r.f. choke, 500 ma. (Hammarlund CH-500).

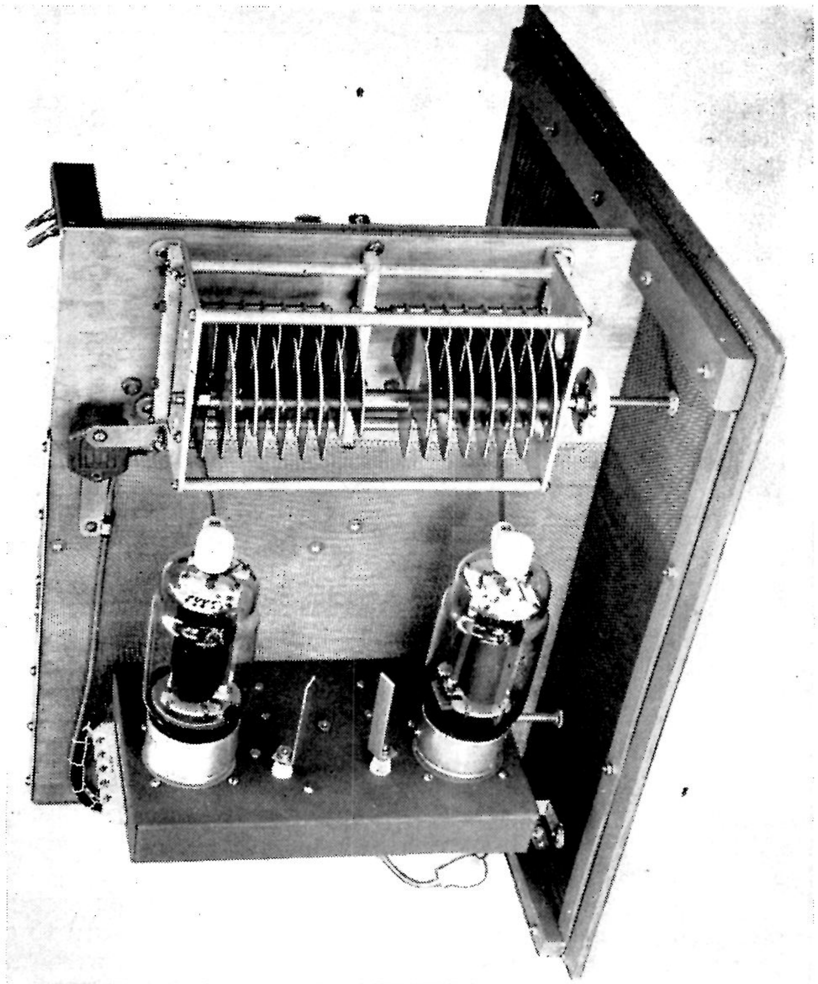


Fig. 6-71 — **The amplifier side of the partition in the enclosed 1-kw. transmitter. This view shows the plate tank condenser and the plate by-pass. The aluminum strips between the two 813s, mounted on stand-off insulators, are the neutralizing condensers.**

adjustment consists of clipping off the ends of the strips about 1/16 inch at a time until the amplifier is neutralized. Any of the usual indicators of neutralization may be employed, the most convenient method being to alter the neutralizing capacitance as described until the grid current remains steady as the plate tank condenser is swung through resonance.

After neutralizing, reduced high voltage may be applied to the amplifier and its plate tank circuit tuned to resonance as indicated by a dip in plate current. The antenna should not be coupled to the output stage until it has been tuned as described, the link being swung as far out as possible during preliminary adjustment. When the point of resonance has been found, full voltage may be applied and the antenna circuit coupled and tuned in the manner proper for the type of antenna system and antenna tuning arrangement used. Regardless of the system employed, it should be remembered that the last adjustment in coupling and adjusting the antenna to the transmitter is that of tuning the amplifier tank circuit for minimum plate current. This should always be done after every adjustment of antenna coupling or tuning. Otherwise, the amplifier may be operating very inefficiently off resonance and exceeding the dissipation rating of the tubes. Tuning the first 807 as an oscillator is similar

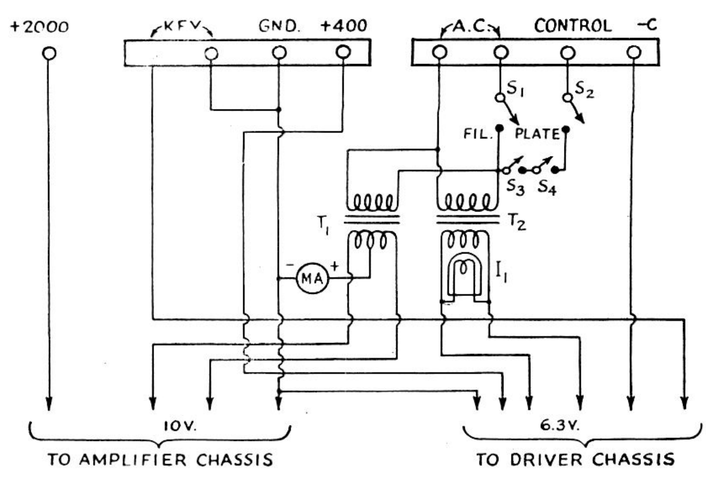


Fig. 6-72 — **Schematic of the filament-power and power-terminal wiring of the enclosed 1-kw. transmitter. Two interlocks are included in the control circuit, to turn off the plate power whenever the enclosure is opened.**

I_1 — 6.3-volt pilot-lamp assembly.
MA — 0–100 milliammeter, shunted to read 1000 ma.
S_1 — 10-amp. toggle switch.
S_2 — 15-amp. toggle switch.
S_3, S_4 — Interlock switches. See text.
T_1 — 10-volt 10-ampere filament transformer.
T_2 — 6.3-volt 3-ampere filament transformer.

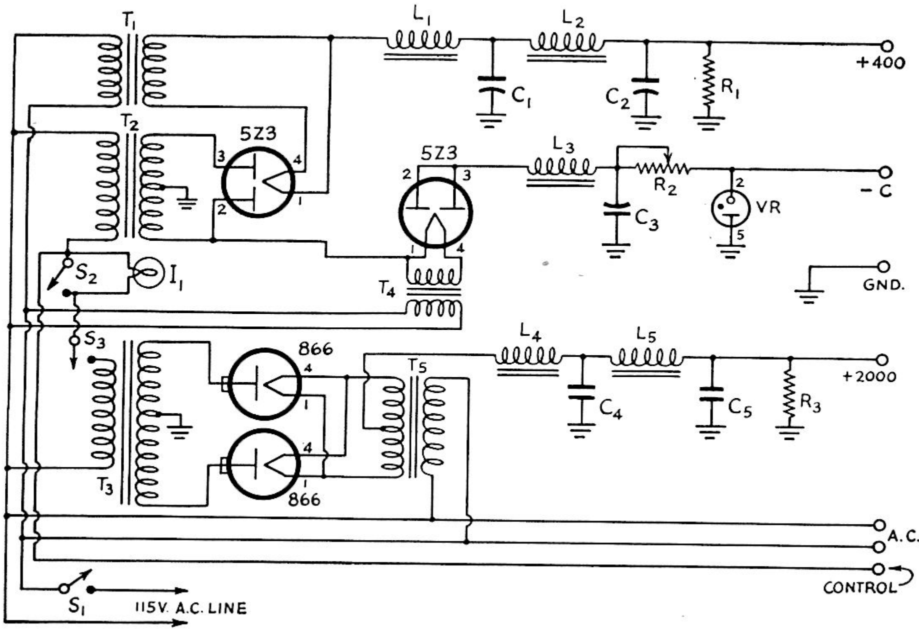


Fig. 6-73 — Circuit diagram of a power supply for the enclosed 1-kw. transmitter.

C_1, C_2, C_3 — 8-μfd. 600-volt-wkg. electrolytic.
C_4 — 2-μfd. 2500-volt oil.
C_5 — 4-μfd. 2500-volt oil.
R_1 — 20,000 ohms, 25 watts.
R_2 — 50,000 ohms, 25 watts.
R_3 — 50,000 ohms, 200 watts.
L_1 — 5/25-hy. 300-ma. choke.
L_2 — 20-hy. 300-ma. choke.
L_3 — 30-hy. 50-ma. choke.
L_4 — 5/25-hy. 500-ma. choke.
L_5 — 20-hy. 500-ma. choke.
I_1 — 150-watt 115-volt lamp.
S_1, S_3 — 10-amp. toggle.
S_2 — 5-amp. toggle.
T_1, T_4 — 5-v. 3-a. fil. trans.
T_2 — 400 v. d.c., 250–300 ma.
T_3 — 2000 v. d.c., 500 ma. or more.
T_5 — 2.5 volts, 10-amp., 10,000-volt insulation.
VR — Voltage-regulator tube.

to the method outlined for the second tube.

The adjustment of the second tube as a multiplier is simply the selection of the proper coil and tuning to resonance, making certain that it is not tuned to an undesired harmonic.

Table 6-IV shows typical current values which may be expected. They were taken at 400 volts and may vary somewhat because of differences in crystal response and length of leads in the oscillator circuits which may affect feed-back.

The Tri-tet oscillator may be expected to self-oscillate with the crystal removed. With the crystal operating normally, however, no trouble of this sort should be experienced.

At the maximum rated input of just under 1 kw., this transmitter should deliver 600 watts or better on all bands.

TABLE 6-IV

Combination	*1st 807 at Resonance — Key Open — Ma.*	*1st 807 at Resonance — Key Closed — Ma.*	*2nd 807 at Resonance — Ma.*	*Final Grid — Ma. No Plate Voltage*	** Final Grid — Full Load — Ma.*
A	—	—	40–60	40–50	40–50
B	—	—	75	40	42
C	—	—	65–70	43	46
D	46	48	80	38	39
E	15	20	64	30	30
F	16	100	78	30	32
G	40	50	86	18	25
H	73	55	81	18	28

* With excitation control at maximum.

A Simple VFO Crystal Substitute

Figs. 6-74, 6-75 and 6-77 show different views of a VFO unit with sufficient power output to drive the average crystal-oscillator tube. As the circuit diagram of Fig. 6-76 shows, it consists of a 6SK7 ECO followed by a pair of 6F6s as isolating amplifiers. The primary frequency range covered by the oscillator is 3500–4000 kc., but this range may be shifted lower to cover 3395–3800 kc. for multiplying to cover the frequencies in the 10- and 11-meter bands by readjustment of the band-setting condenser, C_2.

Construction

The oscillator portion is constructed as a separate unit in a standard 3 × 4 × 5-inch steel box. The tuning condenser, C_1, and the coil form for L_1 are fastened to the rear wall of the box. C_1 is coupled to the National Type AM dial by a short extension shaft and a flexible coupling. The band-setting air condenser, C_2, is mounted against the right side of the box near the lower rear corner where it can be adjusted from the outside with a screw-driver to set the beginning of the tuning range. The tube is mounted externally on top of the box where it will be well ventilated and where its heat will have minimum effect upon the tuned circuit. The coupling lead between the plate of the oscillator tube and the grid of the first 6F6 is made with flexible wire passed through National TPB polystyrene bushings, one in the oscillator compartment and one in the base chassis, the rigid wire which comes with the bushing having first been removed by warming with a soldering iron. The power and keying leads are brought out in a similar manner through holes lined with rubber grommets. The oscillator box is shock-mounted by means of long machine screws at each corner of the bottom plate. The screws pass through grommet-lined holes in the top of the chassis.

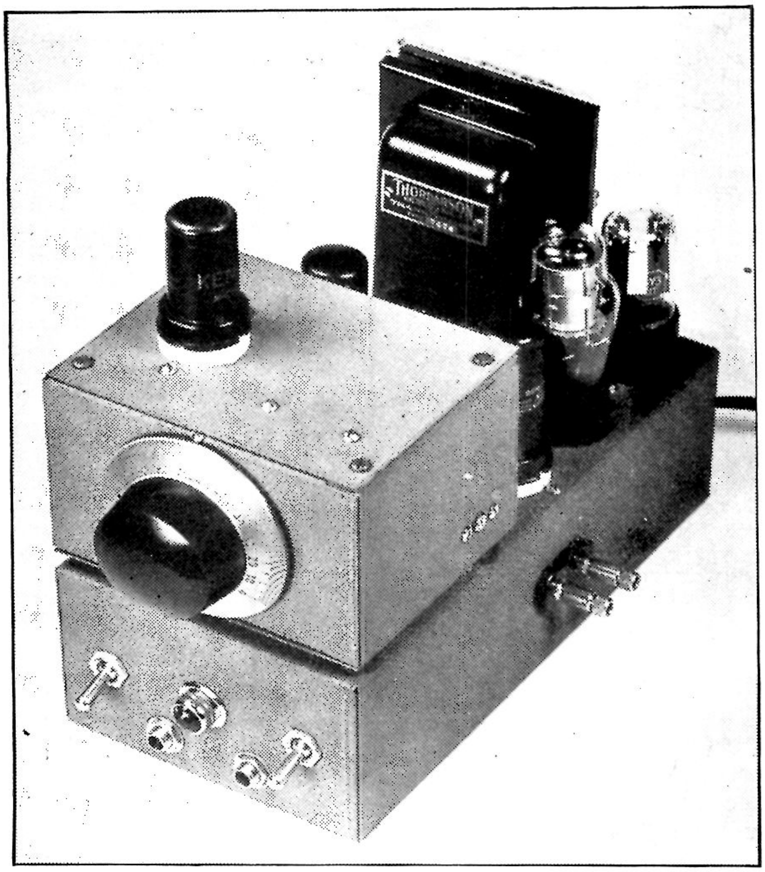


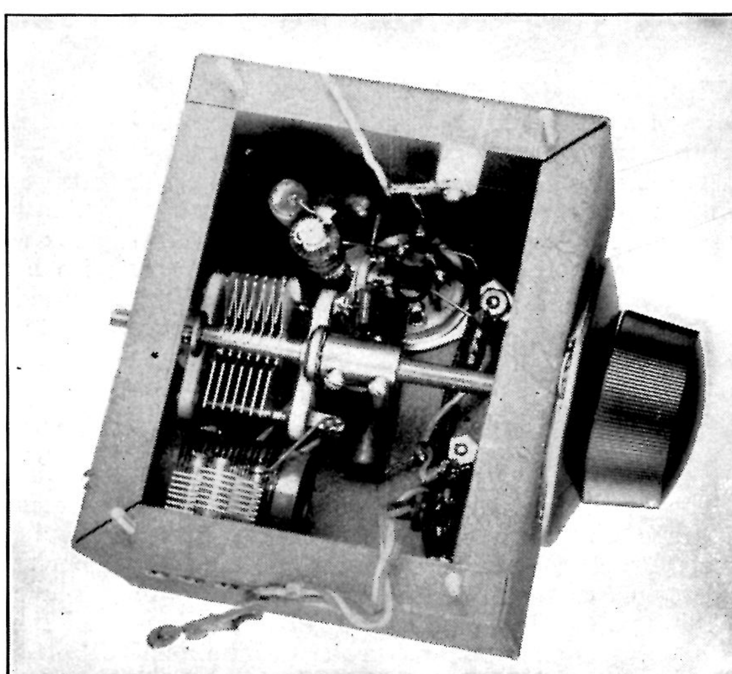
Fig. 6-74 — The complete VFO unit. The oscillator is housed in a separate compartment which is shock-mounted on rubber grommets. The oscillator tube is on top of the compartment. To the rear are the two 6F6 amplifier tubes, the VR tube, the rectifier and the power transformer. In front are the stand-by switch, the power switch, pilot lamp and the two keying jacks. The output terminals are to the right.

The base chassis is 5 × 10 × 3 inches. The two 6F6s are mounted on either side of the chassis immediately behind the oscillator compartment. Underneath, the filter choke is fastened against the side of the chassis in the left rear near the two filter condensers, C_{14} and C_{15}. The two plate r.f. chokes, RFC_2 and RFC_3, are mounted near their associated tube sockets. On the front edge are the control switches, S_1 for power and S_2 which is the stand-by switch, cutting off plate voltage to all stages. Terminals in parallel with S_2 are mounted in the rear edge of the chassis to connect to a send-receive relay if this is found desirable. The output terminals are set in the right-hand side.

Adjustment

The resistance of R_5 should be adjusted experimentally so that the VR tube is ignited with the key either closed or open. If the glow disappears when the key is closed, the resistance of R_5 should be reduced. With the dial set for maximum capacitance of C_1, C_2 should be adjusted with a screwdriver to set the

Fig. 6-75 — Bottom view of the oscillator compartment. The tuning condenser and the coil are fastened to the rear wall of the box, while the air trimmer is mounted on the lower end in the photograph. The small cone insulator supports the coupling lead to the first amplifier stage.



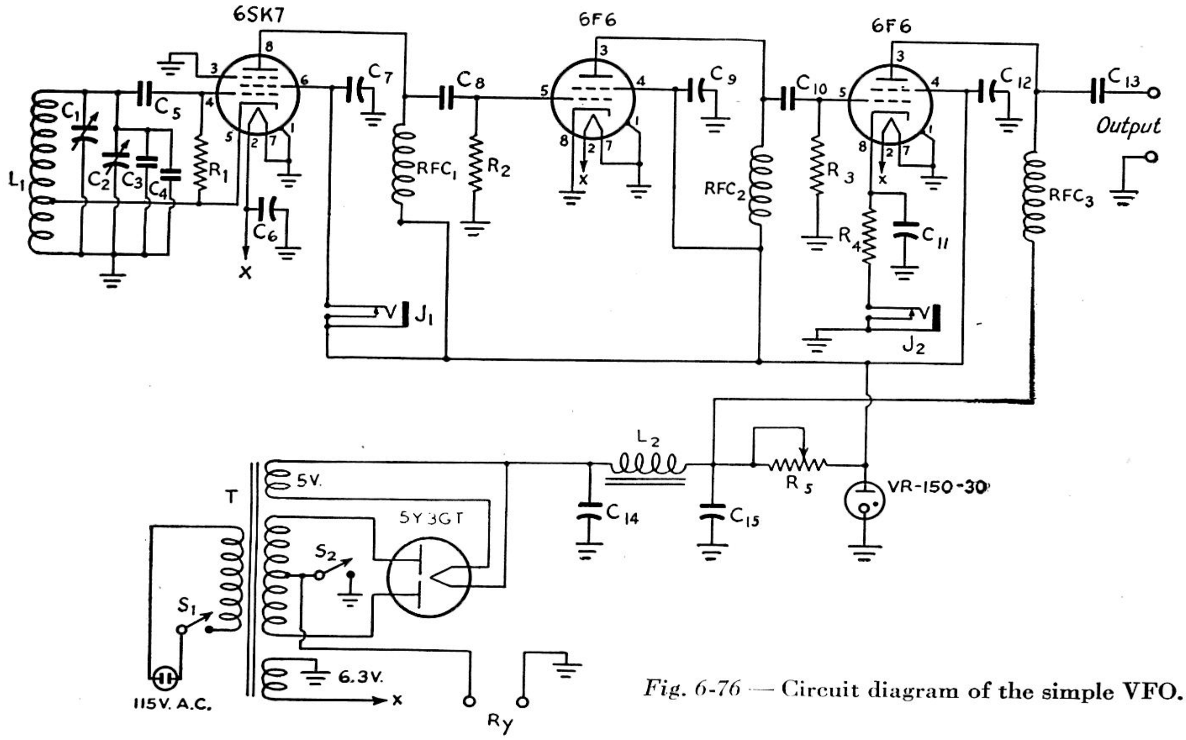


Fig. 6-76 — Circuit diagram of the simple VFO.

C1 — 100-μμfd. variable (Hammarlund MC-100S).
C2 — 75-μμfd. variable (Hammarlund APC75).
C3 — 220-μμfd. zero-temp.-coef. mica.
C4 — 68-μμfd. zero-temp.-coef. mica.
C5, C8, C10, C13 — 100-μμfd. mica.
C6, C7, C9, C11, C12 — 0.01-μfd. paper.
C14, C15 — 8-μfd. 450-volt electrolytic.
R1, R2 — 47,000 ohms, ½ watt.
R3 — 0.1 megohm, ½ watt.
R4 — 220 ohms, 1 watt.
R5 — 5000 ohms, 25 watts, adjustable.
L1 — 17 turns No. 20 enam., 1⅛ inches long, 1-inch diam., tapped 5 turns from ground end.
L2 — 30 hy., 50 ma. (Stancor C-1003).
J1, J2 — Closed-circuit jack.
RFC1, RFC3 — 2.5-mh. r.f. choke.
RFC2 — Millen 47002 (½-inch diam. by 2½ inches long) polystyrene form wound full with No. 30 d.s.c. wire.
S1, S2 — S.p.s.t. toggle switch.
T — 340 volts each side center, 55 ma.; 5 v., 2 a.; 6.3 v., 1½ amp.

frequency at 3500 kc. (3395 for 10- and 11-meter operation). C_1 should then cover the range to 4000 kc. (or 3800 kc.).

Coupling to the crystal oscillator in most transmitters is simply a matter of running a wire from the "hot" output terminal (the terminal connected to the plate of the output tube through C_{13}) to the grid of the oscillator tube, and the other output terminal to the chassis of the transmitter. In Tri-tet and grid-plate oscillator circuits, the cathode tanks should be short-circuited. In triode or tetrode crystal-oscillator circuits using parallel plate feed, it may be necessary to shift to series feed to prevent low-frequency parasitic oscillation because of the r.f. chokes in both the input and output circuits. In Pierce circuits, the oscillator tube may be fed as a grounded-grid amplifier by connecting the output terminals of the VFO in series between the cathode and the biasing resistor and by-pass. As an alternative, in this type of circuit, the oscillator tube may be eliminated and the VFO fed to the grid of the next tube.

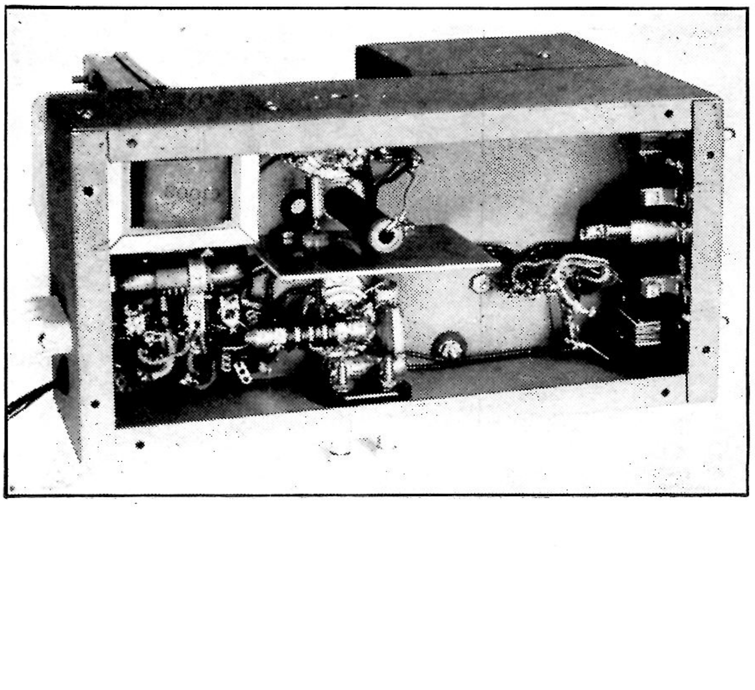


Fig. 6-77 — Bottom view of the VFO unit showing the filter choke and the various r.f. chokes and by-pass condensers associated with the isolating amplifiers.

Keying

Best keying characteristics will be obtained by keying the output stage although a second keying jack, J_1, is included for use if break-in operation is necessary. Since the key would be at 150 volts above ground, a keying relay or vacuum-tube keyer should be used here to avoid the danger of shock. In keying the oscillator, any key-click-filter lag should be kept at the minimum required for satisfactory click suppression, to avoid chirps. Usually, r.f. chokes only at the relay terminals will be sufficient. As much lag as is desired can be used when keying the output stage, since keying at this point does not affect the frequency.

The oscillator draws 8 ma. in the plate circuit and 3 ma. in the screen circuit. The plate current of the first amplifier should run about 15 ma. with the oscillator key closed and 32 ma. when excitation is removed. The output-stage currents should be 17 ma. with excitation and 25 ma. without excitation.

A 100-Watt Output Bandswitching Transmitter or Exciter

The transmitter pictured in Figs. 6-78, 6-80 and 6-81 incorporates bandswitching over all bands from 3.5 to 28 Mc. It consists of a 6V6 Tri-tet oscillator which gives either fundamental or second-harmonic output from a 3.5-Mc. crystal, a 6N7 dual-triode frequency multiplier with its first triode section operating as a doubler from 7 to 14 Mc. and the second section doubling from 14 to 28 Mc., and a final stage with two 807s in parallel. The Tri-tet cathode coil may be cut in or out of the circuit as desired, so that the 6V6 may be used as a straight tetrode crystal oscillator on either 3.5 or 7 Mc. Provision is made for crystal switching, six crystal sockets being included, and a seventh switch position is used for external VFO input. The power output on all bands is in excess of 100 watts when the 807s are operated at ICAS c.w. telegraph ratings.

Circuit

The circuit diagram of the transmitter is given in Fig. 6-79. The switching circuit is so arranged that the grids of unused 6N7 triode sections are disconnected from the preceding stage and grounded; thus excitation is not applied to idle doubler tubes. Only one coil is used in the 6V6 stage to cover both 3.5 and 7 Mc.; for 3.5 Mc. an air padding condenser, C_2, is switched in parallel with the 7-Mc. tank circuit to extend the tuning range to 3.5 Mc.

Capacitance coupling between stages is used throughout. The plates of the first three stages are parallel-fed so that the plate tuning condensers can be mounted directly on the metal chassis. Coupling to the 807 grids is through a tap on each plate coil; this "tapping down" not only provides the proper load for the various driver stages but also helps overcome the effect on the driver tuning ranges of the rather large shunt capacitance resulting from operating the two beam tetrodes in parallel. Series feed is used in the plate circuit of the 807s, the tank condenser being of the type that is insulated from the chassis. Operating bias for the 807s is obtained from a grid-leak resistor, and the screen voltage is obtained through a dropping resistor from the plate supply.

Plate currents of all tubes are read by a 0–100 d.c. milliammeter which can be switched to any plate circuit by means of S_4. One switch position is provided for checking the final-

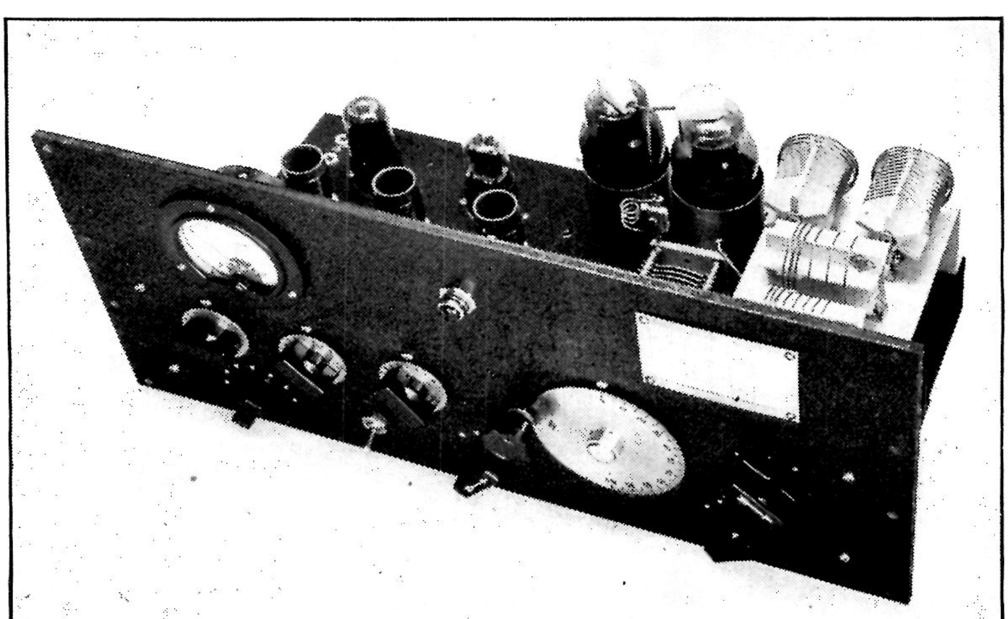


Fig. 6-78 — A 100-watt output transmitter or exciter with bandswitching over four bands. The output stage uses parallel 807s. Crystal switching, with provision for VFO input, and meter switching are incorporated. Tuning controls, from left to right, are crystal oscillator-doubler, 14-Mc. doubler, 28-Mc. doubler, and (large dial) final amplifier. The crystal switch is at the lower left corner, driver bandswitch in the center, and meter switch at the lower right. The amplifier bandswitch is above the meter switch and to the right of the amplifier tuning dial.

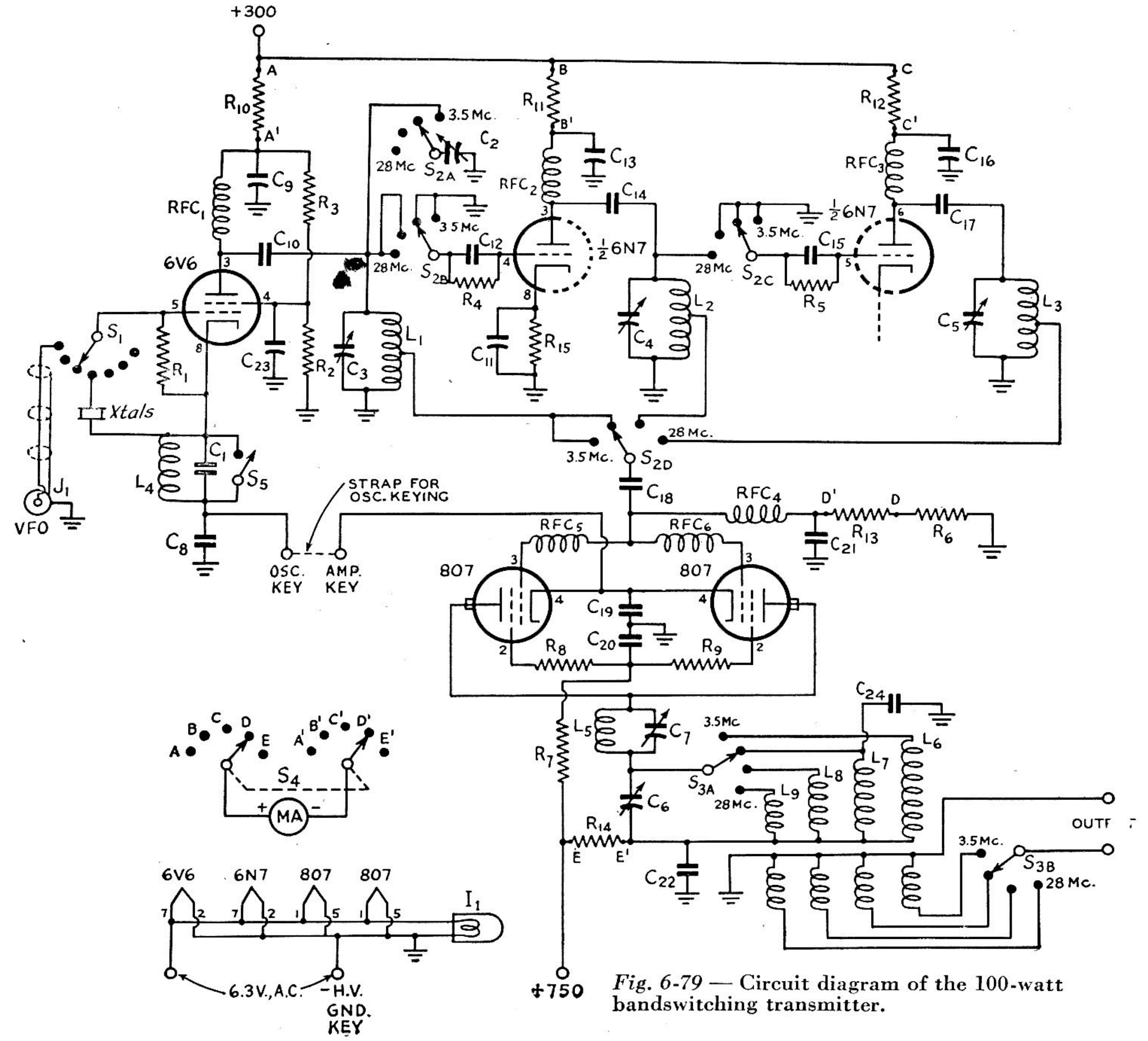


Fig. 6-79 — Circuit diagram of the 100-watt bandswitching transmitter.

C_1 — 220-μμfd. mica (mounted inside L_4).
C_2 — 140-μμfd. air padder.
C_3, C_4, C_5 — 100-μμfd. variable (National ST-100).
C_6 — 150-μμfd. variable, 0.05-inch plate spacing (Hammarlund HFB-150-C).
C_7 — 3–30-μμfd. ceramic padder.
C_8, C_{19}, C_{21} — 0.0047-μfd. mica.
C_9, C_{11}, C_{13}, C_{16}, C_{23} — 0.01-μfd. paper, 600 volts.
C_{10}, C_{14}, C_{17} — 0.0022-μfd. mica, 500 volts.
C_{12}, C_{15}, C_{18} — 100-μμfd. mica.
C_{20} — 470-μμfd. mica, 2500 volts.
C_{22} — 0.0022-μfd. mica, 2500 volts.
C_{24} — See text.
R_1 — 0.1 megohm, ½ watt.
R_2, R_3 — 47,000 ohms, 1 watt.
R_4 — 47,000 ohms, ½ watt.
R_5 — 22,000 ohms, ½ watt.
R_6 — 12,000 ohms, 1 watt.
R_7 — 25,000 ohms, 10 watts.
R_8, R_9 — 68 ohms, ½ watt.
R_{10}, R_{11}, R_{12}, R_{13}, R_{14} — 22 ohms, ½ watt (R_{14} shunted as described below).
R_{15} — 470 ohms, 1 watt.

NOTE: R_{14} is shunted by a length of No. 30 wire (about 8 or 10 inches) wound around the resistor, the wire length being adjusted to make the meter read one-fifth normal, increasing the full-scale range to 500 ma.

L_1 — 21 turns No. 18 on 1-inch form, length 1 inch; tapped 15 turns from ground.
L_2 — 10 turns No. 18 on 1-inch form, length 1 inch; tapped 7 turns from ground.
L_3 — 5 turns No. 18 on 1-inch form, length 1 inch; tapped 2 turns from ground.
L_4 — 13 turns No. 18 on 1-inch form, length 1 inch.
L_5 — 4 turns No. 18, diam. ⅜ inch, length ⅝ inch, mounted on C_7.
L_6 — 22 turns No. 20, diam. 1½ inches, length 1⅜ inches. Link: 3 turns.
L_7 — 13 turns No. 16, diam. 1½ inches, length 1⅜ inches. Link: 3 turns.
L_8 — 7 turns No. 16, diam. 1½ inches, length 1⅜ inches. Link: 3 turns.
L_9 — 4 turns No. 16, diam. 1½ inches, length 1½ inches. Link: 3 turns.

NOTE: L_1, L_2, L_3 wound on Millen 45004 forms, L_4 on Millen 45000 form; L_6, L_7, L_8, L_9 are Coto CI680E, CI640E, CI620E and CI610E, respectively, with turns removed to conform to specifications above.

I_1 — 6.3-volt pilot-lamp assembly.
J_1 — Coaxial-cable socket (Amphenol).
MA — 0–100 d.c. milliammeter.
RFC_1, RFC_2 — 2.5-mh. r.f. choke (National R-100).
RFC_3 — 2.5-mh. r.f. choke (National R-100U).
RFC_4 — 2.5-mh. r.f. choke (Millen 34102).
RFC_5, RFC_6 — 18 turns No. 20 d.c.c., ¼-inch diam., close-wound on 1-watt resistor (any high value of resistance may be used).
S_1 — Ceramic wafer switch, 7 positions.
S_2 — Four-gang 6-position ceramic wafer switch (4 positions used).
S_3 — Two-gang 4-position ceramic wafer switch (Yaxley 162C).
S_4 — Two-gang 6-position ceramic wafer switch (5 positions used).
S_5 — S.p.s.t. toggle switch.

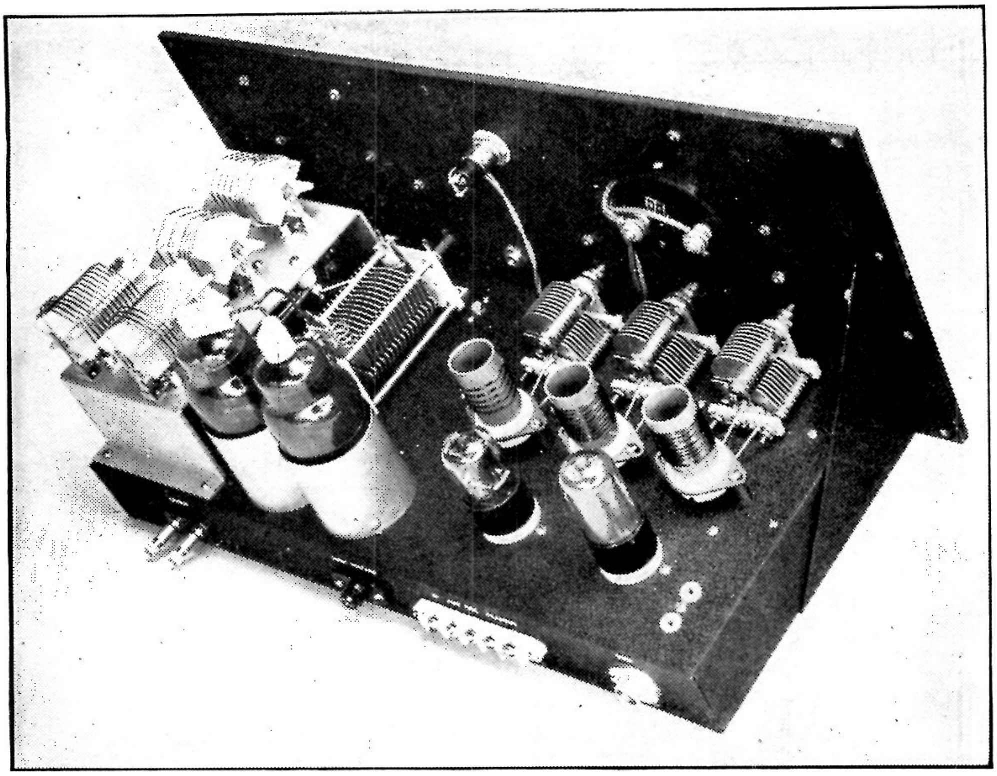


Fig. 6-80 — Top view of the 100-watt bandswitching transmitter. The oscillator and doubler coils are of the plug-in type for convenience in mounting and adjustment, but do not need to be changed to cover the frequency range from 3.5 to 30 Mc. The cable terminal on the chassis wall at the right is for VFO input; r.f. output terminals are at the extreme left.

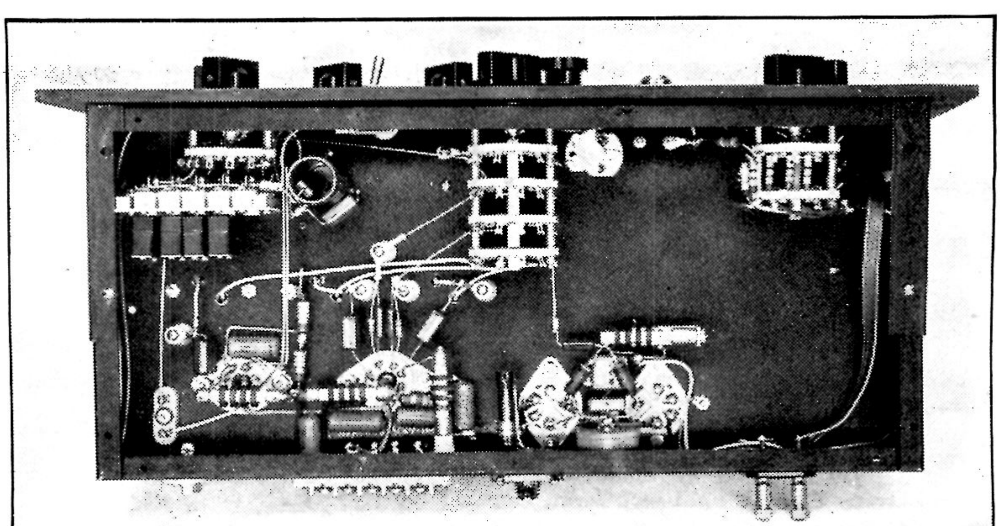
stage grid current. The d.c. cathode returns of both the 6V6 and the 807s are brought out to terminals so that a choice of keying is offered. If the 6V6 cathode lead is grounded, the amplifier alone may be keyed in the cathode circuit; if the two cathode returns are connected together, the oscillator and amplifier may be keyed simultaneously for break-in operation. (The oscillator alone cannot be keyed with the 807 cathodes grounded, because without fixed bias on the latter tubes the plate input would be excessive under key-up conditions.)

To prevent parasitic v.h.f. oscillations, small chokes (RFC_5 and RFC_6) are connected in the grid leads to the 807s, and a 68-ohm resistor is connected in each screen lead. These suppressors are mounted as closely as possible to the tube sockets. A parasitic trap, L_5C_7, is connected in the common plate lead to the 807s. Because of the high power sensitivity of the paralleled 807s and the fact that the grid-plate capacitance is doubled by the parallel connection, the tubes may oscillate in t.g.t.p. fashion at the operating frequency if the amplifier is run with no load on the plate tank. However, this tendency toward oscillation disappears with a small load (less than one-fourth rated plate current) and the amplifier is perfectly stable under normal loading conditions.

Construction

As shown in Fig. 6-80, the amplifier plate coils are mounted on an aluminum bracket supported by the main chassis. The bracket dimensions are 6½ inches long by 4 inches wide on top, with mounting legs 2½ inches high. Half-inch lips bent outward from the bottoms of the legs provide means for mounting to the chassis. The amplifier bandswitch, S_3, is mounted underneath the coil bracket, with the two switch wafers spaced out so they are ap-

Fig. 6-81 — Bottom view of the 100-watt bandswitching transmitter. The chassis dimensions are 8 × 17 × 2 inches and the panel (of crackle-finished Masonite) is 8¾ × 19 inches. Parts layout is described in the text. The 750-volt lead is brought through a Millen safety terminal, and all other power and keying connections go to a ceramic terminal strip at the rear. The connection between the crystal switch and the VFO input socket is through a short length of RG/58U cable.



proximately two inches apart. This brings the plate switch section directly under the 28-Mc. tank coil so that the shortest leads can be obtained at the highest frequency. The output link connection runs from the other switch section (at the front) through a length of 300-ohm feeder to terminals on the rear wall of the chassis. Because of the low ratio of plate voltage to plate current, a rather low L/C ratio must be used in the plate tank circuit to secure a reasonable Q. The standard coils used are therefore modified to the dimensions given in Fig. 6-79. Other types of manufactured coils (100-watt rating) may be used if desired, provided turns are taken off to bring the 3.5-Mc. band near maximum capacitance on the 150-

28-Mc. doubler, and the rotor of the last section to the grids of the 807s. In this view the right-hand section of the 6N7 is the 14-Mc. doubler. Grid and plate blocking condensers are supported between the tube-socket terminals and small ceramic pillars which serve as tie-points for r.f. wiring. The coil taps to the 807 switch drop through holes in the chassis directly below the proper prongs on the coil sockets. The crystal switch, crystal-holder assembly, oscillator-cathode tuned circuit, and shorting switch, S_5, are in the upper left-hand corner. The crystal sockets (for the new small crystals) are mounted in a row on a 1½ × 3-inch piece of aluminum secured to the chassis by mounting pillars of square alumi-

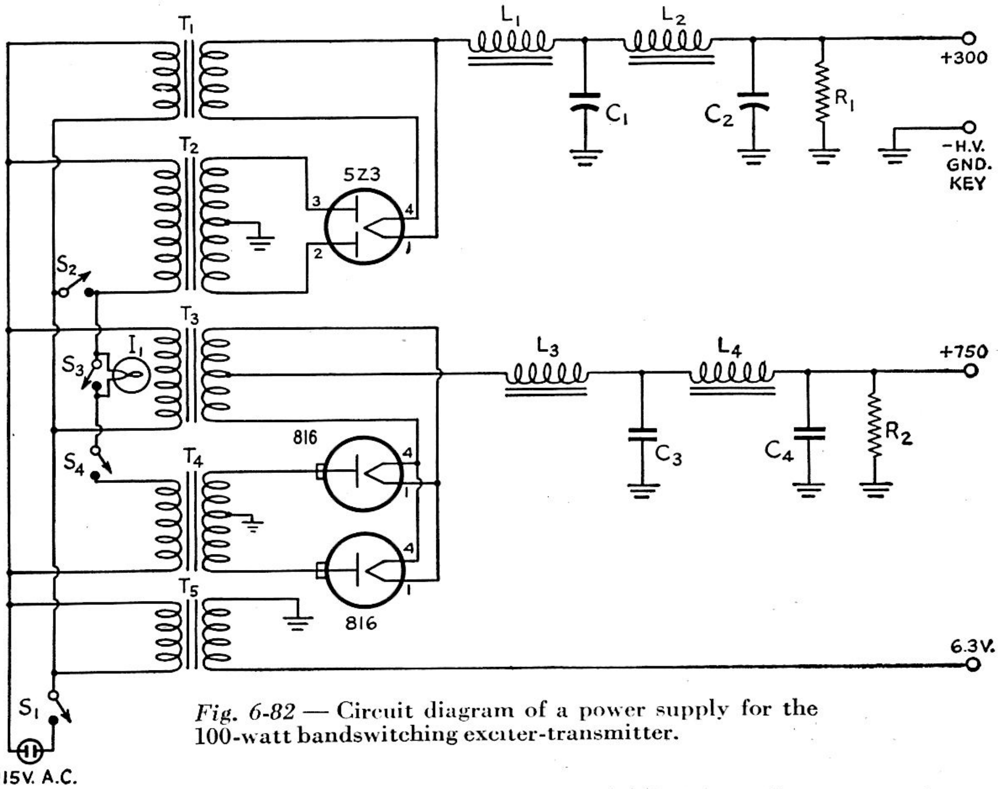


Fig. 6-82 — Circuit diagram of a power supply for the 100-watt bandswitching exciter-transmitter.

C_1, C_2 — 16-μfd. 450-volt electrolytic.
C_3, C_4 — 4-μfd. 1000-volt oil-filled.
R_1 — 15,000 ohms, 25 watts.
R_2 — 25,000 ohms, 50 watts.
L_1, L_2 — 20-hy. filter choke.
L_3 — 5/25-hy. 250-ma. swinging choke.
L_4 — 20-hy. 250-ma. smoothing choke.
I_1 — 100-watt 115-volt lamp.
S_1, S_2 — 10-amp. toggle switch.
S_3, S_4 — 5-amp. toggle switch.
T_1 — 5-volt 3-amp. filament transformer.
T_2 — Plate transformer, 300 v. d.c., 100 ma. or more.
T_3 — 2.5-volt 4-amp. filament transformer.
T_4 — Plate transformer, 750 v. d.c., 250 ma.
T_5 — 6.3-volt 4-amp. filament transformer.

S_1 turns on all filaments in the power supply and transmitter and sets up circuit for S_2. S_2 turns on low-voltage supply and sets up circuit for S_4 which turns on high-voltage supply. When S_3 is open, high voltage is reduced by I_1 in series with the primary of T_4. In operating the transmitter, all switches except S_2 are closed. S_2, then, is the stand-by switch controlling both plate supplies simultaneously.

μμfd. tank condenser, the 7-Mc. band at 65 to 70 per cent of maximum, and the 14-Mc. band to approximately 30 per cent of maximum. The 28-Mc. band may tune at nearly minimum capacitance, since the minimum circuit capacitance is fairly large.

In the bottom view, Fig. 6-81, the meter switch with its shunting resistors is at the right. The driver bandswitch, S_2, is in the center; the section nearest the panel is for C_2, the rotor of the next section goes to the grid of the 14-Mc. doubler, the rotor of the third section to the

num rod. The spare crystal socket on top of the chassis is for old-type crystal holders with ¾-inch pin spacing. In general, chokes and by-pass condensers are grouped as closely as possible about the tube sockets with which they are associated, to keep r.f. leads short. In the 807 circuit, the screen by-pass condenser, C_{20}, is mounted vertically from a small metal angle between the two tube sockets, and all grounds for the cathode, screen and grid circuits are brought to a common point between the two sockets.

The condenser, C_{24}, across only the 7-Mc. 807 tank coil, is actually a 1 × 1-inch piece of copper with a short tab at one end. The tab is soldered to the plate lead from the coil just under the coil bracket and then bent so that the 1 × 1 portion is parallel to the bracket and separated from it by about 1/8 inch. The coil by itself resonated with the stray capacitance at 28 Mc. and absorbed considerable energy when the transmitter was operating on that band; the small capacitance detunes it and prevents such absorption. It may not be needed with other types of coils or different construction.

Tuning

Preliminary tuning should be done with the plate voltage for the 807s disconnected. Set S_2 and S_3 for 28-Mc. output, set S_4 to read oscillator plate current, and close the key, if oscillator keying is being used. With a 3.5-Mc. crystal, make sure S_5 is open; with a 7-Mc. crystal S_5 should be closed. Rotate C_3 for a small kick in the plate current that indicates resonance at the crystal harmonic, in the case of the Tri-tet, and for the marked dip in plate current that indicates oscillation with the tetrode oscillator. The current should be in the vicinity of 16 to 18 ma. Switch the meter to the 14-Mc. doubler and adjust C_4 to obtain minimum plate current. This should be about 15 ma. Check the 28-Mc. doubler plate current similarly; it should be between 25 and 30 ma. at resonance. The final-amplifier grid current should be 7 to 8 ma.

Next, connect a 70-ohm dummy antenna or 100-watt lamp to the output terminals, set C_6 near minimum capacitance, and apply plate voltage to the 807s. Adjust C_6 for minimum plate current, which should be about 200 ma. with this load. Readjust the driver circuits for maximum grid current to the 807s.

Tuning procedure for other bands is much the same, except that the amplifier cannot be loaded to full input on the lower frequencies by either the dummy antenna or lamp, with the links furnished with the coils specified. In such cases an antenna should be used to load the transmitter after it has been determined that the various stages are working properly. On 3.5 Mc., C_2 should be adjusted so that a crystal on 3500 kc. can be made to oscillate with C_3 set near maximum capacitance. Generally, C_2 will be set at approximately full capacity.

The transmitter requires a power supply delivering 60 to 70 ma. at 300 volts for the oscillator and doublers, and one delivering 200 ma. at 750 volts for the 807s. The supply of Fig. 6-82 is suitable.

A 450-Watt Bandswitching Amplifier

Figs. 6-83, 6-85 and 6-86 show the details of a bandswitching push-pull amplifier for the 3.5-, 7-, 14- and 28-Mc. bands. It is suitable for use with any of the popular 1000- or 1500-volt 100- to 150-ma. triodes. The tubes shown in the photographs are 812s.

As shown in the circuit diagram of Fig. 6-84, all of L_1 in the grid tank circuit and all of L_4 in the plate tank circuit are used for 3.5 Mc. Low-frequency padders, C_1 in the grid circuit and C_{10} in the plate, are switched across the coils simultaneously. For 7 Mc., the padding condensers are cut out and L_1 and L_4 are tapped so that only a portion of each coil is in use. At 14 Mc., the coils L_2 and L_3 are used with the padders, while at 28 Mc. the same coils are used without the padders. Links for the two coils in each tank circuit are connected in series.

The components are assembled on a standard 19-inch panel, 10½ inches high. The two tubes, the neutralizing condensers and L_2 are

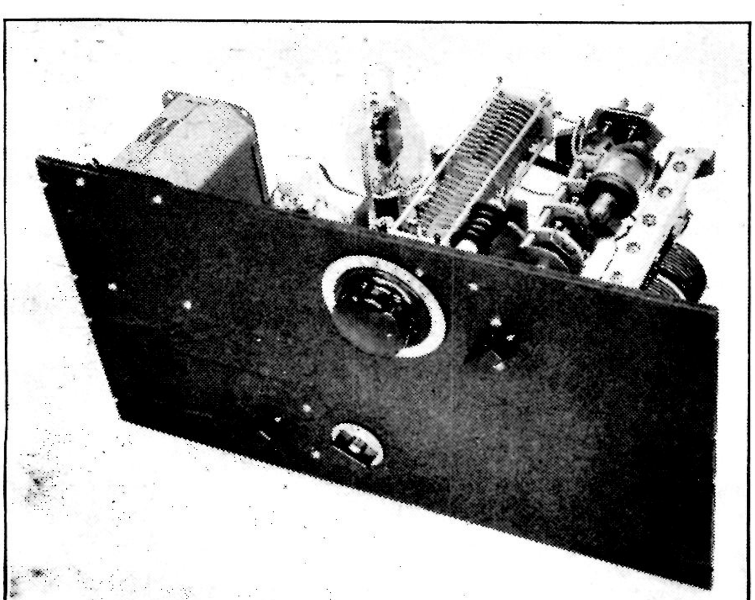


Fig. 6-83 — Top view of the bandswitching amplifier. The plate-tank switching assembly is to the right.

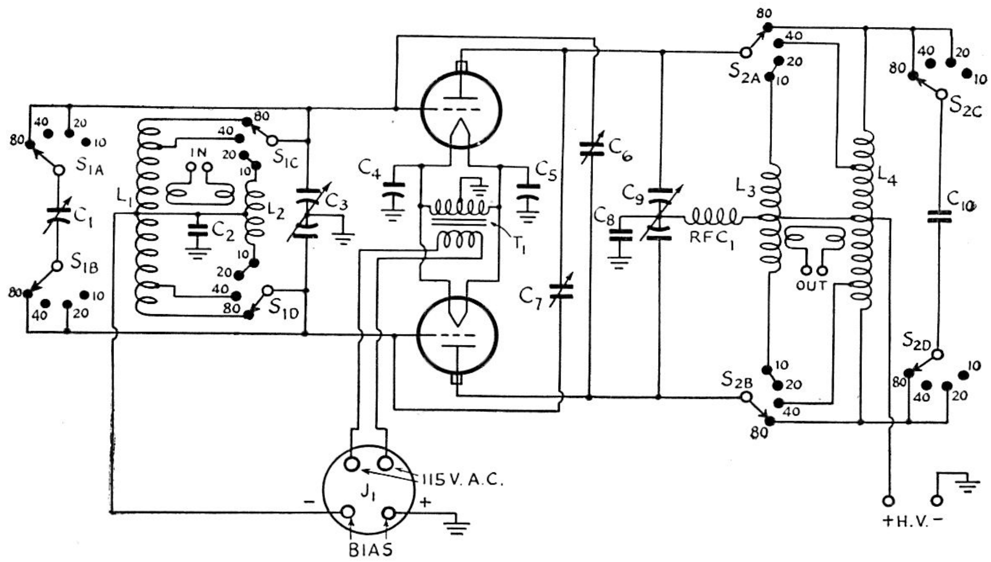


Fig. 6-84 — Circuit diagram of the bandswitching push-pull amplifier.

C_1 — 30-$\mu\mu$fd. variable, 0.07-inch spacing (Cardwell ZT-30-AS).
C_2 — 0.001-μfd. mica.
C_3 — 35-$\mu\mu$fd.-per-section variable (Millen 24935).
C_4, C_5 — 0.01-μfd. paper.
C_6, C_7 — Neutralizing condenser (National NC-800).
C_8 — 0.001-μfd. 5000-volt mica.
C_9 — 65-$\mu\mu$fd.-per-section variable (Hammarlund HFBD-65-F).
C_{10} — 50-$\mu\mu$fd. vacuum capacitor (Type GE GL-1L38).
L_1 — B & W 80BCL, tapped at 12th turn from each end.
L_2 — 10 turns No. 14 enam., 1¼-inch diam., 1 inch long.
L_3 — B & W 10TCL.
L_4 — B & W 80TCL reduced to 24 turns, tapped at 3rd turn from each end.
J_1 — 4-prong socket connector.
RFC_1 — 1-mh. r.f. choke (National R-154U)
S_1, S_2 — 4-gang 4-position ceramic rotary switch (Mallory 164-C).
T_1 — 6.3 volts, 8 amp. (UTC S61).

mounted on top of a 5 × 10 × 3-inch chassis fastened to the panel with its center 7 inches from the left-hand edge and its bottom edge ¾ inch above the lower edge of the panel. The tubes are spaced 5¼ inches, center to center, and their sockets are submounted and centered 1¾ inches from the right-hand edge of the chassis as viewed from the rear. L_2 is wound on a polystyrene form mounted on a National AR coil-plug strip. Its socket is centered between the tubes and ⅝ inch from the edge of the chassis. A 5¾ × 2-inch cut-out is made in the outside edge of the chassis to clear the grid bandswitch, S_1. A 1¾-inch piece of the cut-out is left and bent inward at right angles to provide a mounting for the switch. The coil for L_1 is removed from its plug strip and transferred to a Millen plug strip which has the required additional contacts for the 7-Mc. taps. The cut-out is notched at the top to provide clearance for the terminals of the coil socket.

Fig. 6-85 — Rear view of the bandswitching amplifier.

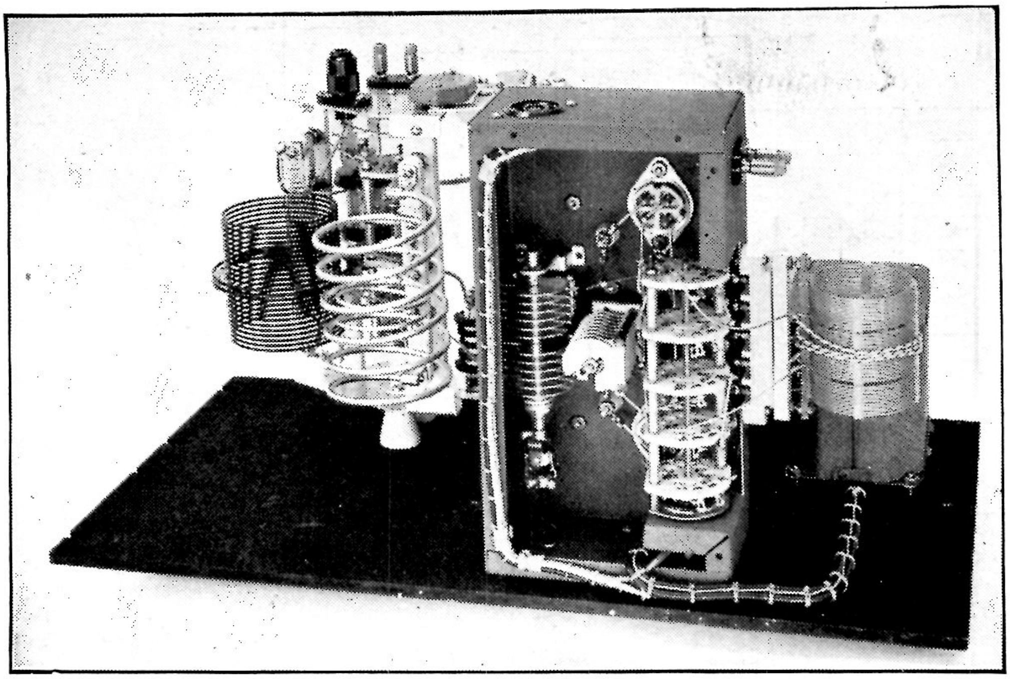


Fig. 6-86 — Bottom view of the bandswitching amplifier showing the grid-circuit assembly to the right and the plate-circuit group to the left.

Underneath the chassis, C_1 is mounted vertically on spacers at the center, while the grid tuning condenser, C_3, is mounted as close to the inside edge as possible. Leads between the lower terminals of the neutralizing condensers and the grid terminals of the tube sockets are fed down through the top of the chassis via small feed-through insulators. Link input terminals are mounted on the outside edge of the chassis, near the rear, while 115-volt a.c. and biasing connections are made through a cable socket set in the rear edge. The filament transformer is mounted on the upper right-hand corner of the panel, as viewed from the rear of the unit.

The plate tuning condenser, C_9, is mounted on aluminum-strip brackets fastened to the chassis to bring its shaft 8¾ inches from the right-hand edge of the panel (as viewed from the front) and 2½ inches from the top. Alumi-

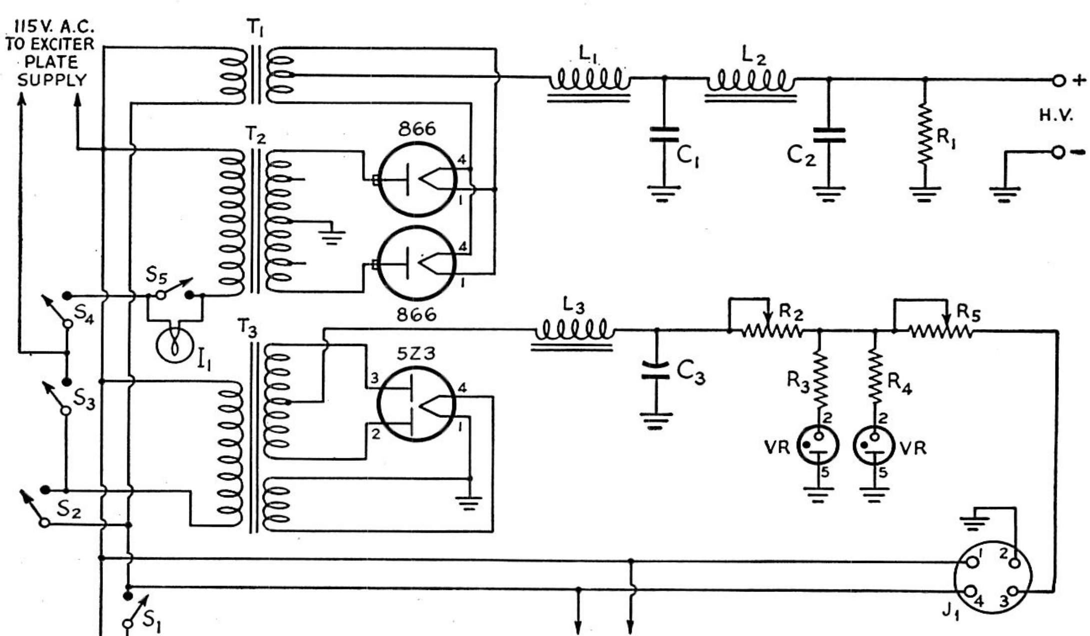


Fig. 6-87 — Circuit diagram of a power supply and control system for the 450-watt bandswitching amplifier.

C_1, C_2 — 4-μfd. 2000-volt oil-filled.
C_3 — 8-μfd. 450-volt electrolytic.
R_1 — 25,000 ohms, 100 watts.
R_2 — 20,000 ohms, 25 watts, with slider.
R_3, R_4 — 100 ohms, 1 watt.
R_5 — 2500 ohms, 10 watts, with slider.
L_1 — 5/25-hy. 400-ma. swinging choke.
L_2 — 20-hy. 400-ma. smoothing choke.
L_3 — 30-hy. 50-ma. filter choke.
I_1 — 150-watt 115-volt lamp.
J_1 — 4-prong socket connector.
S_1, S_2, S_3, S_4 — 10-amp. switch.
S_5 — 5-amp. switch.
T_1 — 2.5-volt 10-ampere filament transformer, 10,000-volt insulation.
T_2 — Plate transformer, 1500/1250 v. d.c., 400 ma.
T_3 — Power transformer, 650 volts c.t., 50 ma.; 5 volts, 3 amp.
VR — Voltage-regulator tubes — VR75 (see text).

num sheet is cut to form end plates for a subassembly which includes the switch, S_2, the two coil sockets, and a mounting for the padder, C_{10}. As viewed from the rear, L_4 is to the left and L_3 to the right. Pillar-type ceramic insulators form spacers for the mounting angles that support the cartridge-fuse clips in which the vacuum-type padding condenser, C_{10}, is mounted. The assembly is spaced from the panel on 1¼-inch cone stand-offs, placed so that the shaft comes 5½ inches from the right-hand edge of the panel and 2¾ inches below the top edge. The Millen safety terminal for the high-voltage connection, the link output terminals and the insulating condenser, C_8, are fastened to the rear end plate of the assembly. The plate r.f. choke is fastened to the panel between the plate tank condenser and the switch assembly.

Reference should be made to earlier sections in this chapter for tuning and adjusting procedures.

Power Supply

Fig. 6-87 shows the circuit of a suitable power supply and control system for this amplifier. The plate-supply transformer, T_2, is tapped for either 1500 or 1250 volts d.c. output from the filter, making it suitable for operating the amplifier at maximum ratings, 'phone or c.w. The bias supply employs a small transformer and the output voltage is regulated. A pair of VR tubes are used in parallel to carry the required grid current. The resistor, R_2, should be adjusted, without excitation to the amplifier, until the VR tubes just ignite. The voltage of the pack should then hold constant over a wide range of grid-current values. VR tubes should be selected with voltage ratings between the value required to cut off plate current and the recommended value of operating bias for the amplifier tubes used. The difference between the VR-tube voltage and the recommended operating value then is made up by grid-leak action through R_5. R_5 should be adjusted so that the operating bias is the recommended value with rated grid current flowing and the amplifier loaded to rated plate current.

The control system is arranged so that S_1 turns on the 866 filaments in the power supply, amplifier and exciter filaments, and sets up circuit for S_2 which turns on the bias supply. S_2 also sets up circuit for S_3 which turns on the exciter plate supply and sets up circuit for S_4 which controls the high-voltage supply. When S_5 is open, power is reduced for adjustments since I_1 is in series with the primary of T_2. In operating the transmitter, all switches except S_3 are closed. S_3 then serves as the stand-by switch, controlling all plate power supplies simultaneously.

A 500-Watt Beam-Tube Amplifier

The photographs of Figs. 6-88, 6-90, 6-91 and 6-92 show the construction of a single-tube screen-grid amplifier using a Type 813 which will handle an input of up to 500 watts. The circuit is shown in Fig. 6-89. The amplifier is designed for link coupling in both input and output circuits. Bandswitching is employed in the grid circuit principally because of the problem of providing plug-in coils with satisfactory shielding. To assure good stability, the amplifier is neutralized.

The triode-connected 6Y6 is used to protect the tube against overload in case of removal or failure of excitation. This system is used in preference to protective bias because of the difficulty of limiting the input to a safe value without exceeding the recommended operating bias for operating conditions when screen

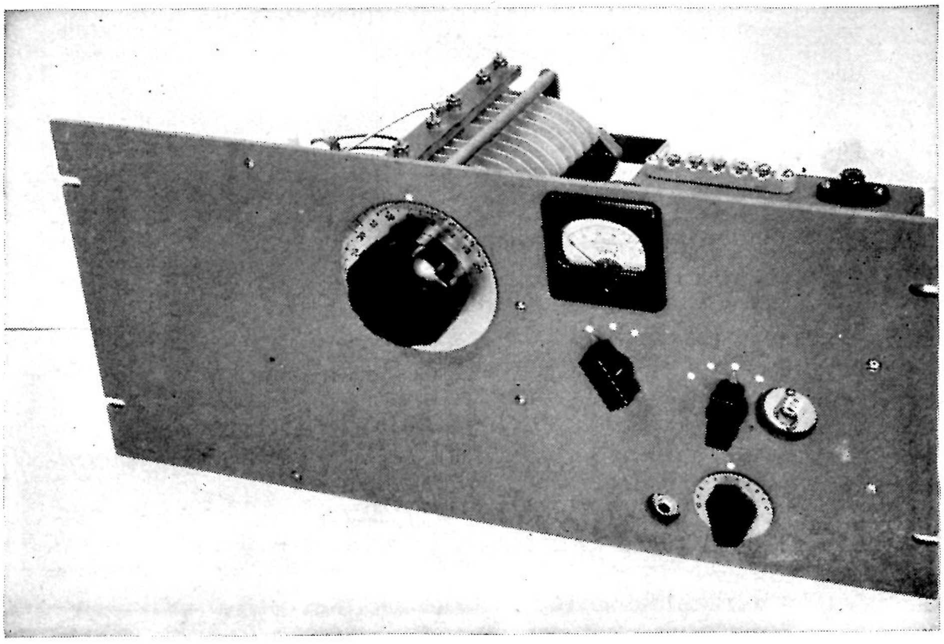


Fig. 6-88 — **Front-panel view of the stabilized 813 amplifier. In addition to the meter and the plate and grid tuning controls, the panel contains the r.f. input jack, the key jack, a three-position meter switch, and a four-position bandswitch for the grid circuit.**

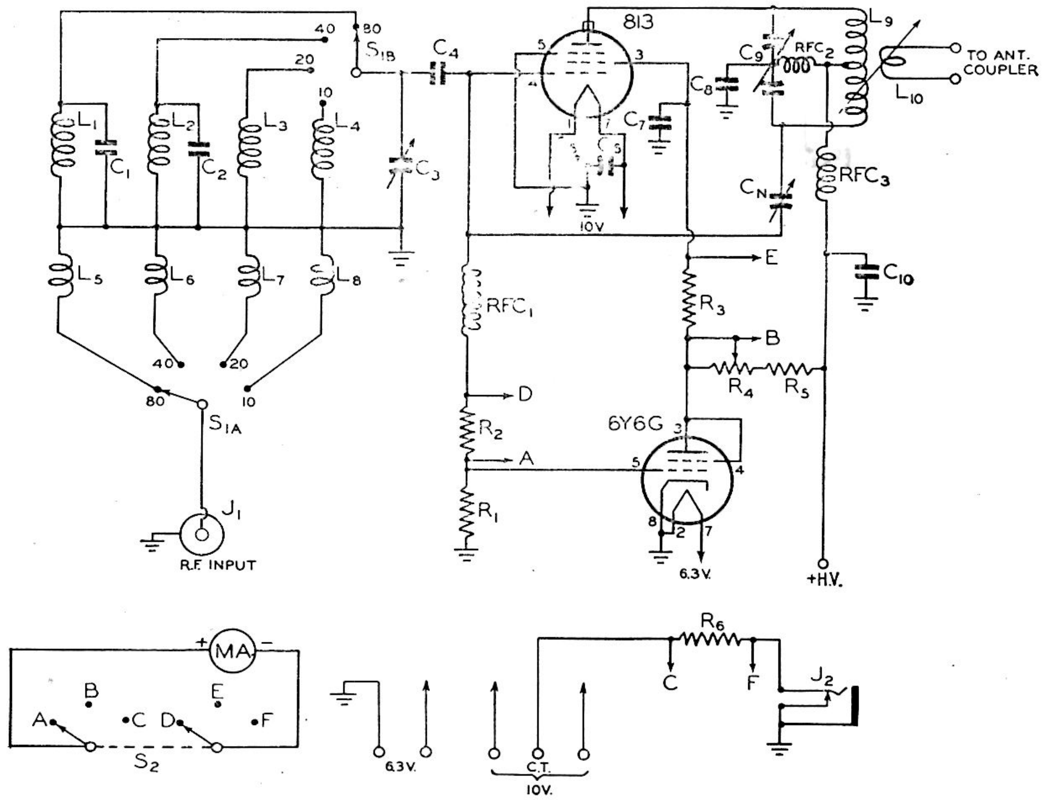


Fig. 6-89 — Schematic diagram of the 813 amplifier.

C_1 — 100-$\mu\mu$fd. mica.
C_2 — 68-$\mu\mu$fd. mica.
C_3 — 50-$\mu\mu$fd. receiving-type variable (Millen Type 19050).
C_4 — 0.0022-μfd. mica.
C_5, C_6 — 0.01-μfd. paper.
C_7 — 0.001-μfd. 2500-volt mica.
C_8 — 0.001-μfd. 5000-volt mica.
C_9 — 50-$\mu\mu$fd.-per-section dual transmitting type, 0.171-inch spacing (Cardwell XG-50-XD).
C_{10} — 0.001-μfd. 5000-volt mica.
C_N — See text.
R_1 — 10,000 ohms, 5 watts. (See text.)
R_2, R_3 — 100 ohms, ½ watt.
R_4 — 35,000 ohms, 50 watts, with slider.
R_5 — 15,000 ohms, 50 watts.
R_6 — Meter shunt. Wound with No. 30 d.s.c. wire, length as required to multiply meter scale by ten.
L_1 — 26 turns No. 22 d.s.c. spaced to occupy 1¼ inches on a 1-inch diam. form.
L_2 — 15 turns No. 18 d.c.c. spaced to occupy 1¼ inches on a 1-inch diam. form.
L_3 — 10 turns No. 18 d.c.c. spaced to occupy 1¼ inches on a 1-inch diam. form.
L_4 — 5 turns No. 18 d.c.c. spaced to occupy 1¼ inches on a 1-inch diam. form.
L_5, L_6, L_7, L_8 — Two-turn links, No. 18 insulated stranded wire, wound over ground ends of L_1 through L_4 inclusive.
L_9 — Note: These coils are B & W TVH series, for use with the B & W TVH swinging-link assembly. The coils are modified as described below.
80 meters: B & W 160-TVH with 4 turns removed from each end. (54 turns No. 18 enameled, 2½ inches diameter, winding length 4⅞ inches.)
40 meters: B & W 80-TVH with 8 turns removed from each end. (22 turns No. 14 enameled, 2½ inches diameter, winding length 3⅜ inches.)
20 meters: B & W 20-TVH with 1 turn removed from each end. (12 turns No. 12 enameled, 2½ inches diameter, winding length 4½ inches.)
10 meters: B & W 10-TVH with 1 turn removed from each end. (6 turns ⅛-inch copper tubing, 2½ inches diameter, winding length 5¼ inches.) (Winding lengths specified above include ⅝-inch separation between halves of the coil for entrance of swinging link coil.)
L_{10} — 3-turn link assembly, part of B & W TVH swinging-link assembly.
J_1 — Coaxial connector.
J_2 — Closed-circuit jack.
MA — 0–50 d.c. milliammeter.
RFC_1 — 2.5 mh. (Millen Type 34104).
RFC_2 — 2.5 mh. (National R-100).
RFC_3 — 2.5 mh. (National R-300).
S_1 — Single-gang 2-pole 5-position ceramic wafer switch. (Centralab S-2505.)
S_2 — Two-gang 2-pole 5-position ceramic wafer switch. (Centralab S-2511).

voltage is obtained from a series resistance — recommended practice if the amplifier is to be plate-screen modulated. So long as normal grid current flows to the 813, the 6Y6 is biased to cut-off, so that it has no effect. However, when excitation is removed from the amplifier, the bias on the 6Y6 disappears and it draws current through the screen resistor, causing the screen voltage to drop to a value that reduces both plate and screen currents to safe values.

The single milliammeter may be switched by S_2 to read grid current, screen current or cathode current. A multiplier shunt increases the range of the 50-ma. meter to 500 ma. when it is switched to read cathode current. A jack, J_2, is provided so that the amplifier may be keyed in the center-tap.

Construction

The entire amplifier unit is suspended from a standard 19 × 8¾-inch panel. The grid-circuit components are housed in the 6 × 6 × 6-inch steel box to the left in Fig. 6-90,

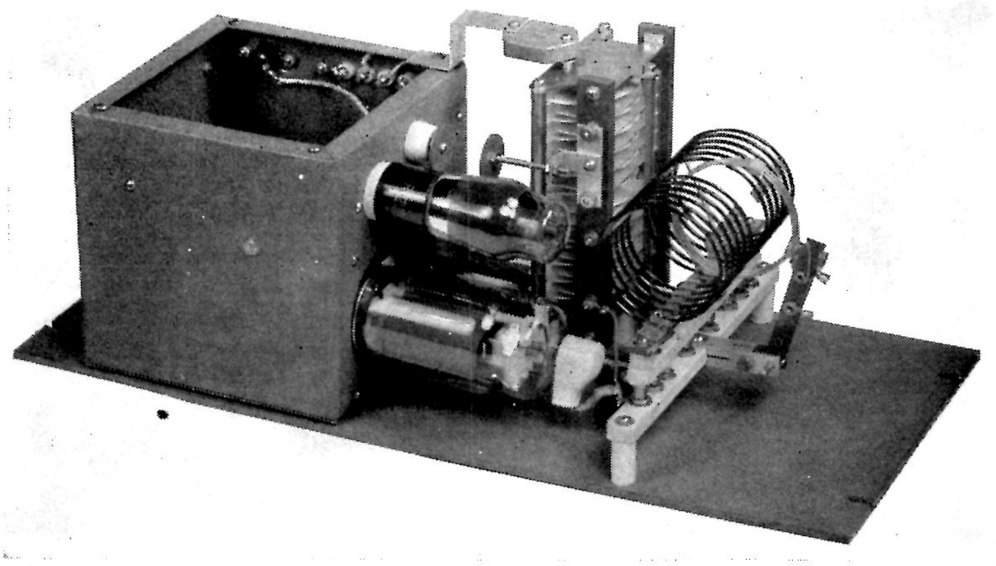


Fig. 6-90 — Rear view of the 813 amplifier. The steel utility box used to shield the input circuits is bolted to the rear of the panel. The home-built neutralizing condenser is below the mica by-pass condenser which forms a part of the rear support for the plate condenser. The plate condenser and the swinging-link assembly are mounted directly on the panel with ceramic stand-off insulators.

while the plate tank condenser and coil are mounted on the panel to the right. The 813 protrudes horizontally from the right-hand side of the box, its socket being submounted on brackets inside the box so that that portion of the tube which extends above its internal shielding plate is exposed. The 6Y6 is mounted alongside the 813.

The r.f. input jack, the grid coils, grid tuning condenser, bandswitch, key jack, and the meter switch are built as one assembly constructed on one of the cover plates of the box as shown in Fig. 6-92. All ground connections in this assembly are made to soldering lugs slipped under the screws which mount the coil forms. The coils themselves are held away from the chassis by National GS-10 stand-off insulators. Care should be taken in locating the mounting holes for the coils and the bandswitch to be sure that they will clear the lip of the utility box when the time comes for final assembly. If required, additional clearance may be obtained by filing semicircular notches in the lips of the box. The coils should be connected to the bandswitch before the coupling links are wound. This keeps the assembly clear of obstructions and makes wiring easier. Padding condensers C_1 and C_2, used with the 40- and 80-meter coils respectively, are connected from the grid end of the coil to the same soldering lugs used for grounding the cold ends of the coils. When the links are wound on later, their ground connections are also made to these same lugs.

The meter switch provides mounting terminals for meter shunts R_2, R_3 and R_6, and for the grid resistor, R_1. The leads to the meter itself are passed through the top of the box through

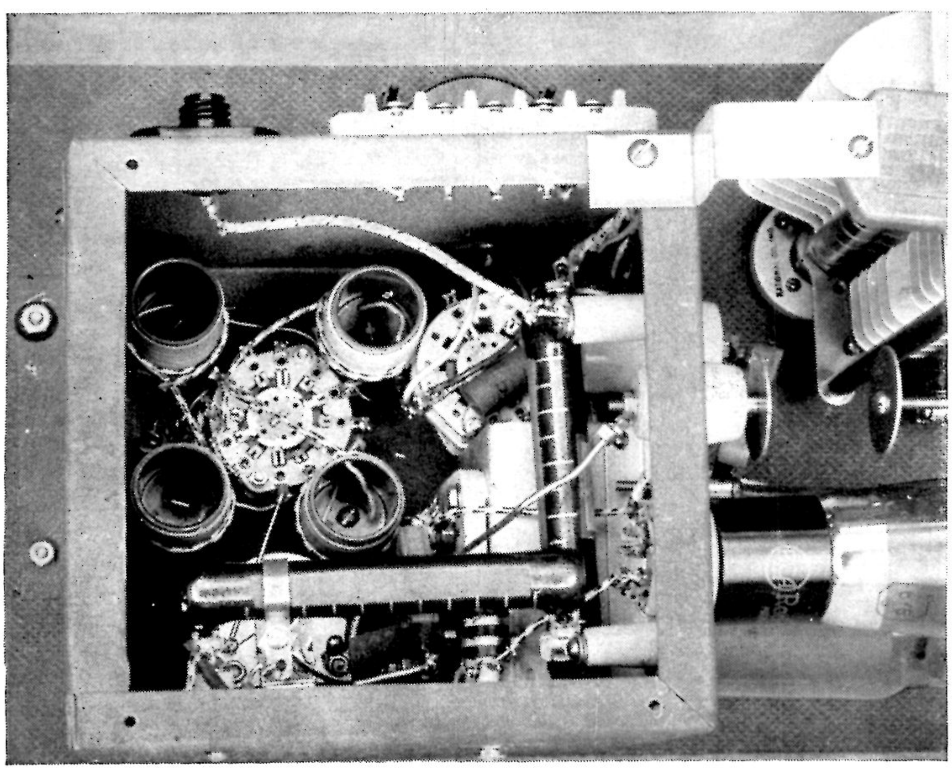


Fig. 6-91 — The interior of the shield box. The socket for the 813 is mounted on a bracket visible to the right of the four grid coils. The two large resistors are the screen-dropping units. This view also shows the construction of the neutralizing condenser, one plate of which mounts on a ceramic bushing on the wall of the box, the other being supported by a bracket from the plate tuning condenser.

a grommet-lined hole after assembly. The other leads to the metered circuits are cabled and are run along the top of the box.

All of the by-pass condensers associated with the screen and filament circuits are mounted on the socket and should be grounded at a common point. All of this wiring, together with the filament and screen leads, should be soldered in place before the 813 socket bracket is mounted within the box. The grid blocking condenser, C_4, may also be soldered in position, leaving one end free to be connected to the stator plates of the grid tuning condenser after assembly. The mounting of the screen dropping resistors is shown in Fig. 6-91. Both are supported by small ceramic stand-off insulators. High voltage for the plate-and-screen supply enters the top of the box through a Millen safety connector, and is passed through the side of the box to the plate coil through a ceramic bushing. A bushing requiring a ¾-inch hole was used to provide maximum insulation. The fixed plate of the neutralizing condenser is mounted on a similar bushing just above the socket for the 6Y6G. The exact location of this hole should be determined after temporarily assembling the panel, the plate tuning condenser, and the box, because the fixed plate must be aligned with the variable plate, which is supported by the plate tuning condenser.

The plate tuning condenser is mounted on the front panel by three ceramic stand-off insulators. This is necessary because the condenser rotor is at full plate potential above ground. The rotor shaft is cut off about ¼ inch from the rotor bushing, to permit the insertion of a high-voltage type shaft coupling. An insulated shaft made of ¼-inch bakelite rod couples the rotor of the condenser to the dial. Both r.f. chokes used in the plate tank circuit are mounted on the jack-bar into which the coils plug. The high-voltage lead runs from the center-tap of the coil to the ceramic bushing on the side of the box, at which point the plate by-pass condenser, C_{10}, is mounted. The ground end of this condenser is mounted on a spacer which is held in place by one of the screws which passes through the side of the box to hold the socket mounting bracket in place. The rear of the plate tuning condenser is held to the rear of the box by a small aluminum bracket, bent to provide adequate clearance between itself and the rotor. Blocking condenser C_8 is made a part of this bracket.

The variable plate of the neutralizing condenser is supported by a small bracket bolted to the stator connectors of the tuning condenser. The copper disks used are each 1 inch in diameter. A hole is drilled in the center of each disk to pass a mounting screw. The "stator" disk is bolted to the ceramic feed-through bushing, and is held away from it by a ¼-inch spacer. The other end of the screw which goes through the bushing is fitted with a soldering lug to which the grid connection is soldered. The "rotor" disk is fastened to a 2-inch machine screw with a nut. The threaded end of the screw is then passed through the mounting bracket and is held in position firmly by two nuts, one on each surface of the bracket. This plate should be put in position first, after which the location of the hole for the bushing can be determined to provide proper alignment of the two plates.

After the three separate assemblies have been built and wired, the few remaining interconnections should be made. These include the connection of the metering leads to the proper points of the circuit, the connection of the grid coupling condenser to the stator plates of the grid tuning condenser, and the connection of the leads between the common terminals of the meter switch and the meter itself. The entire box assembly is then fastened to the front panel using angle brackets and 6-32 machine screws.

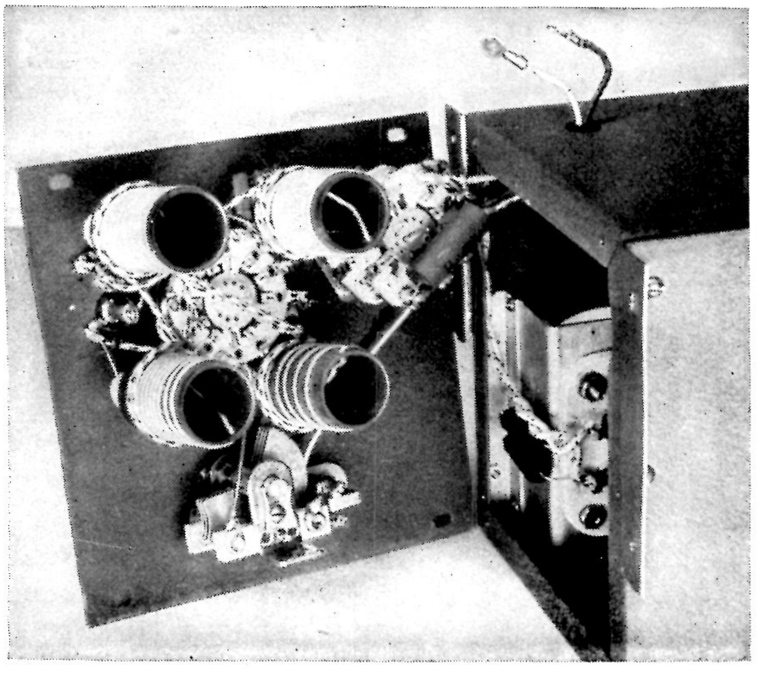


Fig. 6-92 — The grid coils are grouped around their bandswitch on one of the covers of the utility box. The coaxial input jack is mounted between the two coils at the left. The meter switch is in the upper right-hand corner, and the grid tuning condenser is at the bottom. The two leads coming through the top of the box run from the meter switch to the meter.

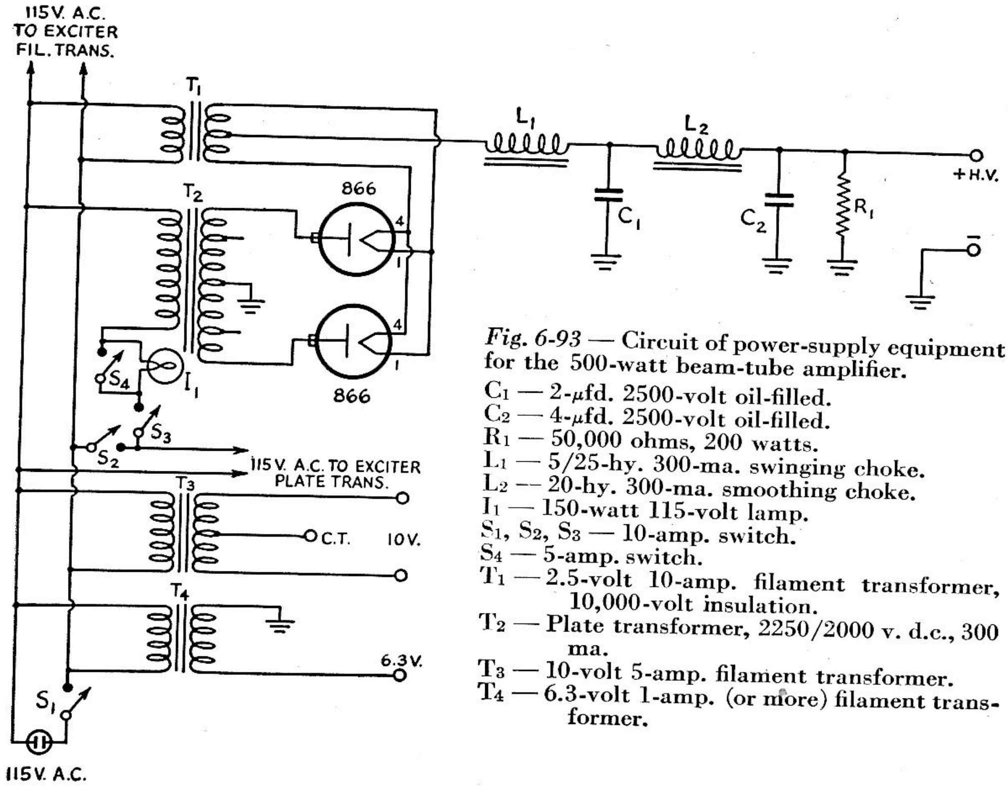


Fig. 6-93 — Circuit of power-supply equipment for the 500-watt beam-tube amplifier.

C_1 — 2-μfd. 2500-volt oil-filled.
C_2 — 4-μfd. 2500-volt oil-filled.
R_1 — 50,000 ohms, 200 watts.
L_1 — 5/25-hy. 300-ma. swinging choke.
L_2 — 20-hy. 300-ma. smoothing choke.
I_1 — 150-watt 115-volt lamp.
S_1, S_2, S_3 — 10-amp. switch.
S_4 — 5-amp. switch.
T_1 — 2.5-volt 10-amp. filament transformer, 10,000-volt insulation.
T_2 — Plate transformer, 2250/2000 v. d.c., 300 ma.
T_3 — 10-volt 5-amp. filament transformer.
T_4 — 6.3-volt 1-amp. (or more) filament transformer.

Power Supply

The circuit diagram of a plate and filament supply and a suggested control system is shown in Fig. 6-93. The plate transformer is tapped so that voltage may be reduced to keep within the tube ratings when modulating the amplifier.

The control system is arranged to take care of the exciter as well as the amplifier. S_1 turns on all filaments in the exciter, amplifier and power supply, and sets up circuit for S_2 which turns on the exciter plate supply. Closing S_2 also sets up circuit for S_3 which turns on the high-voltage supply. When S_4 is open, I_1 is in series with the primary of T_2 to reduce voltage while adjustments are being made. When the transmitter is in operation, all switches except S_2 are closed. S_2 then serves as the stand-by switch, controlling both exciter and amplifier plate-voltage supplies simultaneously.

Adjustment

The amplifier is neutralized most accurately by applying excitation with the positive high-voltage lead disconnected and checking for r.f. in the plate tank circuit with an absorption-type indicator (see Chapter Sixteen). Starting with the neutralizing condenser wide open, the capacitance should be increased slowly. At some point within the range of the neutralizing condenser, the indicator should show minimum indication (or no indication) of r.f. as the plate tank condenser is swung through its range. If further increase in the capacitance of the neutralizing condenser causes an increase in the reading of the indicator, the setting of the neutralizing condenser should be brought back to the minimum point.

Tube data sheets furnish proper operating values for a choice of several plate voltages and these should be followed closely. For operating at maximum c.w. ratings, the plate voltage should be 2250. A screen resistor of 46,000 ohms and a grid leak of 10,000 ohms should be used. When the amplifier is loaded to a plate current of 220 ma. and the excitation adjusted to give a grid current of 15 ma., the d.c. grid voltage should be −155 volts and the screen voltage 400 at a screen current of 40 ma. For maximum plate/screen-modulated ratings, the plate voltage should be 2000, the screen resistor 41,000 ohms and the grid leak 11,000 ohms. When the amplifier is loaded to the maximum rated plate current of 200 ma. and the grid current adjusted to 16 ma., the bias should be 175 volts and the screen voltage 350 at 40 ma. The driver should be capable of an output of 15 to 20 watts to allow for coupling losses. For c.w. operation with a 1500-volt supply and a plate current of 180 ma., the recommended screen voltage is 300. The screen current should be 30 ma. and the required screen voltage-dropping resistor 40,000 ohms. The grid current under load should be 12 ma. through a 7500-ohm grid leak. For 'phone operation at 1600 volts, the following values are recommended: plate current 150 ma., screen voltage 400 at 20 ma., grid bias 130 volts at 6 ma., screen voltage-dropping resistor 60,000 ohms, grid leak 22,000 ohms.

Perhaps the most critical adjustment is that of obtaining proper excitation. Overdriving results in excessive screen current. Excessive screen current causes abnormal voltage drop in the screen resistor, resulting in reduced output from the tube. Since both screen and control-grid current will vary with the loading of the amplifier, it is important that the excitation adjustment be made with the amplifier loaded to rated plate current. Underloading can quite readily result in excessive screen dissipation unless the screen resistor and excitation are readjusted to suit the conditions.

If the amplifier is properly neutralized, it should be possible to remove both load and excitation without encountering any indication of self-oscillation. Under this condition, the cathode current should fall to a low value.

A Push-Pull Amplifier for 200 to 500 Watts Input

Figs. 6-95, 6-96 and 6-97 show various views of a compact push-pull amplifier using tubes of the 1500-volt 150-ma. class, although the design is also suitable for use with tubes of the 1000-volt 100-ma. class. With the lower plate voltages a plate tank condenser with a spacing between plates of 0.05 inch, and smaller tank coils, may be used.

The circuit, shown in Fig. 6-94, is quite conventional, with link coupling at both input and output. The tuned circuits, L_3C_6 and L_4C_5, are traps important for the prevention of v.h.f. parasitic oscillations. The 100-ma. meter may be shifted between the grid and cathode circuits for reading either grid current or cathode current. When shifted to read cathode current,

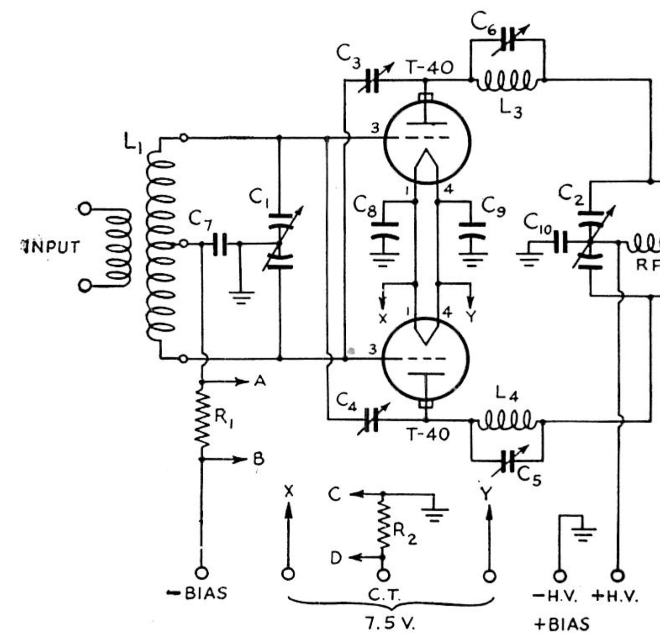


Fig. 6-94 — Circuit diagram of the 450-watt push-pull amplifier.

C_1 — 100 μμfd. per section, 0.03-inch spacing (Hammarlund HFAD-100-B).
C_2 — 100 μμfd. per section, 0.07-inch spacing (Hammarlund HFBD-100-E).
C_3, C_4 — Neutralizing condenser (National NC-800).
C_5, C_6 — 3–30-μμfd. mica trimmer (National M-30).
C_7, C_8, C_9 — 0.01-μfd. paper.
C_{10} — 0.001-μfd. mica, 7500-volt rating (Aerovox 1653).
R_1 — 22 ohms, 1 watt.
R_2 — See text.
L_1 — B & W JCL series, dimensions as follows:
— 3.5 Mc. — 44 turns No. 20, 2⅛ inches long.
— 7 Mc. — 26 turns No. 16, 2⅛ inches long.
— 14 Mc. — 14 turns No. 16, 1⅞ inches long (remove 2 turns from B & W coil).
— 28 Mc. — 6 turns No. 16, 1⅞ inches long (remove 2 turns from B & W coil).
(All 1½-inch diam. 3-turn links.)
L_2 — B & W TCL series, dimensions as follows:
— 3.5 Mc. — 26 turns No. 12, 3½-inch diam., 4½ inches long.
— 7 Mc. — 22 turns No. 12, 2½-inch diam., 4½ inches long.
— 14 Mc. — 10 turns No. 12, 2½-inch diam., 4¼ inches long. Remove one turn from each end of coil.
— 28 Mc. — 4 turns ⅛-inch copper tubing, 2½-inch diam., 4½ inches long. Remove one turn from each end.
(All coils fitted with 2-turn links.)
L_3, L_4 — 4 turns No. 14, ½-inch diam., ¾ inch long.
MA — 100-ma. milliammeter.
RFC — 1-mh. r.f. choke (National R-154U).
S_1 — 2-section 2-position rotary switch.

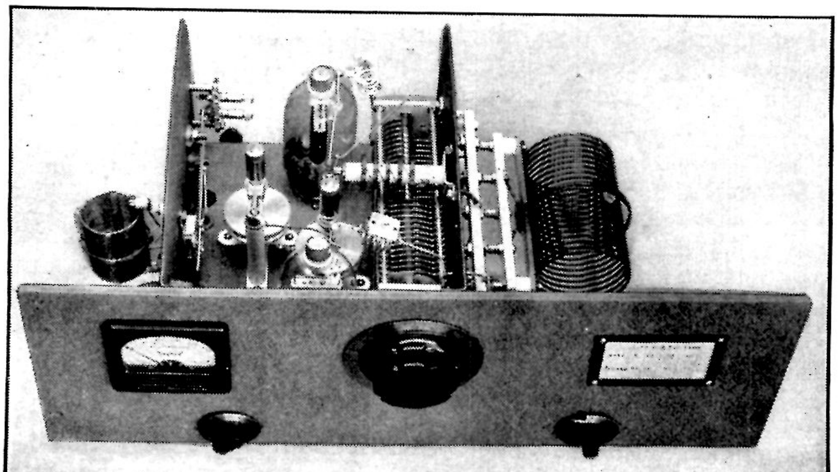


Fig. 6-95 — A general view of the compact 450-watt push-pull amplifier, showing the front-panel and top-of-chassis arrangement. Mounted on a standard relay rack, the height is only 7 inches and the depth 9 inches. Grid and plate tank circuits are isolated from each other by the double shielding partitions. On the panel are the 0–100-ma. milliammeter, which is switched to read current in all circuits, the plate-tank tuning dial, and a chart giving coil and tuning data. The small knob at the left below is the grid-circuit tuning control, while the one to the right is for the meter switch.

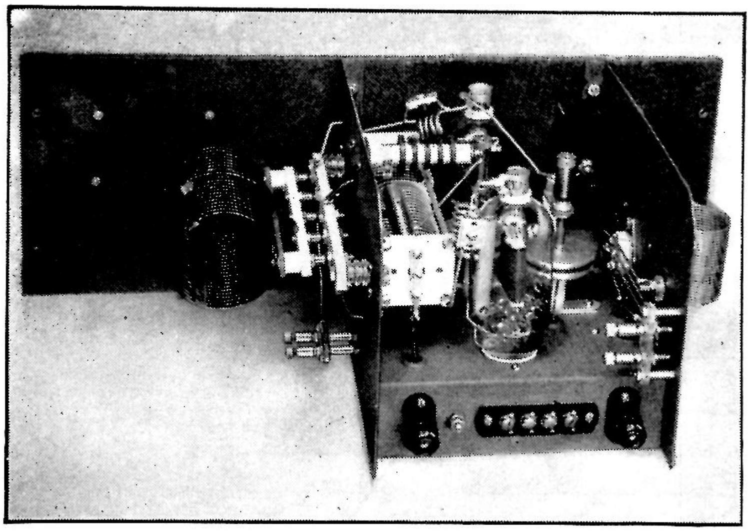


Fig. 6-96 — Rear view of the 450-watt push-pull amplifier. The plate tank condenser is mounted on the left-hand partition. The plate tank-coil jack-bar is mounted centrally, opposite the condenser. The socket for the grid tank coil is mounted to the right just above the chassis line.

the meter is shunted by a resistor, R_2, which multiplies the scale reading by five. This resistor is wound with No. 26 copper wire, the length being determined experimentally to give the desired scale multiplication.

Construction

The mechanical arrangement shown in the photographs results in a compact unit requiring a minimum of panel space. All components are assembled around a small metal chassis 7 × 2 × 9 inches deep. The partitions are standard 6½ × 10-inch interstage shields. The tank condenser is mounted on the left-hand partition (Fig. 6-96) at a height which brings its shaft down 2⅝ inches from the top of the panel. The plate-tank-coil jack-bar is mounted centrally with the condenser on spacers which give a ½-inch clearance between the strip and the partition. C_{10} is mounted with a small angle on the partition under the center of C_2. Leads from both ends of the rotor shaft are brought to one side of C_{10} for symmetry.

The two tube sockets are mounted in a line through the center of the chassis and at opposite ends of the plate tank condenser. They are spaced about one inch below the chassis on long machine screws. The neutralizing condensers are placed between the two tubes, so that the leads from the plate of one tube to the grid of the other are short. The r.f. choke is mounted just above the tank condenser.

The right-hand partition is cut out at the forward edge to clear the meter. This cut-out can be readily made with a socket punch and a hack saw. The socket for the grid tank coil is mounted 4½ inches behind the panel, just above the chassis line.

The grid tank condenser, C_1, is mounted under the chassis without insulation. Large clearance holes, lined with rubber grommets, are drilled for connecting wires which must be run through the chassis or partitions. The parasitic traps are made self-supporting in the plate leads from the tank condenser to the tube caps. The panel is placed so that the plate tank-condenser shaft comes at the center. The meter switch is mounted to balance the knob controlling C_1. Power-supply connections are made at the rear of the chassis.

Power Supply and Excitation

To operate the T40s shown in the photographs at maximum ratings, the driver should be capable of an output of 25 to 40 watts.

The circuit diagram of a suitable plate and bias supply with control switches is shown in Fig. 6-98. The bias supply should be adjusted as described in connection with the power supply for the 450-watt bandswitching amplifier

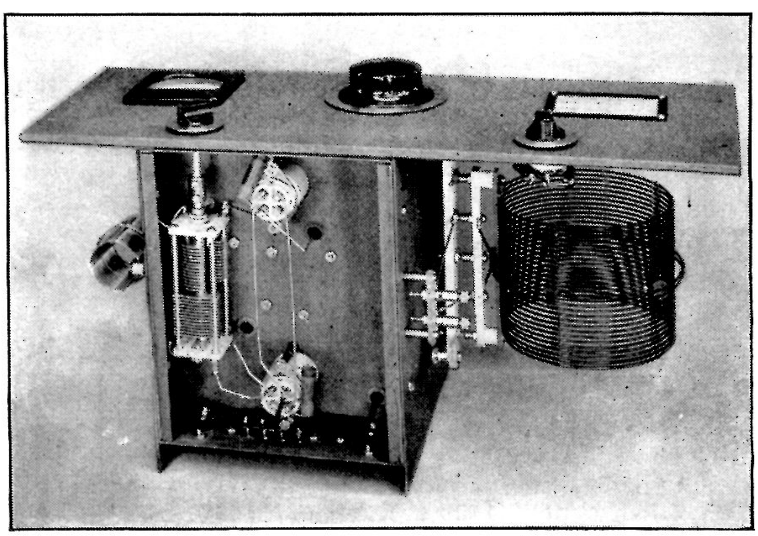


Fig. 6-97 — Bottom view of the 450-watt push-pull amplifier. The grid tank condenser is mounted between the two tube sockets which are set below the chassis on brackets. Connections between the condenser terminals and the coil socket above pass through grommet-lined holes in the chassis. The partitions provide shielding between input and output tank coils.

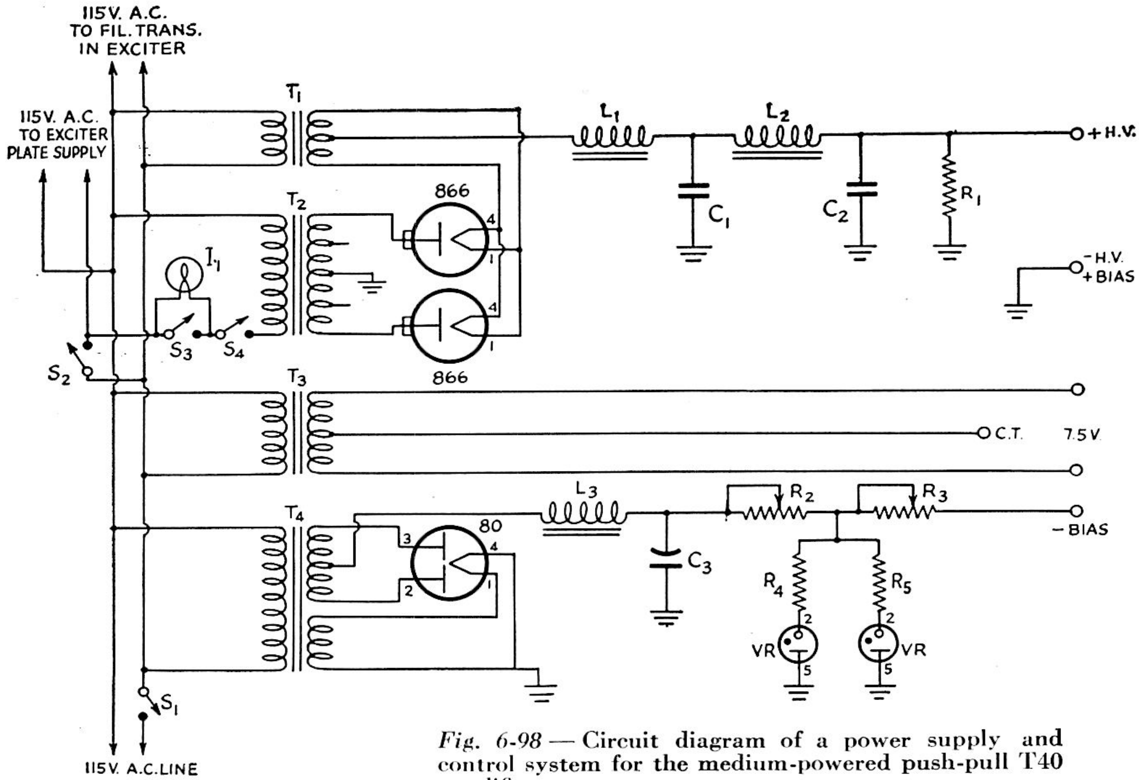


Fig. 6-98 — Circuit diagram of a power supply and control system for the medium-powered push-pull T40 amplifier.

C_1, C_2 — 4-μfd. 2000-volt oil-filled.
C_3 — 8-μfd. 450-volt electrolytic.
R_1 — 25,000 ohms, 100 watts.
R_2 — 25,000 ohms, 25 watts, with slider.
R_3 — 3000 ohms, 25 watts, with slider.
R_4, R_5 — 100 ohms, 1 watt.
L_1 — 5/25-hy. 400-ma. swinging choke.
L_2 — 20-hy. 400-ma. smoothing choke.
L_3 — 30-hy. 50-ma. filter choke.
I_1 — 150-watt 115-volt lamp.
S_1, S_2 — 10-amp. switch.
S_3, S_4 — 5-amp. switch.
T_1 — 2.5-volt 10-amp. filament transformer, 10,000-volt insulation.
T_2 — Plate transformer, 1500/1250 v. d.c., 400 ma.
T_3 — 7.5-volt 5-amp. filament transformer.
T_4 — Power transformer, 650 v. a.c., c.t., 50 ma. or more, 5 volts, 2 amp.
VR — See text.

of Fig. 6-87. For T40s, VR-90 regulators may be used. For operating at maximum c.w. ratings, an additional 50 volts of bias should be obtained from the grid leak, R_3. At the rated grid current of 30 ma. per tube, a resistance of about 850 ohms will be required at R_3.

Tuning

After the amplifier has been neutralized, a test should be made for parasitic oscillation. The bias should be reduced until the amplifier draws a plate current of about 100 ma. without excitation. With C_1 adjusted to various settings, C_2 should be varied through its range and the plate current watched closely for any abrupt change. Any change will indicate oscillation, in which case C_5 and C_6 should be adjusted simultaneously in slight steps until the oscillation disappears. Unless the wiring differs appreciably from the original, complete suppression will be obtained with the two condensers at full capacity.

The amplifier should now be tuned up and the excitation adjusted so that a grid current of 60 ma. is obtained with the amplifier fully loaded. Full loading will be indicated when the cathode-current meter registers 360 ma. Under these conditions the biasing voltage should rise to 150 volts, dropping to 90 volts without excitation when the plate current will fall to zero.

If the amplifier is to be plate-modulated, the plate voltage should be reduced to 1250 and the loading decreased to reduce the plate current to 250 ma. The same bias-supply adjustment will be satisfactory for this type of operation but excitation may be reduced to give a grid current of 40 ma., bringing the total cathode current to 290 ma.

For operating conditions for tubes of other types tube data should be consulted.

A Compact 450-Watt Push-Pull Amplifier

The photographs of Figs. 6-99, 6-101 and 6-102 show an amplifier designed along the lines of the type of construction often referred to as "dish type." This style of construction has many advantages, although its use normally is confined to components of moderate physical dimensions and weight.

The tank coils may be mounted so that very little metal of the normal rack structure is in the immediate fields of the tank coils — a condition almost impossible to approach in the usual form of construction with metal panels and side brackets. Plug-in coils are made much more accessible for changing and the direction of "pull" in removing coils is outward away from the rack rather than upward into the next rack unit above. Terminals may be mounted so that the wiring between rack units may be made inconspicuous and so that the chances of personal injury from accidental contact with exposed terminals at the rear are greatly reduced. Lastly, this form of construction usually reduces the required height of the unit which is a particular advantage in table racks where vertical space is at a premium.

The circuit of the amplifier shown in the diagram of Fig. 6-100 is standard in every way except in the method of metering. By means of the two-gang six-position switch it is possible to measure the individual grid and cathode currents of each tube as well as total grid or total cathode currents. To accomplish this, two small filament transformers are used, one for each tube, instead of a single large transformer. The meter is switched across shunting resistances in each circuit to simplify switching. In the cathode circuits, the shunting resistors should be carefully adjusted to provide a scale multiplication of ten, giving a full-scale reading of 1000 ma.

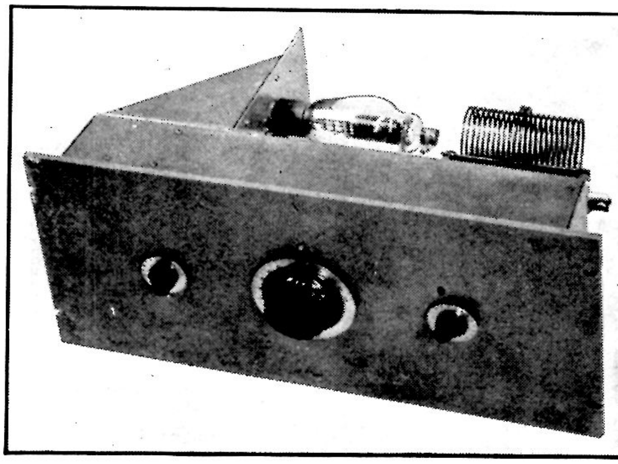


Fig. 6-99 — The three controls of the 450-watt "dish-type" amplifier are arranged symmetrically. The meter switch is at the right, the control for the plate tank condenser at the center and the grid-circuit control at the left. The panel which is 8¾ × 19 inches is fitted with panel bearings for the condenser-shaft extensions. It is fastened to the chassis by flat-head screws after the bottom edges of the chassis have been drilled and tapped.

In doing the r.f. wiring, care should be taken

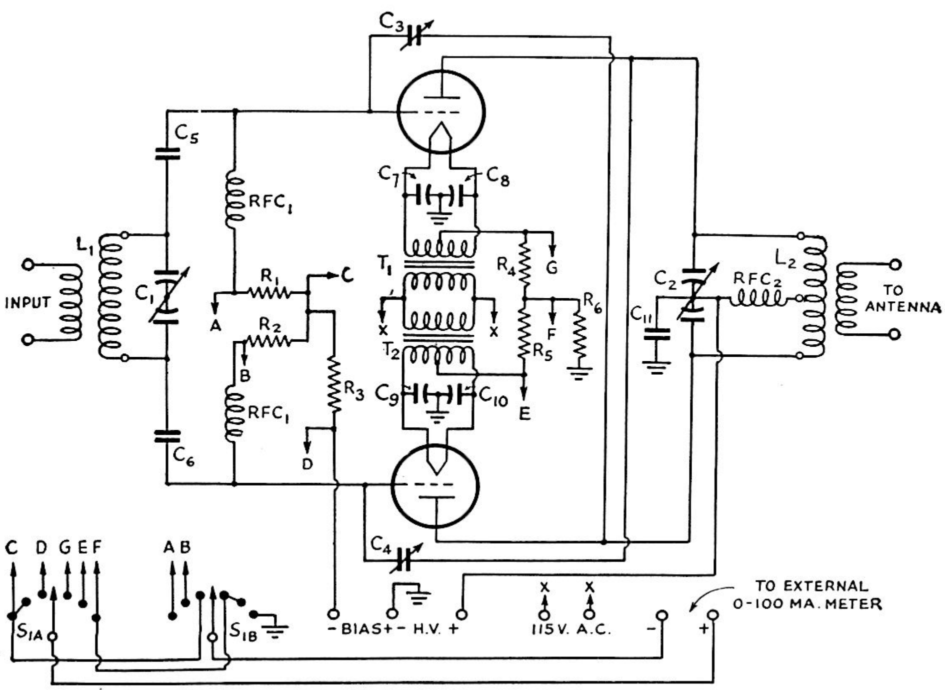


Fig. 6-100 — Circuit diagram of the "dish-type" push-pull 450-watt amplifier.

C_1 — 100 $\mu\mu$fd. per section (Hammarlund MCD100M).
C_2 — 100 $\mu\mu$fd. per section (Cardwell MT100GD), 0.07-inch spacing.
C_3, C_4 — Neutralizing condenser, 10 to 15 $\mu\mu$fd. (Hammarlund N10).
C_5, C_6 — 470-$\mu\mu$fd. 600-volt mica.
C_7, C_8, C_9, C_{10} — 0.01-μfd. 600-volt paper.
C_{11} — 0.002-μfd. 5000-volt mica.
R_1, R_2, R_3 — 25 to 50 ohms, 2 watts.
R_4, R_5, R_6 — Cathode-current meter shunts (see text).
L_1 — National AR series coils with center link (variable-link type recommended).
Substitute coils may be wound on 1½-inch diam. form as follows:
— 3.5 Mc. — 44 turns, 2 inches long.
— 7 Mc. — 22 turns, 2 inches long.
— 14 Mc. — 10 turns, 1½ inches long.
— 28 Mc. — 6 turns, 1½ inches long.
L_2 — B & W TL series with center links.
Substitute coils may be wound as follows on 2½-inch diam. forms:
— 3.5 Mc. — 36 turns, 4 inches long.
— 7 Mc. — 18 turns, 4 inches long.
— 14 Mc. — 10 turns, 3 inches long.
— 28 Mc. — 6 turns, 3 inches long.
RFC_1 — 2.5-mh. r.f. choke.
RFC_2 — 1-mh. r.f. choke (National 154-U).
S_1 — 2-gang 6-position rotary switch (Mallory).
T_1, T_2 — 6.3 volts, 6 amp.

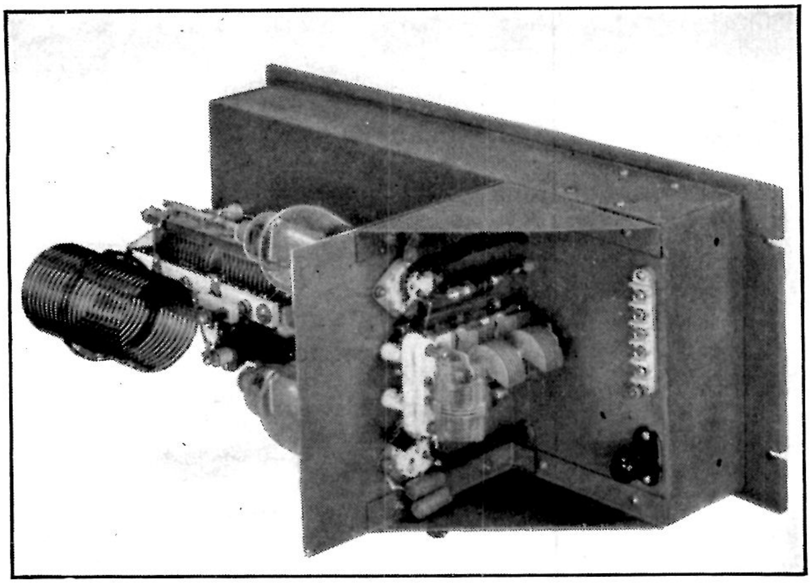


Fig. 6-101 — The grid-circuit components of the "dish-type" 450-watt amplifier are mounted on this side of the partition which is braced by standard 5-inch triangular brackets. The tank condenser is mounted by means of a screw in the hole which remains when the shield between the stators is removed. The ceramic terminal strip is for all external connections except for positive high voltage for which a special safety terminal is provided. A large clearance hole should be cut in the chassis for the condenser shaft. The shaft, which should come at the center line of the chassis, should be provided with a flexible insulating coupling.

to keep it as symmetrical as possible. In forming the long wires between the neutralizing condensers and the tank-condenser stators, the lengths should be made identical. The wire connecting to the rear condenser stator should go directly in a straight line, while the one going to the front stator section may be bent to make up for the difference in distance between the neutralizing condensers and the two stators. The plate leads to the tubes should be tapped on these long wires at points which will make the wire length between neutralizing condenser and plate and between tank condenser and plate equal on each side.

The positive high-voltage lead, run inside the chassis with high-voltage cable, comes up through a feed-through insulator near the plate choke.

The rotors of the grid tank condenser are not grounded, since experience has shown that an amplifier of this type usually neutralizes more readily without the ground connection and excitation usually divides more evenly between the two tubes.

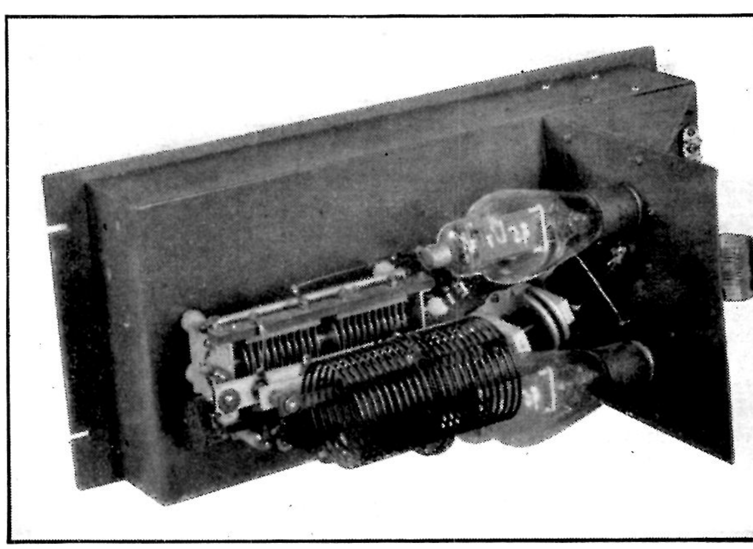
The leads from the neutralizing condensers to the grid terminals are crossed over before they pass through small feed-through points mounted in the partition. The grid r.f. chokes are self-supporting between the tube grid terminals and the feed-through points in the chassis which carry the biasing leads inside to the individual meter shunts. Filament wires are run through ⅜-inch holes lined with rubber grommets.

Inside the chassis, the separate meter-shunting resistances are supported on fiber lug strips. The leads going to the switch should be soldered in place, formed into cables, and the other ends connected to the switch on the panel as the last operation before putting the panel in place.

This amplifier is suitable for use with any of the 1000-volt 100-ma. to 1500-volt 150-ma. triodes. Those shown in the photographs are 812s.

For 1500-volt tubes, the power supply shown in Fig. 6-103 is suitable for use with this amplifier. The bias supply should be adjusted following the suggestions given in connection with Fig. 6-87. For 812s, VR-90 regulators will provide adequate protective bias. If these tubes are to be operated at maximum c.w. ratings, an operating bias of 175 volts is required. The difference between the fixed voltage (90

Fig. 6-102 — The plate tank-coil jack strip of the 450-watt push-pull amplifier is fastened to the tank-condenser frame with strip-metal brackets. The assembly, mounted on ⅝-inch standoff insulators is placed at the center of the chassis as far to the left as possible. The condenser shaft is extended at right angles through the bearing in the center of the chassis by means of two Millen 45-degree shaft joints connected together by a short length of bakelite shafting. The sockets for the tubes are submounted on the 6 × 8-inch partition, 3½ inches up from the chassis and 1⅞ inches from each edge and are orientated so that the plates of the tubes will be in a vertical plane.



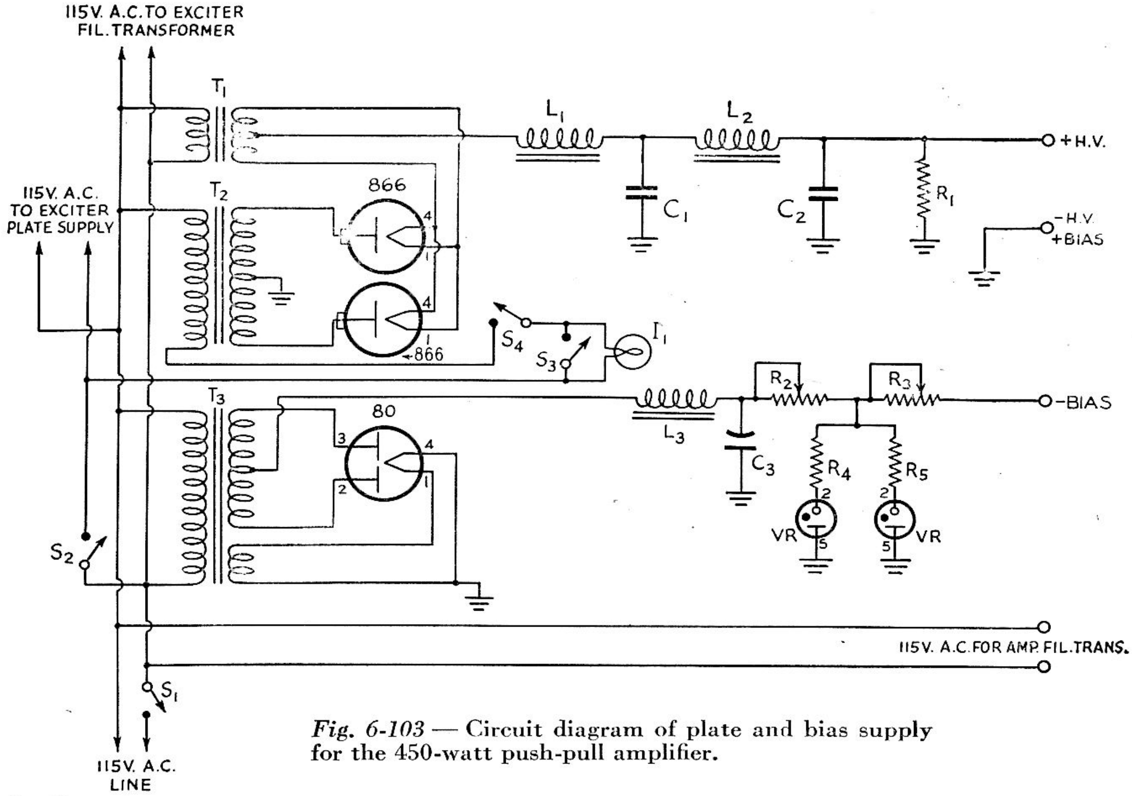


Fig. 6-103 — Circuit diagram of plate and bias supply for the 450-watt push-pull amplifier.

C_1, C_2 — 4-μfd. 2000-volt oil-filled.
C_3 — 8-μfd. 450-volt electrolytic.
R_1 — 25,000 ohms, 100 watts.
R_2 — 25,000 ohms, 25 watts, with slider.
R_3 — 5000 ohms, 25 watts, with slider.
R_4, R_5 — 100 ohms, 1 watt.
L_1 — 5/25-hy. 400-ma. swinging choke.
L_2 — 20-hy. 400-ma. smoothing choke.
L_3 — 30-hy. 50-ma. filter choke.
I_1 — 150-watt 115-volt lamp.
S_1, S_2, S_3 — 10-amp. switch.
S_4 — 5-amp. switch.
T_1 — 2.5-volt 10-amp. filament transformer, 10,000-volt insulation.
T_2 — 1500/1250-v. d.c. 400-ma. plate transformer.
T_3 — Power transformer, 650 v. a.c., c.t., 50 ma. or more; 5 volts, 2 amp.
VR — Voltage-regulator tubes (see text).

volts) and the operating bias, 85 volts, is obtained from the grid leak, R_3. At the rated grid current of 50 ma. for the two tubes, R_3 should be adjusted to 1700 ohms. R_2 should be adjusted so that the VR tubes just ignite without excitation applied to the amplifier.

The control switching system is similar to the ones previously described. The amplifier requires a driver delivering 25 to 40 watts output.

If the layout and wiring have been followed carefully, no difficulties should be encountered in neutralizing nor with parasitics. Both grid and plate currents should check the same within ten per cent.

The meter, when switched to read grid current, forms a good neutralizing indicator. Both neutralizing condensers should be kept at equal settings and adjusted simultaneously until the grid current remains perfectly steady as the plate tank condenser is tuned through resonance. Neutralizing is always done with the plate-voltage lead removed. Operating voltages and currents for other tubes or operating conditions for lower plate voltages should be taken from tube data sheets.

Link output is provided for connecting directly to a "flat" line or coupling to any type of antenna system through an antenna tuner (see Chapter Ten).

A 1-Kw. Push-Pull Amplifier

The push-pull amplifier shown in the photographs of Figs. 6-104, 6-106 and 6-107 is built around a pair of Eimac 250TH triodes. It will handle a full kw. input at a plate voltage of 2000 or less, although the plate tank-condenser spacing is sufficient for 3000-volt operation with plate modulation. The driving stage should be capable of delivering approximately 100 watts. The amplifier may be shifted to any amateur band by a system of plug-in coils.

The circuit, shown in Fig. 6-105, is standard for a push-pull link-coupled neutralized amplifier. The only departure from strict conventionality is the use of the fixed vacuum-type padding condenser (C_9) across the plate tank coil when operating at 3.5 Mc. A filament transformer is included on the chassis to permit short leads which must carry the high heating current.

The components are mounted on a standard 10 × 17 × 3-inch chassis, with the 10-inch side against the panel to provide the necessary depth. The B & W "butterfly"-type plate tank condenser is mounted on heavy 2-inch

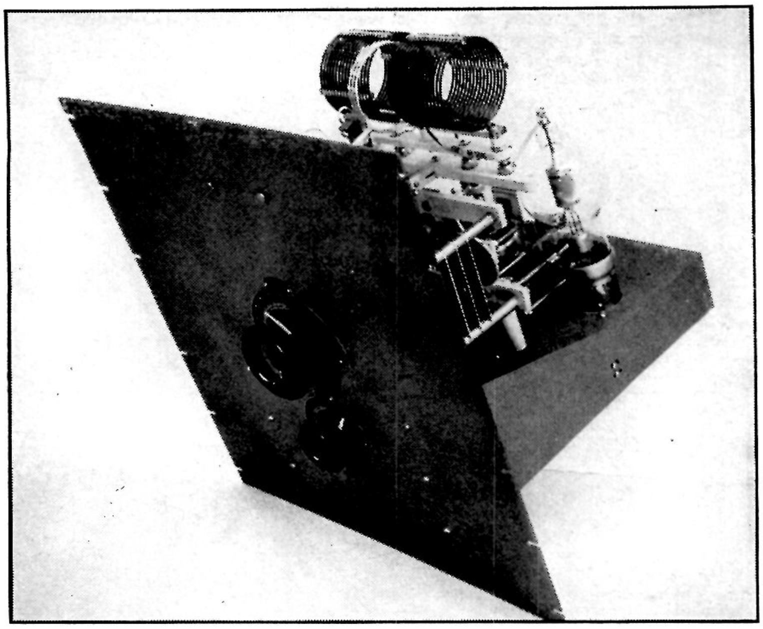


Fig. 6-104 — **Front view of the kilowatt amplifier. The panel is 21 inches high and of standard 19-inch width.**

stand-off insulators, with its shaft along the center line of the chassis and its front mounting feet centered 2 inches from the panel. Since its rotor is connected to the high-voltage supply, use of a good insulating shaft coupling is of utmost importance as a safety measure. The output tank-coil base assembly, with its adjustable link, is fastened to the two upper-rear stator nuts of the condenser by means of a pair of aluminum angle pieces. Similarly, the clips for the 3.5-Mc. vacuum-type padding condenser are mounted at the front of the condenser. Link output terminals are provided by the large stand-off insulators fastened to the rear of the panel near the top.

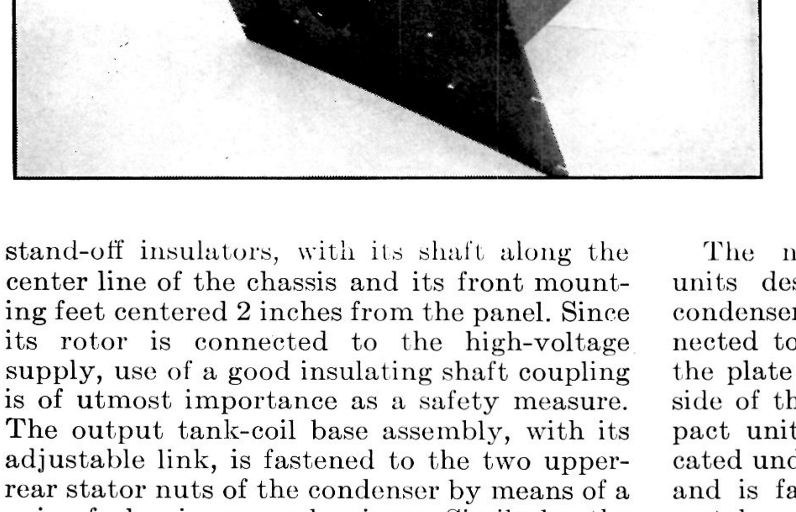


Fig. 6-105 — **Circuit diagram of the high-power push-pull amplifier.**

C_1 — 100 $\mu\mu$fd. per section, 0.05-inch spacing (Hammarlund HFBD-100-C).
C_2 — 60 $\mu\mu$fd. per section, 0.25-inch spacing (B & W CX62-C).
C_3, C_4 — Disk-type neutralizing condenser (B & W N-3).
C_5, C_6, C_8 — 0.01-μfd. paper, 600 volts.
C_7 — 0.001-μfd. mica, 10,000 volts.
C_9 — 25 $\mu\mu$fd., 16,000 volts (GE GL122).
L_1 — B & W BCL coils.
L_2 — B & W HDVL coils.
RFC — 1-mh. r.f. choke (Hammarlund CH-500).
T — 5 volts, 22 amperes (Stancor P6302, see text).

The neutralizing condensers are special units designed as accessories to the tank condenser. Each consists of a single disk connected to the grids, the rear stator plates of the plate tank condenser serving as the other side of the neutralizing condenser, for a compact unit. The by-pass condenser, C_7, is located under the rear end of the tank condenser and is fastened to the chassis with a small metal angle piece which makes the ground connection.

The sockets for the 250THs are submounted. They are spaced 5 inches, center to center, and 4 inches in from the rear edge of the chassis. The grid tank condenser is mounted between the tubes with an extension shaft to the front of the panel. The rotor plates are grounded to the chassis. The high-voltage line to the plate tank condenser and the plate r.f. choke is brought up through the chassis via a large ceramic feed-through insulator.

Underneath, the jack-bar for the grid coil is centered between the tube sockets. Connections between this coil mounting and the condenser on top are made through large clearance holes lined with rubber grommets. Short, direct leads connect the tank circuit to the grid terminals of the tubes.

The filament transformer is mounted directly underneath the plate tank condenser. Since this transformer, as well as the grid coil, protrudes from the underside of the chassis, the chassis is set with its bottom edge 2½ inches above the bottom edge of the panel. The transformer shown in the photographs, and listed under Fig. 6-105, is one designed for rectifier service and has high-voltage insulation. If

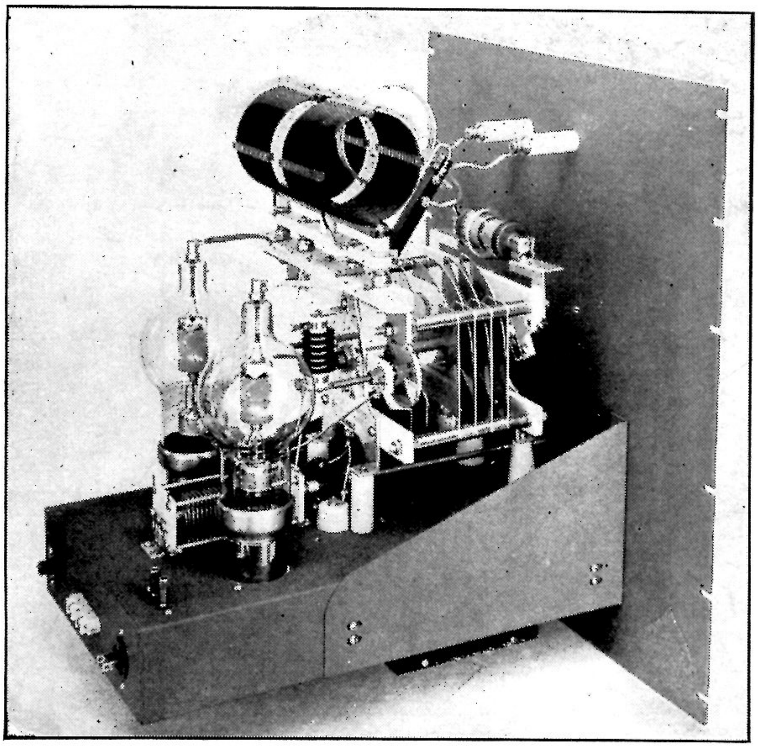


Fig. 6-106 — Rear view of the push-pull 250TH amplifier showing the mounting of the plate tank coil and 3.5-Mc. padding condenser.

one with 1600- or 2000-volt insulation is available it may be substituted, of course. A Millen safety terminal for the positive high-voltage connection, a three-terminal ceramic strip for bias and ground connections, and a male power plug for the 115-volt connection to the filament transformer are set in the rear edge of the chassis while a pair of insulated terminals in the left rear corner are for the excitation input.

Power Supply

Fig. 6-108 shows the details of a suitable high-voltage plate and biasing supply for this amplifier. For a plate voltage of 2500, VR-90s in the bias supply will provide adequate voltage for plate-current cut-off. Five of them in parallel should be used to handle the necessary grid current. R_2 should be adjusted so that the tubes just ignite without excitation to the 250THs. For an operating bias of 150 volts, 60 volts must be obtained from the grid leak, R_3. At a grid current of 150 ma. under operating conditions, this will require a resistance of 400 ohms for R_3. The control switching system operates as described in connection with previously-mentioned supplies.

Adjustment

When the amplifier is completed and ready for operation, the first step in adjustment is the neutralization. This may be done with the amplifier set up with all external connections made, except for the antenna and high voltage.

With the coils for the desired band plugged in, the tuning of the grid tank circuit should be adjusted until a grid-current reading is obtained. Then the neutralizing condensers should be adjusted simultaneously, bit by bit, keeping the spacing equal. When the amplifier is not neutralized, a dip in grid current will be found as the plate tank condenser is tuned through resonance. The neutralizing condensers should be adjusted until no change in grid current occurs as the plate tank condenser is swung through its range. This should occur with the adjustable plates of the neutralizing condensers spaced about $1\frac{3}{16}$ inches away from the rear stator plates of the tank condenser.

Although plenty of plate dissipation is available, it is desirable to do the preliminary tun-

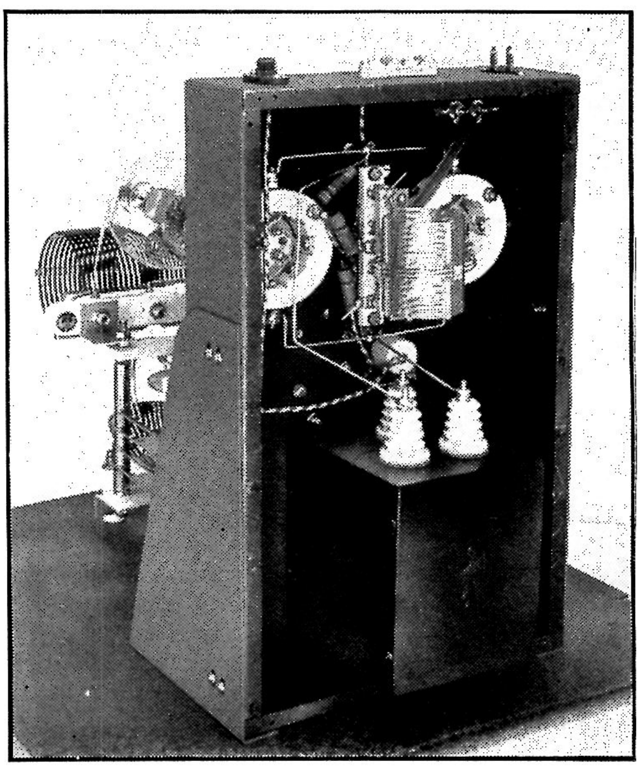


Fig. 6-107 — The filament transformer and grid coil are mounted underneath the chassis.

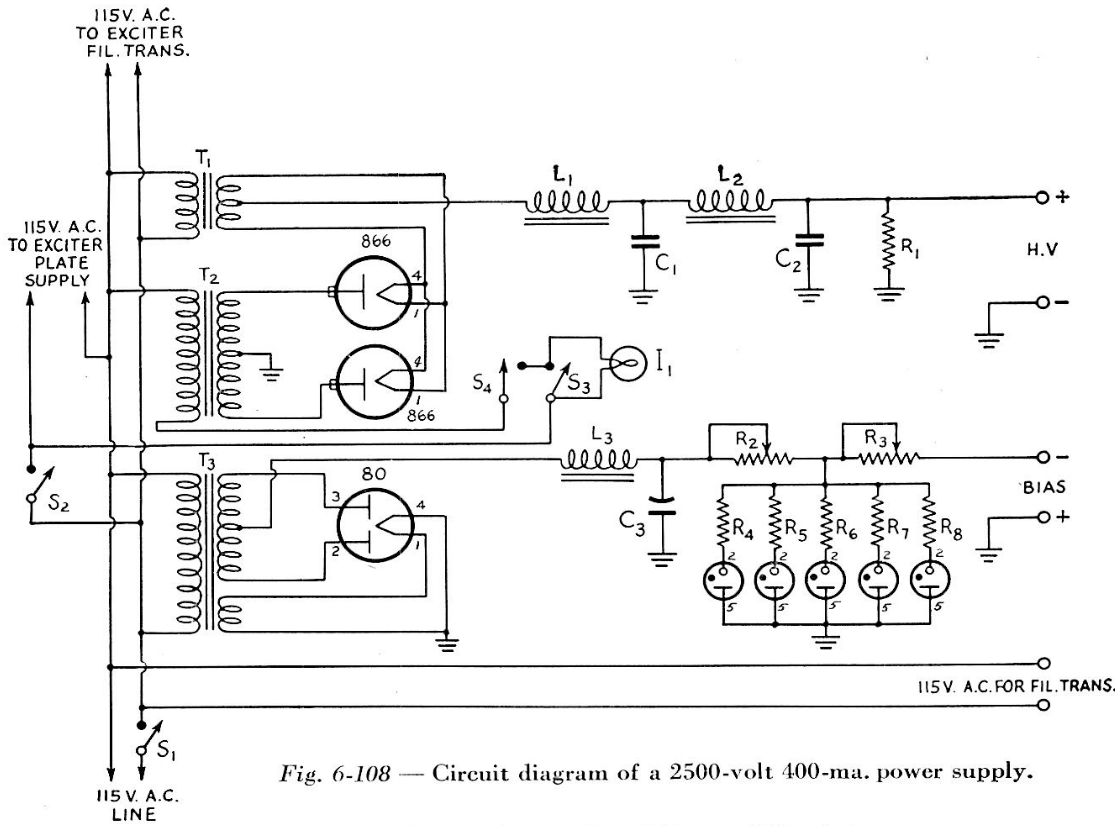


Fig. 6-108 — Circuit diagram of a 2500-volt 400-ma. power supply.

C_1, C_2 — 4-μfd. 300-volt oil-filled.
C_3 — 8-μfd. 450-volt electrolytic.
R_1 — 50,000 ohms, 200 watts.
R_2 — 10,000 ohms, 25 watts, with slider.
R_3 — 1000 ohms, 25 watts, with slider.
R_4, R_5, R_6, R_7, R_8 — 100 ohms, 1 watt.
L_1 — 5-25-hy. 500-ma. swinging choke.
L_2 — 20-hy. 500-ma. smoothing choke.
L_3 — 30-hy. 50-ma. filter choke.
I_1 — 150-watt 115-volt lamp.
S_1, S_2, S_4 — 15-amp. switch.
S_3 — 5-amp. switch.
T_1 — 2.5-volt 10-amp. filament transformer, 10,000-volt insulation.
T_2 — 2500-v. d.c. 500-ma. plate transformer.
T_3 — Power transformer, 650 v. a.c., c.t., 50 ma. or more; 5 volts, 2 amp.
See text for voltage-regulator tube data.

ing and loading of the amplifier at reduced plate voltage. Before plate voltage is applied, a grid-current reading of at least 150 to 200 ma. should be possible. The antenna link should be swung out to the minimum-coupling position. As soon as plate voltage and excitation are applied, the plate tank condenser should be adjusted for minimum plate current. Grid current still should be above 150 ma. When the excitation is removed, there should be no indication of oscillation at any setting of the grid- or plate-tank condenser.

The output link may be connected directly to a properly-terminated low-impedance line, or through a link-coupled antenna tuner to the feeders of any antenna system. With excitation and plate power applied, the plate current should increase as the link coupling is tightened and the antenna system tuned to resonance. With each adjustment of coupling or antenna tuning, the plate tank condenser should be retuned for minimum plate current. The minimum reading will increase as the coupling is tightened with the antenna tuned to resonance. The loading may be increased up to the point where the minimum reading is 400 ma., when the input will be 1 kw. at 2500 volts. With the amplifier loaded, the excitation should be adjusted to about 150 ma. for the two tubes.

A Complete 350-Watt 'Phone-C.W. Transmitter

The 350-watt 'phone-c.w. transmitter shown in Fig. 6-109 is made up in three sections. The center section contains a bandswitching exciter and speech amplifier, each on a separate chassis. The top section is shared by a plate modulator and a push-pull final amplifier with grid bandswitching and plug-in plate coils. The bottom unit contains the two power supplies from which the transmitter is operated. All bands from 3.5 to 28 Mc. are covered and the entire apparatus is housed in a standard-rack-width cabinet 36¾ inches high overall.

Bandswitching Exciter

The bandswitching exciter and speech amplifier are shown in Figs. 6-111 and 6-112. The circuit of the exciter, shown in Fig. 6-110, follows quite closely that of the exciter unit of Fig. 6-79. The tube line-up consists of a 6V6 Tri-tet crystal oscillator giving fundamental or second-harmonic output using 3.5-Mc. crystals or fundamental output using 7-Mc.

crystals, a 6N7 dual-triode frequency multiplier with the first section doubling from 7 Mc. to 14 Mc., the second section of the same tube doubling from 14 Mc. to 28 Mc., and an 807 buffer-driver stage.

A 12-position wafer switch, S_1, is used to select one of 12 crystal sockets or to switch to external VFO input. The Tri-tet cathode coil may be switched out of the circuit by S_4 to permit straight-through crystal-oscillator operation of the 6V6 with either 3.5- or 7-Mc. crystals. For 27-Mc. band output, suitable crystals must of course be selected.

Provision is made in the bandswitching circuit, controlled by the 4-section switch, S_2, to disconnect grids of unused triode sections of the 6N7 from the preceding stage and to ground them, thus avoiding applying excitation to idle stages. Both 3.5 and 7 Mc. are covered with one coil, L_1, an extra condenser (air-padder C_3) being connected across it in parallel to extend the tuning range to cover the 3.5-Mc. band.

The output of the 807 is link-coupled to the grid of the final amplifier but all exciter stages are capacitance-coupled. Parallel feed is used in the first three stages so that the tuning condensers, C_4, C_5 and C_6, need not be insulated from the metal panel. The coupling to the 807 grid is through a tap on each plate coil; this provides proper loading of the various driver stages. C_{23}, connected across the 3.5-Mc. output link winding, was found necessary to detune the link, which resonated at 28 Mc., absorbing a considerable amount of power when operating in the ten-meter band. Grid-leak bias is used in the 807 stage. Screen voltage for the 807 is obtained from the 600-volt supply through a dropping resistor, R_7, and approximately 300 volts is applied to the driver plates from a tap on the voltage divider, $R_{10}R_{11}$, across the 600-volt supply. Excitation to the 807 may be adjusted by R_2 which varies the oscillator screen voltage.

The d.c. cathode returns of both the oscillator and the 807 stage are connected to closed-circuit jacks, offering a choice of keying the 807 stage only or keying both oscillator and

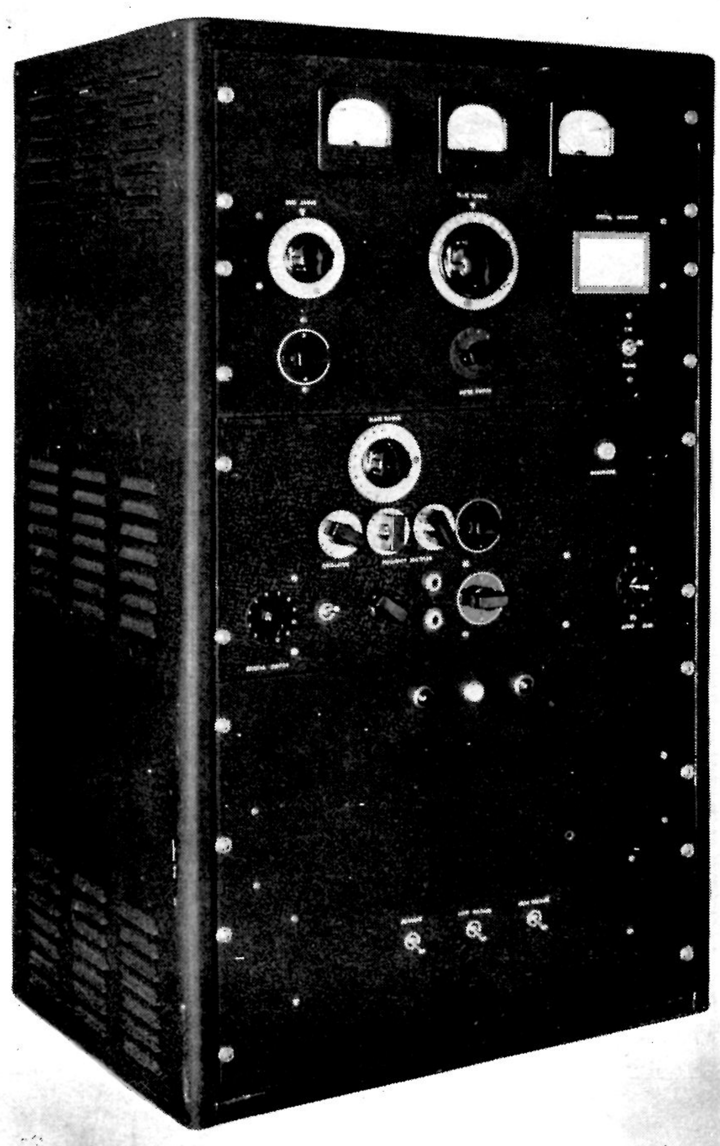


Fig. 6-109 — A bandswitching medium-power 'phone-c.w. transmitter, completely self-contained and compactly housed in a metal cabinet 36¾ inches high, 21½ inches wide and 15 inches deep. The panels are standard 19-inch width and total 35 inches in height. The meter at the left in the row at the top of the panel reads filament voltage. The milliammeter on the right measures modulator plate current while that in the center can be switched to read final-amplifier grid current and plate currents in each r.f. stage. The final-amplifier plate-tank tuning control is centrally located in the top panel and the dial in line at the left is for grid-tank tuning. The 'phone-c.w. switch is at the bottom right of the top panel and the bandswitch for the final grid is at the left. The knob in the middle is for the meter switch. The tuning control for the 807 plate is located high on the left of the middle panel under which are controls, left to right, for oscillator, first doubler, second doubler and bandswitch for the 807 output tanks. The crystal-selector switch is at the lower left, with the cathode coil switch at its right. The excitation control next to the right is flanked by the two key jacks. Under the bandswitch for the output tanks is the one for the earlier stages. The audio gain control is on the extreme right lower corner. On the power-supply panel, switches in the a.c. circuits to control filament, 600-volt and 1250-volt supplies are matched at the top with panel lights.

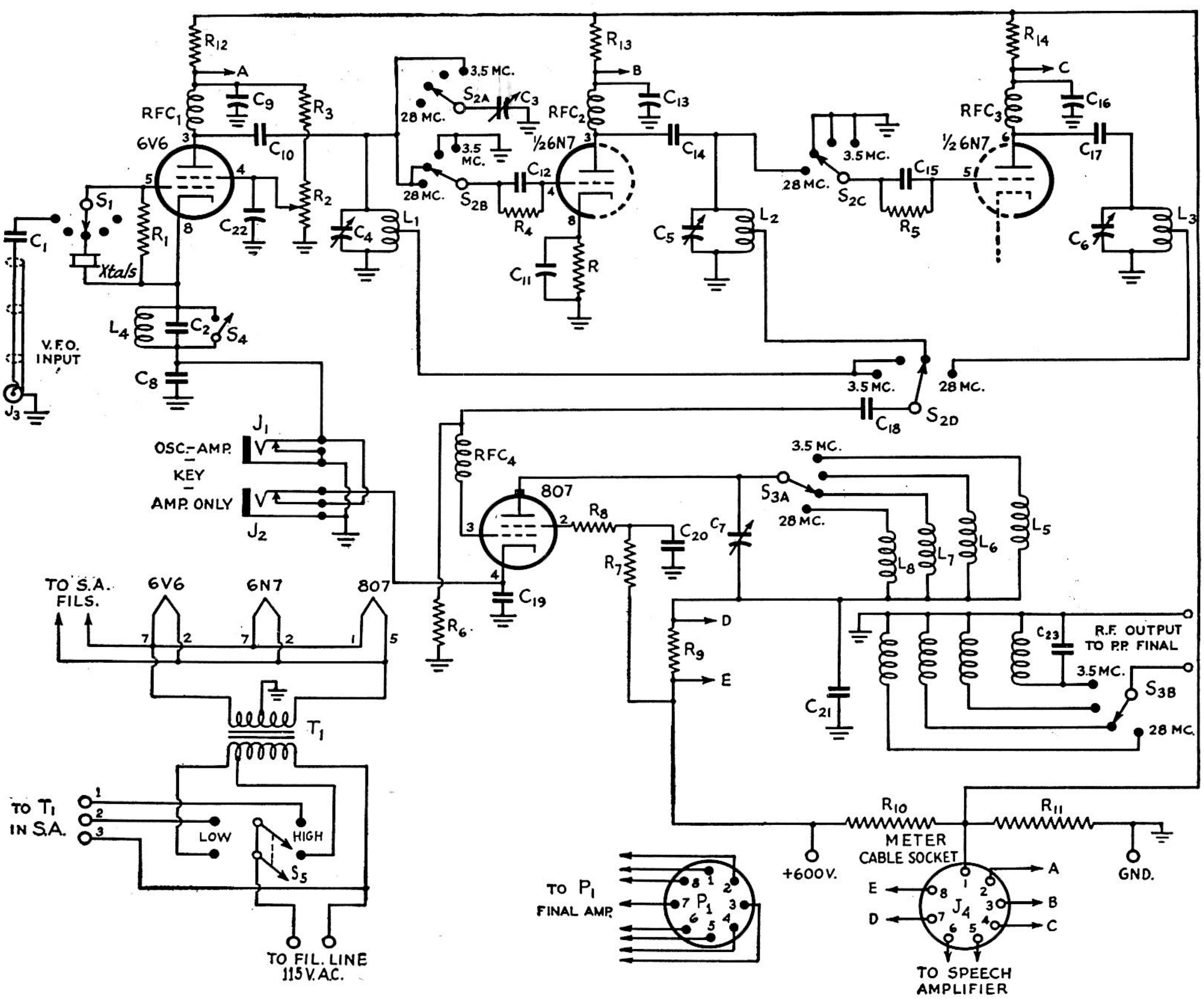


Fig. 6-110 — Circuit diagram of the r.f.-exciter unit.

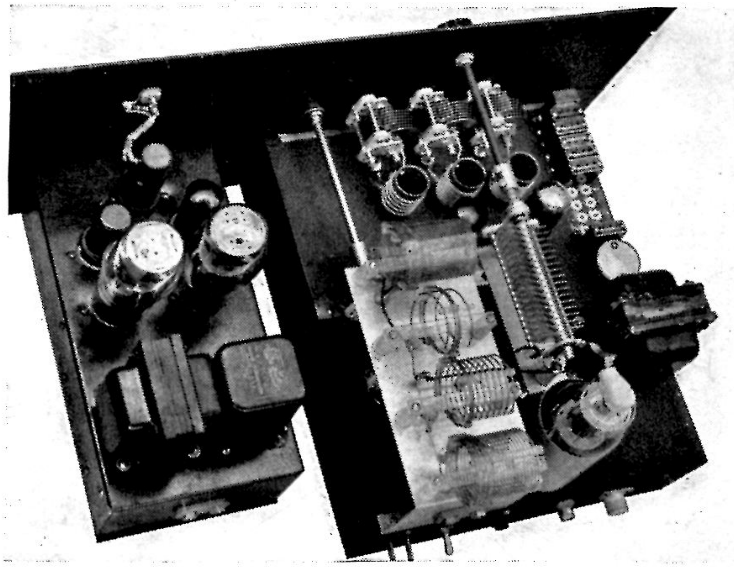
C_1, C_{10}, C_{14}, C_{17} — 0.0022-μfd. mica.
C_2 — 220-$\mu\mu$fd. mica.
C_3 — 140-$\mu\mu$fd. air padder.
C_4, C_5, C_6 — 100-$\mu\mu$fd. variable (National ST-100).
C_7 — 100-$\mu\mu$fd. variable (Hammarlund MC-100-SX).
C_8, C_{19} — 0.0047-$\mu\mu$fd. mica.
C_9, C_{11}, C_{13}, C_{16}, C_{22} — 0.01-μfd. 600-volt paper.
C_{12}, C_{15}, C_{18} — 100-$\mu\mu$fd. mica.
C_{20} — 500-$\mu\mu$fd. 2500-volt mica.
C_{21} — 0.002-μfd. 2500-volt mica.
C_{23} — 22-$\mu\mu$fd. mica.
R — 470 ohms, 1 watt.
R_1 — 0.1 megohm, ½ watt.
R_2 — 50,000-ohm potentiometer, 10 watts.
R_3 — 47,000 ohms, 1 watt.
R_4 — 47,000 ohms, ½ watt.
R_5 — 22,000 ohms, ½ watt.
R_6 — 22,000 ohms, 1 watt.
R_7 — 50,000 ohms, 10 watts.
R_8 — 47 ohms (carbon), ½ watt.
R_9, R_{12}, R_{13}, R_{14} — 22 ohms, ½ watt.
R_{10} — 3000 ohms, 50 watts.
R_{11} — 15,000 ohms, 25 watts.
L_1 — 21 turns No. 18 on 1-inch diam. form, length 1 inch; tapped 15 turns from ground.
L_2 — 10 turns No. 18 on 1-inch diam. form, length 1 inch; tapped 7 turns from ground.
L_3 — 5 turns No 18 on 1-inch diam. form, length 1 inch; tapped 2 turns from ground.
L_4 — 13 turns No. 18 on 1-inch diameter form, length 1 inch.
NOTE — L_1, L_2, L_3 and L_4 are wound on Millen Type 45000 forms.
L_5, L_6, L_7, L_8 — Millen 43082, 43042, 43022 and 43012.
J_1, J_2 — Closed-circuit jack.
J_3 — Coaxial-cable socket (Amphenol).
J_4 — Octal socket.
P_1 — Octal plug.
RFC_1, RFC_2, RFC_3 — 2.5-mh. r.f. choke (National R-100U).
RFC_4 — 20 turns No. 20 d.c.c. close-wound on 1-watt resistor (any high value of resistance may be used).
S_1 — Single-gang 12-position wafer switch.
S_2 — Four-gang four-position ceramic wafer switch.
S_3 — Two-gang four-position ceramic wafer switch.
S_4 — S.p.s.t. toggle switch.
S_5 — D.p.d.t. toggle switch.
T_1 — 6.3.-volt 4-amp. filament transformer (Stancor P-4019).

buffer-amplifier stages simultaneously. With no fixed bias on the 807, the oscillator alone may not be keyed since the 807 is not provided with protective bias. The 6N7 is protected by cathode bias.

Exciter Construction

The exciter chassis is shown in Figs. 6-111 and 6-112. It is built on a 14 × 10 × 3-inch chassis and is mounted, with the speech-amplifier chassis, on a standard rack panel 8¾ inches

Fig. 6-111 — Top view of the speech-amplifier/r.f.-exciter unit. The speech-amplifier equipment is mounted on the 3 × 5 × 10-inch standard chassis to the left. The r.f. unit is spaced two inches from it with interconnections cabled through a grommetted hole in the side of each chassis. The coil assembly for the plate circuit of the 807 stage is mounted on a bracket bent from sheet aluminum. It is 3½ inches wide, 6½ inches long, and 2½ inches high.



high. In Fig. 6-111, the row of eleven crystal sockets to accommodate new-style crystal holders is mounted along the right-hand edge of the chassis. A spare socket to the rear of the others is provided for old-style crystals with ¾-inch pin spacing and is wired in parallel with the eleventh socket from the panel. The 6.3-volt transformer to supply the heaters in both the r.f. exciter and the speech amplifier is located to the rear of the crystal sockets.

Coils for the crystal-oscillator stage and the first two doublers are wound on Millen 1-inch diameter forms and secured to the chassis with small machine screws. The leads from these coils are fed to the 4-gang bandswitch, S_2, below, through small insulating bushings immediately in front of the coils. The 6V6 crystal-oscillator tube is slightly to the right of the oscillator coil and the 6N7 is directly to the left.

The tuning condenser for the 807 driver stage is mounted on small ceramic stand-offs on a bracket formed of sheet aluminum, to permit the fiber shaft extension rod to clear the oscillator and doubler coils and condensers. In line with this condenser and immediately to the rear of it are the socket and shield can for the 807. A short length of braid connects the plate cap of the tube to the stator terminal of the condenser.

The coils for the bandswitching assembly for the 807 stage are mounted on small ceramic stand-off insulators and fastened to another sheet-aluminum platform below which is mounted the 2-gang 807-stage bandswitch, S_3. The wafers of S_3 are spaced about 2½ inches so that one section is almost directly under the 28-Mc. coil, to permit shortest possible leads to that coil. The 14-Mc. coil is placed next in line to the rear and the 7-Mc. coil is farthest to the rear of the subbase. The 3.5-Mc. coil is nearest the panel. The switch section at the front is used to switch the links for the various coils. The National Type FWJ banana-jack terminal for r.f. output is set in the rear end of the coil-supporting subbase.

Looking at the bottom of the exciter in Fig. 6-112, the crystal-selector switch is in the lower right-hand corner below the row of crystal sockets. The voltage-divider resistors, R_{10} and

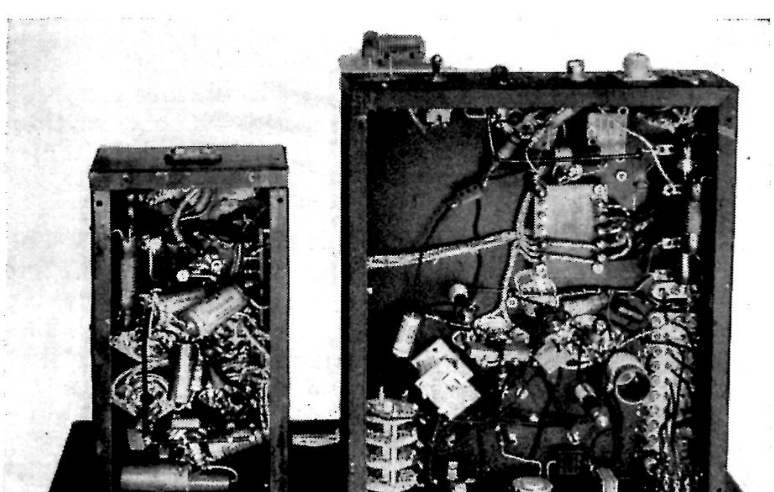


Fig. 6-112 — Bottom of the r.f.-exciter/speech-amplifier unit, with covers removed.

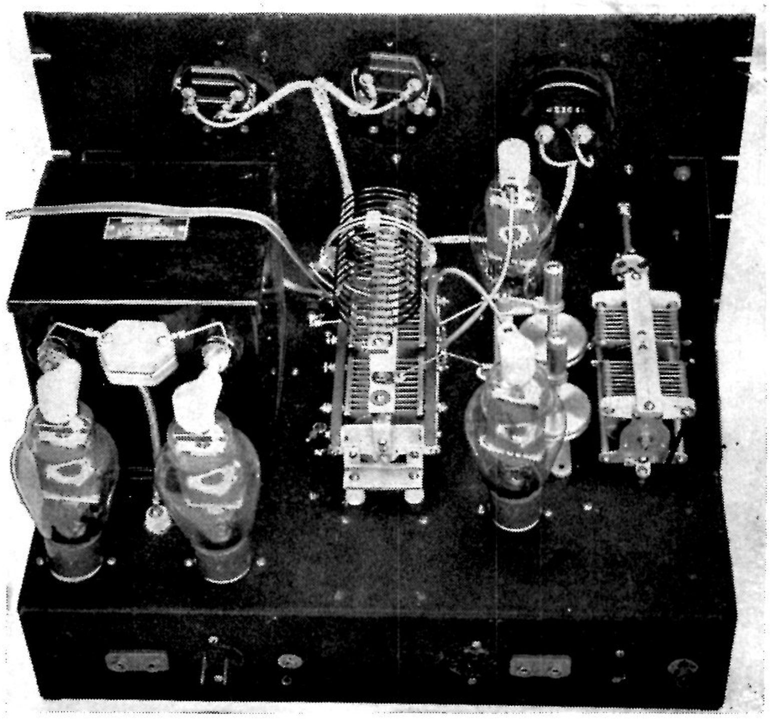


Fig. 6-113 — The final amplifier and modulator. The grid tank condenser and neutralizing condensers are to the right of the tubes. The plate-tank components with the coil mounted on top of the condenser are to the left. Grid coils are located underneath the chassis. The modulator occupies the left-hand end of the chassis. All meters in the transmitter are mounted on the panel of this unit.

R_{11}, are mounted toward the rear of the chassis on angle brackets. The crystal-oscillator tube socket is at right center, with the cathode coil and condenser toward the panel and slightly to the right. The switch to short out the cathode coil is mounted on the panel immediately to the left of the crystal-selector switch. The excitation-control potentiometer, R_2, is mounted centrally just to the right of the two key jacks. The bandswitch S_2 is at the extreme left-hand front of the chassis with the 3.5-Mc. plate-tank padding condenser, C_3, mounted at an angle to the right. The shaft of the latter extends through the chassis for screwdriver adjustment from above.

Related components are mounted wherever convenient to permit leads to be as short as possible. Much of the non-r.f. wiring, including connections to the speech amplifier, is cabled and placed around the edge of the chassis. The terminal board, mounted on small pillars, facilitates wiring. The parasitic-suppressor choke, RFC_4, is wound using a 1-watt resistor of 0.1 megohm as a form. The 115-volt male connector at the left of the back side of the chassis is the input terminal for the filament-transformer primaries. The high-low line-voltage switch, S_3, is next to the right. The Millen safety terminal is for 600-volt supply with a banana-plug jack ground connection next to it. An octal socket at the extreme right rear edge of the chassis is for the cable containing metering leads and other interunit connections. To its left is an Amphenol coaxial connector for VFO input. A length of RG-58U cable leads along the lip of the chassis to the blocking condenser, C_1, soldered to the No. 12 crystal selector-switch lug. A chassis bottom plate, removed for the picture, forms part of the shielding for the unit.

Final Amplifier and Modulator

The final amplifier shares the top chassis with the modulator. The wiring of this chassis is shown in Fig. 6-114.

Bandswitching is employed only in the grid circuit of the final amplifier because of the bulk that plate-coil switching would involve. One side of each link joins a common line and the other side is switched in automatically when a band is selected. Both ends of the grid tank coils are switched. The individual 500-ohm resistances at the center-tap of each coil help to isolate unused coils. The common resistor, R_5, makes up the balance of the grid leak. L_5C_1 and L_6C_2 are trap circuits to suppress v.h.f. parasitic oscillation.

The plate spacing of the plate tank condenser is reduced to a minimum by arranging the circuit so that d.c. and audio voltages do not appear across the condenser section. This requires that the condenser rotor be insulated from the chassis and that the shaft be provided with a high-voltage insulating coupling. The 5514s require no protective bias so they may be operated safely with grid-leak bias only.

Hytron 5514s are used also in the Class B modulator; its circuit is included in Fig. 6-114. High-frequency response is limited by shunting condensers C_7 and C_8 across the primary and secondary of the modulation transformer. This added capacitance acts in conjunction with the leakage reactance of the transformer windings to form a low-pass filter which attenuates the highs, including those arising because of modulator distortion. Since transformers vary, the proper value of capacitance must be determined experimentally. In this particular case, a capacitance of 0.003 μfd. results in a rather sharp cut-off above 3000 cycles.

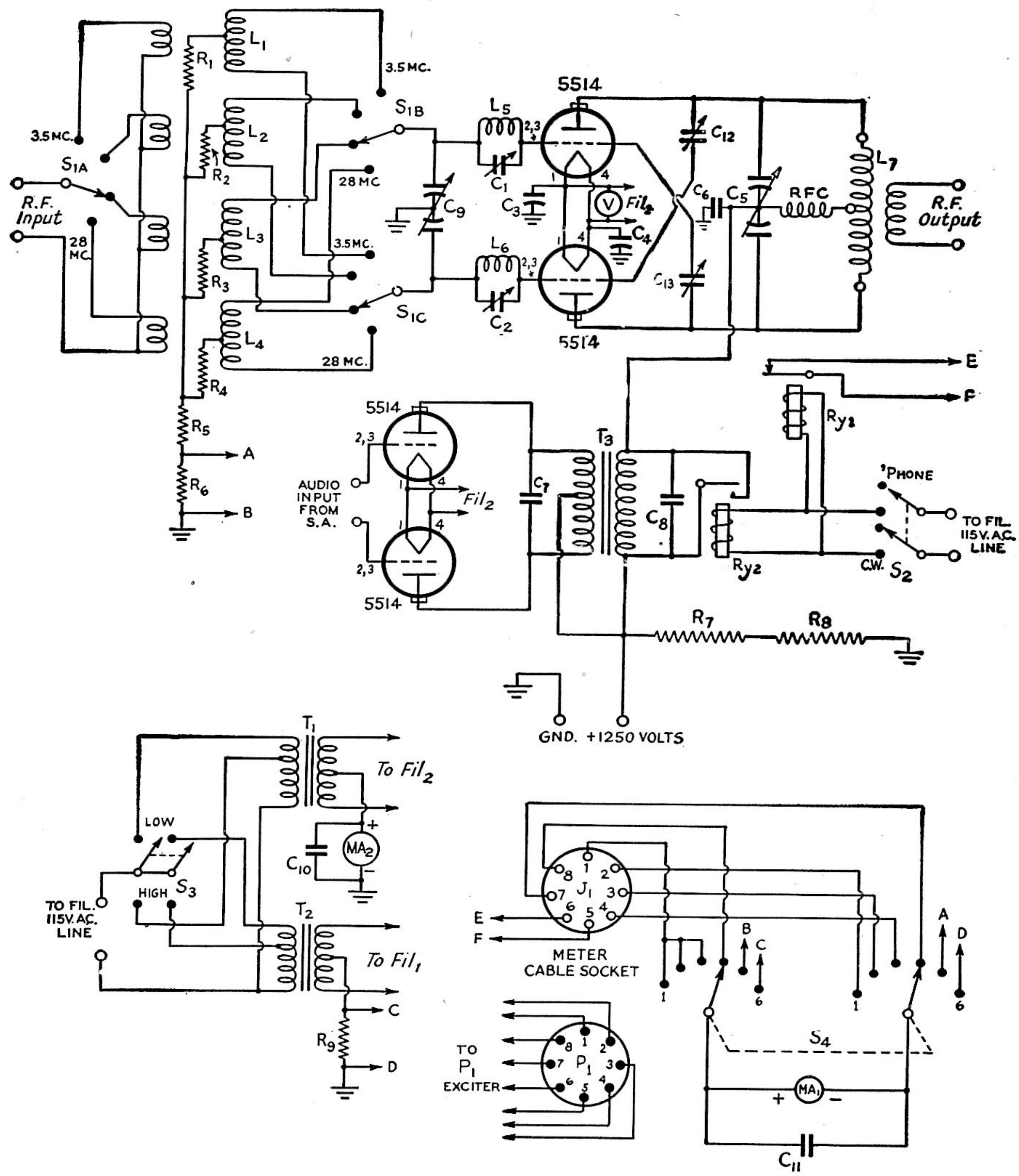


Fig. 6-114 — Circuit diagram of the final-amplifier-and-modulator unit.

C_1, C_2 — 3–30-$\mu\mu$fd. mica trimmers.
C_3, C_4 — 0.01-μfd. 600-volt paper.
C_5 — 100-$\mu\mu$fd.-per-section variable, 0.07-inch spacing (Cardwell PL7030).
C_6 — 0.02-μfd. 2500-volt mica.
C_7, C_8 — 0.003-μfd. 2500-volt mica (see text).
C_9 — 100-$\mu\mu$fd.-per-section variable, 0.047-inch spacing (National TMK-100D).
C_{10}, C_{11} — 0.001-μfd. mica.
C_{12}, C_{13} — Neutralizing condenser (National NC-800).
R_1, R_2, R_3, R_4 — 500 ohms, 10 watts.
R_5 — 1300 ohms, 10 watts.
R_6 — 22 ohms, ½ watt.
R_7, R_8 — 10,000 ohms, 75 watts.
R_9 — 22 ohms, ½ watt, shunted by a length of No. 30 copper wire wound around the resistor. The wire length should be adjusted to make the milliammeter read one-tenth its normal value, increasing the full-scale range to 1000 ma.
L_1, L_2, L_3, L_4 — Millen Types 43081, 43041, 43021 and 43011 coils.
L_5, L_6 — 5 turns No. 14 bare copper wire, ¾-inch diameter, ¾ inch long.
L_7 — B & W BXL series.
J_1 — Octal socket.
MA_1 — 0–100 d.c. milliammeter.
MA_2 — 0–300 d.c. milliammeter.
P_1 — Octal plug.
RFC — 1-mh. r.f. choke (National R-300).
R_{y1} — D.p.d.t. 115-volt coil relay (Ward-Leonard 507–549 used as s.p.s.t.).
R_{y2} — D.p.d.t. 115-volt coil relay (Ward-Leonard 507–531 used as s.p.s.t.).
S_1 — 3-gang 4-position ceramic wafer switch.
S_2 — D.p.s.t. toggle switch.
S_3 — D.p.d.t. toggle switch.
S_4 — 2-gang 6-position ceramic wafer switch.
T_1, T_2 — 7.5-volt 5-amp. filament transformer (Stancor P-4091).
T_3 — Modulation transformer, 5514s to Class C (Thordarson T-14M49).
V — 0–10 a.c. voltmeter.

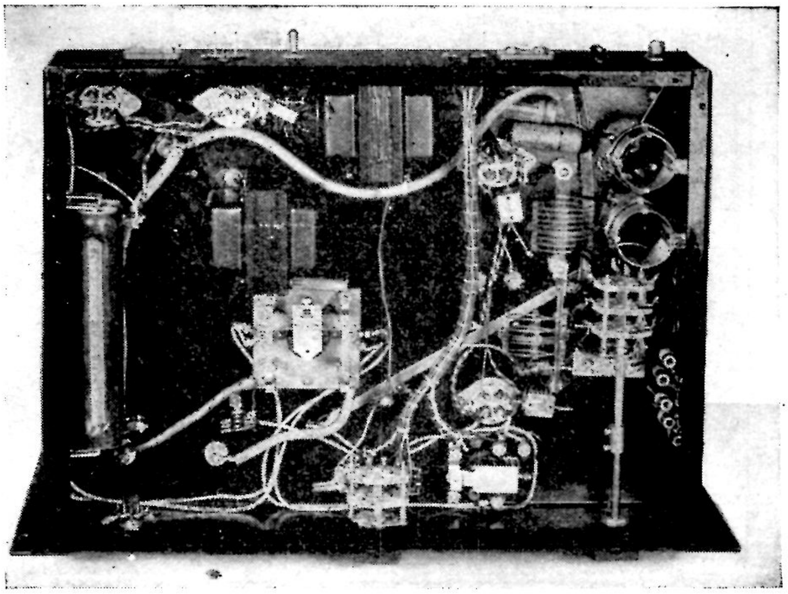


Fig. 6-115 — Under the final-amplifier/modulator chassis. The toggle switch controlling the 'phone-c.w. relays is shown in the lower left-hand corner of the chassis.

Metering System

A single milliammeter and switching system is used to check the plate current of all exciter stages as well as the grid and cathode currents of the final amplifier. The double-gang switch, S_4, Fig. 6-114, connects the meter MA_1 across low-value resistors in each circuit. The resistance of R_9, R_{12}, R_{13} and R_{14}, Fig. 6-110, and R_6 in Fig. 6-114, is sufficiently high so that it does not affect the reading of the meter. However, R_9, Fig. 6-114, in the filament center-tap of the final amplifier, is a lower-resistance shunt that multiplies the meter-scale reading by ten. A separate milliammeter, MA_2, is provided for checking modulator cathode current, while the a.c. voltmeter, V, Fig. 6-114, serves as a check on filament voltage.

Switch S_2 is the 'phone-c.w. switch. When it

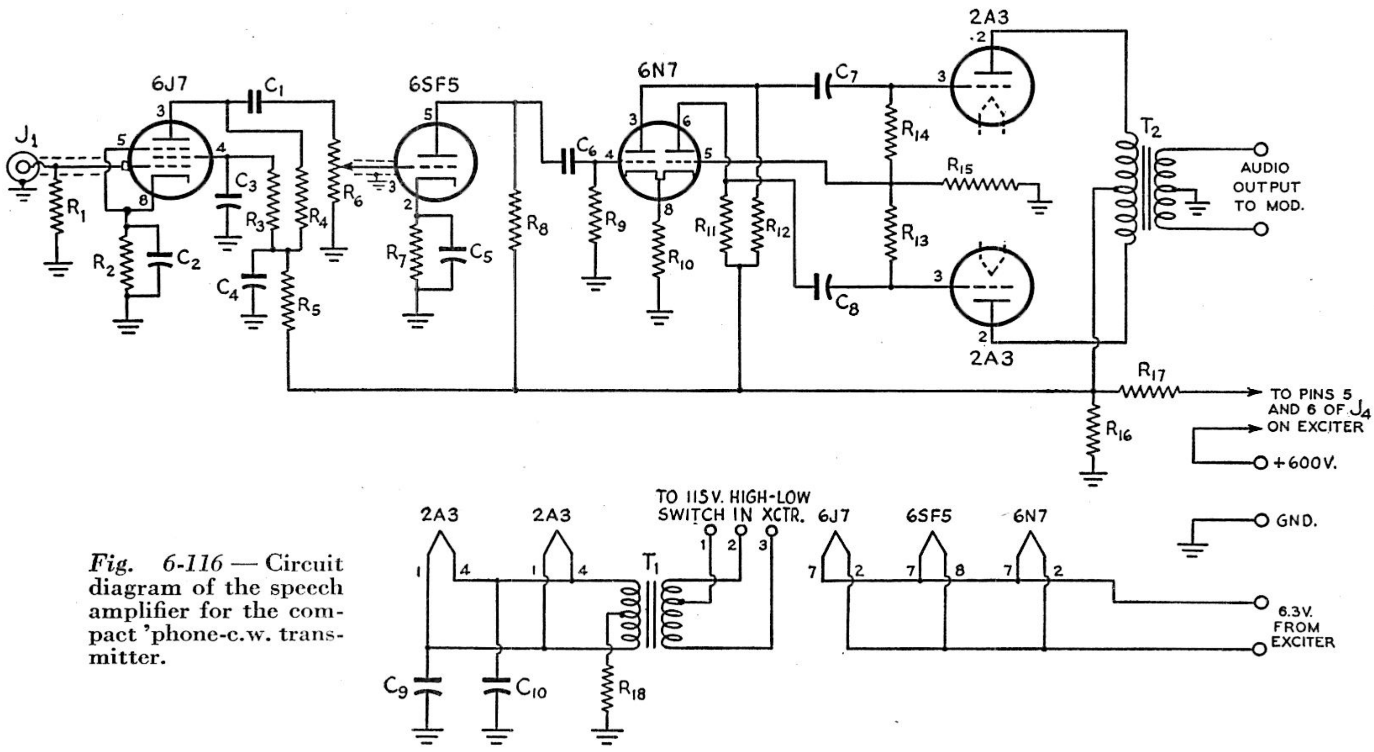


Fig. 6-116 — Circuit diagram of the speech amplifier for the compact 'phone-c.w. transmitter.

C_1, C_6 — 0.0047-μfd. mica.
C_2, C_5 — 25-μfd. 50-volt electrolytic.
C_3, C_7, C_8, C_9, C_{10} — 0.1-μfd. 440-volt paper.
C_4 — 8-μfd. 450-volt electrolytic.
R_1 — 4.7 megohms, 1 watt.
R_2 — 2200 ohms, 1 watt.
R_3 — 2.2 megohms, 1 watt.
R_4, R_8 — 0.47 megohm, 1 watt.
R_5 — 47,000 ohms, 1 watt.
R_6 — 0.5-megohm potentiometer, 1 watt.
R_7 — 4700 ohms, 1 watt.
R_9 — 0.47 megohm, 1 watt.
R_{10} — 1500 ohms, 1 watt.
R_{11}, R_{12} — 0.1 megohm, 1 watt.
R_{13}, R_{14}, R_{15} — 0.22 megohm, ½ watt.
R_{16} — 15,000 ohms, 15 watts.
R_{17} — 4500 ohms, 35 watts.
R_{18} — 750 ohms, 10 watts.
J_1 — Microphone jack.
T_1 — Filament transformer, 2.5 volts, 2.5 amperes (Stancor P-4082).
T_2 — Output transformer to match p.p. 2A3s to Class B grids (Stancor A-4212).

is closed for c.w. operation, Ry_2 short-circuits the output of the modulator and Ry_1 opens the high-voltage line to the speech amplifier.

Building the Final Amplifier

In Fig. 6-113, the dual-section variable condenser for the plate circuit, C_5, Fig. 6-114, is mounted centrally on the chassis on small ceramic stand-off insulators. *A large ceramic-insulated coupling must be used between the shaft of this condenser and the dial.* The jack-bar for the plug-in plate coils is fastened to the condenser frame with small angle pieces. Sockets for the 5514s are mounted just far enough apart to permit mounting the neutralizing condensers in between, while the grid tank condenser is fastened directly to the chassis at the right. The plate by-pass condenser, C_6, and r.f. choke are to the left of the plate tuning condenser.

The amplifier grid-tank coils are grouped closely around the triple-gang selector switch, S_1, shown at the right-hand side in Fig. 6-115. The switch is mounted on a metal bracket about halfway back to the rear edge. The 7- and 3.5-Mc. coils are mounted on ceramic stand-off insulators on the side of the chassis and to the rear. The 28-Mc. coil is mounted on small angle brackets just to the left of the bandswitch and the 14-Mc. coil to the rear of the switch. The parasitic-trap circuits, L_5C_1 and L_6C_2, supported by the grid leads, are placed as close as possible to the grid pins of the tube sockets. The grid resistors are mounted on a terminal board fastened to the side of the chassis, just forward of the coil-selector switch.

The modulator occupies the left-hand side of the chassis in Fig. 6-113. The modulation transformer, T_3, Fig. 6-114, is placed as close to the edge of the chassis as possible with the two 5514s directly to the rear. Two 0.0015-μfd. condensers in parallel make up the required 0.003-μfd. capacitors for C_7 and C_8 and these are fastened directly across the transformer input and output terminals. The high-voltage connection is made to the center-tap of the primary of T_3 and fed through a ceramic feed-through insulator in the chassis. The two filament transformers for the 5514s, T_1 and T_2, and the bleeder resistors for the 1250-volt supply, R_7 and R_8, Fig. 6-114, also are mounted underneath the chassis of this unit.

The relay just below the filament transformers is Ry_2 which short-circuits the modulation transformer during c.w. operation. The smaller relay at the bottom is Ry_1, the supply-voltage control relay for the speech amplifier.

The three meters are mounted above the tuning controls on the final-amplifier panel, while the meter switch, S_4, is located under the chassis at the center of the front edge of the same unit. Connections between the switch and the exciter unit are made through the cabling system.

Banana-plug jacks for r.f. link input and audio input to the modulator, a 115-volt line plug for the filament transformers, the high-low filament switch, S_3, Fig. 6-114, a Millen safety terminal for the high-voltage connection and another banana-plug jack for ground connection are mounted along the rear edge.

Speech Amplifier

The speech amplifier is a separate unit built on a 5 × 10 × 3-inch chassis that shares the same panel as the exciter unit. It is designed for use with a crystal microphone but, by altering slightly the circuit shown in Fig. 6-116, any type of microphone may be used. A 6J7 input stage is followed by a high-gain triode stage with a 6SF5. A 6N7 phase inverter feeds a pair of 2A3s in push-pull which drive the 5514 modulator stage. The gain control is inserted in the grid of the second stage. Low-capaci-

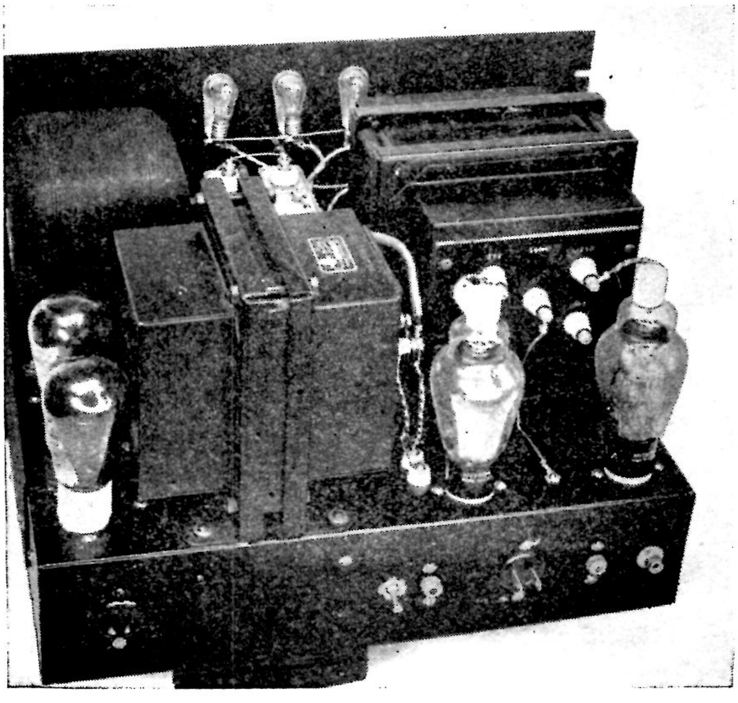


Fig. 6-117 — A 1250-volt 550-ma. and 600-volt 200-ma. dual power supply. Components are mounted both above and below the 17 × 13 × 4-inch chassis. Close to the panel are the filter choke, L_4, the filter condensers, C_1 and C_2, and the 1250-volt transformer, T_1. Along the rear are the 866 Jrs., the choke, L_2, and the 866s. The female socket at the left is for the a.c. line to the filament transformers on the other chassis. The toggle switch selects the proper tap on the primaries of the filament transformers to partially compensate for low or high line voltage and the male Amphenol socket is for the a.c. input line from the safety switches on the top and back doors. The Millen safety terminal to the right of the toggle switch is the 600-volt output terminal while the one near the right-hand edge of the chassis is for the high-voltage output. At the extreme right-hand edge of the chassis is the ground connection, a banana jack mounted on a small spacer.

tance coupling condensers are used throughout to reduce low-frequency response.

In Fig. 6-111, the 6J7 input tube is at the front of the speech-amplifier chassis with its input resistor and shielded lead to the microphone terminal. The 6SF5 is located a little to the rear and to the left of the 6N7 phase inverter. The two 2A3 driver tubes occupy the center of the chassis, directly in front of the driver transformer and the 2½-volt transformer for the 2A3 filaments, T_1, Fig. 6-116. The National FWJ output terminal is at the center of the back end of the chassis.

Under the chassis, the gain control, R_6, is at the lower left as viewed from the rear. The voltage-divider resistors, R_{16} and R_{17}, are mounted along the left-hand side of the chassis and the internal terminal strip along the right-hand side. Holes in the rear cut with a socket punch allow entrance of the leads from the two transformers mounted above.

The grid lead of the 6SF5 is run through grounded shielding braid. Connections to the terminal strip are cabled and fed through rubber-grommetted holes in the sides of the chassis to appropriate external terminals. A bottom plate covers the chassis of this unit.

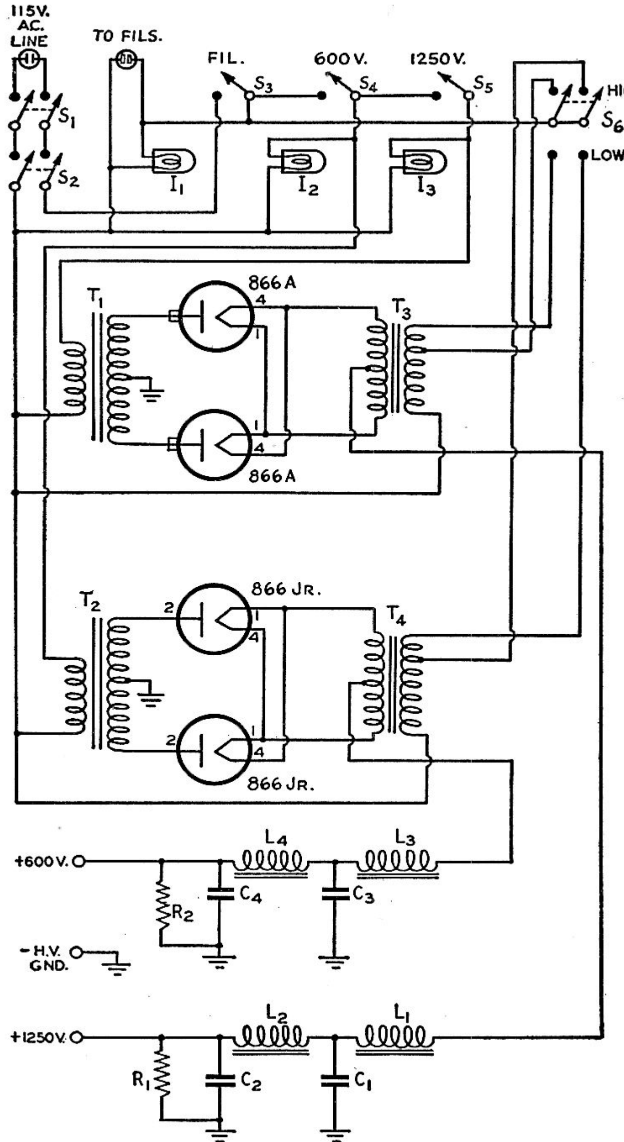


Fig. 6-118 — Circuit diagram of the dual power supply for the medium-power bandswitching transmitter, delivering 1250 volts at 550 ma. and 600 volts at 200 ma.

C_1, C_2 — 4-μfd. 2000-volt filter condenser (C-D TJU 20040).
C_3 — 2-μfd. 1000-volt filter condenser (C-D TJU 10020).
C_4 — 4-μfd. 1000-volt filter condenser (C-D TJU 10040).
R_1 — 0.5 megohm, 5 watts.
R_2 — 0.5 megohm, 2 watts.
L_1 — Swinging choke, 5–20 hy., 550 ma., 75 ohms (Thordarson T-19C38).
L_2 — Smoothing choke, 8 hy., 550 ma., 75 ohms (Stancor C1415).
L_3 — Swinging choke, 6–19 hy., 300 ma., 125 ohms (Thordarson T-19C36).
L_4 — Smoothing choke, 11 hy., 300 ma., 125 ohms (Thordarson T-15C46).
I_1, I_2, I_3 — 115-volt indicator lamps.
S_1, S_2 — D.p.s.t. push-button interlock switch.
S_3, S_4, S_5 — S.p.s.t. toggle switch.
S_6 — D.p.d.t. toggle switch.
T_1 — Plate transformer, 1250 volts each side of center, 550 ma. (Stancor P8027).
T_2 — Plate transformer, 600 volts each side of center, 200 ma. (Stancor P8042).
T_3, T_4 — Rectifier filament transformer, 2.5 volts, center-tapped, 10 amperes; 10,000-volt insulation (Stancor P3025).

Power Supplies

Two power supplies provide plate voltage for all tubes in the transmitter. A 600-volt 200-ma. section supplies voltage for the 807 and, through voltage dividers and series voltage-dropping resistors, voltage for the exciter and speech-amplifier tubes as well. A single 1250-volt 550-ma. section provides plate voltage for the four 5514s in the final amplifier and modulator. Both supplies are assembled on a single 17 × 13 × 4-inch chassis behind a 14-inch panel that occupies the lower part of the transmitter cabinet.

The circuits are shown in Fig. 6-118. S_1 and S_2 are interlock switches that operate when the rear door and hinged top lid of the cabinet are opened and closed. The control switches, S_3, S_4 and S_5, are arranged so that neither of the high-voltage transformers can be turned on before the filament switch, S_3, is closed, nor can the 1250-volt supply be turned on until the 600-volt switch, S_4, has been thrown. In operation, S_5 is closed and then S_4 serves to control both plate supplies simultaneously. Signal lamps I_1, I_2 and I_3 are provided for each switch.

Figs. 6-117 and 6-119 show the general placement of parts, which will probably vary somewhat in individual cases depending upon the available components. The chassis is fastened to the panel 2 inches up from the bottom edge, and large side brackets are used to add strength to the assembly. To provide sufficient room, it may be necessary to cut and bend the chassis lip at certain points so that the unit may be fastened to the edge of the cabinet. Wire with high-voltage insulation should be used for all except the primary circuits.

The three pilot lamps are mounted in the upper part of the panel, while the three toggle switches, S_3, S_4 and S_5, are along the bottom edge. Line a.c. input and high-voltage output

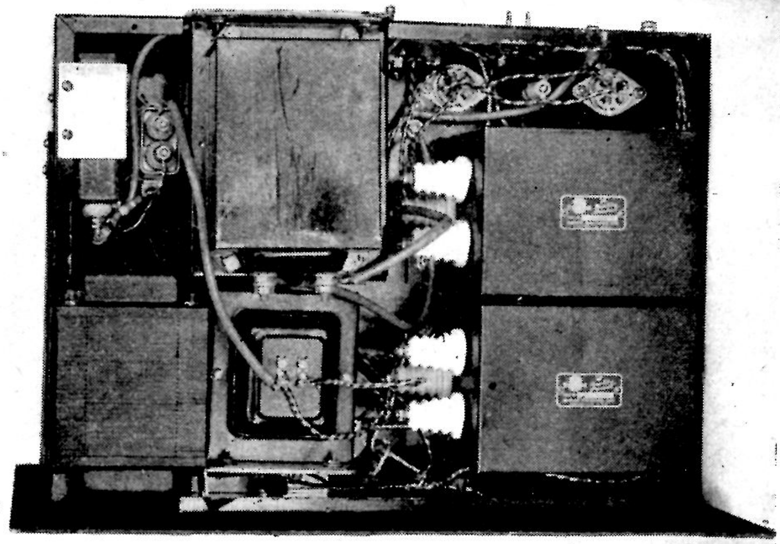


Fig. 6-119 — Bottom view of the dual power supply. The two rectifier filament transformers, T_3 and T_4, are at the right with sockets for the 866As to the rear. The sockets for the 866 Jrs. in the 600-volt supply are located under the filter condensers, C_3 and C_4, in the upper left-hand corner. Switches for control of the a.c. lines are set in the front edge of the chassis. The lip of the chassis is turned down to make room for mounting of the 600-volt transformer, T_2, at the lower left. The filter choke for the low-voltage supply, L_3 — lower center — is supported on an aluminum bracket near the panel to allow space for switches and associated wiring. The choke L_1 is above.

connections are made at the back, Millen safety terminals being provided for the latter.

Tuning Procedure

The tuning procedure is quite simple. The 'phone-c.w. switch should be in the c.w. position. With the key connected to the buffer only, set the exciter and final-grid bandswitches for 28-Mc. output. Set the meter switch to read oscillator plate current (Position 1). With a 3.5-Mc. crystal, the cathode-coil switch should be open; for a 7-Mc. crystal, it should be closed. Switch on the 600-volt supply and, *without closing the key*, rotate the oscillator plate tank condenser to resonance as indicated by a dip in plate current. Switch the meter to the first doubler (Position 2) and rotate the first-doubler tank condenser for a similar resonance-indicating dip. Check the 28-Mc. doubler stage in like manner.

With these driver stages tuned to resonance, close the key and rapidly rotate the 807 tank condenser for resonance. Then adjust the grid current to the final amplifier by rotating the final-amplifier grid condenser. It may be necessary to retune the plate circuit of the 807 to bring it back to resonance after adjusting the final-grid tuning. Grid current to the final should read 80 to 100 ma.

The final amplifier should then be neutralized in the usual manner. After neutralizing, voltage may be applied to the final and the output tank resonated and the amplifier loaded in conventional manner.

'Phone Operation

For 'phone operation the plate supplies are switched off and the 'phone-c.w. switch changed to the 'phone position. The key should be closed or the keying plug removed entirely from the jack. First the 600-volt and then the 1250-supply should be switched on, then the gain control adjusted to proper level after which the 600-volt supply switch alone may be used to control the transmitter by leaving the high-voltage supply switch in the "on" position.

Rack Construction

Most of the units described in the constructional chapters of this *Handbook* are designed for standard rack mounting. The assembly of a selected group of units to form a complete transmitter is, therefore, a relatively simple matter. While standard metal racks are available on the market, many amateurs prefer to build their own less expensively from wood. With care, an excellent substitute can be made.

The plan of a rack of standard dimensions is shown in Fig. 6-120. The rack is constructed entirely of 1 × 2-inch stock of smooth pine, spruce or redwood, with the exception of the trimming strips, *M*, *N*, *O* and *P*. Since the actual size of standard 1 × 2-inch stock runs appreciably below these dimensions, a much sturdier job will result if pieces are obtained cut to the full dimensions.

Each of the main vertical supporting members of the wooden rack is comprised of two pieces (*A* and *B*, and *I* and *J*) joined together at right angles. Each pair of these members is fastened together by No. 8 flat-head screws, with heads countersunk.

Before fastening these pairs together, pieces *A* and *J* should be made exactly the same length and drilled in the proper places for the mounting screws, using a No. 30 drill. The length of pieces *A*, *J*, *B* and *I* should equal the total height of all panels required for the transmitter plus *twice* the sum of the thickness and width of the material used. If the dimensions of the stock are exactly 1 × 2 inches, then 6 inches must be added to the sum of the panel heights. An inspection of the top and bottom of the rack in the drawing will reveal the reason for this. The first mounting hole should come at a distance of ¼ inch plus the sum of the thickness and width of the material from either end of pieces *A* and *J*. This distance will be 3¼ inches for stock exactly 1 × 2 inches. The second hole will come 1¼ inches from the first, the third ½ inch from the second, the fourth 1¼ inches from the third and so on, alternating spacings between ½ inch and 1¼ inches (see detail drawing Fig. 6-121). All holes should be placed ⅜ inch from the inside edges of the vertical members. Accompanying Table 6-V shows standard panel heights and drilling dimensions.

The two vertical members are fastened together by cross-member *K* at the top and *L* at the bottom. These should be of such a length that the inside edges of *A* and *J* are exactly 17½ inches apart at all points. This will bring the lines of mounting holes 18¼ inches center to center. Extending back from the bottoms of the vertical members are pieces *G* and *D* connected together by cross-members *L*, *Q* and *E*, forming the base. The length of the pieces *D* and *G* will depend upon space requirements of the largest power-supply unit which will rest upon it. The vertical members are braced against the base by diagonal members *C* and *H*. Rear support for heavy units placed above the base may be provided by mounting angles on *C* and *H* or by connecting these members with cross-braces as shown at *F*.

To finish off the front of the rack pieces of ¼-inch oak strip (*M*, *N*, *O*, *P*) are fastened around the edges with small-head finishing nails. The heads are set below the surface and the holes plugged with putty or plastic wood.

The top and bottom edges of *M* and *O* should be ¼ inch from the first mounting holes, and the distance between the inside edges of the vertical strips, *N* and *P*, 19$\frac{1}{16}$ inches. To prevent the screw holes from wearing out when panels are changed frequently, ½ × $\frac{1}{16}$ or $\frac{1}{32}$-inch iron or brass strip may be used to back up the vertical members of the frame.

The outside surfaces should be sandpapered thoroughly and given one or two coats of flat black, sandpapering between coats. A finishing surface of two coats of glossy black "Duco" is then applied, again sandpapering between coats. It is very important to allow each coat to dry thoroughly before applying the next, or sandpapering.

Since the combined weights of power supplies, modulator equipment, etc., may total to a surprising figure, the rack should be provided with rollers or wheels so that it may be moved about when necessary after the transmitter has been assembled. Ball-bearing roller-skate wheels are suitable for the purpose.

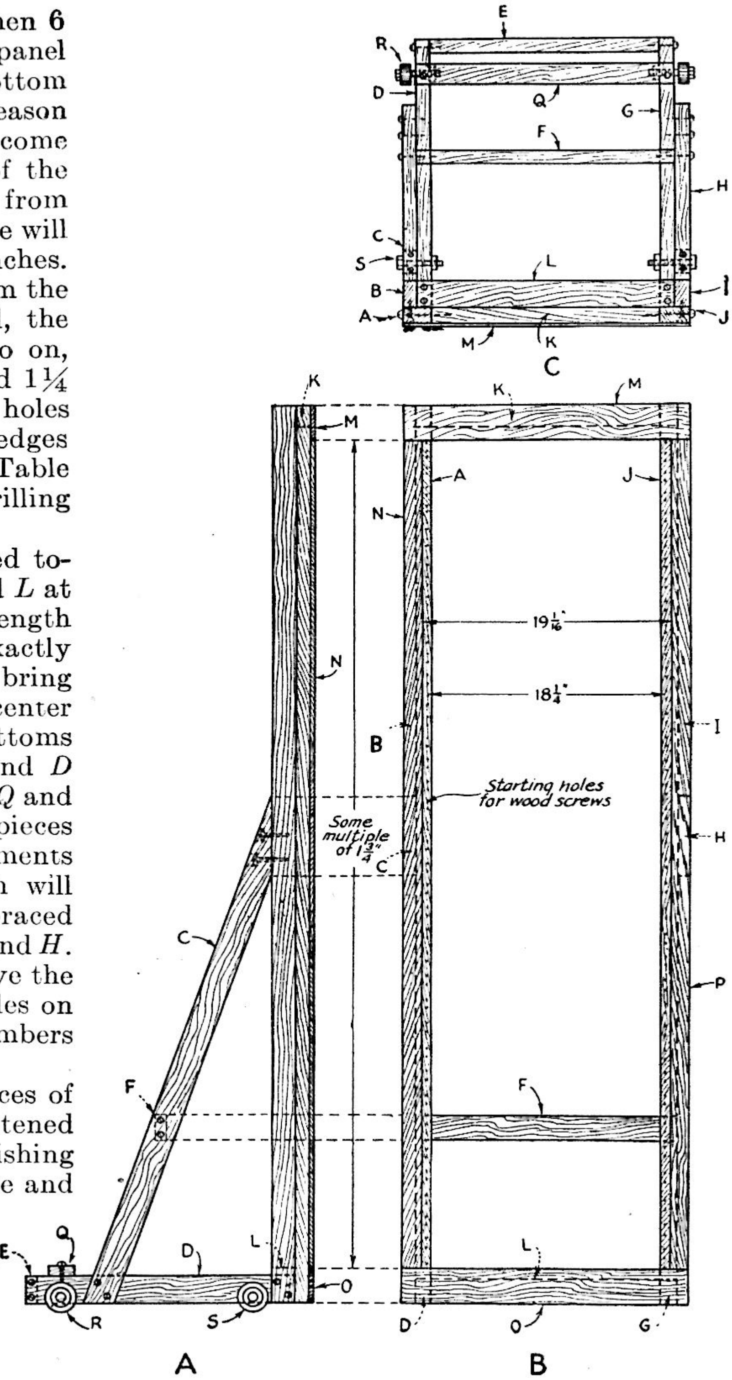


Fig. 6-120 — Detail drawing of a standard rack made of wood. A — Side view. B — Front view. C — Top view.

Standard metal chassis are 17 inches wide. Standard panels are 19 inches wide and multiples of 1¾ inches high. Panel mounting holes start with the first one ¼ inch from the edge of the panel, the second 1¼ inches from the first, the third ½ inch from the second, the fourth 1¼ inches from the third, and the distances between holes from there on alternated between ½ inch and 1¼ inches. (See Fig. 6-121.) In a panel higher than two or three rack units (1¾ inches per unit), it is common practice to drill only sufficient holes to provide a secure mounting. All panel holes should be drilled ⅜ inch in from the edge.

If desired, the rack may be enclosed by completing a framework of one-by-two strip, using ¼-inch plywood for the panels. The panels

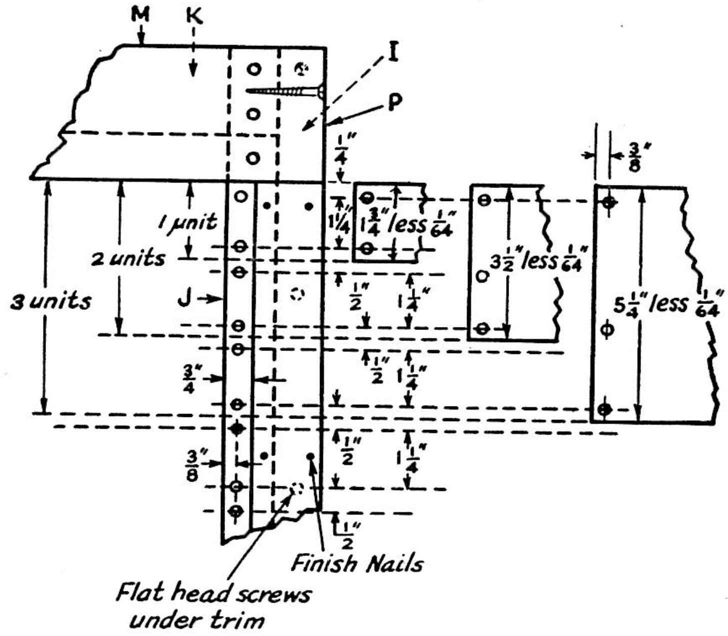


Fig. 6-121 — **Detail sketch showing proper drilling for standard rack and panels. As shown for the 3½- and 5¼-inch panels, only sufficient holes are drilled in the panel to provide the necessary strength. When the panels are drilled as shown, they may be moved up and down in steps of 1¾ inches and the holes will always match.**

may be hinged so that three sides are made accessible for servicing. If the transmitter is to be operated in an enclosure, provision should be made for a small amount of forced-air ventilation; otherwise the panels should be open while the transmitter is in operation.

TABLE 6-V

Panel Height (Inches)	1¾	3½	5¼	7	8¾	10½	12¼	14	15¾
Panel Drilling (Inches)*	¼ 1½	2 3¼	3¾ 5	5½ 6¾	7¼ 8½	9 10¼	10¾ 12	12½ 13¾	14¼ 15½
Panel Height (Inches)	17½	19¼	21	22¾	24½	26¼	28	29¾	31½
Panel Drilling (Inches)*	16 17¼	17¾ 19	19½ 20¾	21¼ 22½	23 24¼	24¾ 26	26½ 27¾	28¼ 29½	30 31¼

* Additional holes for this size panel. Any or all holes given for panels smaller than this size may be added, as required for support.

Power Supplies

Essentially pure direct-current plate supply is required for receivers to prevent hum in the output. Government regulations require the use of d.c. plate supply for transmitters to prevent modulation of the carrier by the supply, which would result in undesired hum in the case of voice transmissions and an unnecessarily broad c.w. signal.

The filaments of tubes in a transmitter may be operated from a.c. Those in a receiver, excepting the power audio tubes, may be a.c. operated only if the cathodes are indirectly heated.

The comparative high cost and inconvenience of batteries and d.c. generators preclude their use except where commercial a.c. lines are not available. Wherever such lines are available, it is universal practice to obtain low a.c. voltage for filaments and heaters from a step-down transformer, and the required high-voltage d.c. by means of a transformer-rectifier-filter system. Such a system is shown in the block diagram of Fig. 7-1. Power from the a.c. line is fed to a transformer which steps the voltage up to that required. The stepped-up voltage is changed to pulsating d.c. by passing through a rectifier — usually of the vacuum-tube type. The pulsations then are smoothed out to the required extent by a filtering system.

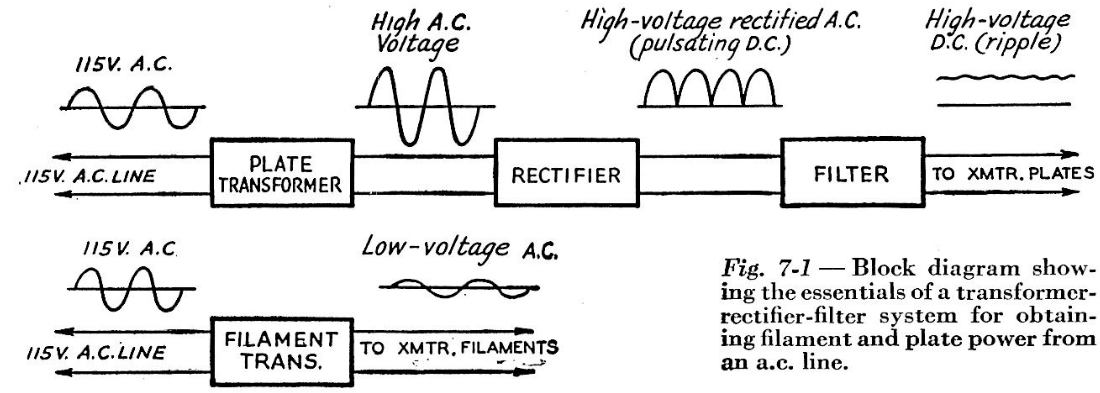


Fig. 7-1 — Block diagram showing the essentials of a transformer-rectifier-filter system for obtaining filament and plate power from an a.c. line.

Rectifier Circuits

Half-Wave Rectifier

Fig. 7-2 shows three rectifier circuits covering most of the common applications in amateur equipment. Fig. 7-2A is the circuit of a half-wave rectifier. During that half of the a.c. cycle when the rectifier plate is positive with respect to the cathode, current will flow through the rectifier and load. But during the other half of the cycle, when the plate is negative in respect to the cathode, no current can flow. The shape of the output wave is shown at the right. It shows that the current always flows in the same direction but that the flow of current is not continuous and is pulsating in amplitude.

The average output voltage — the voltage read by the usual d.c. voltmeter — with this circuit is 0.45 times the r.m.s. value of the a.c. voltage delivered by the transformer secondary. Because the frequency of the pulses in the output wave is relatively low, considerable filtering is required to provide adequately smooth d.c. output, and for this reason this circuit is usually limited to applications where the current involved is small, such as in supplies for cathode-ray tubes and for protective bias in a transmitter.

Full-Wave Center-Tap Rectifier

The most universally-used rectifier circuit is shown in Fig. 7-2B. Being essentially an arrangement in which the outputs of two half-wave rectifiers are combined, it makes use of both halves of the a.c. cycle. A transformer with a center-tapped secondary, or two identical transformers with their secondaries connected in series (with proper polarization), is required with the circuit. When the plate of rectifier No. 1 is positive, current flows through the load to the center-tap. Current cannot flow through rectifier No. 2 because at this instant its cathode is positive in respect to its plate. When the polarity reverses, rectifier No. 2 conducts and current again flows through the

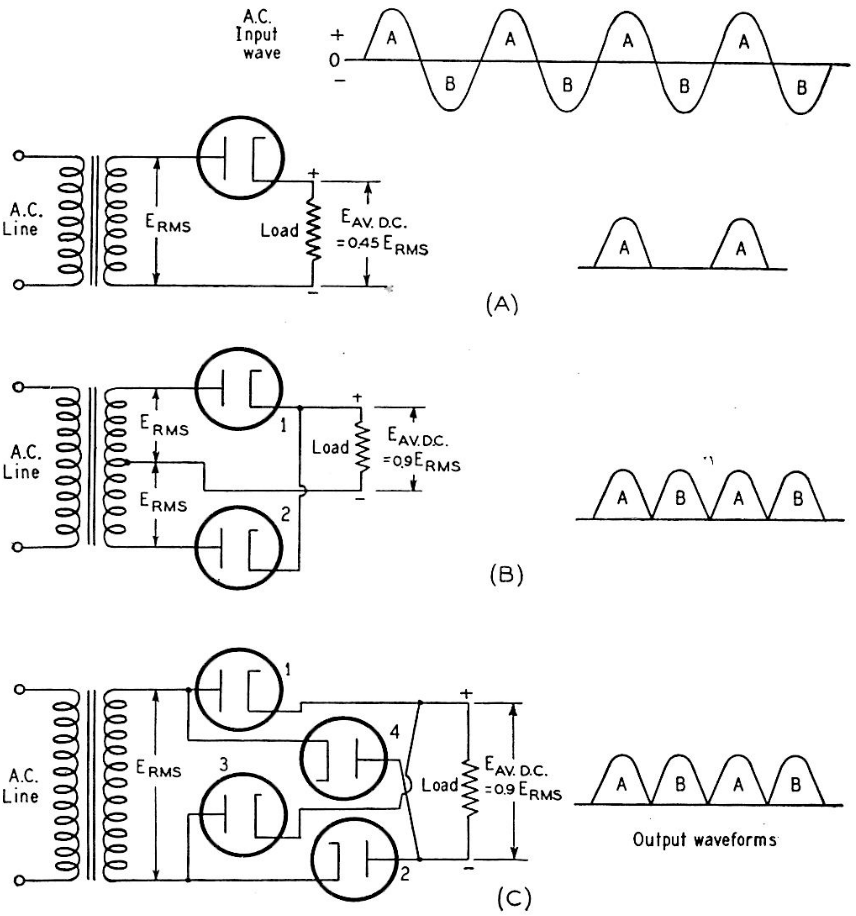


Fig. 7-2 — Fundamental vacuum-tube rectifier circuits.

load to the center-tap, this time through rectifier No. 2.

The average output voltage is 0.9 times the r.m.s. value of the voltage across *half* of the transformer secondary. For the same *total* secondary voltage, the average output voltage will be the same as that delivered with a half-wave rectifier. However, as can be seen from the sketch of the output waveform, the frequency of the output pulses is twice that of the half-wave rectifier. Therefore much less filtering is required. Since the rectifiers work alternately, each handles half of the average load current. Therefore the load current which may be drawn from this circuit is twice the rated load current of a single rectifier.

Full-Wave Bridge Rectifier

Another full-wave rectifier circuit is shown in Fig. 7-2C. In this arrangement, two rectifiers operate in series on each half of the cycle, one rectifier being in the lead to the load, the other being in the return lead. Over that portion of the cycle when the upper end of the transformer secondary is positive in respect to the other end, current flows through rectifier No. 1, through the load and thence through rectifier No. 2. During this period current cannot flow through rectifier No. 4 because its plate is negative in respect to its cathode. Over the other half of the cycle, current flows through rectifier No. 3, through the load and thence through rectifier No. 4. The crossover connection keeps the current flowing in the same direction through the load. The output waveshape is the same as that from the simple center-tap rectifier circuit. The output voltage obtainable with this circuit is 0.9 times the r.m.s. voltage delivered by the transformer secondary. For the same total transformer-secondary voltage, the average output voltage when using the bridge rectifier will be twice that obtainable with the center-tap rectifier circuit. However, when comparing rectifier circuits for use *with the same transformer*, it should be remembered that the *power* which a given transformer will handle remains the same regardless of the rectifier circuit used. If the output voltage is doubled by substituting the bridge circuit for the center-tap rectifier circuit, only half the rated load current can be taken from the transformer without exceeding its normal rating. The value of load current which may be drawn from the bridge rectifier circuit is twice the rated d.c. load current of a single rectifier.

Rectifiers

Cold-Cathode Rectifiers

Tube rectifiers fall into three general classifications as to type. The cold-cathode type of rectifier is a diode which requires no cathode heating. Certain types will handle up to 350 ma. at 200 volts d.c. output. The internal voltage drop in most types lies between 60 and 90 volts. Rectifiers of this kind are produced in both half-wave (single diode) and full-wave (double diode) types.

High-Vacuum Rectifiers

High-vacuum rectifiers depend entirely upon the thermionic emission from a heated cathode and are characterized by a relatively high internal resistance. For this reason, their application usually is limited to low power, although there are a few types designed for medium and high power in cases where the relatively high internal voltage drop may be tolerated. This high internal resistance makes them less susceptible to damage from temporary overload and they are free from the bothersome electrical noise sometimes associated with other types of rectifiers.

Some rectifiers of the high-vacuum full-wave type in the so-called receiver-tube classification will handle up to 250 ma. at 400 to 500 volts d.c. output. Those in the higher-power class can be used to handle up to 500 ma. at 2000 volts d.c. in full-wave circuits. Most low-power high-vacuum rectifiers are produced in the full-wave type, while those for greater power are invariably of the half-wave type.

Mercury-Vapor Rectifiers

In mercury-vapor rectifiers the internal resistance is reduced by the introduction of a small amount of mercury which vaporizes under the heat of the filament, the vapor ionizing upon the application of voltage. The voltage drop through a rectifier of this type is practically constant at approximately 15 volts regardless of the load current. Tubes of this type are produced in sizes that will handle any voltage or current likely to be encountered in amateur transmitters. For high power they have the advantage of cheapness. Rectifiers of this type, however, have a tendency toward a certain type of oscillation which produces noise in near-by receivers. When encountered, this can usually be eliminated by suitable filtering.

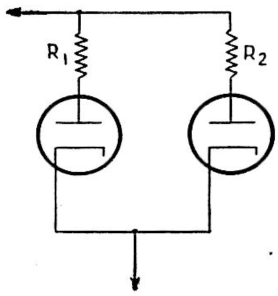


Fig. 7-3 — Connecting rectifiers in parallel for heavier currents. R_1 and R_2 should have the same value, between 50 and 100 ohms.

Selenium Rectifiers

Selenium rectifiers for power applications are a comparatively recent development. Units are now available with which it is possible to design a power supply capable of delivering up to 400 or 450 volts, 200 ma. These units have the advantage of compactness as well as low internal voltage drop (about 5 volts). Since they develop little heat if operated within their ratings, they are especially suitable for use in equipment requiring minimum temperature variation. Electrical noise filtering sometimes is required.

Rectifier Ratings

Vacuum-tube rectifiers are subject to limitations as to breakdown voltage and current-handling capability. Some types are rated in terms of the maximum r.m.s. voltage which should be applied to the rectifier plate, while others, particularly mercury-vapor types, are rated according to maximum inverse peak voltage — the peak voltage which appears between plate and cathode during the time the tube is not conducting. In all of the circuits shown in Fig. 7-2, the inverse peak voltage across each rectifier is 1.4 times the r.m.s. value of the voltage delivered by the entire transformer secondary.

The maximum d.c. output current is the maximum load current which can be drawn safely from the output of the filter. The value listed in tube tables is the value considered to be the safe maximum under average conditions. The exact value is dependent to a considerable extent, however, upon the nature of the filter that follows the rectifier.

A more significant rating is the maximum peak plate current. It is the peak value of the current pulses passing through the rectifier. This peak value can be much greater than the load current, especially if a large condenser is placed across the output of the rectifier as part of the filtering system, because of the large instantaneous charging current drawn by the condenser if there is no impedance between the rectifier and the condenser. These peaks do not run as high with high-vacuum-type rectifiers as they do with rectifiers of the mercury-vapor type because of the relatively high series resistance of the former.

Rectifiers may be connected in parallel for current higher than the rated current of a single unit. This includes the use of the sections of a double diode for this purpose. Equalizing resistors of 50 to 100 ohms should be connected in series with each plate, as shown in Fig. 7-3, as a measure toward maintaining an equal division of current between the two rectifiers.

Operation of Rectifiers

In operating rectifiers requiring filament or cathode heating, care should be taken to provide the correct filament voltage at the tube terminals. Low filament voltage can cause excessive voltage drop in high-vacuum rectifiers and a considerable reduction in the inverse peak voltage which a mercury-vapor tube will withstand without breakdown. Filament connections to the rectifier socket should be firmly soldered, particularly in the case of the larger mercury-vapor tubes whose filaments operate at low voltage and high current. The socket should be selected with care, not only as to contact surface but also as to insulation, since the filament usually is at full output voltage to ground. Bakelite sockets will serve at voltages up to 500 or so, but ceramic sockets, well spaced from the chassis, always should be used at the higher voltages. Special filament transformers with high-voltage insulation between primary and secondary are required for rectifiers operating at voltages in excess of 1000 volts inverse peak.

The rectifier tubes should be placed in the equipment with adequate free space surrounding them to provide for proper ventilation. When mercury-vapor tubes are first placed in service, they should be allowed to run only with filament voltage for ten minutes before applying high voltage.

Filters

The pulsating d.c. wave shown in Fig. 7-2 is not sufficiently smooth to prevent modulation. A filter consisting of chokes and condensers, as shown in Fig. 7-4, is connected between the rectifier output and the load circuit (transmitter or receiver) to smooth out the wave to the required degree.

The filter makes use of the energy-storage properties of the inductance of the choke and the capacitance of the condenser, energy being stored over the period during which the voltage and current are rising and releasing it to the load circuit during the period when the amplitude of the pulse is falling, thus leveling off the output by both lopping off the peaks and filling in the valleys.

Ripple Frequency and Voltage

The pulsations in the output of the rectifier can be considered to be the resultant of an alternating current superimposed upon a steady direct current. From this viewpoint, the filter may be considered to consist of shunting condensers which short-circuit the a.c. component while not interfering with the flow of the d.c. component, and series chokes which pass d.c. readily but which impede the flow of the a.c. component.

The alternating component is called the ripple. The effectiveness of the filter can be expressed in terms of per cent ripple which is the ratio of the r.m.s. value of the ripple to the d.c. value in terms of percentage. For c.w. transmitters, a reduction of the ripple to 5 per cent is considered adequate. The ripple in the output of power supplies for voice transmitters and VFOs should be reduced to 0.25 per cent or less. High-gain speech amplifiers and receivers may require a reduction to as low as 0.1 per cent to avoid objectionable hum.

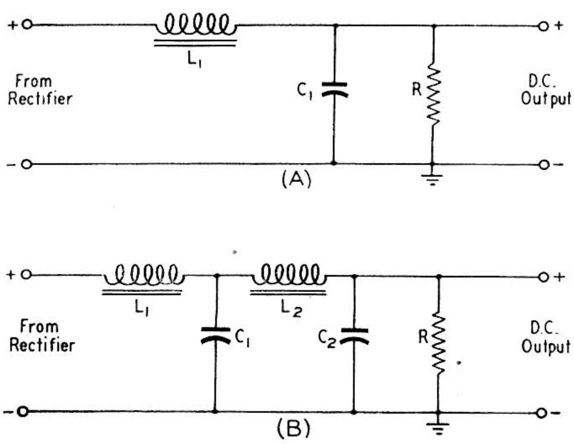


Fig. 7-4 — **Choke-input filter circuits. A — Single section. B — Double section.**

Ripple frequency is the frequency of the pulsations in the rectifier output wave — the number of pulsations per second. The frequency of the ripple with half-wave rectifiers is the same as the frequency of the line supply — 60 cycles with 60-cycle supply. Since the output pulses are doubled with a full-wave rectifier, the ripple frequency is doubled — to 120 cycles with 60-cycle supply.

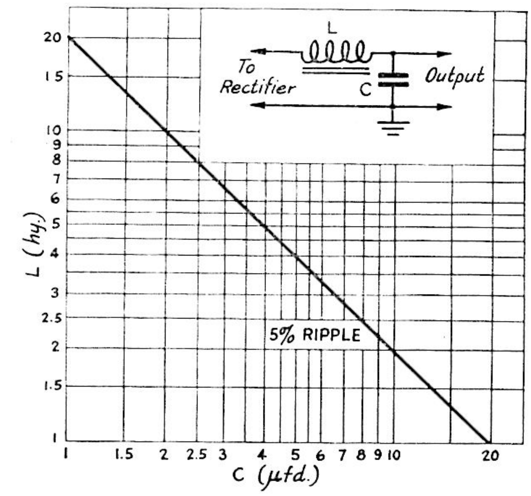


Fig. 7-5 — **Graph showing combinations of inductance and capacitance that may be used to reduce ripple to 5 per cent with a single-section choke-input filter.**

The amount of filtering (values of inductance and capacitance) required to give adequate smoothing depends upon the ripple frequency, more filtering being required as the ripple frequency is lower.

CHOKE-INPUT FILTERS

The filters shown in Fig. 7-4 are known as choke-input filters because the first element in the filter is a choke. This term is used in contrast to a condenser-input filter in which the first element is a condenser.

The percentage ripple output from a single-section filter (Fig. 7-4A) made up of any values of inductance and capacitance may be determined to a close approximation from the following formula:

$$\left.\begin{array}{l}\text{Single-}\\\text{Section}\\\text{Filter}\end{array}\right\} \textit{Percentage ripple} = \frac{100}{LC}$$

where L is in hy. and C in μfd.

Example: $L = 5$ hy., $C = 4$ μfd.

$$\text{Percentage ripple} = \frac{100}{(5)\ (4)} = \frac{100}{20} = 5 \text{ per cent}$$

Fig. 7-5 shows various other combinations of inductance and capacitance which will reduce the ripple to 5 per cent — the required minimum reduction for a supply for a c.w. transmitter.

Example: With a 10-hy. choke, what capacitance is required to reduce the ripple to 5 per cent?

Referring to Fig. 7-5, following the 10-hy. line horizontally, it intersects the ripple line at the 2-μfd. vertical line. Therefore the filter capacitance should be 2 μfd.

Example: With a 4-μfd. condenser, what choke inductance is required to reduce the ripple to 5 per cent?

Follow the vertical $C = 4$-μfd. line to the point where it intersects the ripple line; then follow the horizontal line at that point to read 5 hy., the required inductance.

Double-Section Filter

If sufficient smoothing cannot be obtained with a single set of inductance and capacitance of reasonable value (Fig. 7-4A), another *section* of filter may be added as shown at B. In cases where the ripple must be reduced to less than 5 per cent, the required smoothing usually can be obtained most economically by the use of a two-section filter.

The ripple percentage in the output of a double-section filter, when the ripple frequency is 120 cycles, is given by:

$$\left.\begin{array}{l}\text{Double-}\\\text{Section}\\\text{Filter}\end{array}\right\} \textit{Percentage ripple} = \frac{650}{L_1L_2\,(C_1 + C_2)^2}$$

L being in hy. and C in μfd.

Example: $L_1 = 5$ hy., $L_2 = 20$ hy., $C_1 = 2$ μfd., $C_2 = 4$ μfd.

$$\text{Percentage ripple} = \frac{650}{(5)\ (20)\ (2+4)^2} = \frac{650}{3600}$$
$$= 0.18 \text{ per cent}$$

The curves of Fig. 7-6 show the *product* of the inductances and *sum* of the capacitances which will reduce the ripple to 5 per cent, 0.25 per cent or 0.1 per cent. In the above example, the product of the inductances is $5 \times 20 = 100$, and the sum of the capacitances is $2 + 4 = 6$. In Fig. 7-6 the horizontal line from $C_1 + C_2 = 6$ intersects the vertical line from $L_1 \times L_2 = 100$ at a point between the 0.25 and 0.1 per-cent-ripple line.

Reversing the process, select any point on the desired ripple-percentage line, follow the horizontal graph line out to the left to find the required product of inductances and the vertical line down from the same point to find the required sum of the capacitances.

Example: Suppose two filter chokes are at hand, one with an inductance of 5 hy. and the other an inductance of 10 hy. The product is $5 \times 10 = 50$. If it is desired to reduce the ripple to 0.25 per cent, follow the horizontal line at 50 to the right until it intersects the 0.25 per cent line. At this point, follow the vertical line down to 7.5, which is the required sum of the capacitances. Two 4-μfd. condensers (sum 8) will be suitable.

When the line frequency is other than 60 cycles, the values of both inductance and capacitance should be multiplied by the ratio of 60 to the actual line frequency to obtain the same degree of filtering.

Example: Line frequency = 25 cycles. Multiplying factor to be applied to values of inductance and capacitance based on 60 cycles = $60/25 = 2.4$. For a line frequency of 50 cycles the factor would be $60/50 = 1.2$.

In the case of a half-wave rectifier, the value of each inductance and capacitance in the filter arrived at on the basis of a ripple frequency of 120 cycles must be doubled. It requires twice as much inductance and capacitance for the same degree of filtering with the half-wave circuit.

From the consideration of ripple reduction, any combination of inductances and capacitances which will give the required product and sum respectively will give the same ripple reduction. However, two other factors must be taken into consideration in the design of the filter. These are the peak rectifier current and voltage regulation.

Voltage Regulation

Unless the power supply is designed to prevent it, there may be a considerable difference between the output-terminal voltage of the supply when it is running free without an external load and the value when the external load is connected. Application of the load usually will be accompanied by a reduction in terminal voltage and this must be taken into consideration in the design of the supply. Regulation is commonly expressed as the percentage change in output voltage between no-load and full-load conditions in relation to the full-load voltage.

$$\textit{Per cent regulation} = \frac{100\,(E_1 - E_2)}{E_2}$$

Example: No-load voltage $= E_1 = 1550$ volts. Full-load voltage $= E_2 = 1230$ volts.

$$\text{Percentage regulation} = \frac{100\ (1550 - 1230)}{1230}$$
$$= \frac{32{,}000}{1230} = 26 \text{ per cent}$$

With proper design and the use of conservatively-rated components, a regulation of 10 per cent or less at the output terminals of the supply unit is possible. Good voltage regulation may or may not be of primary importance depending upon the nature of the load. If the load is constant, as in the case of a receiver, speech amplifier or the stages of a transmitter which are not keyed, voltage regulation, so far as that contributed by filter design is concerned, may be of secondary importance. The highly-stabilized voltage desirable for high frequency-stability of oscillators in receivers and transmitters is obtained by other means. Power supplies for the keyed stage of a c.w. transmitter and the stages following, and for Class B modulators, should have good regulation.

The Input Choke

The rectifier peak current and the power-supply voltage regulation depend almost entirely upon the inductance of the input choke in relation to the load resistance. The function of the choke is to raise the ratio of average to peak current (by its energy storage), and to prevent the d.c. output voltage from rising above the average value of the a.c. voltage ap-

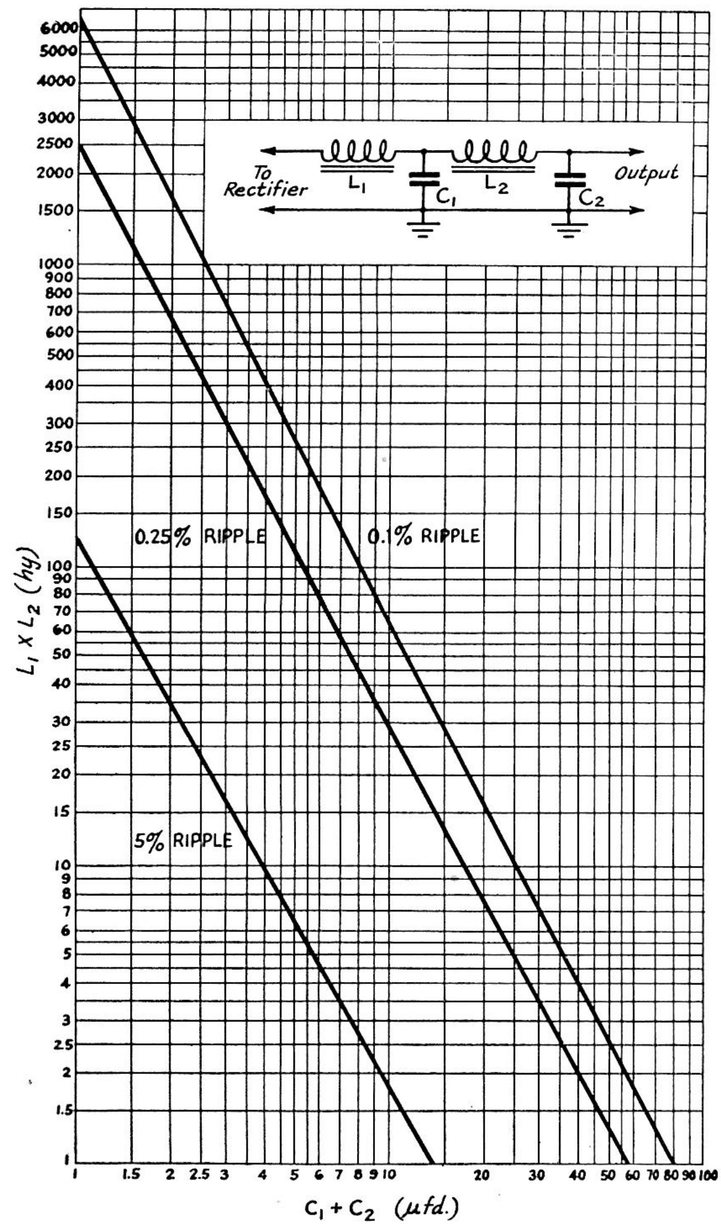


Fig. 7-6 — **Chart which may be used in determining values of inductance and capacitance necessary to reduce ripple to 5, 0.25 or 0.1 per cent with a 2-section choke-input filter. Conversely, the approximate ripple to be expected with any combination of inductance and capacitance may be found. The vertical axis is in terms of the *sum* of the two condenser capacitances used, while the horizontal axis is in terms of the *product* of the inductances of the two filter chokes.**

plied to the rectifier. For both purposes, its impedance to the flow of the a.c. component must be high.

The value of input-choke inductance which prevents the d.c. output voltage from rising above the average of the rectified a.c. wave is the **critical inductance.** For 120-cycle ripple, it is given by the approximate formula:

$$L_{\text{crit.}} = \frac{\textit{Load resistance}\ (\text{ohms})}{1000}$$

For other ripple frequencies, the inductance required will be the above value multiplied by the ratio of 120 to the actual ripple frequency.

With inductance values less than critical, the d.c. output voltage will rise because the filter tends to act as a condenser-input filter. With critical inductance, the peak plate current of one tube in a center-tap rectifier will be approximately 10 per cent higher than the d.c. load current taken from the supply.

An inductance of twice the critical value is called the **optimum** value. This value gives a further reduction in the ratio of peak-to-average plate current, and represents the point at which further increase in inductance does not give correspondingly improved operating characteristics.

Swinging Chokes

The formula for critical inductance indicates that the minimum inductance required varies widely with the load resistance. In the case where there is no load except the bleeder on the power supply, the critical inductance required is the highest; much lower values are satisfactory when the full-load current is being delivered. Since the inductance of a choke tends to rise as the direct current flowing through it is decreased, it is possible to effect an economy in materials by designing the choke to have a "swinging" characteristic so that it has the required critical inductance value with the bleeder load only, and about the optimum inductance value at full load. If the bleeder resistance is 20,000 ohms and the full-load resistance (including the bleeder) is 2500 ohms, a choke which swings from 20 henrys to 5 henrys over the full output-current range will fulfill the requirements. With any given input choke, the bleeder resistance (or other steady minimum load) should be 1000 times the maximum inductance of the choke in henrys.

Example: With a swinging choke of 5 to 20 hy., the bleeder resistance (or the resultant of the bleeder plus other steady load in parallel) should not exceed (20) (1000) = 20,000 ohms.

Output Condenser

If the supply is intended for use with an audio-frequency amplifier, the reactance of the last filter condenser should be small (20 per cent or less) compared to the other a.f. resistance or impedance in the circuit, usually the tube plate resistance and load resistance. On the basis of a lower a.f. limit of 100 cycles for speech amplification, this condition usually is satisfied when the output capacitance (last filter capacitance) of the filter is 4 to 8 μfd., the higher value of capacitance being used in the case of lower tube and load resistances.

Resonance

Resonance effects in the series circuit across the output of the rectifier which is formed by the first choke (L_1) and first filter condenser (C_1) must be avoided, since the ripple voltage would build up to large values. This not only is the opposite action to that for which the filter is intended, but also may cause excessive rectifier peak currents and abnormally-high inverse peak voltages. For full-wave rectification the ripple frequency will be 120 cycles for a 60-cycle supply, and resonance will occur when the product of choke inductance in henrys times condenser capacitance in microfarads is equal to 1.77. The corresponding figure for 50-cycle supply (100-cycle ripple frequency) is 2.53, and for 25-cycle supply (50-cycle ripple frequency), 13.5. At least twice these products should be used to ensure against resonance effects.

Output Voltage

Provided the input-choke inductance is at least the critical value, the output voltage may be calculated quite closely by the following equation:

$$E_o = 0.9E_t - \frac{(I_b + I_L)\,(R_1 + R_2)}{1000} - E_r$$

where E_o is the output voltage; E_t is the r.m.s. voltage applied to the rectifier (r.m.s. voltage between center-tap and one end of the secondary in the case of the center-tap rectifier); I_b and I_L are the bleeder and load currents, respectively, in milliamperes; R_1 and R_2 are the resistances of the first and second filter chokes; and E_r is the drop between rectifier plate and cathode. These voltage drops are shown in Fig. 7-7. At no load I_L is zero, hence the no-load voltage may be calculated on the basis of bleeder current only. The voltage regulation may be determined from the no-load and full-load voltages.

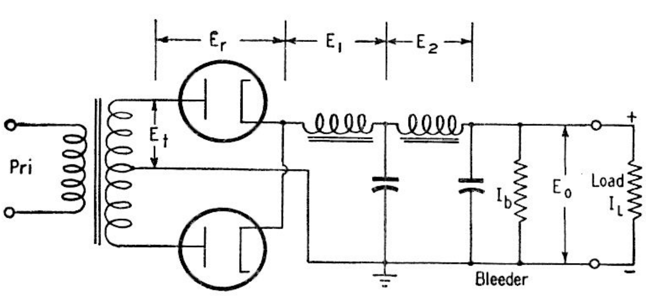


Fig. 7-7 — Diagram showing various voltage drops that must be taken into consideration in determining the required transformer voltage to deliver the desired output voltage.

● CONDENSER-INPUT FILTERS

The conventional condenser-input filter is shown in Fig. 7-8A. No simple formulas are available for computing the ripple voltage, but it will be smaller as both capacitance and inductance are made larger. Adequate smoothing for transmitting purposes usually can be secured by using 4 to 8 μfd. at C_1 and C_2 and 20 to 30 hy. at L_1, for full-wave 60-cycle rectifiers.

As in the case of choke-input filters, if additional smoothing is required, another filter section may be added as shown in Fig. 7-8B. In such supplies the three condensers generally are 8 μfd. each, although the input condenser, C_1, sometimes is reduced to 4 μfd. Inductances of 10 to 20 hy. each will give satisfactory filtering, for receivers and similar applications, with these capacitance values.

For ripple frequencies other than 120 cycles, the inductance and capacitance values should be multiplied by the ratio of $120/f$, where f is the actual ripple frequency.

The bleeder resistance, R, should be chosen to draw about 10 per cent or less of the rated output current of the supply. Its value is equal to $1000E/I$, where E is the output voltage and I the bleeder current in milliamperes.

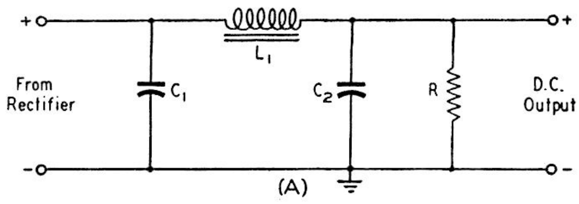
The ratio of rectifier peak current to average load current is high with a condenser-input filter. Small rectifier tubes designed for low-voltage supplies (Type 80, etc.) generally carry load-current ratings based on the use of condenser-input filters. With rectifiers for higher power, such as the 866/866-A, the load current should not exceed 25 per cent of the rated peak plate current for one tube when a full-wave rectifier is used, or one-eighth the half-wave rating.

The d.c. output voltage from a condenser-input supply will, with light loads or no load, approach the peak transformer voltage. This is 1.41 times the r.m.s. voltage of the transformer secondary, in the case of Fig. 7-2A and C or 1.41 times the voltage from the center-tap to one end of the secondary in Fig. 7-2B. At heavy loads, it may decrease to the *average* value of secondary voltage or about 90 per cent of the r.m.s. voltage, or even less. Because of this wide range of output voltage with load current, the voltage regulation is inherently poor.

The output voltage obtainable from a given supply with condenser input cannot readily be calculated, since it depends critically upon the load current and filter constants. Under average conditions the voltage will be approximately equal to or somewhat less than the r.m.s. voltage between the center-tap and one end of the secondary in the full-wave center-tap rectifier circuit.

Ratings of Components

Although filter condensers in a choke-input filter are subjected to smaller variations in d.c. voltage than in the condenser-input filter, it is advisable to use condensers rated for the peak transformer voltage in case the bleeder resistor



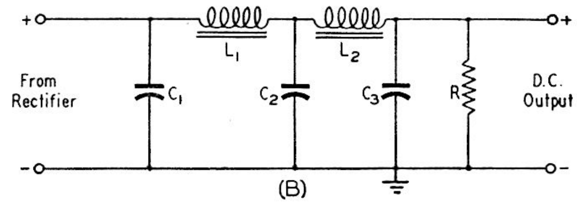


Fig. 7-8 — Condenser-input filter circuits. A — Single section. B — Double section.

should burn out when there is no external load on the power supply, since the voltage then will rise to the same maximum value as with a condenser-input filter.

In a condenser-input filter, the condensers should have a working-voltage rating at least as high and preferably somewhat higher, as a safety factor. Thus, in the case of a center-tap rectifier having a transformer delivering 550 volts each side of the center-tap, the minimum safe condenser voltage rating will be 550 × 1.41 or 775 volts. An 800-volt condenser should be used, or preferably a 1000-volt unit to allow a margin of safety.

Filter condensers are made in several different types. Electrolytic condensers, which are available for voltages up to about 800, combine high capacitance with small size, since the dielectric is an extremely-thin film of oxide on aluminum foil. Condensers for higher voltages usually are made with a dielectric of thin paper impregnated with oil. The **working voltage** of a condenser is the voltage that it will withstand continuously.

The input choke may be of the swinging type, the required no-load and full-load inductance values being calculated as described above. The second choke **(smoothing choke)** should have constant inductance with varying d.c. load currents. Values of 10 to 20 henrys ordinarily are used. Since chokes usually are placed in the positive leads, the negative being grounded, the windings should be insulated from the core to withstand the full d.c. output voltage of the supply and be capable of handling the required load current.

Filter chokes or inductances are wound on iron cores, with a small gap in the core to prevent magnetic saturation of the iron at high currents. When the iron becomes saturated its permeability decreases, consequently the inductance also decreases. Despite the air gap, the inductance of a choke usually varies to some extent with the direct current flowing in the winding; hence it is necessary to specify the inductance at the current which the choke is intended to carry. Its inductance with little or no direct current flowing in the winding may be considerably higher than the value when full load current is flowing.

The Plate Transformer

Output Voltage

The output voltage which the plate transformer must deliver depends upon the required d.c. load voltage and the type of rectifier circuit. With condenser-input filters, the r.m.s. secondary voltage usually is made equal to or slightly more than the d.c. output voltage, allowing for voltage drops in the rectifier tubes and filter chokes as well as in the transformer itself. The full-wave center-tap rectifier requires a transformer giving this voltage each side of the secondary center-tap, the *total* secondary voltage being twice the desired d.c. output voltage.

With a choke-input filter, the required r.m.s. secondary voltage (each side of center-tap for a center-tap rectifier) can be calculated by the equation:

$$E_t = 1.1\left[E_o + \frac{I(R_1 + R_2)}{1000} + E_r\right]$$

where E_o is the required d.c. output voltage, I is the load current (including bleeder current) in ma., R_1 and R_2 are the resistances of the chokes, and E_r is the voltage drop in the rectifier. E_t is the full-load r.m.s. secondary voltage; the open-circuit voltage usually will be 5 to 10 per cent higher than the full-load value.

Volt-Ampere Rating

The volt-ampere rating of the transformer depends upon the type of filter (condenser or choke input). With a condenser-input filter the heating effect in the secondary is higher because of the high ratio of peak to average current, consequently the volt-amperes consumed by the transformer may be several times the watts delivered to the load. With a choke-input filter, provided the input choke has at least the critical inductance, the secondary volt-amperes can be calculated quite closely by the equation:

$$Sec.\ V.A. = 0.00075EI$$

where E is the *total* r.m.s. voltage of the secondary (between the outside ends in the case of a center-tapped winding) and I is the d.c. output current in milliamperes (load current plus bleeder current). The primary volt-amperes will be 10 to 20 per cent higher because of transformer losses.

Building Small Transformers and Chokes

Power transformers for both filament heating and plate supply for all transmitting and rectifying tubes are available commercially, but occasionally the amateur wishes to build a transformer for some special purpose or has a core from a burned-out transformer on which he wishes to put new windings.

Most transformers that amateurs build are for use on 115-volt 60-cycle supplies. The number of turns necessary on the 115-volt winding depends on the kind of iron used in the core and on the cross-sectional area of the core. Silicon steel is best, and a flux density of about 50,000 lines per square inch can be used. This is the basis of the table of cross-sections given.

An average value for the number of primary turns to be used is 7.5 turns per volt per square inch of cross-sectional area. This relation may be expressed as follows:

$$No.\ primary\ turns = 7.5 \left(\frac{E}{A}\right)$$

where E is the primary voltage and A the number of square inches of cross-sectional area of the core. For 115-volt primary transformers the equation becomes:

$$No.\ primary\ turns = \frac{863}{A}$$

When a small transformer is built to handle a continuous load, the copper wire in the windings should have an area of 1500 circular mils for each ampere carried. (See Wire Table in Chapter Twenty-Four.) For intermittent use, 1000 circular mils per ampere is permissible.

The primary wire size is given in Table 7-I; the secondary wire size should be chosen according to the current to be carried, as previously described. The Wire Table in Chapter Twenty-Four shows how many turns of each wire size can be wound into a square inch of window area, assuming that the turns are wound regularly and that no insulation is used between layers. The primary winding of a 200-watt transformer, which has 270 turns of No. 17 wire, would occupy 270/329 or 0.82 square inch if wound with double-cotton-covered wire, for example. This makes no allowance for a layer of insulation between the windings (in general, it is good practice to wind a strip of paper between each layer) so that the winding area allowance should be increased if layer insulation is to be used. The figures also are based on accurate winding such as is done by machines; with hand-winding it is probable that somewhat more area would be required. An increase of 50 per cent should take care of both hand-winding and layer thickness. The area to be taken by the secondary winding should be estimated, as should also the area likely to be occupied by the insulation between the core

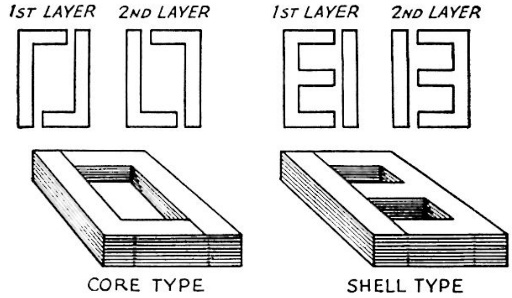


Fig. 7-9 — **Two different types of transformer cores and their laminations.**

and windings and between the primary and secondary windings themselves. When the total window area required has been figured — allowing a little extra for contingencies — laminations having the desired leg-width and window area should be purchased. It may not be possible to get laminations having exactly the dimensions wanted, in which case the nearest size should be chosen. The cross-section of the core need not be square but can be rectangular in shape so long as the core area is great enough. It is easier to wind coils for a core of square cross-section, however.

Transformer cores are of two types, "core" and "shell." In the core type, the core is simply a hollow rectangle formed from two "L"-shaped laminations, as shown in Fig. 7-9. Shell-type laminations are "E"- and "I"-shaped, the transformer windings being placed on the center leg. Since the magnetic path divides between the outer legs of the "E," these legs are each half the width of the center leg. The cross-sectional area of a shell-type core is the cross-sectional area of the center leg. The shell-type core makes a better trans-

TABLE 7-I
Transformer Design

Input (Watts)	*Full-Load Efficiency*	*Size of Primary Wire*	*No. of Primary Turns*	*Turns Per Volt*	*Cross-Section Through Core*
50	75%	23	528	4.80	1¼" × 1¼"
75	85	21	437	3.95	1⅜ × 1⅜
100	90	20	367	3.33	1½ × 1½
150	90	18	313	2.84	1⅝ × 1⅝
200	90	17	270	2.45	1¾ × 1¾
250	90	16	248	2.25	1⅞ × 1⅞
300	90	15	248	2.25	1⅞ × 1⅞
400	90	14	206	1.87	2 × 2
500	95	13	183	1.66	2⅛ × 2⅛
750	95	11	146	1.33	2⅜ × 2⅜
1000	95	10	132	1.20	2½ × 2½
1500	95	9	109	0.99	2¾ × 2¾

TABLE 7-II
Filter-Choke Design

L (Hy.)	*Ma.*	*Stack Size (Inches)*	*Core Length*		*Gap (Inches)*	*Winding Form*		*Turns*	*Wire Size*	*Feet*
			Long Piece	*Short Piece*		*b*	*c*			
15	50	½ × ½	½ × 2.2	½ × 0.85	0.035	1	0.68	9500	33	3500
10	100	¾ × ¾	¾ × 2.6	¾ × 0.95	0.03	1	0.67	5000	30	2250
15	100	1 × 1	1 × 3.1	1 × 0.9	0.035	0.96	0.65	4800	30	2550
10	250	2 × 2	2 × 5.2	2 × 1	0.4	1.05	0.68	2000	26	1750
20	250	2 × 2	2 × 5.6	2 × 1.2	0.28	1.43	0.95	4000	26	3820
5	500	2 × 2	2 × 5.5	2 × 1.15	0.17	1.35	0.9	1800	23	1700
10	500	2 × 2	2 × 6.2	2 × 1.5	0.4	2	1.3	3800	23	4100

former than the core type, because it tends to prevent leakage of the magnetic flux. Calculations are the same for both types.

Fig. 7-10 shows the method of putting the windings on a shell-type core. The primary is usually wound on the inside — next to the core — on a form made of fiber or several layers of cardboard. This form should be slightly larger than the core leg on which it is to fit so that it will be an easy matter to slip in the laminations after the coils are completed and ready for mounting. The terminals are brought out to the side. After the primary is finished, the secondary is wound over it, several layers of insulating material being put between. If the transformer is for high voltages, the high-voltage winding should be carefully insulated from the primary and core by a few layers of Empire Cloth or tape. A protective covering of heavy cardboard or thin fiber should be put over the outside of the secondary

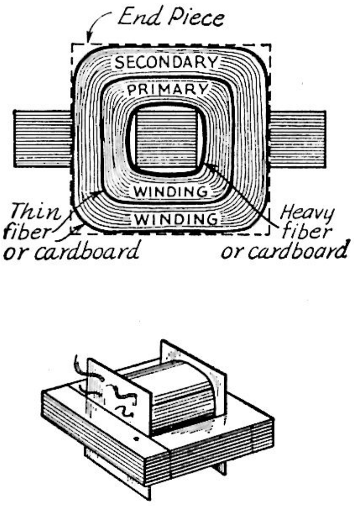


Fig. 7-10 — A convenient method of assembling the windings of a shell-type core. Windings can be similarly mounted on core-type cores, in which case the coils are placed on one of the sides. High-voltage core-type transformers sometimes are made with the primary on one core leg and the secondary on the opposite.

to protect it from damage and to prevent the core from rubbing through the insulation. Square-shaped end pieces of fiber or cardboard usually are provided to protect the sides of the windings and to hold the terminal leads in place. High-voltage terminal leads should be enclosed in Empire Cloth tubing or spaghetti.

After the windings are finished the core should be inserted, one lamination at a time. Fig. 7-9 shows the method of building up the core. Alternate "E"-shaped laminations are pushed through the core opening from opposite sides. The "I"-shaped laminations are used to fill the end spaces, butting against the open ends of the "E"-shaped pieces. This method of building up the core ensures a good magnetic path of low reluctance. All laminations should be insulated from each other to prevent eddy currents from flowing. If there is iron rust or a scale on the core material, that will serve the purpose very well — otherwise one side of each piece can be coated with thin shellac. It is essential that the joints in the core be well made and be square and even. After the transformer is assembled, the joints can be hammered up tight using a block of wood between the hammer and the core to prevent damaging the laminations. If the winding form does not fit tightly on the core, small wooden wedges may be driven between it and the core to prevent vibration. Transformers built by the amateur can be painted with insulating varnish or waxed to make them rigid and moistureproof. A mixture of melted beeswax and rosin makes a good impregnating mixture. Melted paraffin should not be used because it has too low a melting point. Double-cotton-covered wire can be coated with shellac as each layer is put on. However, enameled wire should never be treated with shellac as it may dissolve the enamel and hurt the insulation, and it will not dry because the moisture in the shellac will not be absorbed by the insulation. Small transformers can be treated with battery compound after they are wound and assembled. Strips of thin paper between layers of small enameled wire are necessary to keep each layer even and to give added insulation. Thick paper must be avoided since it keeps in the heat generated in the winding so that the temperature may become dangerously high.

Keep watch for shorted turns and layers. If just a single turn should become shorted in the entire winding, the voltage set up in it would

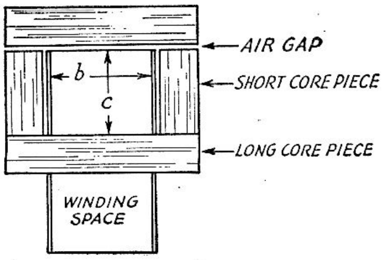


Fig. 7-11 — Core arrangement for filter choke coils. The dimensions *b* and *c* refer to Table 7-II.

cause a heavy current to flow which would burn it up, making the whole transformer useless.

Taps can be taken off as the windings are made if it is desired to have a transformer giving several voltages. Taps should be arranged whenever possible so that they come at the ends of the layers.

After leaving the primary winding connected to the line for several hours it should be only slightly warm. If it draws much current or gets hot there is something wrong. Some short-circuited turns are probably responsible and will continue to cause overheating.

Building Filter Chokes

Filter choke coils may be either of the core or shell type. The laminations should not be interleaved, a butt joint being used instead. An air gap must be provided at some point in the core circuit to prevent magnetic saturation by the d.c. flowing through the winding.

Table 7-II may be used as an approximate guide in winding choke coils. For the same core size, air gap and ampere turns, the inductance will vary approximately as the square of the number of turns. The arrangement of the core is shown in Fig. 7-11 and the dimensions *b* and *c* in the table refer to this sketch. The core may be built from straight pieces as shown or with "L"-shaped laminations.

Voltage Dropping

Series Voltage-Dropping Resistor

Certain plates and screens of the various tubes in a transmitter or receiver often require a variety of operating voltages differing from the output voltage of available power supplies. In most cases, it is not economically feasible to provide a separate power supply for each of the required voltages. If the current drawn by an electrode, or combination of electrodes operating at the same voltage, is reasonably constant, under normal operating conditions, the required voltage may be obtained from a supply of higher voltage by means of a voltage-dropping resistor in series, as shown in Fig. 7-12A. The value of the series resistor, R_1, may be obtained from Ohm's Law, $R = \frac{E_d}{I}$, where E_d is the voltage *drop* required from the supply voltage to the desired voltage and I is the total rated current of the load.

Example: The plate of the tube in one stage and the screens of the tubes in two other stages require an operating voltage of 250. The nearest available supply voltage is 400 and the total of the rated plate and screen currents is 75 ma. The required resistance is

$$R = \frac{400 - 250}{0.075} = \frac{150}{0.075} = 2000 \text{ ohms.}$$

The power rating of the resistor is obtained from P (watts) $= I^2R = (0.075)^2\,(2000) = 11.2$ watts. A 25-watt resistor is the nearest safe rating to be used.

Voltage Dividers

The regulation of the voltage obtained in this manner obviously is poor, since any change in current through the resistor will cause a directly-proportional change in the voltage drop across the resistor. The regulation can be improved somewhat by connecting a second resistor from the low-voltage end of the first to the negative power-supply terminal, as shown in Fig. 7-12B. Such an arrangement constitutes **a voltage divider.** The second resistor, R_2, acts as a constant load for the first, R_1, so that any variation in current from the tap becomes a smaller percentage of the total current through R_1. The heavier the current drawn by the resistors when they alone are connected across the supply, the better will be the voltage regulation at the tap.

Such a voltage divider may have more than

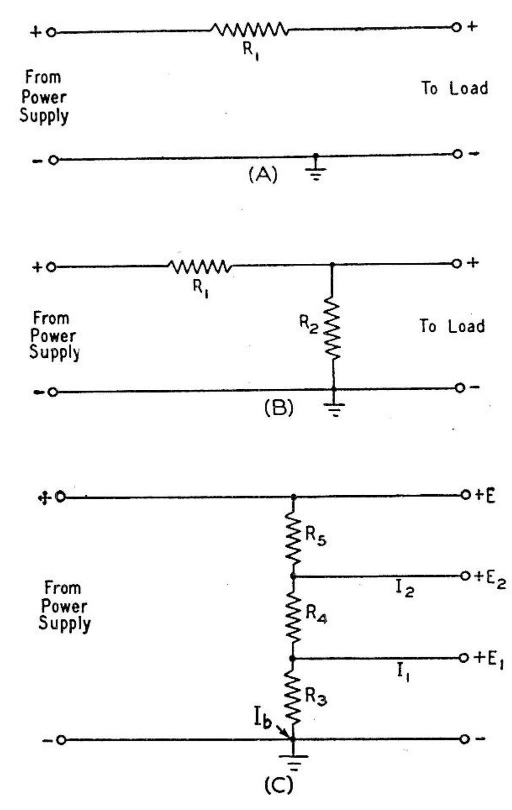


Fig. 7-12 — A — Series voltage-dropping resistor. B — Simple voltage divider. C — Multiple divider circuit.

$$R_3 = \frac{E_1}{I_b};\; R_4 = \frac{E_2 - E_1}{I_b + I_1};\; R_5 = \frac{E - E_2}{I_b + I_1 + I_2}$$

a single tap for the purpose of obtaining more than one value of voltage. A typical arrangement is shown in Fig. 7-12C. The terminal voltage is E, and two taps are provided to give lower voltages, E_1 and E_2, at currents I_1 and I_2 respectively. The smaller the resistance between taps in proportion to the total resistance, the smaller the voltage between the taps. For convenience, the voltage divider in the figure is considered to be made up of separate resistances R_3, R_4, R_5, between taps. R_3 carries only the bleeder current, I_b; R_4 carries I_1 in addition to I_b; R_5 carries I_2, I_1 and I_b. To calculate the resistances required, a bleeder current, I_b, must be assumed; generally it is low compared to the total load current (10 per cent or so). Then the required values can be calculated as shown in Fig. 7-12C, I being in amperes.

The method may be extended to any desired number of taps, each resistance section being calculated by Ohm's Law using the voltage drop across it and the total current through it. The power dissipated by each section may be calculated either by multiplying I and E or I^2 and R.

Voltage Stabilization

Gaseous Regulator Tubes

There is frequent need for maintaining the voltage applied to a low-voltage low-current circuit (such as the oscillator in a superhet receiver or the frequency-controlling oscillator in a transmitter) at a practically constant value, regardless of the voltage regulation of the power supply or variations in load current. In such applications, gaseous regulator tubes (VR105-30, VR150-30, etc.) can be used to good advantage. The voltage drop across such tubes is constant over a moderately wide current range. Tubes are available for regulated voltages of 150, 105, 90 and 75 volts and will carry a maximum current of 40 ma.

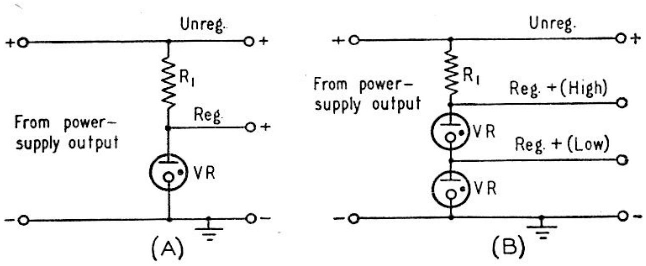


Fig. 7-13 — **Voltage-stabilizing circuits using VR tubes.**

The fundamental circuit for a gaseous regulator is shown in Fig. 7-13A. The tube is connected in series with a **limiting resistor,** R_1, across a source of voltage that must be higher than the **starting** voltage. The starting voltage is about 30 per cent higher than the operating voltage. The load is connected in parallel with the tube. For stable operation, a minimum tube current of 5 to 10 ma. is required. The maximum permissible current with most types is 40 ma.; consequently, the load current cannot exceed 30 to 35 ma. if the voltage is to be stabilized over a range from zero to maximum load current.

The value of the limiting resistor must lie between that which just permits minimum tube current to flow and that which just passes the maximum permissible tube current when there is no load current. The latter value is generally used. It is given by the equation:

$$R = \frac{1000\ (E_s - E_r)}{I}$$

where R is the limiting resistance in ohms, E_s is the voltage of the source across which the tube and resistor are connected, E_r is the rated voltage drop across the regulator tube, and I is the maximum tube current in milliamperes (usually 40 ma.).

Fig. 7-13B shows how two tubes may be used in series to give a higher regulated voltage than is obtainable with one, and also to give two values of regulated voltage. The limiting resistor may be calculated as above, using the sum of the voltage drops across the two tubes for E_r. Since the upper tube must carry more current than the lower, the load connected to the low-voltage tap must take small current. The total current taken by the loads on both the high and low taps should not exceed 30 to 35 milliamperes.

Fig. 7-14 — **A receiver-type supply that delivers 250 volts at 35 ma. and a regulated potential of 150 volts at 15 ma. The amount of current which can be drawn from the 150-volt tap can be made higher or lower by selecting a suitable limiting resistor for the regulator tube; the current output will increase as the resistance value is reduced. The total current drain imposed on the supply should not exceed 50 ma. unless a transformer of greater current capacity is used. The four octal tube sockets on top of the chassis are wired in parallel with screw-type terminals and pin jacks at the rear to provide an assortment of terminals to which external circuits may be connected. The wiring diagram for the supply is shown in Fig. 7-15.**

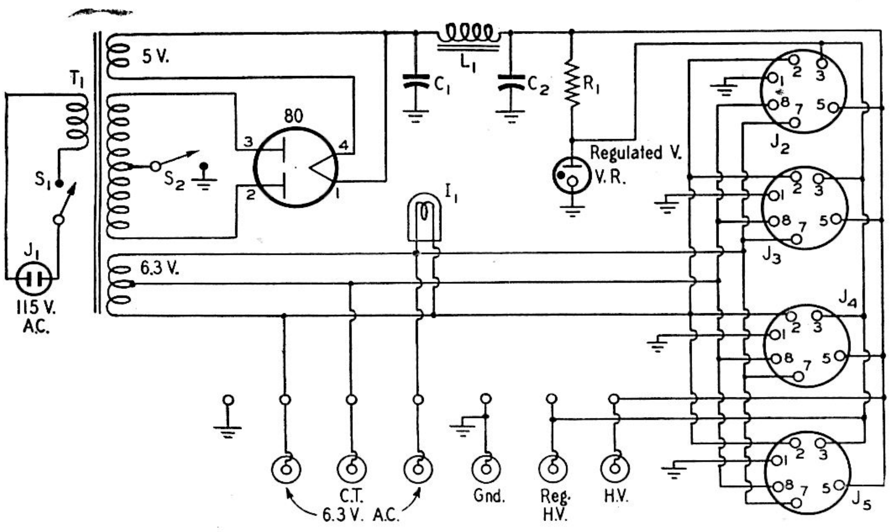


Fig. 7-15 — Circuit diagram of the receiver-type power supply.

C_1, C_2 — 8-μfd. 450-volt electrolytic.
R_1 — 15,000 ohms, 10 watts.
L_1 — 10-hy. 130-ma. 100-ohm filter choke.
I_1 — 6.3-volt pilot lamp.
J_1 — Panel-mounting a.c. plug (Amphenol 61M1).
J_2, J_3, J_4, J_5 — Octal socket.
S_1, S_2 — S.p.s.t. toggle switch.
T_1 — Replacement-type power transformer: 290 volts each side of center-tap, 50 ma.; 5 volts, 3 amp.; 6.3 volts c.t., 2 amp.

A dual-unit electrolytic condenser may be used. The filter choke should have a fairly high current rating as suggested above in order that the output voltage of the supply will not be reduced because of high resistance in the filter. Most available low-current chokes have a d.c. resistance of 500 ohms or more.

Voltage regulation of the order of 1 per cent can be obtained with circuits of this type.

A small receiver-type power supply with a regulated tap is shown in Fig. 7-14 and the circuit diagram appears in Fig. 7-15.

Electronic Voltage Regulation

A voltage-regulator circuit suitable for higher voltages and currents than the gaseous tubes, and also having the feature that the output voltage can be varied over a rather wide range, is shown in Fig. 7-16. A high-gain voltage-amplifier tube, usually a sharp cut-off pentode, is connected in such a way that a small change in the output voltage of the power supply causes a change in grid bias, and thereby a corresponding change in plate current. Its plate current flows through a resistor (R_5), the voltage drop across which is used to bias a second tube — the "regulator" tube — whose plate-cathode circuit is connected in series with the load circuit. The regulator tube therefore functions as an automatically-variable series resistor. Should the output voltage increase slightly the bias on the control tube will become more positive, causing the plate current of the control tube to increase and the drop across R_5 to increase correspondingly. The bias on the regulator tube therefore becomes more negative and the effective resistance of the regulator tube increases, causing the terminal voltage to drop. A decrease in output voltage causes the reverse action. The time lag in the action of the system is negligible, and with proper circuit constants the output voltage can be held within a fraction of a per cent throughout the useful range of load currents and over a wide range of supply voltages.

An essential in this system is the use of a constant-voltage bias source for the control tube. The voltage change which appears at the grid of the tube is the *difference* between a fixed negative bias and a positive voltage which is taken from the voltage divider across the output. To get the most effective control, the negative bias must not vary with plate current. The most satisfactory type of bias is a dry battery of 45 to 90 volts, but a gaseous regulator tube (VR75–30) or a neon bulb of the type without a resistor in the base may be used instead. If the gas tube or neon bulb is used, a negative-resistance type of oscillation may take place at audio frequencies or higher, in which case a condenser of 0.1 μfd. or more should be connected across the tube. A similar condenser between the control-tube grid and cathode also is frequently helpful in this respect.

The variable resistor, R_3, is used to adjust the bias on the control tube to the proper operating value. It also serves as an output-voltage control, setting the value of regulated voltage within the existing operating limits.

The maximum output voltage obtainable is equal to the power-supply voltage minus the minimum drop through the regulator tube. This drop is of the order of 50 volts with the tubes ordinarily used. The maximum current also is limited by the regulator tube; 100 milli-

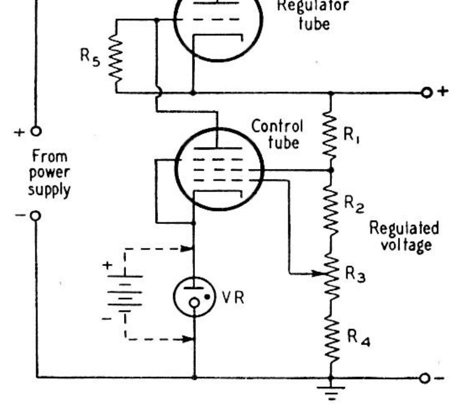


Fig. 7-16 — Electronic voltage regulator. The regulator tube is ordinarily a 2A3 or a number of them in parallel, the control tube a 6SJ7 or similar type. The filament transformer for the regulator tube must be insulated for the plate voltage, and cannot supply current to other tubes when a filament-type regulator tube is used. Typical values: R_1, 10,000 ohms; R_2, 22,000 ohms; R_3, 10,000-ohm potentiometer; R_4, 4700 ohms; R_5, 0.47 megohm.

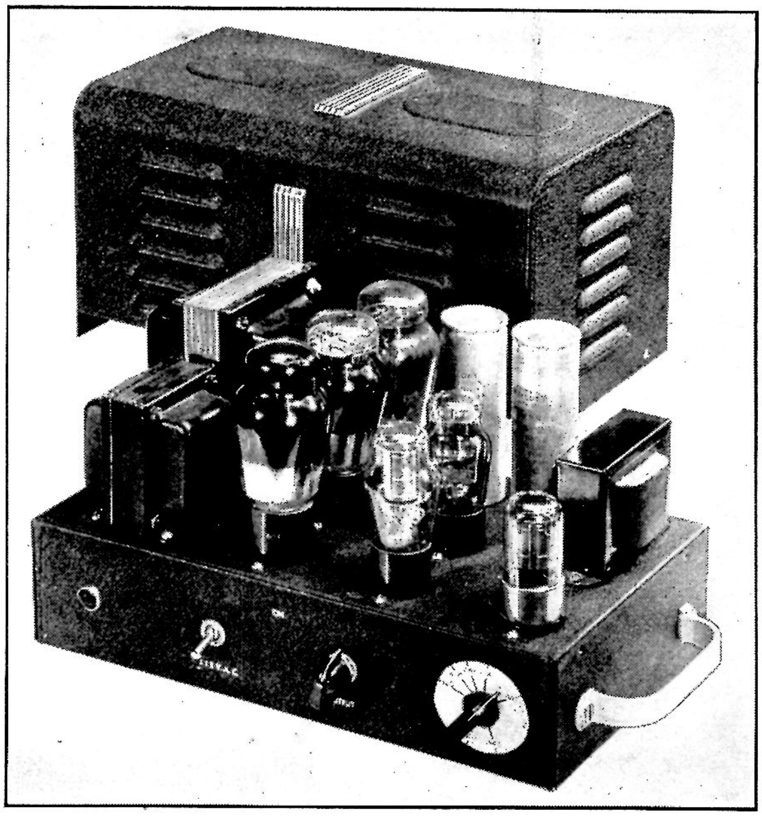


Fig. 7-17 — A heavy-duty regulated power supply capable of delivering 150 ma. over a range of 120 to 340 volts. The output, without regulation, is 435 volts. A negative potential of 150 volts is also available. Two 6B4G tubes are connected in parallel to provide regulation and a 6SJ7GT is used as the control tube. The negative voltage is obtained by connecting a 1-V rectifier tube between the secondary of the power transformer and a VR-150 regulator tube. This front view of the supply shows the placement of the power and filament transformers, tubes, and filter choke. The pilot light, on-off switches, and voltage-control potentiometer are mounted on the front wall of the chassis. The wiring diagram for the supply is shown in Fig. 7-18.

amperes is a safe value for the 2A3. Two or more regulator tubes may be connected in parallel to increase the current-carrying capacity, with no change in the circuit.

A heavy-duty supply of this type is shown in Fig. 7-17 and the circuit is shown in Fig. 7-18. The unit is built on a 7 × 12 × 3-inch chassis. The transformers are to the left in Fig. 7-17. The 83 and 6B4Gs are immediately to the right followed by the 1-V, VR150 and the 6SJ7GT. Condensers C_1 and C_2 and the choke, L_1, are placed along the rear edge.

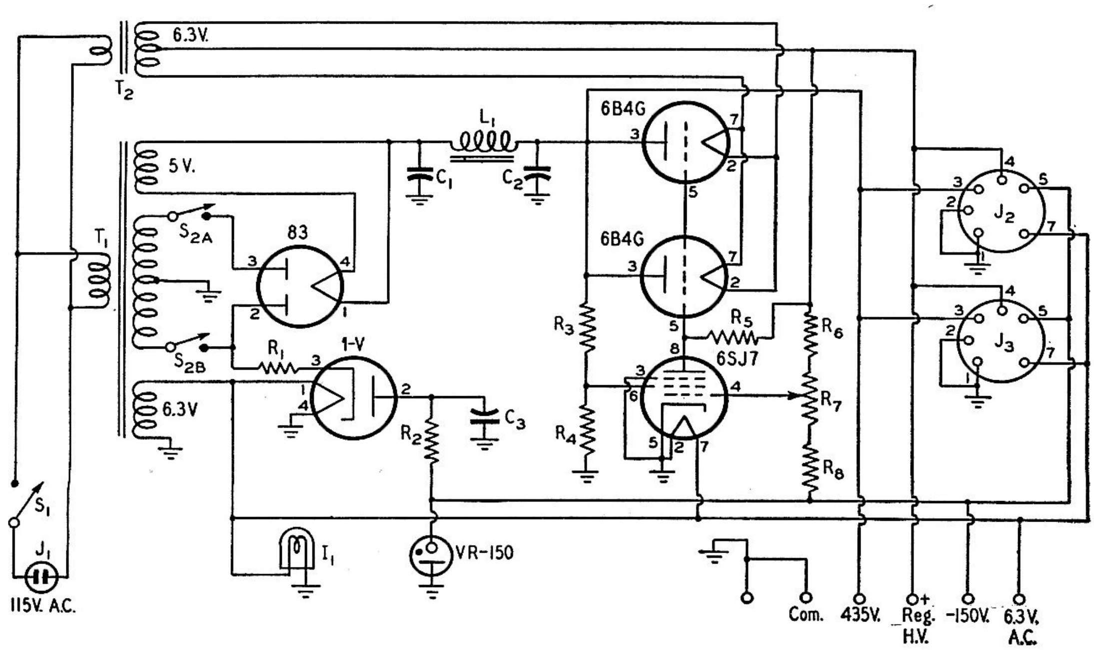


Fig. 7-18 — Circuit diagram of the heavy-duty regulated power supply.

C_1, C_2 — 8-μfd. 600-volt electrolytic.
C_3 — 8-μfd. 450-volt electrolytic.
R_1 — 2500 ohms, 10 watts.
R_2 — 7500 ohms, 10 watts.
R_3 — 50,000 ohms, 10 watts.
R_4 — 25,000 ohms, 2 watts.
R_5 — 0.47 megohm, ½ watt.
R_6 — 0.18 megohm, ½ watt.
R_7 — 75,000-ohm potentiometer.
R_8 — 0.1 megohm, ½ watt.
L_1 — 8-hy. 160-ma. 100-ohm filter choke.
I_1 — 6.3-volt pilot lamp.
J_1 — Panel-mounting a.c. plug (Amphenol 61 M1).
J_2, J_3 — Octal socket.
S_1 — S.p.s.t. toggle switch.
S_2 — 2-gang 2-position ceramic rotary switch.
T_1 — Power transformer: 400 volts a.c. each side of center-tap, 160 ma.; 5 volts, 3 amp.; 6.3 volts, 6 amp.
T_2 — 6.3-volt 2-amp. c.t. filament transformer.

Miscellaneous Power-Supply Circuits

Duplex Plate Supplies

In some cases it may be advantageous economically to obtain two plate-supply voltages from a single power supply, making one or more of the components serve a double purpose. Circuits of this type are shown in Figs. 7-19 and 7-20.

In Fig. 7-19, a bridge rectifier is used to obtain the full transformer voltage, while a connection is also brought out from the center-tap to obtain a second voltage corresponding to half the total transformer secondary voltage. The sum of the currents drawn from the two taps should not exceed the d.c. ratings of the rectifier tubes and transformer. Filter values for each tap are computed separately.

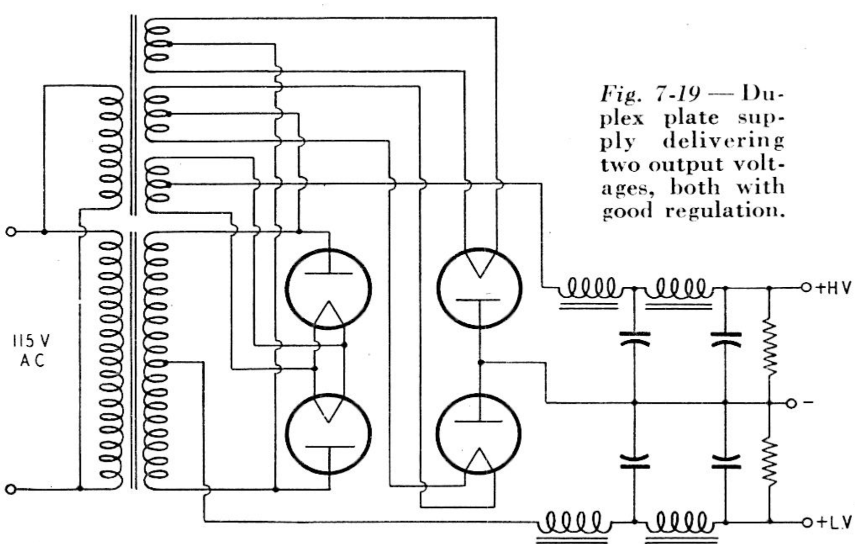


Fig. 7-19 — Duplex plate supply delivering two output voltages, both with good regulation.

Fig. 7-20 shows how a transformer with multiple secondary taps may be used to obtain both high and low voltages simultaneously. A separate full-wave rectifier is used at each pair of taps. The filter chokes are placed in the common negative lead, but separate filter condensers are required. The sum of the currents drawn from each pair of taps must not exceed the transformer rating, and the chokes must carry the total load current. Each bleeder should have a value in ohms 1000 times the maximum rated inductance in henrys of the swinging choke, L_1, for best regulation. A power supply of this type is shown in Figs. 7-21 and 7-22. In this case two sets of chokes are used to divide the load current.

Transformerless Plate Supplies

The line voltage is rectified directly, without a step-up power transformer, for certain applications (such as some types of receivers) where the low voltage so obtained is satisfactory. A simple power supply of this variety, often called the "a.c.-d.c." type, is shown in Fig. 7-23. Rectifier tubes for this purpose have heaters operating at relatively high voltages (12.6, 25, 35, 45, 50, 70 or 115 volts), which can be connected across the a.c. line in series with other tube heaters and/or a resistor, R, of suitable value to limit the heater current to the rated value for the tubes.

The half-wave circuit shown has a fundamental ripple frequency equal to the line frequency and hence requires more inductance and capacitance in the filter for a given ripple percentage than the full-wave rectifier. A condenser-input filter generally is used. The input condenser should be at least 16 μfd. and preferably 32 or 40 μfd., to keep the output voltage high and to improve voltage regulation. Frequently a second filter section is required to provide additional smoothing.

No ground connection can be used on the power supply unless the grounded side of the power line is connected to the grounded side of the supply. Receivers using an a.c.-d.c. supply usually are grounded through a low-capacitance (0.05 μfd.) condenser, to avoid short-circuiting the line should the line plug be inserted in the socket the wrong way.

Voltage-Multiplier Circuits

Transformerless voltage-multiplier circuits make it possible to obtain d.c. voltages higher than the line voltage without using step-up transformers. By alternately charging two or more condensers to the peak line voltage and allowing them to discharge in series, the total output voltage becomes the sum of the voltages appearing across the individual condensers. The required switching operation is performed automatically by rectifiers associated with the condensers provided they are connected in the proper relationship.

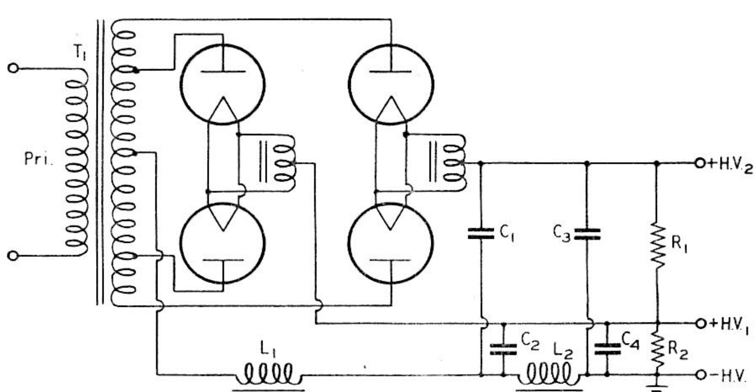


Fig. 7-20 — Power supply in which a single transformer and set of chokes serve for two different output voltages.

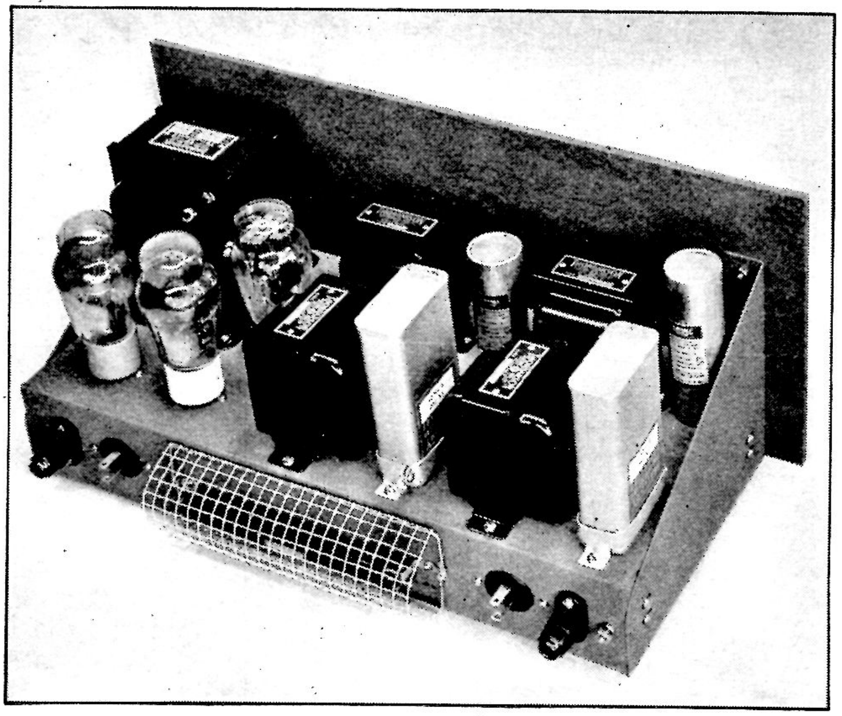


Fig. 7-21 — This power supply makes use of a combination transformer and a dual filter system, delivering 1000 volts at 125 ma. and 400 volts at 150 ma., or 400 volts and 750 volts simultaneously, depending upon the transformer selected. The circuit diagram is given in Fig. 7-22. The 1000-volt bleeder resistor is mounted on the rear edge of the chassis, with a protective guard made of a piece of galvanized fencing material to provide ventilation. Millen safety terminals are used for the two high-voltage terminals. Ceramic sockets should be used for the 866 Jrs. The chassis measures 8 × 17 × 3 inches and the standard rack panel is 8¾ inches high.

A half-wave voltage doubler is shown in Fig. 7-24A. In this circuit when the plate of the lower diode is positive the tube passes current, charging C_1 to a voltage equal to the peak line voltage less the tube drop. When the line polarity reverses at the end of the half-cycle the voltage resulting from the charge in C_1 is added to the line voltage, the upper diode meanwhile similarly charging C_2. C_2, however, does not receive its full charge because it begins discharging into the load resistance as soon as the upper diode becomes conductive. For this reason, the output is somewhat less than twice the line peak voltage. As with any half-wave rectifier, the ripple frequency corresponds to the line frequency.

The full-wave voltage doubler at B is more popular than the half-wave type. One diode charges C_1 when the polarity between its plate and cathode is positive while the other section charges C_2 when the line polarity reverses. Thus each condenser is charged separately to the same d.c. voltage, and the two discharge in series into the load circuit. The ripple frequency with the full-wave doubler is twice the line frequency. The voltage regulation is inherently poor and depends upon the capacitances of C_1 and C_2, being better as these capacitances are made larger. A supply with 16 μfd. at C_1 and C_2 will have an output voltage of approximately 300 at light loads, as shown in Fig. 7-25.

The voltage tripler in Fig. 7-24C comprises four diodes in a full-wave doubler and half-wave rectifier combination. The ripple frequency is that of the line as in a half-wave circuit, because of the unbalanced arrangement, but the output voltage of the combination is very nearly three times the line voltage, and the regulation is better than in other voltage-multiplier arrangements, as shown in Fig. 7-25.

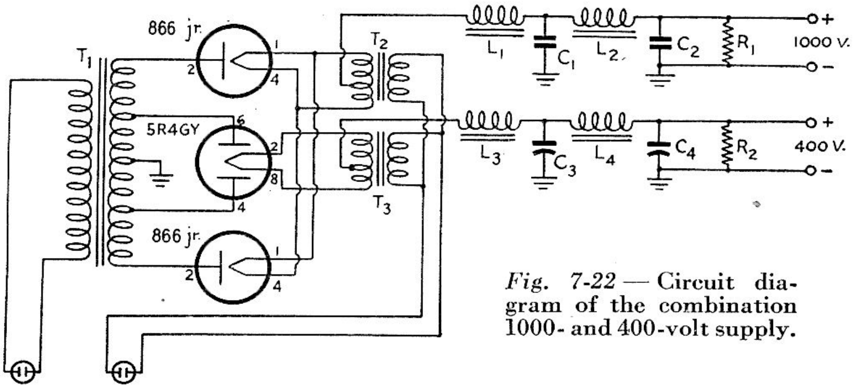


Fig. 7-22 — Circuit diagram of the combination 1000- and 400-volt supply.

C_1, C_2 — 2-μfd. 1000-volt paper (Mallory TX805).
C_3 — 4-μfd. 600-volt electrolytic (C-D 604).
C_4 — 8-μfd. 600-volt electrolytic (C-D 608).
R_1 — 20,000 ohms, 75 watts.
R_2 — 20,000 ohms, 25 watts.
L_1, L_3 — 5/20-hy. swinging choke, 150 ma. (Thordarson T-19C39).
L_2, L_4 — 12-hy. smoothing choke, 150 ma. (Thordarson T-19C46).
T_1 — High-voltage transformer, 1075 and 500 volts r.m.s. each side, 125- and 150-ma. simultaneous current rating (Thordarson T-19P57).
T_2 — 2.5 volts, 5 amp. (Thordarson T-19F88).
T_3 — 5 volts, 4 amp. (Thordarson T-63F99).

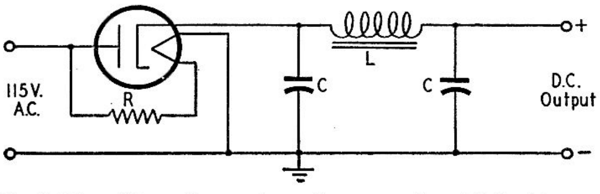


Fig. 7-23 — Transformerless plate supply with half-wave rectifier. Other heaters are connected in series with *R*.

Fig. 7-24D is a voltage quadrupler with two half-wave doublers connected in series, discharging the sum of the accumulated voltages in the associated condensers into the filter input. The quadrupler is by no means the ultimate limit in voltage multiplication. Practical power supplies have been built using up to twelve doubler stages in series.

Selenium rectifiers can be used in these circuits to arrive at a very compact and lightweight power unit for portable work.

In the circuits of Fig. 7-24, C_2 should have a working voltage rating of 350 volts and C_1 of 250 volts for a 115-volt line. Their capacitances

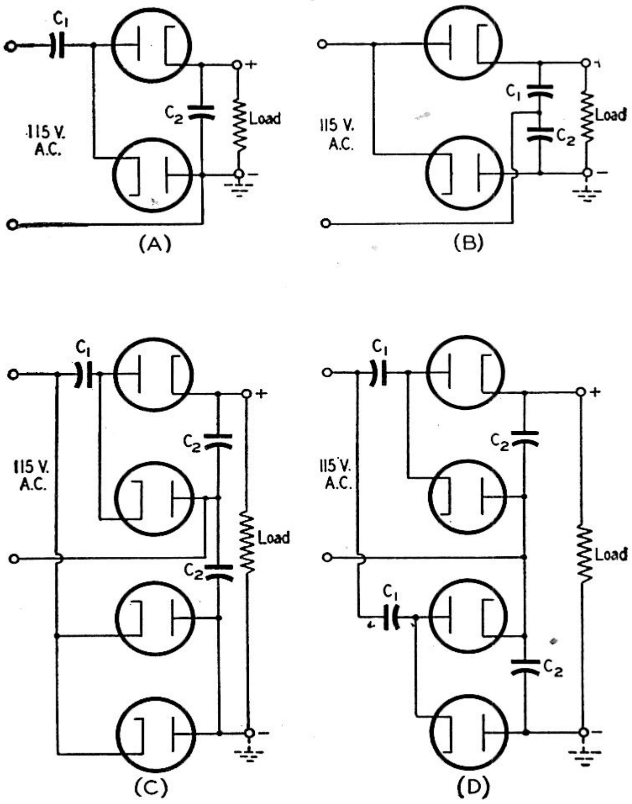


Fig. 7-24 — **Voltage-multiplier circuits. A, half-wave voltage doubler. B, full-wave doubler. C, tripler. D, quadrupler. Dual-diode rectifier tubes may be used.**

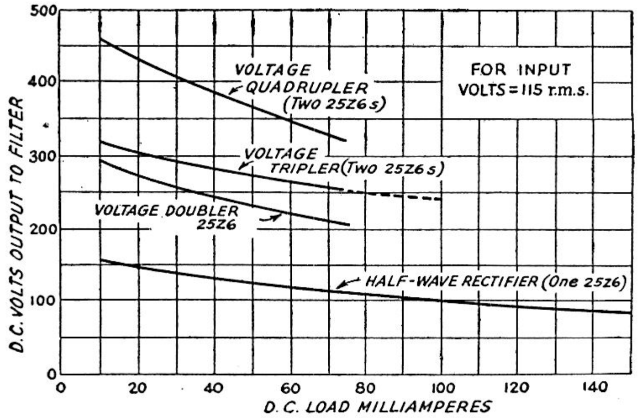


Fig. 7-25 — **Curves showing the d.c. output voltage and the regulation under load for voltage-multiplier circuits.**

should be at least 16 μfd. each. Subsequent filter condensers must, however, withstand the *peak* total output voltage — 450 volts in the case of the tripler and 600 for the quadrupler.

No direct ground can be used on any of these supplies or on associated equipment. If an r.f. ground is made through a condenser the capacitance should be small (0.05 μfd.), since it is in shunt from plate to cathode of one rectifier. In addition to the fact that care must be exercised in avoiding direct ground connection or observation of proper line polarization to prevent short-circuiting the power line, transformerless supplies frequently give rise to other difficulties. For this reason their application is recommended only where economy or space is a prime consideration. A regenerative receiver operating from a transformerless supply has a greater tendency toward "tunable hum" than when operating from a supply equipped with a transformer. Apparatus operating from a transformerless supply often is the source of a rough hum when a near-by broadcast receiver is tuned to a carrier. A line filter in the supply, or a switch of line polarization, when this is permissible, sometimes will eliminate trouble of this type, but sometimes only the use of a transformer will be effective.

Bias Supplies

As discussed in Chapter Six, the chief function of a bias supply for the r.f. stages of a transmitter is that of providing protective bias, although under certain circumstances, a bias supply, or pack, as it is sometimes called, can provide the operating bias if desired.

Simple Bias Packs

Fig. 7-26A shows the diagram of a simple bias supply. R_1 should be the recommended grid leak for the amplifier tube. No grid leak should be used in the transmitter with this type of supply. The output voltage of the supply, when amplifier grid current is not flowing, should be some value between the bias required for plate-current cut-off and the recommended operating bias for the amplifier tube. The transformer peak voltage (1.4 times the r.m.s. value) should not exceed the recommended operating-bias value, otherwise the output voltage of the pack will soar above the operating-bias value when rated grid current flows.

This soaring can be reduced to a considerable extent by the use of a voltage divider across the transformer secondary, as shown at B. Such a system can be used when the transformer voltage is higher than the operating-bias value. The tap on R_2 should be adjusted to give amplifier cut-off bias at the output terminals. The lower the total value of R_2, the less the soaring will be when grid current flows.

A full-wave circuit is shown in Fig. 7-26C. R_3 and R_4 should have the same total resistance and the taps should be adjusted symmetrically. In all cases, the transformer must be designed to furnish the current drawn by these resistors plus the current drawn by R_1.

Regulated Bias Supplies

The inconvenience of the circuits shown in Fig. 7-26 and the difficulty of predicting values in practical application can be avoided in most cases by the use of gaseous voltage-regulator tubes across the output of the bias supply, as shown in Fig. 7-27A. A VR tube with a voltage rating anywhere between the biasing-voltage value which will reduce the input to the amplifier to a safe level when excitation is removed, and the operating value of bias, should be chosen. R_1 is adjusted, without amplifier excitation, until the VR tube just ignites and draws about 5 ma. Any additional voltage to bring the bias up to the operating value when excitation is applied can be obtained from a grid leak, as discussed in Chapter Six. If the VR-tube voltage rating is the same as the required operating voltage, no grid leak need be used.

Each VR tube will handle 40 ma. of grid current. If the grid current exceeds this value under any condition, similar VR tubes should be added in parallel, as shown in Fig. 7-27B, for each 40 ma., or less, of additional grid current. The resistors R_2 are for the purpose of helping to maintain equal currents through each VR tube.

If the voltage rating of a single VR tube is not sufficiently high for the purpose, other VR tubes may be used in series (or series-parallel if required to satisfy grid-current requirements) as shown in Fig. 7-27C and D.

If a single value of fixed bias will serve for more than one stage, the biasing terminal of each such stage may be connected to a single supply of this type, provided only that the total grid current of all stages so connected does not exceed the current rating of the VR tube or tubes. Alternatively, other separate VR-tube branches may be added in any desired combination to the same supply, as shown in Fig. 7-27E, to suit the requirements of each stage.

Providing the VR-tube current rating is not exceeded, a series arrangement may be tapped for lower voltage, as shown at F.

Other Sources of Biasing Voltage

In some cases, it may be convenient to obtain the biasing voltage from a source other than a separate supply. A half-wave rectifier may be connected with reversed polarization to obtain biasing voltage from a low-voltage plate supply, as shown in Fig. 7-28A. In another arrangement, shown at B, a spare filament winding can be used to operate a filament transformer of similar voltage rating in reverse to obtain a voltage of about 130 from the winding that is customarily the primary. This will be sufficient to operate a VR75 or VR90. If a selenium rectifier is used, no additional filament voltage for the bias rectifier is needed.

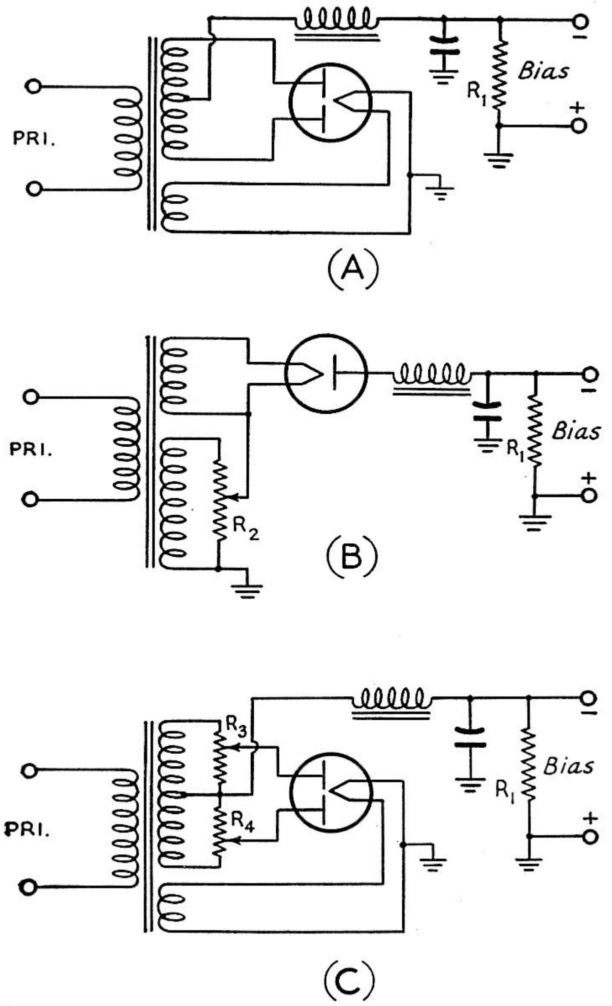


Fig. 7-26 — **Simple bias-supply circuits. In A, the peak transformer voltage must not exceed the operating value of bias. The circuits of B (half-wave) and C (full-wave) may be used to reduce transformer voltage to the rectifier. R_1 is the recommended grid-leak resistance.**

A bias supply of any of the types discussed requires relatively little filtering, if the peak output-terminal voltage does not approach the operating-bias value, because the effect of the supply is entirely or largely "washed out" when grid current flows.

● FILAMENT SUPPLY

Except for tubes designed for battery operation, the filaments or heaters of vacuum tubes used in both transmitters and receivers are universally operated on alternating current obtained from the power line through a step-down transformer delivering a secondary voltage equal to the rated voltage of the tubes used. The transformer should be designed to carry the current taken by the number of tubes which may be connected in parallel across it. The filament or heater transformer generally is center-tapped, to provide a balanced circuit for eliminating hum.

For medium- and high-power r.f. stages of

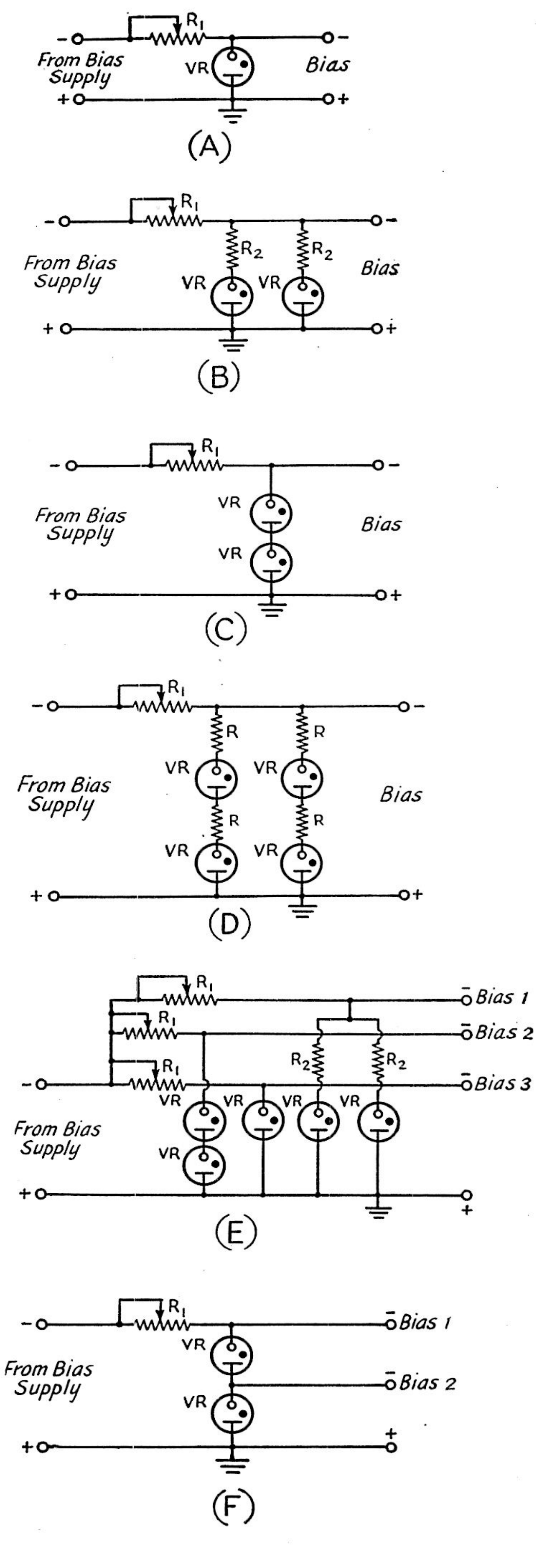


Fig. 7-27 — Illustrating the use of VR tubes in stabilizing protective-bias supplies. R_1 is a resistor whose value is adjusted to limit the current through each VR tube to 5 ma. before amplifier excitation is applied. R and R_2 are current-equalizing resistors of 50 to 100 ohms.

transmitters, and for high-power audio stages, it is desirable to use a separate filament transformer for each section of the transmitter, installed near the tube sockets. This avoids the necessity for abnormally large wires to carry the total filament current for all stages without appreciable voltage drop. Maintenance of rated filament voltage is highly important, especially with thoriated-filament tubes, since under- or over-voltage may reduce filament life.

● LINE-VOLTAGE ADJUSTMENT

In certain communities trouble is sometimes experienced from fluctuations in line voltage. Usually these fluctuations are caused by a variation in the load on the line and, since most of the variation comes at certain fixed times of the day or night, such as the times when lights are turned on and off at evening, they may be taken care of by the use of a manually-operated compensating device. A simple arrangement is shown in Fig. 7-29A. A toy transformer is used to boost or buck the line voltage as required. The transformer should have a tapped secondary varying between 6 and 20 volts in steps of 2 or 3 volts and its secondary should be capable of carrying the full load current of the entire transmitter, or that portion of it fed by the toy transformer.

The secondary is connected in series with the line voltage and, if the phasing of the windings is correct, the voltage applied to the primaries of the transmitter transformers can be brought up to the rated 115 volts by setting the toy-transformer tap switch on the right tap. If the phasing of the two windings of the toy transformer happens to be reversed, the voltage will be reduced instead of increased. This connection may be used in cases where the line voltage may be above 115 volts. This method is preferable to using a resistor in the primary of a power transformer since it does not affect the voltage regulation as seriously. The circuit of 7-29B illustrates the use of a variable transformer (Variac) for adjusting line voltage to the desired value.

Another scheme by which the primary voltage of each transformer in the transmitter may be adjusted to deliver the desired secondary voltage, with a master control for compensating for changes in line voltage, is described in Fig. 7-30.

This arrangement has the following features:

1) Adjustment of the switch S_1 to make the voltmeter read 105 volts automatically adjusts all transformer primaries to the predetermined correct voltage.

2) The necessity for having all primaries work at the same voltage is eliminated. Thus, 110 volts can be applied to the primary of one transformer, 115 to another, etc.

3) Independent control of the plate transformer is afforded by the tap switch S_2. This permits power-input control and does not require an extra autotransformer.

CONSTRUCTION OF POWER SUPPLIES

The length of most leads in a power supply is unimportant so that the arrangement of components from this consideration is not a factor in construction. More important are the points of good high-voltage insulation, adequate conductor size for filament wiring, proper ventilation for rectifier tubes and — most important of all — safety to the operator. Exposed high-voltage terminals or wiring which might be bumped into accidentally should not be permitted to exist. They should be covered

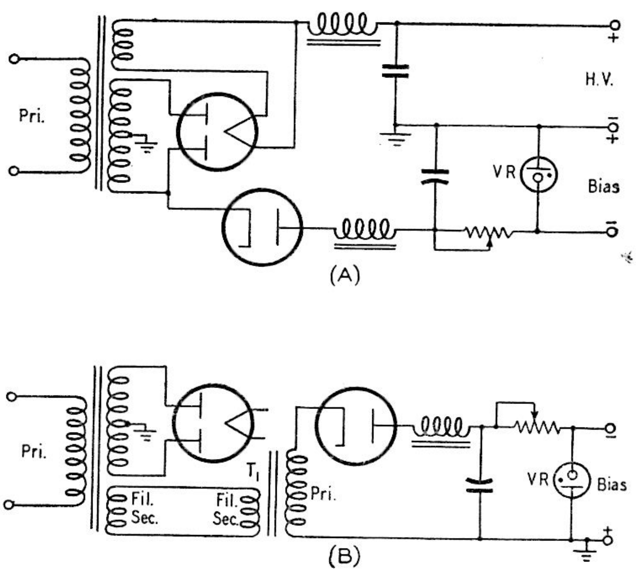


Fig. 7-28 — **Convenient means of obtaining biasing voltage. A — From a low-voltage plate supply. B — From spare filament winding. T_1 is a filament transformer, of a voltage output similar to that of the spare filament winding, connected in reverse to give 115 volts r.m.s. output. If cold-cathode or selenium rectifiers are used, no additional filament supply is required.**

with adequate insulation or placed inaccessible to contact during normal operation and adjustment of the transmitter.

Rectifier filament leads should be kept short to assure proper voltage at the rectifier socket, and the sockets should have good insulation and adequate contact surface. Plate leads to mercury-vapor tubes should be kept short to minimize the radiation of noise.

Where high-voltage wiring must pass through a metal chassis, grommet-lined clearance holes will serve for voltages up to 500 or 750, but ceramic feed-through insulators should be used for higher voltages. Bleeder and voltage-dropping resistors should be placed where they are open to air circulation. Placing them in confined space reduces the power rating.

It is highly preferable from the standpoint of operating convenience to have separate filament transformers for the rectifier tubes, rather than to use combination transformers, such as those used in receivers. This permits the plate voltage to be switched on without the

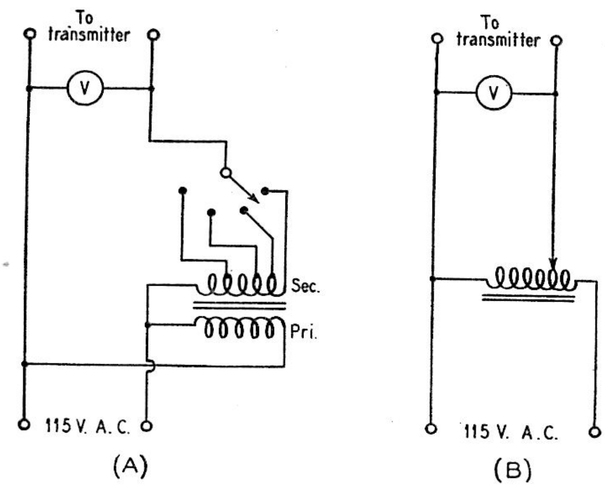


Fig. 7-29 — **Two methods of transformer primary control. At A is a tapped toy transformer which may be connected so as to boost or buck the line voltage as required. At B is indicated a variable transformer or autotransformer (Variac) in series with the transformer primaries.**

necessity for waiting for rectifier filaments to come up to temperature after each time the high voltage has been turned off.

A bleeder resistor with a power rating giving a considerable margin of safety should be used across the output of all transmitter power supplies so that the filter condensers will be discharged when the high-voltage transformer is turned off. To guard against the possibility of danger to the operator should the bleeder resistor burn out without his knowledge, a relay with its winding connected in parallel with the high-voltage transformer primary and its contacts in series with a 1000-ohm resistor across the output of the power supply sometimes is used. The relay should be arranged so that the contacts open when the relay is energized.

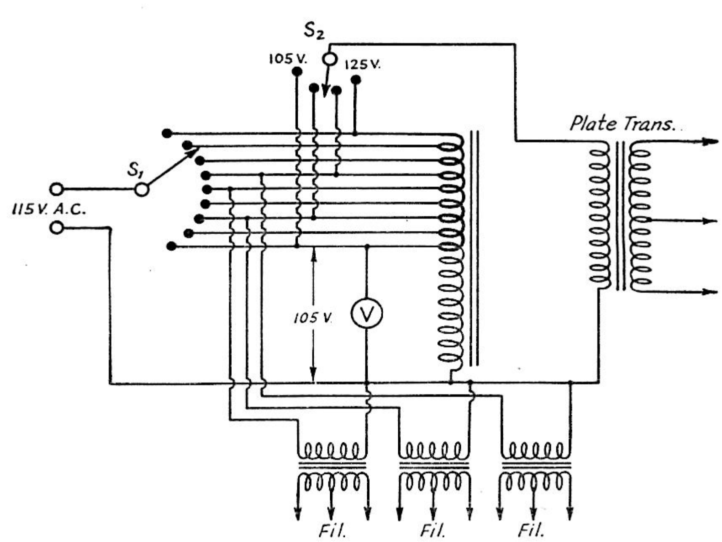


Fig. 7-30 — **With this circuit, a single adjustment of the tap switch S_1 places the correct primary voltage *on all* transformers in the transmitter. Information on constructing a suitable autotransformer at negligible cost is contained in the text. The light winding represents the regular primary winding of a revamped transformer, the heavy winding the voltage-adjusting section.**

Control Systems

A well-planned system of controlling power-supply equipment is not only a matter of safety to the operator but also a factor in the convenient and efficient operation of the station while on the air.

The diagrams of power supplies suggested for use with transmitters described in Chapter Six include a suitable control system for each. In general principle they are the same, varying only in the details of special considerations for the specific case at hand.

As a minimum, except possibly in the case of simple transmitters employing a single power supply, there should be a filament switch that controls simultaneously all filaments in the power supplies as well as in the transmitter. This switch sometimes also controls the bias supply if one is used. There should be a separate switch for each plate-voltage supply and one that controls all plate supplies simultaneously. This latter switch is the "stand-by" switch by which power to the transmitter may be turned off quickly during receiving periods. The switches should be arranged in series, so that the plate voltage cannot be applied before filament and bias voltages have been turned on.

Figs. 7-31 and 7-32 show a complete control system for a multistage c.w. and 'phone transmitter. Indicator lamps, proper line fusing and automatic protective features are included. These circuits are more or less basic and will cover all requirements of most transmitters. They are similar except that the circuit of Fig. 7-31 is for use with a 115-volt line, while that of Fig. 7-32 is suitable for a 3-wire 220-volt line.

The system starts out with a polarized plug, P_1, for the line connection. The side of the line indicated should be the grounded side. One or more utility outlets which are not affected by the switching may be connected at J_1. The line-fuse indicator lamp, I_1, should not light unless the line fuse, F_1, is blown.

Turning on S_1 at the transmitter or S_2 at the operating position turns on all r.f. and r.f. power-supply filament transformers, which are connected in parallel at T_1, and the indicator lamp, I_2, lights. If the 'phone-c.w. switch, S_3, is thrown to the 'phone position, all audio and a.f.-supply filament transformers, which are connected in parallel at T_2, will also be turned on by S_1 and the 'phone indicator lamp, I_3, will light. If S_3 is in the c.w. position, the c.w. indicator lamp, I_4, will light, and the a.f. power supplies will be cut off. S_{3B} short-circuits the modulation-transformer secondary.

If the safety interlock switch, S_4, is closed, the bias-supply plate and filament voltages (T_3) will be turned on. As soon as the rectifier of this supply (an indirectly-heated rectifier such as a 6X5G) warms up, and the supply delivers full voltage, the delay relay, Ry_2, will close, extinguishing the bias-indicator lamp, I_7, and setting up the circuit for the plate-supply relay, Ry_3. The time which the bias rectifier takes to come up to temperature provides the required delay between the application of filament voltage and the time when it becomes possible to turn on the plate voltages on the r.f. and a.f. tubes.

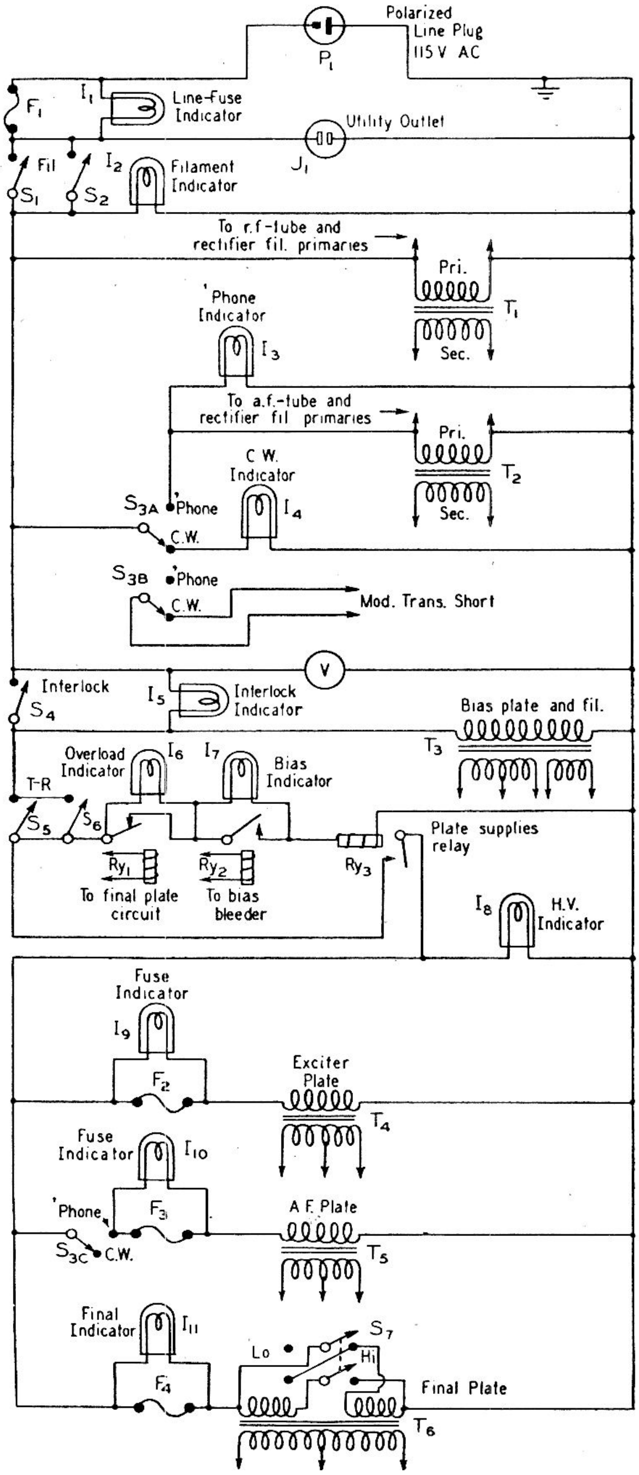


Fig. 7-31 — 115-volt control circuit used at W4DCW. All switches, except S_3, may be 5 amp. S_3 should be a *ceramic rotary* switch. The indicator lamps are 5/8-in. panel type.

With the contacts of Ry_2 closed, the plate-supply relay, Ry_3, can be operated by closing the transmit-receive switch, S_5, or its extension, S_6, at the operating position. Ry_3 turns on all plate voltages, lights the high-voltage indicator, I_8, and the transmitter is ready for operation.

Should the interlock switch S_4 be open, the indicator lamp, I_5, will light. This lamp, in series with the primary of the bias-supply transformer, has sufficient resistance to prevent lighting of the rectifier filament and thus voltage output from the bias pack, and therefore Ry_2 does not close so that Ry_3 cannot be operated and high voltage cannot be applied, making the transmitter safe so long as the interlock switch is open.

Ry_1 is an overload breaker which breaks off the line to the plate-supply relay whenever the plate current to the final amplifier exceeds a value to which it has been set. The winding of this relay is in the filament center-tap of the final-amplifier tubes. It should be of the reset type so that it will not continue to close and open repeatedly until S_5 is opened as it would do if it were not of the reset type. I_9, I_{10} and I_{11} are fuse-indicator lamps which light when their associated fuses blow. S_7 is a switch for changing to low power for tune-up. This system is, of course, applicable only to transformers with dual primaries. With single-primary transformers a switch can be arranged to short-circuit a 150- to 200-watt lamp connected in series with the primary winding for reducing power.

The only switch which need be thrown for stand-by is S_5. Only S_3 need be thrown in changing from 'phone to c.w. No other switching is necessary.

The only difference in Fig. 7-32 is that the filament and bias transformers are operated from one side of the line, while the plate supplies are operated from the other. This connection is preferable whenever it can be applied, since it helps to equalize the loads drawn from each side of a 3-wire line. For high power, or in cases where light blinking is experienced, the plate transformer, T_6, should have a 220-volt primary connected to the two outside wires.

All indicator lamps and panel switches should be marked plainly so that there will be no question as to which circuit each belongs, to facilitate switching and localizing of trouble.

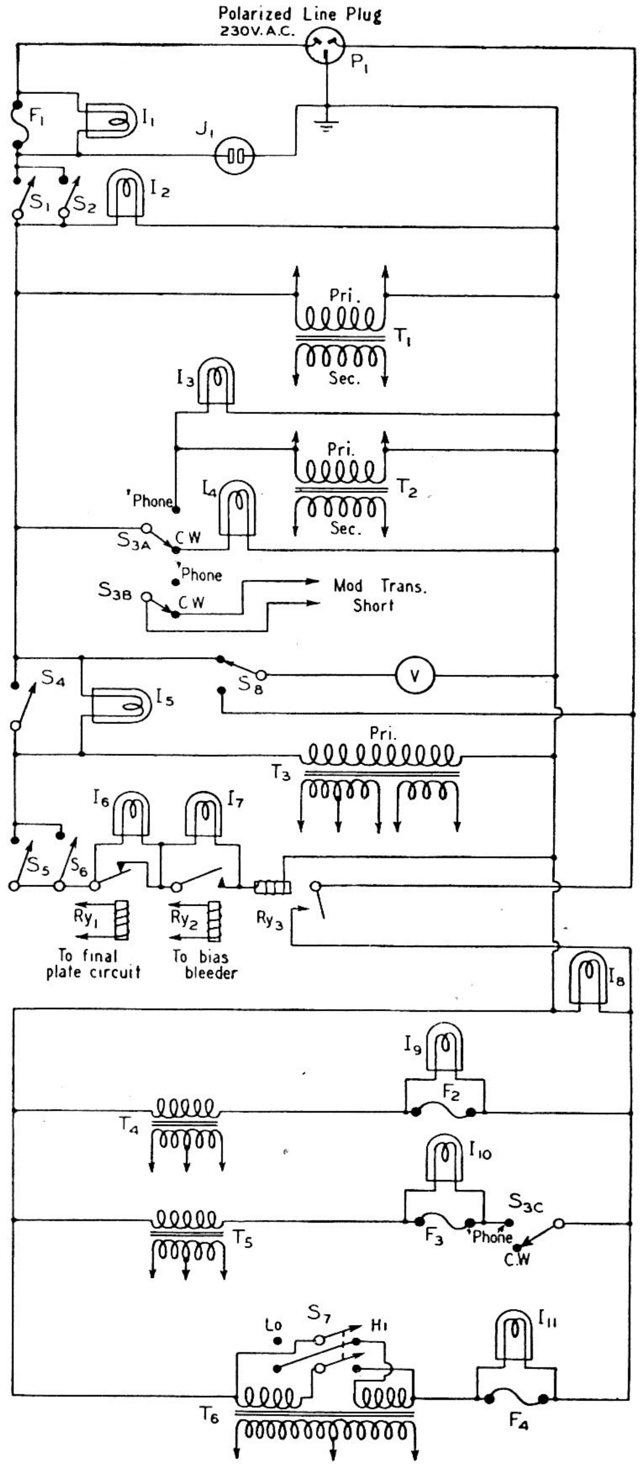


Fig. 7-32 — 230-volt control circuit. Ry_1 is an overload type, Ry_2 is a light-current relay and Ry_3 is a 115-volt a.c. relay with heavy contacts.

Emergency and Independent Power Sources

Emergency power supply which operates independently of a.c. lines is available, or can be built in a number of different forms, depending upon the requirements of the service for which it is intended.

The most practical supply for the average individual amateur is one that operates from a 6-volt car storage battery. Such a supply may take the form of a small motor generator (often called a genemotor), a rotary converter or a vibrator-transformer-rectifier combination.

Dynamotors

A dynamotor differs from a motor generator in that it is a single unit having a double armature winding. One winding serves for the driving motor, while the output voltage is taken from the other. Dynamotors usually are

TABLE 7-III — DYNAMOTORS

Manufacturer's Type No.			Input		Output		Weight
Carter	Eicor	Duty	Volts	Amp.	Volts	Ma.	Lb.
210A		Continuous	6	6.1	200	100	7
	3412[1]		6	4.2	200	100	4⅝
	3415[1]		6	6.1–9.7	200–300	100	5
MA250		Continuous	6	4.2	250	50	4¾
251A		Continuous	6	7.9	250	100	7
MA301		Continuous	6	9.0	300	100	4¾
315A			6	13.4	300	150	7⅞
320A			6	18.2	300	200	9½
	3420[1]		6	18.2 15.0	300 350	200 150	5¾
	41S20[1]		6	31.0 40.0	400 600	300 250	7⅞
351A			6	10	350	100	6½
MAS355		Intermittent	6	15	350	150	4¾
352AR			6	22	350	200	9½
401A			6	13	400	100	7⅞
			6	14.2	400	125	9¼
415A		Continuous	6	18.2	400	150	8
420A		Continuous	6	23.4	400	200	10
425A			6	30	400	225	9½
AF450		Continuous	6	27	400	250	13
AF430		Continuous	6	31	400	300	13
520AS		Intermittent	6	28	500	200	10
650AS		Intermittent	6	39	600	250	10
VSF630		Intermittent	5.5	56	600	300	13

[1] Characteristics are typical for frame size given.

operated from 6-, 12-, 28- or 32-volt storage batteries and deliver from 300 to 1000 volts or more at various current ratings.

Genemotor is a term popularly used when making reference to a dynamotor designed especially for automobile-receiver, sound-truck and similar applications. It has good regulation and efficiency, combined with economy of operation. Standard models of genemotors have ratings ranging from 135 volts at 30 ma. to 300 volts at 200 ma. or 600 volts at 300 ma. (See Table 7-III.) The normal efficiency averages around 50 per cent, increasing to better than 60 per cent in the higher-power units. The voltage regulation of a genemotor is comparable to that of well-designed a.c. supplies.

Successful operation of dynamotors and genemotors requires heavy, direct leads, mechanical isolation to reduce vibration, and thorough r.f. and ripple filtration. The shafts and bearings should be thoroughly "run in" before regular operation is attempted, and thereafter the tension of the bearings should be checked occasionally to make certain that no looseness has developed.

In mounting the genemotor, the support should be in the form of rubber mounting blocks, or equivalent, to prevent the transmission of vibration mechanically. The frame of the genemotor should be grounded through a heavy flexible connector. The brushes on the high-voltage end of the shaft should be by-passed with 0.002-μfd. mica condensers to a common point on the genemotor frame, preferably to a point inside the end cover close to the brush holders. Short leads are essential. It may prove desirable to shield the entire unit, or even to remove the unit to a distance of three or four feet from the receiver and antenna lead.

When the genemotor is used for receiving, a filter should be used similar to that described for vibrator supplies. A 0.01-μfd. 600-volt (d.c.) paper condenser should be connected in shunt across the output of the genemotor, followed by a 2.5-mh. r.f. choke in the positive high-voltage lead. From this point the output should be run to the receiver power terminals through a smoothing filter using 4- to 8-μfd. condensers and a 15- or 30-henry choke having low d.c. resistance.

A.C.-D.C. Converters

In some instances it is desirable to utilize existing equipment built for 115-volt a.c. operation. To operate such equipment with any of the power sources outlined above would require a considerable amount of rebuilding. This can be obviated by using a rotary converter capable of changing the d.c. from 6-, 12- or 32-volt batteries to 115-volt 60-cycle a.c. Such converter units are built to deliver outputs ranging from 40 to 300 watts, depending upon the battery power available.

The conversion efficiency of these units averages about 50 per cent. In appearance and operation they are similar to genemotors of equivalent rating. The over-all efficiency of the converter will be lower, however, because of losses in the a.c. rectifier-filter circuits and the necessity for converting heater (which is supplied directly from the battery in the case of the genemotor) as well as plate power.

Vibrator Power Supplies

The vibrator type of power supply consists of a special step-up transformer combined with a vibrating interrupter (*vibrator*). When the unit is connected to a storage battery, plate power is obtained by passing current from the battery through the primary of the transformer. The circuit is made and reversed rapidly by the vibrator contacts, interrupting the current at regular intervals to give a changing magnetic field which induces a voltage in the secondary. The resulting square-wave d.c. pulses in the primary of the transformer cause an alternating voltage to be developed in the secondary. This high-voltage a.c. in turn is rectified, either by a vacuum-tube rectifier or by an additional synchronized pair of vibrator contacts. The rectified output is pulsating d.c., which may be filtered by ordinary means. The smoothing filter can be a single-section affair, but the filter output capacitance should be fairly large — 16 to 32 μfd.

Fig. 7-33 shows the two types of circuits. At A is shown the *nonsynchronous* type of vibrator. When the battery is disconnected the reed is midway between the two contacts, touching neither. On closing the battery circuit the magnet coil pulls the reed into contact with one contact point, causing current to flow through the lower half of the transformer primary winding. Simultaneously, the magnet coil is short-circuited, deënergizing it, and the reed swings back. Inertia carries the reed into contact with the upper point, causing current to flow through the upper half of the transformer primary. The magnet coil again is energized, and the cycle repeats itself.

The synchronous circuit of Fig. 7-33B is provided with an extra pair of contacts which rectify the secondary output of the transformer, thus eliminating the need for a separate rectifier tube. The secondary center-tap furnishes the positive output terminal when the relative polarities of primary and secondary windings are correct. The proper connections may be determined by experiment.

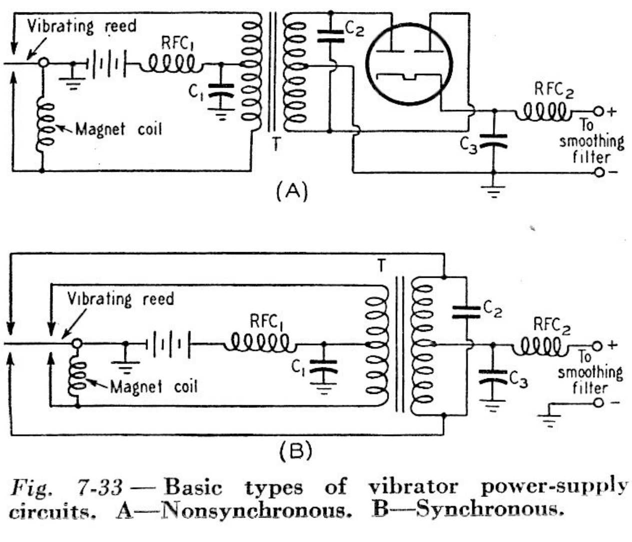


Fig. 7-33 — Basic types of vibrator power-supply circuits. A—Nonsynchronous. B—Synchronous.

The buffer condenser, C_2, across the transformer secondary absorbs the surges that occur on breaking the current, when the magnetic field collapses practically instantaneously and hence causes very high voltages to be induced in the secondary. Without this condenser excessive sparking occurs at the vibrator contacts, shortening the vibrator life. Correct values usually lie between 0.005 and 0.03 μfd., and for 250–300-volt supplies the condenser

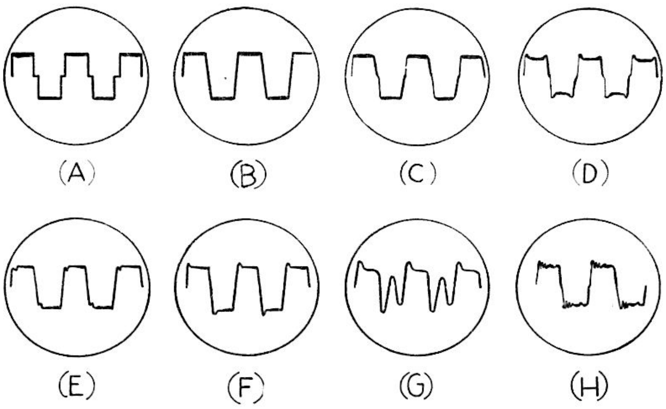


Fig. 7-34 — Characteristic vibrator waveforms as viewed on the oscilloscope. A, ideal theoretical trace for resistive load; current flow stops instantly when vibrator contacts open and resumes approximately 1 microsecond later (for standard 115-cycle vibration frequency) after interrupter arm moves across for the next half-cycle. B, ideal practical waveform for inductive load (transformer primary) with correct buffer capacitance. C, practical approximation of B for loaded nonsynchronous vibrator. D, satisfactory practical trace for synchronous (self-rectifying) vibrator under load; the peaks result from voltage drop in the primary when the secondary load is connected, not from faulty operation.

Faulty operation is indicated in E through H: E, effect of insufficient buffering capacitance (not to be mistaken for "bouncing" of contacts). The opposite condition — excessive buffering capacitance — is indicated by slow build-up with rounded corners, especially on "open." F, overclosure caused by too-small buffer condenser (same condition as in E) with vibrator unloaded. G, "skipping" of worn-out or misadjusted vibrator, with interrupter making poor contact on one side. H, "bouncing" resulting from worn-out contacts or sluggish reed. G and H usually call for replacement of the vibrator.

should be rated at 1500 to 2000 volts d.c. The exact capacitance is critical, and should be determined experimentally. The optimum value is that which results in least battery current for a given rectified d.c. output from the supply. In practice the value can be determined by observing the degree of vibrator sparking as the capacitance is changed. When the system is operating properly there should be practically no sparking at the vibrator contacts. A 5000-ohm resistor in series with C_2 will limit the secondary current to a safe value should the condenser fail.

A more exact check on the operation can be secured with an oscilloscope having a linear sweep circuit that can be synchronized with the vibrator. The vertical plates should be connected across the outside ends of the transformer primary winding to show the input voltage waveshape. Fig. 7-34C shows an idealized trace of the optimum waveform when the

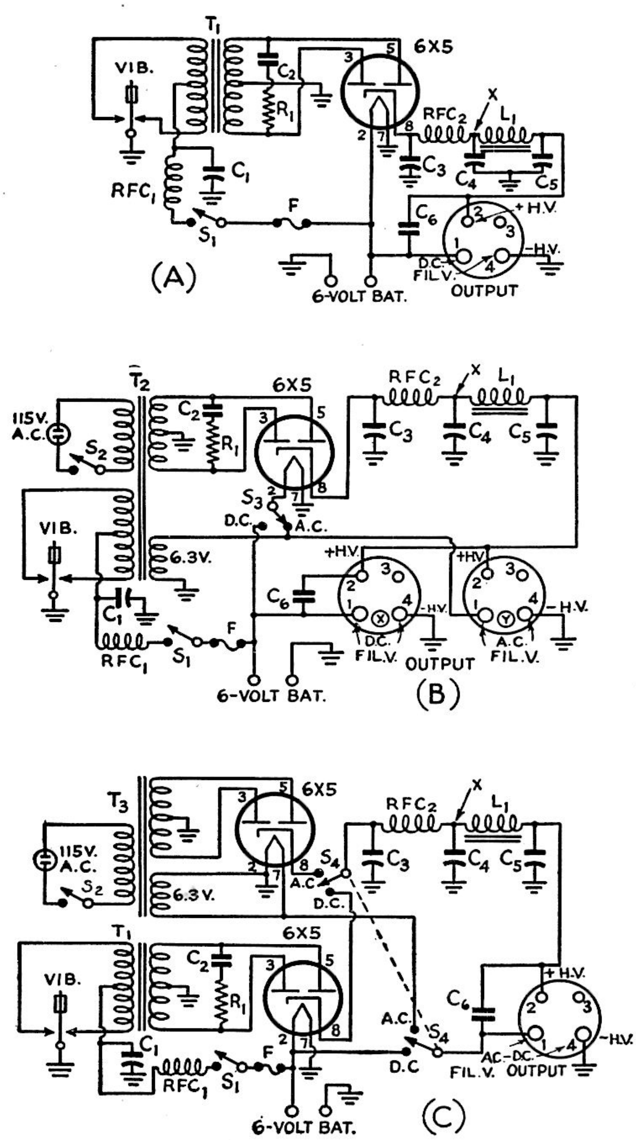


Fig. 7-35 — Typical vibrator-transformer power-supply circuits. The circuit at A shows a simple arrangement for 6-volt d.c. input; the one at B illustrates the use of a combination transformer for operation from either 6 volts d.c. or 115 volts. a.c. The circuit of C is similar to that of B but uses separate transformers.

C_1 — 0.5-μfd. paper, 50-volt rating or higher.
C_2 — 0.005 to 0.01 μfd., 1600 volts.
C_3 — 0.01-μfd. 600-volt paper.
C_4 — 8-μfd. 450-volt electrolytic.
C_5 — 32-μfd. 450-volt electrolytic.
C_6 — 100-μμfd. mica.
R_1 — 4700 ohms, ½ or 1 watt.
L_1 — 10–12-henry 100-ma. filter choke, not over 100 ohms (Stancor C-2303 or equivalent).
F — 15-ampere fuse.
RFC_1 — 55 turns No. 12 on 1-inch form, close-wound.
RFC_2 — 2.5-mh. r.f. choke.
S_1 — S.p.s.t. toggle — battery switch.
S_2 — S.p.s.t. toggle — a.c. power switch.
S_3 — S.p.d.t. toggle — rectifier-heater change-over switch.
S_4 — D.p.d.t. toggle — a.c.-d.c. switch.
T_1 — Vibrator transformer.
T_2 — Special vibrator transformer with 115-volt and 6-volt primaries, to give approximately 300 volts at 100 ma. d.c. (Stancor P-6166 or equivalent).
T_3 — A.c. transformer, 275 to 300 volts each side of center-tap, 100 to 150 ma.; 6.3-volt filament.
VIB — Vibrator unit (Mallory 500P, 294, etc.)
X — Insert a series resistor of suitable value to drop the output voltage to 300 at 100 ma. load, if necessary. If transformer gives over 300 volts d.c., a second filter choke may be used to give additional voltage drop as well as more smoothing.

buffer capacitor is adjusted to give proper operation throughout the life of the vibrator. The horizontal lines in the trace represent the voltage during the time the vibrator contacts are closed, which should be approximately 90 per cent of the total time. When the contacts are open the trace should be partly tilted and partly vertical, the tilted part being 60 per cent of the total connecting trace. The oscilloscope will show readily the effect of the buffer condenser on the percentage of tilt. In actual patterns the horizontal sections are likely to droop somewhat because of the resistance drop in the battery leads as the current builds up through the primary inductance (Fig. 7-34D).

"Hash" Elimination

Sparking at the vibrator contacts causes r.f. interference ("hash," which can be distinguished from hum by its harsh, sharper pitch) when used with a receiver. To minimize this, r.f. filters are incorporated, consisting of RFC_1 and C_1 in the battery circuit, and RFC_2 with C_3 in the d.c. output circuit.

Equally as important as the hash filter is thorough shielding of the power supply and its connecting leads, since even a small piece of wire or metal will radiate enough r.f. to cause interference in a sensitive receiver.

Testing in connection with hash elimination should be carried out with the supply operating a receiver. Since the interference usually is picked up on the receiving antenna leads by radiation from the supply itself and from the battery leads, it is advisable to keep the supply and battery as far from the receiver as the connecting cables will permit. Three or four feet should be ample. The microphone cord likewise should be kept away from the supply and leads.

The power supply should be built on a metal chassis, with all unshielded parts underneath. A bottom plate to complete the shielding is advisable. The transformer case, vibrator cover and the metal shell of the tube all should be grounded to the chassis. If a glass tube is used it should be enclosed in a tube shield. The battery leads should be evenly twisted, since these leads are more likely to radiate hash than any other part of a well-shielded supply. Experimenting with different values in the hash filters should come *after* radiation from the battery leads has been reduced to a minimum. Shielding the leads is not particularly helpful.

PRACTICAL VIBRATOR-SUPPLY CIRCUITS

A vibrator-type power supply may be designed to operate from a six-volt storage battery only, or in a combination unit which may be operated interchangeably from either battery or 115 volts a.c.

Typical circuits are shown in Fig. 7-35. The one shown at A is the simplest, although it operates from a 6-volt d.c. source only. S_1 turns the high voltage on and off.

The circuit of B provides for either 6-volt d.c. or 115-volt a.c. operation with a dual-primary transformer. S_2 is the a.c. on-off switch while S_3 switches the heater of the 6X5 rectifier from the storage battery to the 6.3-volt winding on the transformer. Filament supply for the transmitter or receiver is switched by shifting the power plug to the correct output socket, *X* when operating from a 6-volt d.c. source and *Y* when 115-volt a.c. input is used.

The circuit of Fig. 7-35C may be used when a dual-primary transformer is not available. The filter is switched from one rectifier output to the other by means of the d.p.d.t. switch, S_4, which also shifts filament connections from a.c. to d.c. The filter section of the switch could be eliminated if desired by connecting the filtering circuit permanently to the output terminals of both rectifiers and removing the unused rectifier tube from its socket. Similarly, the filament section of S_4 could be dispensed with by providing two output sockets as in the circuit at B. If a separate rectifier filament winding is available on T_3, directly-heated rectifier types may be substituted for the 6X5 in the a.c. supply. In some cases where the required filament windings are not available, a rectifier of the cold-cathode type, such as the 0Z4, which requires no heater voltage, sometimes may be used to advantage.

If suitable filament windings are available, a regular a.c. transformer will make an acceptable substitute for a vibrator transformer. If the a.c. transformer has two 6.3-volt windings, they may be connected in series, their junction forming the required center-tap. A 6.3-volt and a 5-volt winding may be used in a similar manner even though the junction of the two

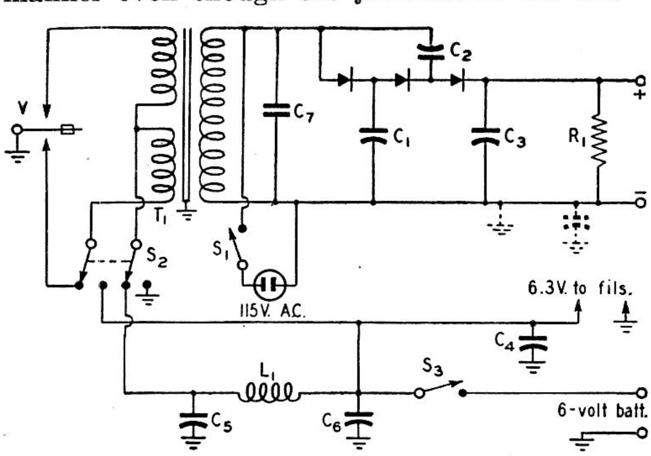


Fig. 7-36 — **Circuit diagram of a compact vibrator-a.c. portable power supply suggested by W9CO.**

C_1 — 60-μfd. 200-volt electrolytic.
C_2 — 60-μfd. 400-volt electrolytic.
C_3 — 60-μfd. 600-volt electrolytic.
C_4 — 25-μfd. 25-volt electrolytic.
C_5, C_6 — 0.5-μfd. 25-volt paper.
C_7 — 0.007-μfd. 1500-volt paper.
R_1 — 25,000 ohms, 10 watts.
L_1 — 25-μhy. 20-amp. choke.
S_1 — 115-volt toggle switch.
S_2 — D.p.d.t. heavy-duty knife switch.
S_3 — 25-amp. switch.
T_1 — See text.
V — Heavy-duty vibrator.

windings does not provide an accurate center-tap. A better center-tap may be obtained if a 2.5-volt winding also is available, since half of this winding may be connected in series with the 5-volt winding to give 6.25 volts.

R.f. filters for reducing hash are incorporated in both primary and secondary circuits. The secondary filter consists of a 0.01-μfd. paper condenser directly across the rectifier output, with a 2.5-mh. r.f. choke in series ahead of the smoothing filter. In the primary circuit a low-inductance choke and high-capacitance condenser are needed because of the low impedance of the circuit. A choke of the specifications given should be adequate, but if there is trouble with hash it may be beneficial to experiment with other sizes. The wire should be large — No. 12, preferably, or No. 14 as a minimum. Manufactured chokes such as the Mallory RF583 are more compact and give higher inductance for a given resistance because they are bank-wound, and may be substituted if obtainable. C_1 should be at least 0.5 μfd.; even more capacitance may help in bad cases of hash.

The smoothing filter for battery operation can be a single-section affair, but there will be some hum (readily distinguishable from hash because of its deeper pitch) unless the filter output capacitance is fairly large — 16 to 32 μfd.

The compactness of selenium rectifiers and the fact that they do not require filament voltage make them particularly suited to compact light-weight power supplies for portable-emergency work.

Fig. 7-36 shows the circuit of a vibrator pack which will deliver an output voltage of 400 at 200 ma. It will work with either 115-volt a.c. or 6-volt battery input. The circuit is that of the familiar voltage tripler whose d.c. output voltage is as a rough approximation, three times the peak voltage delivered by the transformer or line. An interesting feature of the circuit is the fact that the single transformer serves as the vibrator transformer when operating from 6-volt d.c. supply and as the filament transformer when operating from an a.c. line. This is accomplished without complicated switching.

The vibrator transformer, T_1, is a dual-secondary 6.3-volt filament transformer connected in reverse. It may also consist of two single transformers of the same type with their primaries connected in series and secondaries in parallel, both windings being properly polarized. In either event, the filament windings must have a rating of 10 amperes if the full load current of 200 ma. is to be used. Some excellent surplus transformers that will handle the required current are now available on the surplus market. The vibrator also must be capable of handling the current. The hash-filter choke, L_1, must carry a current of 20 amperes.

The following table shows the output voltage to be expected at various load currents, depending upon the size of condensers used at C_1, C_2 and C_3.

C_1, C_2, C_3 (μfd.)	Output Voltage at 50 ma.	100 ma.	150 ma.	200 ma.
60	455	430	415	395
40	425	390	360	330
20	400	340	285	225

In operating the supply from an a.c. line, it is always wise to determine the plug polarity in respect to ground. Otherwise the rectifier part of the circuit and the transformer circuit cannot be connected to actual ground except through by-pass condensers.

Vibrator-Supply Construction

Table 7-IV contains a list of some of the currently-available vibrator-type power supplies on the market. However, supplies of this type are not difficult to construct.

A typical example of vibrator-supply construction is shown in the photographs of Figs. 7-37 and 7-38.

All components in the supply with the exception of the four-prong outlet socket are mounted on a piece of quarter-inch tempered Masonite measuring 3¾ × 9 inches. This fits into a plywood box having inside dimensions (3¾ × 9 × 5½ inches) just large enough to

TABLE 7-IV—VIBRATOR SUPPLIES

	Manufacturer's Type Number				Input	Output				
American Television and Radio Co.	Electronic Labs	Halli-crafters	Mallory	Radiart	Volts	Volts[7]	Ma.	Watts	Rectifier	Output Filter
VPM-F-7					6.3 D.C.	90	10	—	Syn.	Yes
			VP-551[4]		6.3 D.C.	125–150–175–200	25–30–35–40 (100 Max.)	—	Syn.	No
				4201B[6]	6.3 D.C.	250	50	—	Syn.	Yes
			VP-540		6.3 D.C.	250	60	—	Syn.	Yes
	605A				6.3 D.C.	150–200–250–275	35–40–50–65	19	Syn.	No
	604A				6.3 D.C.	225–250–275–300	50–65 80–100	30	Syn.	No
	601				6.3 D.C.	225–250 275–300	50–65 80–100	30	Tube	No
	616				6.3 D.C. and 115 A.C.	115 A.C. 325–350–375–400	125–150–175–200	15	Tube	Input Cond.
	619				6.3 D.C and 115 A.C.	300 6.3 A.C.	100 4.85 Amp.	60	Tube	Yes
	2606				6.3 D.C.	300	100	30	Tube	Yes
VPM-6					6.3 D.C.	250–275–300–325	50–75 100–125	—	Tube	Yes
			VP-552[5]		6.3 D.C.	225–250–275–300	50–65–80–100	—	Syn.	No
		VP-2			6.3 D.C.	300	170	—	Tube	No
		VP-4			6.3 D.C.	320	70	—	Tube	No
			VP-555		6.3 D.C.	300	200	—	Tube	Yes
			VP-557		6.3 D.C.	400	150	—	Tube	Input cond.
				451	6.0 D.C. or 12 D.C.	250–180	60–40	15	Syn.	Yes
				452	6.0 D.C.	300–275–250–225	100–100–100–100	30	Tube	Yes
				452–12	12 D.C.	Same as model 452				
				453	6.0 D.C.	300–275–250–225	100–100–100–100	30	Syn.	Yes
				453–12	12 D.C.	Same as model 453				
				454	6.0 D.C.	300	200	60	Tube	Yes
				454–12	12 D.C.	Same as model 454				
				455	6.0 D.C.	400	150	60	Tube	Yes
				455–12	12 D.C.	Same as model 455				
				456	6 D.C. and 110 A.C.	300–275–250–225 6.3 A.C.	100–110–100–100 5 Amp.	30	Tube	Yes
INVERTERS										
6RSB[1]					6.0 D.C.	110 A.C.	—	75[3]	—	—
12RSB[1]					12 D.C.	110 A.C.	—	100[3]	—	—
6ISO[2]					6 D.C.	110 A.C.	—	75[3]	—	—
12ISO[2]					12 D.C.	110 A.C.	—	100[3]	—	—
6LIC[2]					6 D.C.	110 A.C.	—	25[3]	—	—
12LIC[2]					12 D.C.	110 A.C.	—	35[3]	—	—

All a.c. voltages are 60-cycle.
[1] For use with power factors as low as 80%.
[2] For use with power factors as low as 60%.
[3] Continuous service.
[4] VP-553 same with tube rect.
[5] VP-554 same with tube; VP-G556 same with 12-volt d.c. input.
[6] 4201B2 same with tube rect.
[7] D.c. unless specified.

TABLE 7-V — GASOLINE-ENGINE DRIVEN GENERATORS, AIR-COOLED

Manufacturer			Output				Weight Lb.	Starting Method
Kato	Onan	Pioneer	Volts A.C.	Watts	Volts D.C.	Watts		
		BD-6[1]	110	300	6	200	100	Push-Button
JRA-3[3]			110	350	6	30	65	Rope Crank
	03AAE-1E		115	350	6	—	77	Push-Button
	358RSAL[1]		115	350	12	—	79	Push-Button[2]
	05AH-1R[1]		115	500	12	—	126	Push-Button[2]
23HAB4			115	500	12	13	125	Push-Button
		BA-6[1]	110	600	—	—	135	Push-Button
14HAB4			115	600	12	13	170	Push-Button
	07AH-1R[1]		115	750	12	—	136	Push-Button[2]
		BA-10[1]	110	1000	—	—	170	Push-Button
	10LS[1]		115	1000	12	—	210	Push-Button[2]
26HAB4			115	1000	12	10	265	Remote Contr.
28HAB4			115	1500	18	6	350	Remote Contr.
	105BH-1R[1]		115	1500	12	—	187	Push-Button[2]
		BA-15	110	1500	—	—	365	Push-Button
	2CK-1R[1]		115	2000	12	—	258	Push-Button[2]
41HAB4			115	2500	32	5	450	Remote Contr.
	3CK-1R[1]		115	3000	12	—	266	Push-Button[2]

[1] Available with remote control. [2] Manual starting available. [3] Postwar model expected to be produced.

contain the equipment. The Masonite shelf rests on ¾-inch-square strips, 1¼ inches long, glued to the corners of the box at the bottom. The top and bottom of the box are removable. To provide shielding and thus reduce hash troubles, the box is covered with thin iron salvaged from 5-quart oil cans. Where the edges bend around the box to make a joint, the lacquer is rubbed off with steel wool so the pieces make electrical contact, and the metal is tacked to the plywood with escutcheon pins.

To make sure that the shielding will be complete, the top and bottom of the box slide into place from the side, with the metal covering extending out so that it fits tightly under a lip bent over from the metal on the sides. These lips also are cleaned of lacquer to permit good electrical contact. The general construction should be quite apparent from the photographs. The bottom is provided with rubber feet, and the top has a small knob at each end so that it can be pulled out. This is essential, since the fit is good and there is no way to get either the top or bottom off, once on, without having some sort of handle to grip.

GASOLINE-ENGINE DRIVEN GENERATORS

For higher-power installations, such as for communications control centers during emergencies, the most practical form of independent power supply is the gasoline-engine driven generator which provides standard 115-volt 60-cycle supply.

Such generators are ordinarily rated at a minimum of 250 or 300 watts. They are available up to two kilowatts, or big enough to handle the highest-power amateur rig. Most are arranged to charge automatically an auxiliary 6- or 12-volt battery used in starting. Fitted with self-starters and adequate mufflers and filters, they represent a high order of performance and efficiency. Many of the larger models are liquid-cooled, and they will operate

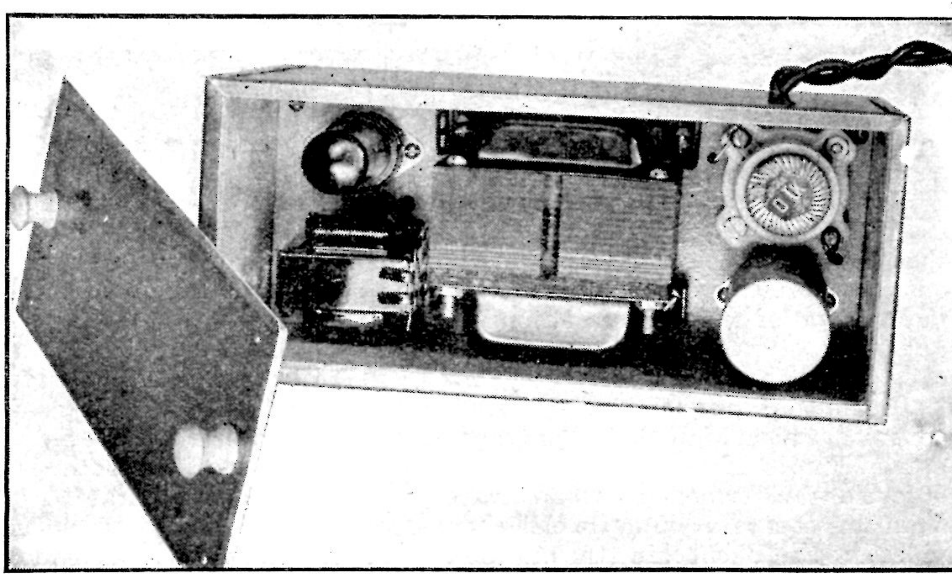


Fig. 7-37 — A view inside a typical vibrator-type power supply. The rectifier tube is at the upper left with the filter choke just below. The primary fuse socket and vibrator are at the right. A synchronous-type vibrator may be substituted for the interrupter type if it is desired to eliminate the rectifier tube.

TABLE 7-VI — PLATE-BATTERY SERVICE HOURS

Estimated to 34-volt end-point per nominal 45-volt section. Based on intermittent use of 3 to 4 hours daily at room temp. of 70° F. (For batteries manufactured in U. S. A. only.)

Manufacturer's Type No.		Weight		Current Drain in Ma.											
Burgess	Eveready	Lb.	Oz.	5	10	15	20	25	30	40	50	60	75	100	150
—	758	14	8	Suggested current range = 7 to 12 Ma.											
21308	—	12	8	1600	1100	690	490	—	300	200	—	130	—	60	30
10308	—	11	4	1300	750	520	350	—	—	130	—	90	—	45	22
—	754	6	8	Suggested current range = 5 to 15 Ma.											
2308	—	8	3	1100	500	330	200	—	150	65	—	34	—	—	—
—	487	4	2	Suggested current range = 7 to 12 Ma.											
B30	—	2	8	350	170	90	50	—	21	17	—	—	—	—	—
A30	—	2	—	260	100	48	28	—	17	7	—	—	—	—	—
—	482	1	14	400	208	122	80	—	—	—	—	—	—	—	—
Z30N	—	1	4	155	70	30	20	15	9.5	—	—	—	—	—	—
—	467	—	12	82	30	—	—	—	—	—	—	—	—	—	—
—	738	1	2	160	70	30	20	10	7	—	—	—	—	—	—
W30FL	—	—	11	70	20	12	7	—	3.5	—	—	—	—	—	—
—	455	—	8	82	30	—	—	—	—	—	—	—	—	—	—
XX30	—	—	9	70	20	12	7	—	3.5	—	—	—	—	—	—

TABLE 7-VII — FILAMENT-BATTERY SERVICE HOURS

Estimated to 1-volt end-point per nominal 1.5-volt unit. Based on intermittent use of 3 to 4 hours per day at room temperature. (For batteries manufactured in U. S. A. only.)

Manufacturer's Type No.		Weight		Voltage	Current Drain in Ma.											
Burgess	Eveready	Lb.	Oz.		30	50	60	120	150	175	180	200	240	250	300	350
—	A-1300	8	4	1.25	—	—	—	—	2000	1715	1500	1333	1250	1200	1000	854
—	740	6	4	1.5	—	—	—	—	—	—	—	870	—	—	—	—
—	741[1]	2	13	1.5	—	—	—	—	—	—	—	460	—	—	270	—
—	743	2	1	1.5	—	—	—	—	—	—	—	300	—	225	175	—
—	742	1	6	1.5	—	—	—	—	—	—	—	170	—	120	90	—
8F[2]	—	2	10	1.5	—	—	1100	600	450	—	—	400	—	320	230	190
4F	—	1	4	1.5	—	—	600	340	230	—	—	160	—	110	95	60
—	A-2300	11	—	2.5	—	—	—	—	2000	1715	1500	1333	1250	1200	1000	854
20F2	—	13	12	3.0	—	—	—	—	1100	—	—	850	—	775	600	500
2F2H	—	1	6	3.0	600	—	340	130	95	—	—	60	—	42	30	—
2F2BP[3]	—	1	5	3.0	600	—	340	130	95	—	—	60	—	42	30	—
F2BP	—	—	12	3.0	340	—	130	45	30	—	—	—	—	—	—	—
G3[4]	—	1	5	4.5	370	200	150	50	35	—	—	—	—	—	—	—
—	746	1	4	4.5	—	225	—	—	—	—	—	—	—	—	—	—
—	718[5]	2	13	6.0	—	415	—	—	—	—	—	—	—	—	—	—
F4PI	—	1	6	6 0	340	150	130	45	30	—	—	—	—	—	—	—

[1] Same life figures apply to 745, wt. 2 lb. 13 oz.
[2] Same life figures apply to 8FL, wt. 2 lb. 15 oz.
[3] Same life figures apply to 2F4, volts 6, wt. 2 lb. 11 oz.
[4] Same life figures apply to G5, volts 7½, wt. 2 lb. 2 oz.
[5] Same life figures apply to 747, wt. 2 lb. 13 oz.

If batteries of another make are to be used, locate ones of similar size and weight on these tables and comparable performance may be expected.

continuously at full load. Ratings of typical engine-driven units are given in Table 7-V.

A variant on the generator idea is the use of fan-belt drive. The disadvantage of requiring that the automobile must be running throughout the operating period has not led to general popularity of this idea among amateurs. Such generators are similar in construction and capacity to the small gas-driven units.

The output frequency of an engine-driven generator must fall between the relatively narrow limits of 50 to 60 cycles if standard 60-cycle transformers are to operate efficiently from this source. A 60-cycle electric clock provides a means of checking the output frequency with a fair degree of accuracy. The clock is connected across the output of the generator and the second hand is checked closely against the second hand of a watch. The speed of the engine is adjusted until the two second hands are in synchronism. If a 50-cycle clock is used to check a 60-cycle generator, it should be remembered that one revolution of the second hand will be made in 50 seconds and the clock will gain 4.8 hours in each 24 hours.

Output voltage should be checked with a voltmeter since a standard 115-volt lamp bulb, which is sometimes used for this purpose, is very inaccurate. Tests have shown that what appears to be normal brilliance in the lamp may occur at voltages as high as 150 if the check is made in bright sunlight.

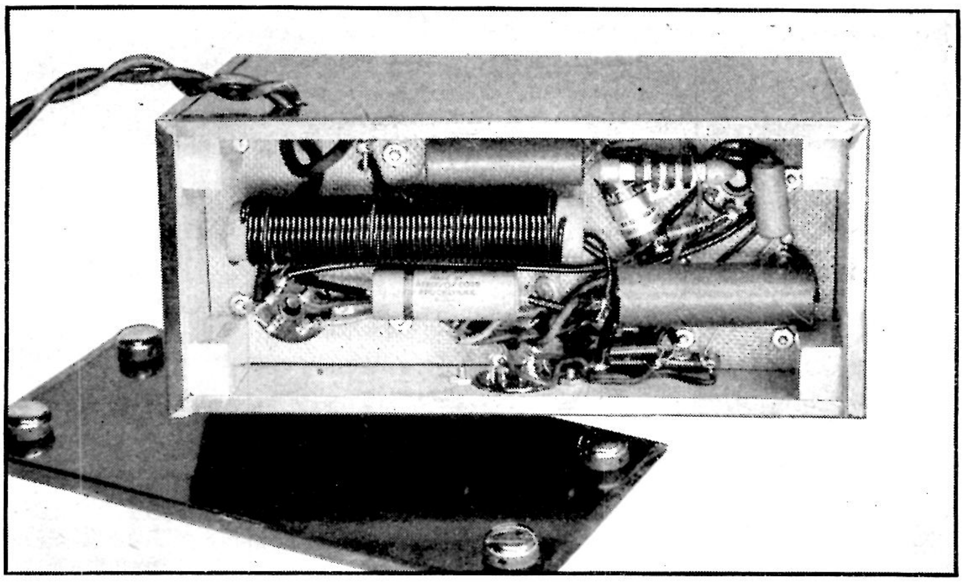


Fig. 7-38 — Hash and smoothing filter components are mounted in the bottom of the low-voltage vibrator power supply. The 4-prong outlet socket is mounted on the side.

Noise Elimination

Electrical noise which may interfere with receivers operating from engine-driven a.c. generators may be reduced or eliminated by taking proper precautions. The most important point is that of grounding the frame of the generator *and* one side of the output. The ground lead should be short to be effective, otherwise grounding may actually increase the noise. A water pipe may be used if a short connection can be made near the point where the pipe enters the ground, otherwise a good separate ground should be provided.

The next step is to loosen the brush-holder locks and slowly shift the position of the brushes while checking for noise with the receiver. Usually a point will be found (almost always different from the factory setting) where there is a marked decrease in noise.

From this point on, if necessary, by-pass condensers from various brush holders to the frame, as shown in Fig. 7-39, will bring the hash down to within 10 to 15 per cent of its original intensity, if not entirely eliminating it. Most of the remaining noise will be reduced still further if the high-power audio stages are cut out and a pair of headphones is connected into the second detector.

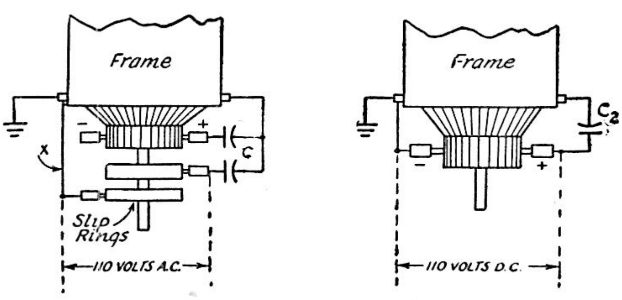


Fig. 7-39 — Connections used for eliminating interference from gas-driven generator plants. *C* should be 1 μfd., 300 volts, paper, while C_2 may be 1 μfd. with a voltage rating of twice the d.c. output voltage delivered by the generator. *X* indicates an added connection between the slip ring on the grounded side of the line and the generator frame.

POWER FOR PORTABLES

Dry-cell batteries are the only practical source of supply for equipment which must be transported on foot. From certain considerations they may also be the best source of voltage for a receiver whose filaments may be operated from a storage battery, since no problem of noise filtering is involved.

Their disadvantages are weight, high cost, and limited current capability. In addition, they will lose their power even when not in use if allowed to stand idle for periods of a year or more. This makes them uneconomical if not used more or less continuously.

Tables 7-VI and 7-VII give service life of representative types of batteries for various current drains, based on intermittent service simulating typical operation. The continuous-service life will be somewhat greater at very low current drains and from one-half to two-thirds the intermittent life at higher drains.

Keying and Break-In

If the proper keying of a transmitter entailed only the ability to turn on and off the output, keying would be a simple matter. Unfortunately, perfect keying is as difficult to obtain as perfect voice quality, and so is not a matter to be dismissed lightly. The keying of a transmitter can be considered satisfactory if the power output is reduced to zero with the key open, or "up," and reaches full output when the key is closed, or "down." The keying system should accomplish this without producing objectionable transients or "clicks," which cause interference with other amateur stations and with local broadcast reception. Furthermore, the keying process should cause no "chirp," which means that the transmitter output frequency should not be affected by the keying process.

Keying Principles and Characteristics

Back-Wave

When the transmitter output is not reduced to zero under key-up conditions, the signal is said to have a **back-wave.** If the amount of back-wave is appreciable, the keying will be difficult to read. A pronounced back-wave may result when the amplifier feeding the antenna is keyed, as a result of the excitation energy feeding through an incompletely-neutralized stage. Magnetic coupling between antenna coils and one of the driver stages on the operating frequency is also a cause of back-wave. Direct radiation from a driver stage ahead of the keyed stage will result in a back-wave, but this type is generally heard only within a few miles of the transmitter, unless the driver stage is fairly high powered.

A back-wave also may be radiated if the keying system does not reduce the input to the keyed stage to zero during keying spaces. This trouble will not occur in keying systems that completely cut off the plate voltage when the key is open. It will occur in grid-block keying systems if the blocking voltage is not great enough, or in power-supply primary keying systems if only the final-stage power-supply primary is keyed. A vacuum-tube keyer will give a back-wave if the "open" key resistance is too low.

Key Clicks

If a transmitter is keyed in such a manner that the power output rises instantly to its full value or drops immediately to zero, the resultant short rise and decay times produce signals (at the times of closing and opening the key) extending from the signal frequency to several hundred kilocycles on either side. These signals are called "key clicks," and they will cause interference to other amateurs and other services. Consequently, keying systems must be used that increase the rise and decay times of the keyed characters, since this results in less click energy removed from the signal frequency.

The simple process of making and breaking any circuit with current flowing through it will produce a brief burst of r.f. energy. This effect can be noticed in a radio receiver when an electric light or other appliance in the house is turned on or off. It is, therefore, not only necessary to delay the rise and decay times of the keyed transmitter to prevent interference with other services, but it may be necessary to filter the r.f. energy generated at the key contacts if this energy is found to interfere with broadcast reception in the amateur's house or vicinity. This interference is also called "key clicks."

Getting back to the discussion of rise and decay times, tests have shown that practically all operators prefer to copy a signal that is "solid" on the "make" end of each dot or dash; i.e., one that does not build up too slowly but just slowly enough to have a slight click when the key is closed. On the other hand, the most-pleasing and least-difficult signal to copy, particularly at high speeds, is one that has a fairly soft "break" characteristic; i.e., one that has practically no click as the key is opened. A signal with heavy clicks on both make and break is difficult to copy at high speeds and also causes considerable interference. If it is too "soft" the dots and dashes will tend to run together and the characters will be difficult to copy. The keying should be adjusted so that for all normal hand speeds (15 to 35 w.p.m.) the readability will be satisfactory without causing unnecessary interference to the reception of other signals near the transmitter frequency.

Chirps

Keying should have no effect upon the frequency of the transmitter. In many cases where sufficient pains have not been taken, keying will cause a frequency change, or "chirp," at the instant of opening or closing the key. The resultant signal is unpleasant and, in cases of extreme chirp, difficult to copy. Multistage transmitters keyed in a stage following the oscillator are generally free from chirp, unless the keying causes line-voltage changes which in turn affect the oscillator frequency. When the oscillator is keyed, as is done for "break-in" operation, particular care must be taken to insure that the signal does not have keying chirps.

Break-In Operation

In code transmission, there are intervals between dots and dashes, and slightly longer intervals between letters and words, when no power is being radiated by the transmitter. If the receiver can be made to operate at normal sensitivity during these intervals, it is possible for the receiving operator to signal the transmitting operator, by holding his key down. This is useful during the handling of messages, since the receiving operator can immediately signal the transmitting operator if he misses part of the message. It is also useful in reducing the time necessary for calling in answer to a "CQ." The ability to hear signals during the short "key-up" intervals is called **break-in operation.**

Selecting the Stage To Key

It is highly advantageous from an operating standpoint to design the c.w. transmitter for break-in operation. In most cases this requires that the oscillator be keyed, since a continuously-running oscillator will create interference in the receiver and prevent break-in on or near one's own frequency. On the other hand, it is easier to avoid a chirpy signal by keying a stage or two following the oscillator. Since the effect of a chirp is multiplied with frequency, it is quite difficult to obtain chirpless oscillator keying in the 14- and 28-Mc. bands. In any case, however, the stages following the keyed stage (or stages) must be provided with sufficient fixed bias to limit the plate currents to safe values when the key is up and the tubes are receiving no excitation voltage. Complete cut-off reduces the possibility of a back-wave if a stage other than the oscillator is keyed, but the keying waveform is not well preserved and some clicks can be introduced, even though the keyed stage itself produces no clicks. *It is a good general rule to bias the tubes following the keyed stage so that they draw a key-up current of about 5 per cent of the normal key-down value.*

The power broken by the key is an important consideration, both from the standpoint of safety to the operator and that of sparking at the key contacts. Keying of the oscillator or a low-power stage is favorable on both counts. The use of a keying relay is recommended when a high-power circuit is keyed.

Keying Circuits

Only general circuits can be shown for keying, since the final decision on where and how to key rests with the amateur and depends upon the power level and type of operation.

● PLATE-CIRCUIT KEYING

Any stage of the transmitter can be keyed by opening and closing the plate-power circuit. Fig. 8-1 shows how the key can be connected to key the plate circuit (A) or the screen circuit (B). The circuit in Fig. 8-1A shows the key in the negative power lead, although it could be placed in the positive lead, at the point marked "X." Either system is recommended only for low-voltage circuits, on the order of 300 or less, unless a relay is used, because of the danger of accidental electrical shock.

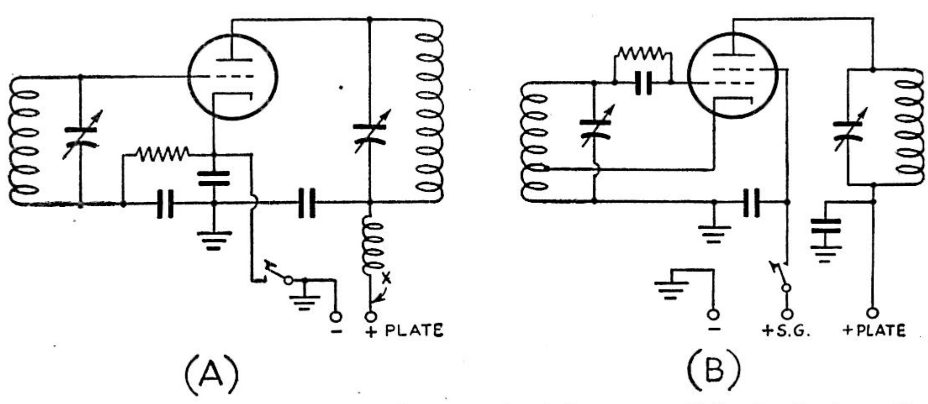


Fig. 8-1 — Plate-circuit keying is shown at A, and screen-grid keying is shown in B. Oscillator circuits are shown in both cases, but the same keying methods can be used with amplifier circuits. Notice the similarity between A and Fig. 8-5 — the only difference is in the way the grid return is connected.

Fig. 8-1B shows the key in the screen lead of an electron-coupled oscillator, and can be considered a variation of 8-1A that has the desirable advantage of breaking less current at a lower voltage.

Both of the circuits shown in Fig. 8-1 respond well to the use of key-click filters, and are particularly suitable for use with crystal- and self-controlled oscillators, which are generally operated at low voltage and low power.

PRIMARY KEYING

A popular method of keying high-powered amplifiers is shown in Fig. 8-2. In its simplest form, as shown in 8-2A, it consists of keying the primary of the plate transformer supplying power to one or more of the driver stages. It has the advantage that the filter, *LC*, acts as a keying filter and prevents clicks. However, too much filter cannot be used or the keying will be too soft, and a single section is all that can normally be used. Since this will introduce some a.c. modulation on the keyed stages, it is essential that the amplifier driven by the keyed stage have sufficient excitation to operate as a Class C amplifier, which tends to eliminate the modulation existing in the excitation voltage. Primary keying of the final plate power supply alone is not recommended, since it is practically impossible to comply with the FCC regulations about "adequately-filtered power supply" and still avoid keying that is too soft.

Primary keying of the driver power supply requires that the following amplifier stage (or stages) be biased to prevent excessive current under key-up conditions. If this bias exceeds the cut-off value for the tube (or tubes) a slightly more elaborate version of primary keying can be used, as shown in Fig. 8-2B. The primaries of both driver and final-amplifier plate supplies are keyed, and the system has the advantage that the final-amplifier plate voltage remains substantially constant under key-up or key-down conditions, and thus no clicks can be introduced by the sudden changes in final-amplifier plate voltage as the excitation is applied or removed. The final-amplifier plate supply will remain charged for several minutes after the last transmission, however, and extreme caution must be exercised. As a safety measure, the final-amplifier power supply can be discharged by a relay that shorts the supply through a 1000-ohm resistor, or the bias can be removed and the final-amplifier tube will discharge the power supply.

The keying system shown in Fig. 8-2B has been used to key an entire transmitter for break-in operation. The oscillator and multiplier/driver stages take their plate power from the supply with the small filter, while the final amplifier is powered from the heavily-filtered supply. It is essential, however, in a transmitter keyed for break-in in this manner,

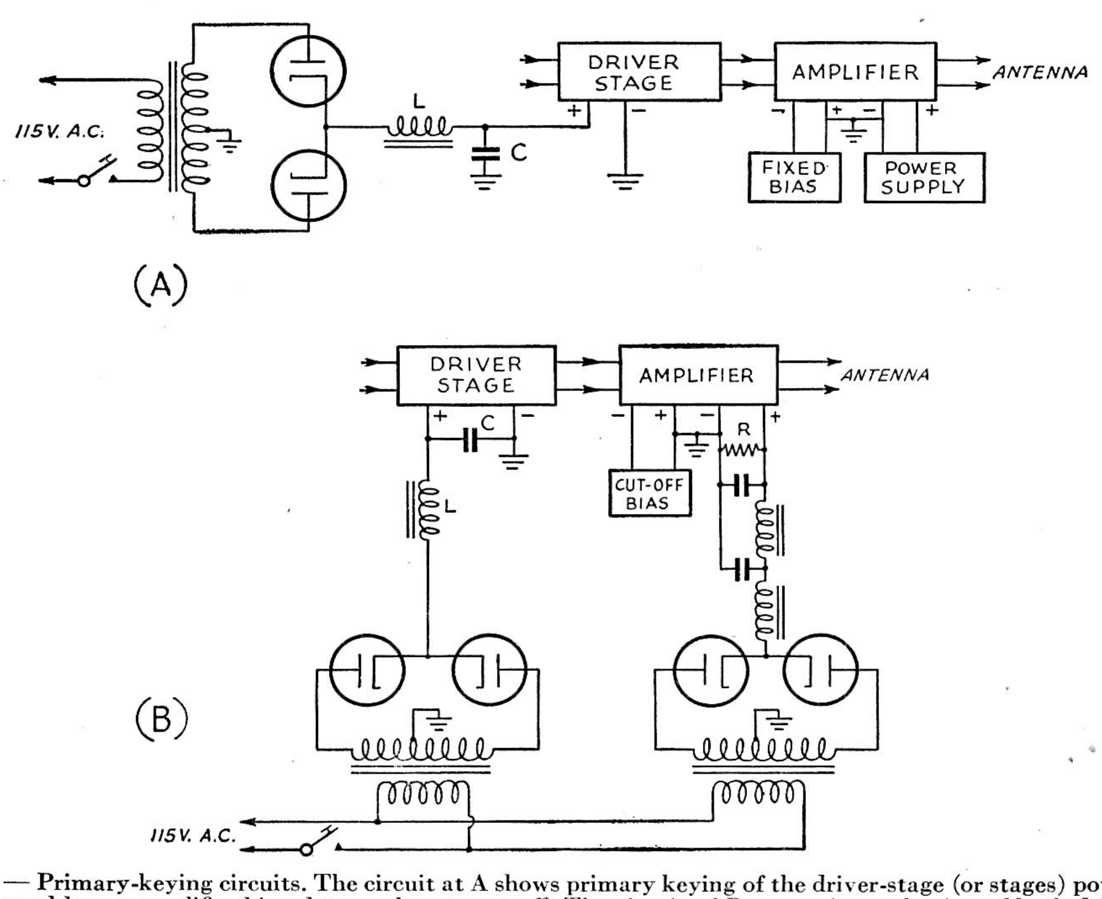


Fig. 8-2 — Primary-keying circuits. The circuit at A shows primary keying of the driver-stage (or stages) power supply, followed by an amplifier biased to or close to cut-off. The circuit of B uses primary keying of both driver and final supplies, and has the advantage that the key-up and key-down voltage on the final amplifier remains substantially constant, thus eliminating the chance of clicks being introduced by the final-amplifier plate-supply regulation.

In either case, *L* and *C* should be as small as possible, consistent with sufficient filtering and rectifier-tube limits. *R* in B need be only about 1000 ohms per volt. If a plate voltmeter is used, the bleed through it is sufficient, since the only function is to remove any long-standing charge from the power supply. A heavy bleed current will reduce the effectiveness of the keying system. See text for other bleeder suggestions.

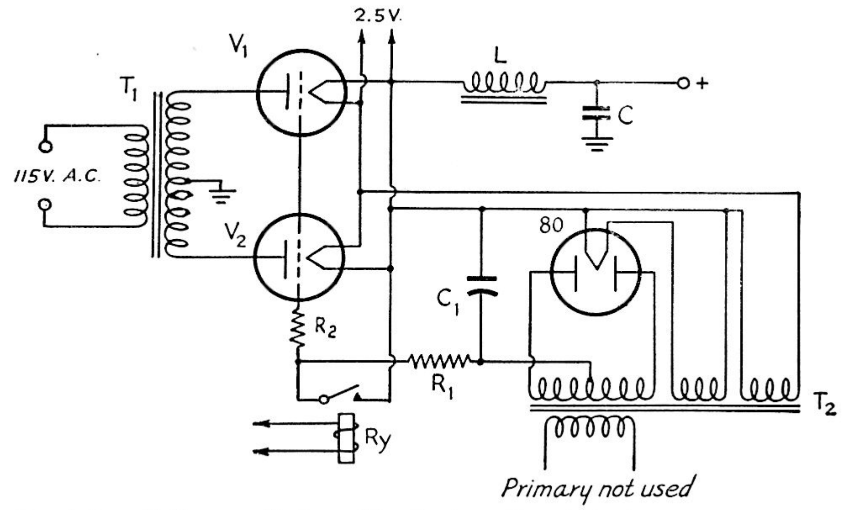


Fig. 8-3 — **Grid-controlled rectifier keying. Circuit is similar to Fig. 8-2, and the values of *L* and *C* are the same. A well-insulated keying relay, *Ry*, is used to control the bias on the rectifiers V_1 and V_2. The bias voltage is obtained from a small receiver power-supply transformer, T_2, the 80 rectifier and filter condenser C_1. T_2 does not need to be insulated for the full plate-supply voltage (obtained from T_1) because it is excited from the filament transformer for V_1 and V_2. It should be well insulated to ground, however. R_1 limits the short-circuit on the bias supply and can be approximately 50,000 ohms in value.**

that the oscillator be free from chirp, and this point should be checked carefully before using the system on the air.

In using primary keying up to several hundred watts, direct keying in the primary circuit is satisfactory. For higher powers, however, a keying relay should be used, because of the arcing at the contacts.

Fig. 8-3 shows **grid-controlled rectifier tubes** in the power supply. By applying suitable bias to the tubes when the key is up, no current flows through the tubes. When the key is closed, the bias is removed and the tubes conduct. The system can be used in the same way that primary keying was used in Fig. 8-2A and B. This system is used only in high-powered high-voltage supplies.

BLOCKED-GRID KEYING

An amplifier tube can be keyed by applying sufficient negative bias voltage to the control

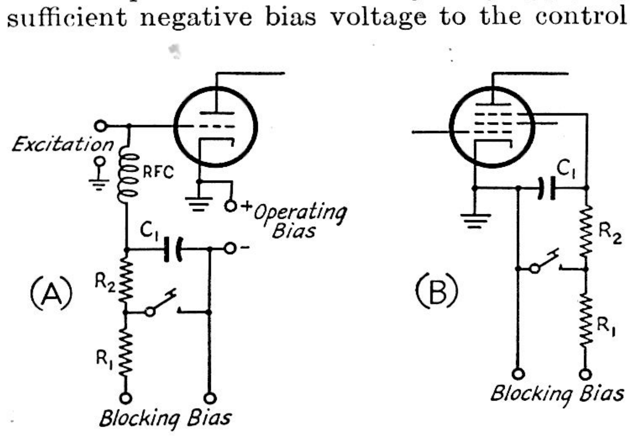


Fig. 8-4 — **Blocked-grid keying. R_1, the current-limiting resistor, should have a value of about 50,000 ohms. C_1 may have a capacity of 0.1 to 1 μfd., depending upon the keying characteristic desired. R_2 also depends on the performance characteristic desired, values being of the order of 5000 to 10,000 ohms in most cases.**

or suppressor grid to cut off plate-current flow when the key is up, and by removing this blocking bias when the key is down. When the bias is applied to the control grid, its value will be considerably higher than the nominal cut-off bias for the tube, since the r.f. excitation voltage must be overcome. The fundamental circuits are shown in Fig. 8-4A and B. The circuits can be applied to oscillator tubes as well as amplifiers. Suppressor-grid keying will not completely turn off a Tri-tet crystal oscillator or electron-coupled self-controlled oscillator, and is likely to cause serious chirps with the latter.

In both circuits the key is connected in series with a resistor, R_1, which limits the current drain on the blocking-bias source when the key is closed. R_2C_1 is a resistance-capacitance filter that controls the rise time on make, the rise time increasing as $R \times C$ is made larger. $C \times (R_1 + R_2)$ controls the decay time on break in the same manner. Since grid current flows through R_2 in Fig. 8-4A when the key is

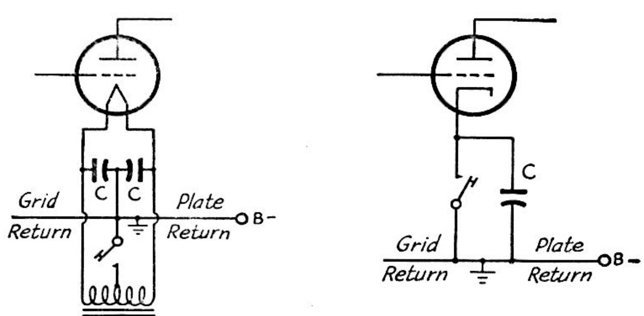


Fig. 8-5 — **Center-tap and cathode keying. The condensers, *C*, are r.f. by-pass condensers. Their capacity is not critical, values of 0.001 to 0.01 μfd. ordinarily being used.**

closed, operating bias is developed, and R_2 is usually the normal grid leak for the tube. Thus C_1 only is varied to obtain the proper rise time.

With blocked-grid keying only a small current is broken compared with other systems, and sparking at the key is slight.

CATHODE KEYING

Keying the cathode circuit of a tube simultaneously opens the grid and plate circuits of the tube. This is shown in Fig. 8-5. The condenser *C* serves as a short path for the r.f. energy, since the keying leads are often long. When a filament-type tube is keyed in this manner, the key is connected in the filament-transformer center-tap lead, as in Fig. 8-5, and the system is called center-tap keying. The condensers *C* serve the same purpose as in cathode keying.

Cathode (or center-tap) keying results in less sparking at the key contacts than does plate-supply keying, for the same plate power. When used with an oscillator it does not respond as readily to key-click filtering as does plate-circuit keying, but it is an excellent method for amplifier keying. If plate voltages above 300 are used, it is highly advisable to use a keying relay, to avoid accidental electrical shock at the key.

KEYING RELAYS

A keying relay can be substituted for a key in any of the keying circuits shown in this chapter. Most keying relays operate from 6.3 or 115 volts a.c., and they should be selected for their speed of operation and adequate insulation for the job to be done. Adequate current-handling capability is also a factor. A typical circuit is shown in Fig. 8-6.

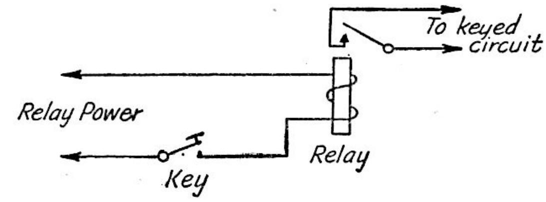


Fig. 8-6— A keying relay can always be substituted for the key, to provide better isolation from the keyed circuit. An r.f. filter is generally required at the key, and the keying filter is connected in the keyed circuit at the relay contacts.

The relay-coil current that is broken by the key will cause clicks in the receiver, and an r.f. filter (see later in this chapter) is often necessary across the key. The normal keying filter connects at the relay armature contacts in the usual manner.

Key-Click Reduction

As pointed out earlier, interference caused by the key breaking current and the fast rise and decay times of the keyed characters is called "key clicks." The elimination of the interference depends upon its type.

R.F. FILTERS

Key clicks caused by the spark (often very minute) at the key contacts can be minimized by isolating the key from the rest of the wiring by a small r.f. filter. Such a filter usually consists of an r.f. choke in each key lead, placed right at the key terminals and by-passed on the line side by a small condenser. Such a circuit is shown in Fig. 8-7. Suitable values are best found by experiment, although 2.5-mh. r.f. chokes and an 0.001-μfd. condenser represent good starting points. The chokes must be capable of carrying the current that is broken, and the condenser must have a voltage rating equal at least to the voltage across the key under key-up conditions. Sometimes a small condenser directly across the key terminals is also necessary to remove the last trace of click.

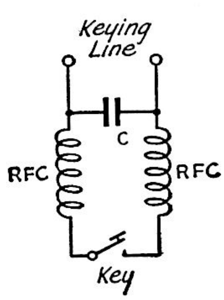


Fig. 8-7 — R.f. filter used for eliminating the radiation effects of sparking at the key contacts. Suitable values for best results with individual transmitters must be determined by experiment. Values for *RFC* range from 2.5 to 80 millihenrys and for *C* from 0.001 to 0.1 μfd.

This type of r.f. filter is required in nearly every keying installation, in addition to the circuits to be described in the following few paragraphs.

Keying Filters

A filter used to give a desired shape to the keyed character, to eliminate clicks in the amateur band and adjacent services, is called a **keying filter** or **lag circuit.** In its simplest form it consists of a condenser and an inductance, connected as in Fig. 8-8. This type of keying filter is suitable for use in the circuits shown in Figs. 8-1 and 8-5. The optimum values of capacitance and inductance must be found by experiment but are not very critical. If a high-voltage low-current circuit is being keyed, a small condenser and a large inductance will be required, while a low-voltage high-current circuit needs a large condenser and small inductance to reduce the clicks properly. For example, a 300-volt 6-ma. circuit will require about 30 henrys and 0.05 μfd., while a 300-volt 50-ma. circuit needs about 1 henry and 0.5 μfd. For any given set of conditions, increasing the inductance will reduce the clicks on "make" and increasing the capacitance will reduce the clicks on "break."

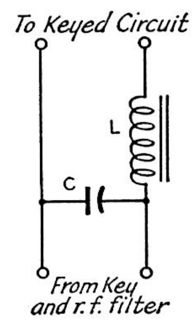


Fig. 8-8 — Lag circuit used for shaping the keying character to eliminate unnecessary sidebands. Actual values for any given circuit must be determined by experiment, and may range from 1 to 30 henrys for *L* and from 0.05 to 0.5 μfd. for *C*, depending on the keyed current and voltage.

Primary keying is adjusted by changing the filter values (*L* or *C* in Fig. 8-2). Since it is unlikely that a variety of chokes will be available to the operator, capacitance changes are usually all that can be made. If the keying is found too "soft," the value of *C* must be reduced.

Blocked-grid keying is adjusted by changing the values of resistors and condensers in the circuit, as outlined under the description of the circuit. The values required for individual installations will vary with the amount of blocking voltage and the value of grid leak.

Tube Keying

A tube keyer is a convenient device for keying the transmitter, because it allows the keying characteristic to be adjusted easily and also removes all dangerous voltages from the key itself. The current broken by the key is negligible and usually no r.f. filter is required at the key. A tube keyer uses a tube (or tubes in parallel) to control the current in the plate or cathode circuit of the stage being keyed. The keyer tube turns off the current flow when a high negative voltage is applied to the grid of the keyer tube. The keying characteristic is shaped through the time constants of the grid circuit of the keyer tube, in exactly the same way that it is controlled in blocked-grid keying. When a tube keyer is used to replace the key in a plate or cathode circuit, the power output of the stage may be reduced somewhat because of the voltage drop across the keyer tube but this is of little importance because the effect is not large.

A Vacuum-Tube Keyer

A tube-keyer unit is shown in Figs. 8-9 and 8-10. T_1, the 80 rectifier, and C_1 and R_1 form the power-supply section that furnishes the blocking voltage for the keyer tubes.

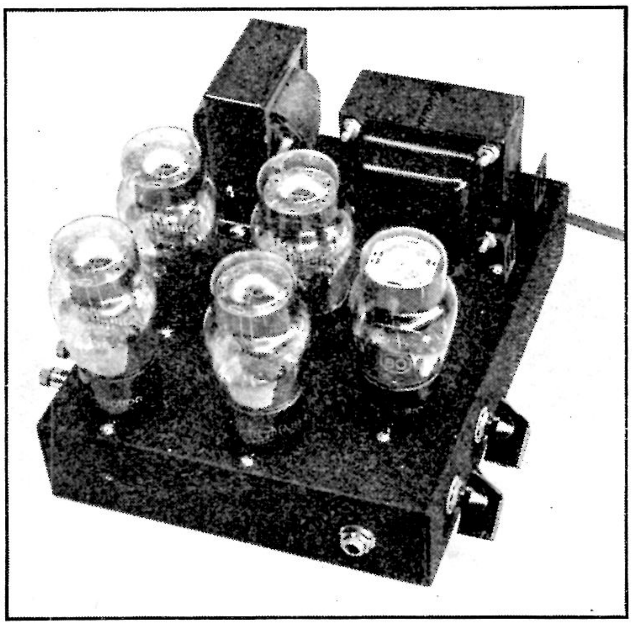


Fig. 8-9 — A vacuum-tube keyer, built up on a 7 × 9 × 2-inch chassis with space for four or less keyer tubes and the power-supply rectifier. The resistors and condensers which produce the lag are underneath, controlled by the knobs at the right. The jack is for the key, while terminals at the left are for the keyed circuit.

S_1 and S_2 and their associated resistors and condensers are included to allow the operator to select the keying characteristic he wants. A simplified version could omit the switches and extra components, since once the values have been selected the components can be soldered permanently in place. The rule for adjusting the keying characteristic is the same as for blocked-grid keying. However, large values of resistors and small values of condensers can be used, since there is no value of grid leak determined by the tube that dictates a starting point.

As many 45s may be added in parallel as desired. The voltage drop through a single tube varies from about 90 volts at 50 ma. to 50 volts at 20 ma. Tubes added in parallel will reduce the drop in proportion to the number of tubes used.

When connecting the output terminals of the keyer to the circuit to be keyed, the grounded output terminal of the keyer must be connected to the transmitter ground. Thus the keyer can be used only in negative-lead or cathode keying.

When the key or keying lead has poor insulation, the resistance may become low enough (particularly in humid weather) to reduce the blocking voltage and allow the keyer tube to pass some current. This may cause a slight back-wave on the signal.

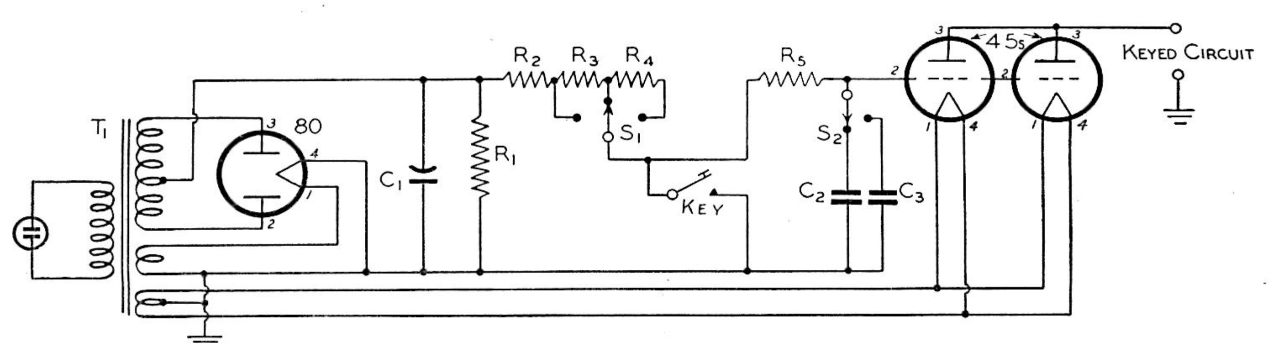


Fig. 8-10 — Wiring diagram of the practical vacuum-tube keyer unit and power supply shown in Fig. 8-9.

C_1 — 2-μfd. 600-volt paper.
C_2 — 0.0033-μfd. mica.
C_3 — 0.0047-μfd. mica.
R_1 — 0.22 megohm, 1 watt.
R_2 — 50,000 ohms, 10 watts.
R_3, R_4 — 4.7 megohms, 1 watt.
R_5 — 0.47 megohm, 1 watt.
S_1, S_2 — 3-position 1-circuit rotary switch.
T_1 — 325-0-325 volts, 5 volts and 2.5 volts (Thordarson T-13R01).

Checking Transmitter Keying

One of the best ways to check your transmitter keying is to enlist the aid of a near-by amateur and trade stations with him for a short time. Not only will you be able to check your own key clicks and chirps, if they exist, but if you have any complaint about the other fellow's signal this is a convenient way to let him know!

A SIGNAL MONITOR

Lacking a conveniently-local amateur, your next best bet is to check your signals with a signal monitor. This consists of a completely-shielded battery-operated simple receiver. The complete shielding reduces the signal from the transmitter to the point where it is possible to listen without having the signal "block" the monitor. The monitor can be used to listen to a harmonic of the transmitter, in the case of high-powered transmitters, or the monitor can be used at some distance from the transmitter and remote keying leads run out for the test. A typical signal monitor is shown in Figs. 8-11, 8-12, 8-13 and 8-14.

The monitor is a two-tube regenerative receiver, as can be seen from the circuit diagram, Fig. 8-12. The 1T4 detector has a medium-C tank circuit and low value of grid leak (R_1) to reduce blocking effects. Capacitance control of regeneration is obtained through C_5. The 1S4 audio amplifier gives reasonable headphone volume with the 45-volt plate supply. By-pass condensers across the headphone jack attenuate signals picked up by the 'phone cords. The jack, J_1, is insulated from the panel by fiber washers to avoid shorting the plate-supply battery.

The monitor is built in a 5 × 9 × 6-inch "utility cabinet." The chassis is a small piece of sheet aluminum supported by the two variable condensers. The variable condensers fasten to the front panel (cover) of the cabinet by their single-hole mountings, and the tapped mounting brackets of the condensers then serve as two brackets to support the chassis. The side walls of the cabinet bearing on the chassis contribute to the rigidity of the assembly.

A shield can is mounted over the antenna post, and is only removed when the signal isn't strong enough to be heard otherwise. Normally the shield can will be left in place. The can is one of the small aluminum cans 35-mm. film is packed in. The cover of the can is fastened to the panel with two screws, and a National XS-7 steatite bushing serves as a feed-through and antenna terminal.

The coils are wound on Silver Type 125 coil forms, which are low-loss tube bases. The winding data are given in Fig. 8-12. For any one range, both coils are wound in the same direction, and the grid and plate leads are taken off at the outside ends of the coils. It isn't necessary to wind coils for every amateur band, since one's listening should be done on the band in use or a higher-frequency one. Running one's hands over the 'phone cords or touching the cabinet at any point should result in no change in frequency. If any is noted, it indicates that the shielding and filtering are not adequate, and the grounding of C_6 and C_7 and the bonding of the cabinet should be thoroughly checked.

SIGNAL CHECKING WITH A RECEIVER

If keying the transmitter does not affect the line voltage, the station communications receiver can be used to check keying. The antenna should be disconnected from the receiver and the antenna posts shorted to ground. This method is satisfactory only when the line voltage is not affected by keying, since any changes in line voltage will probably affect the receiver frequency. Receivers with

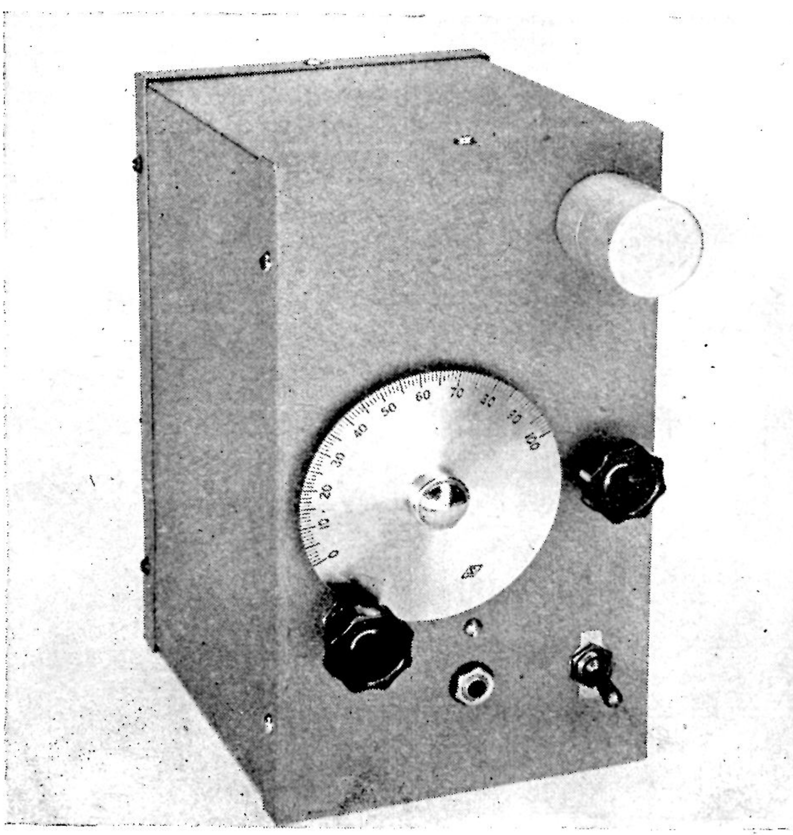


Fig. 8-11 — A two-tube battery-operated monitor. The extra knob is a regeneration control, and the little aluminum box in the upper corner is a shield can for the antenna terminal.

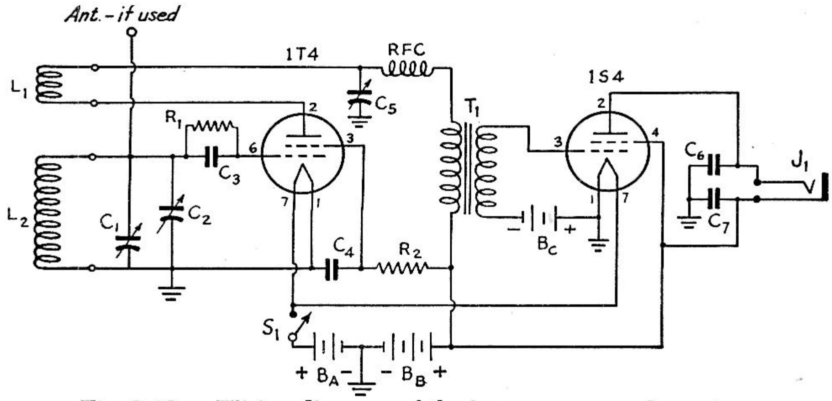


Fig. 8-12 — Wiring diagram of the battery-powered monitor.

C_1 — 10-μμfd. midget variable (Bud LC-1648).
C_2 — 3–30-μμfd. mica trimmer.
C_3 — 47-μμfd. mica.
C_4, C_6, C_7 — 0.001-μfd. mica.
C_5 — 75-μμfd. midget variable (Hammarlund HF-75 or Bud LC-1645).
R_1 — 0.1 megohm, ½ watt.
R_2 — 10,000 ohms, ½ watt.
L_1 — 7 Mc.: 5 turns. 14 Mc.: 3 turns. 28 Mc.: 2 turns.
L_2 — 7 Mc.: 14½ turns. 14 Mc.: 6½ turns. 28 Mc.: 2⅔ turns. L_1 and L_2 are close-wound with No. 24 d.c.c. on 1⅜-inch diameter tube-base forms. Final adjustment of tuning range made by spacing top turns of L_2 and/or setting C_2.
B_A — 1½-volt dry cell (Eveready No. 6 or equiv.).
B_B — 45-volt "B" battery, small size (Burgess XX30).
B_C — 4½ volts. Three "penlite" cells connected in series and wrapped with friction tape.
J_1 — Open-circuit jack.
RFC — 2.5-mh. r.f. choke (National R-100S).
T_1 — Interstage audio transformer, 3:1 ratio (Thordarson T13A34).

good shielding will be more satisfactory than those that allow signals to leak in through the receiver wiring.

Key Clicks

When checking for key clicks, the b.f.o. and a.v.c. of the monitoring receiver should be turned off. If the monitor of Fig. 8-11 is used, the regeneration control should be backed off until the detector is out of oscillation. The keying should be adjusted so that a slight click is heard as the key is closed but practically none heard as the key is opened. When the keying constants have been adjusted to meet this condition, the clicks will be about optimum for all normal amateur work. The receiver gain should be reduced during these tests, since false clicks can be generated in the receiver if the receiver is overloaded. No clicks should be heard off the signal frequency. Checks should be made with no r.f. power but with the key breaking its normal current, to insure that local clicks are not generated by sparking at the key. To do a good job of checking clicks, those caused by sparking at the key must be eliminated independently of those generated by the keyed r.f. carrier.

Chirps

Keying chirps may be checked by tuning in the signal or one of its harmonics on the highest frequency range of the receiver or monitor and listening to the beat-note in the normal manner. The gain should be sufficient to give moderate signal strength, but it should be low enough to avoid overloading. Adjust the tuning to give a low-frequency beat-note and key the transmitter at several different speeds. Any chirp introduced by the keying will show up. The signal should be tuned in on either side of zero beat and at various beat frequencies for a complete check. Listening to a harmonic magnifies the effect of any chirp and makes it easier to detect.

Oscillator Keying

The keying of an amplifier is relatively straightforward and requires no special treatment, but considerable care may be necessary with oscillator keying. Any oscillator, either crystal or self-controlled, should oscillate at low voltages (on the order of two or three volts) and have negligible change in frequency with plate voltage, if it is to key without chirps or clicks. A crystal oscillator will oscillate at low voltages if a regenerative type such as the Tri-

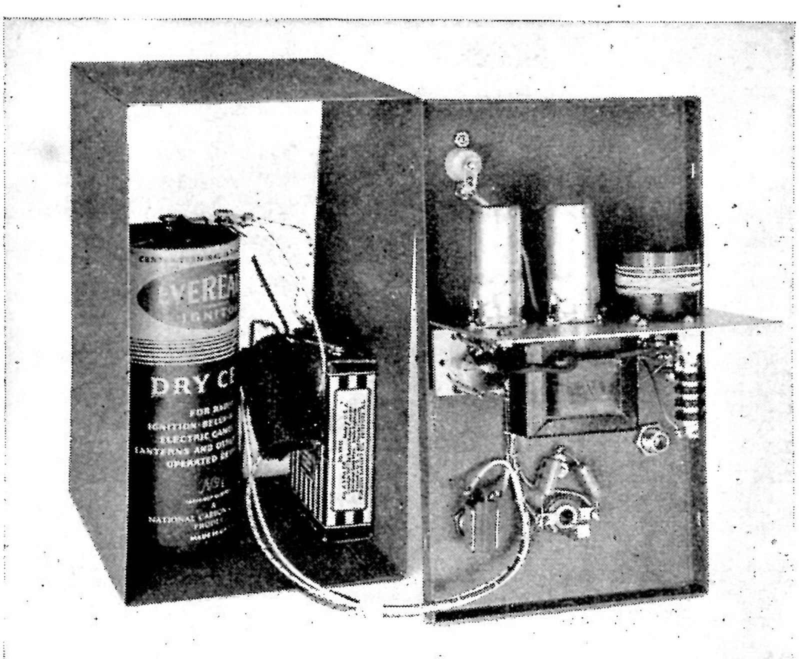


Fig. 8-13 — A view of the monitor disassembled, giving an idea of the arrangement of parts and the batteries. The tube shields cover the audio amplifier (left) and the oscillating detector (center).

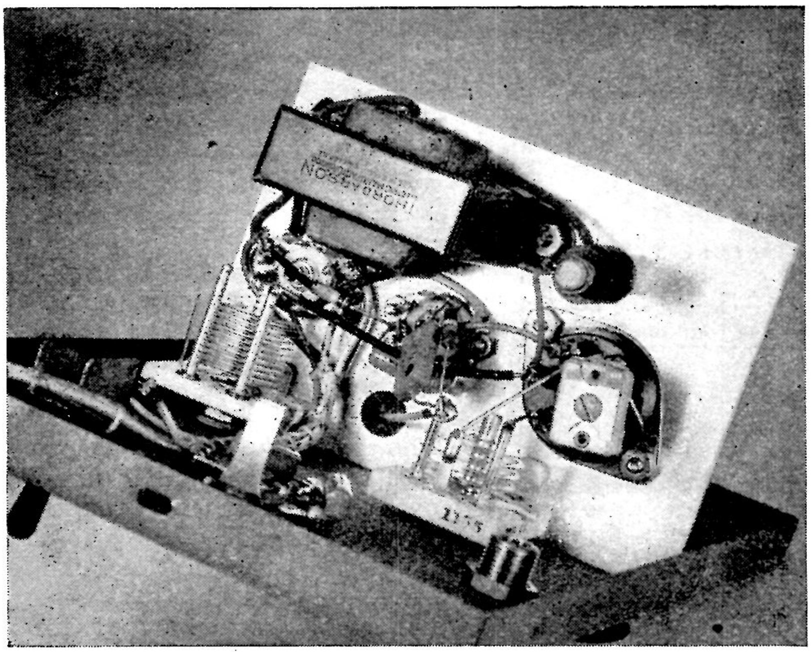


Fig. 8-14 — **A close-up view of the underside of the monitor chassis, showing the main tuning condenser (right), the padding condenser mounted on the coil socket, and the feed-back control condenser.**

tet or grid-plate is used and if an r.f. choke is connected in series with the grid-leak resistor, to reduce loading on the crystal. Crystal oscillators of this type are generally free from chirp unless the crystal is a poor one or if there is too much air gap in the crystal holder.

Self-controlled oscillators are more difficult to operate without chirp, but the important requirements are a high C to L ratio in the tank circuit, low plate (and screen) currents, and careful adjustment of the feed-back. A self-controlled oscillator intended to be keyed should be designed for best keying rather than maximum output.

Stages Following Keying

When a keying filter is being adjusted, the stages following the keyed stage should be made inoperative by removing the plate voltage. This allows the keying to be checked without masking by effects caused in the later stages. The following stages should then be connected in, one at a time, and the keying checked after each addition. An increase in click intensity (for the same carrier strength in the receiver) indicates that the clicks are being added in the stages following the one being keyed. The fixed bias on such stages should be sufficient to reduce the idling plate current (no excitation) to a low value, but not to zero. Under these conditions, any instability or tendency toward parasitic oscillations will show up. The output condensers on the filters of the power supplies feeding these later stages can often be increased to good advantage in reducing clicks introduced by these stages.

Low-frequency *parasitic oscillations* in later stages can cause key clicks removed from the signal frequency by 50 or 100 kc. These clicks are often difficult to track down, but they cause considerable interference and cannot be tolerated. They are most common in beam-tetrode stages, and often can only be eliminated by neutralizing the tetrode stage. Since the parasitic oscillations are of a transient nature, and exist only during the make and break periods of keying, they are much harder to find than parasitics that are not transient.

MONITORING OF KEYING

Most operators find a keying monitor helpful in developing and maintaining a good "fist," especially if a "bug" or semiautomatic key is used. The most popular type of monitor is an audio oscillator which is keyed simultaneously with the transmitter. The output of the audio oscillator is coupled to the receiver headphones or loudspeaker. The circuit diagram for a simple monitor of this type is shown in Fig. 8-15. The plate voltage, as well as the heater voltage, is supplied by a 6.3-volt filament transformer. One section of the 6F8G dual triode is used as the rectifier to supply d.c. for the plate of the other section, and this latter section is used as the oscillator. A change in the value of R_1 will alter the output tone. The output post marked "GND" should be connected directly to the receiver chassis, while "P_1" should be connected to the "hot" side of the headphones. Shunting the headphones with the oscillator may cause some loss in volume from the receiver, unless the cou-

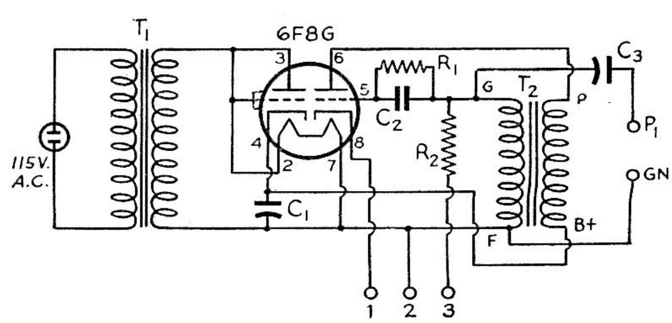


Fig. 8-15 — **Circuit diagram of a keying monitor of the audio-oscillator type, with self-contained power supply.**

C_1 — 25-μfd. 25-volt electrolytic.
C_2 — 220-μμfd. mica.
C_3 — Approximately 0.01 μfd. (see text).
R_1 — 0.15 megohm, ½ watt.
R_2 — Approximately 0.1 megohm, 1 watt.
T_1 — 6.3-volt 1-ampere filament transformer.
T_2 — Small audio transformer, interstage type.

pling capacitor, C_3, is made small. However, the capacitor should be made large enough to provide good transfer of the oscillator signal to the headphones or 'speaker.

If the transmitter oscillator is keyed for break-in, the keying terminals of the oscillator may be connected in parallel with those of the transmitter. With cathode or negative-plate-supply keying, Terminals 1 and 2 should be connected across the key, with Terminal 2 going to the ground side. If blocked-grid keying is used, Terminals 1 and 2 should be connected to the ground side of the key and Terminal 3 to the "hot" (negative) side of the key.

Break-In Operation

Break-in operation requires a separate receiving antenna, since none of the available antenna change-over relays is fast enough to follow keying. The receiving antenna should be installed as far as possible from the transmitting antenna. It should be mounted at right angles to the transmitting antenna and fed with low-pick-up lead-in material such as coaxial cable or 300-ohm Twin-Lead, to minimize pick-up.

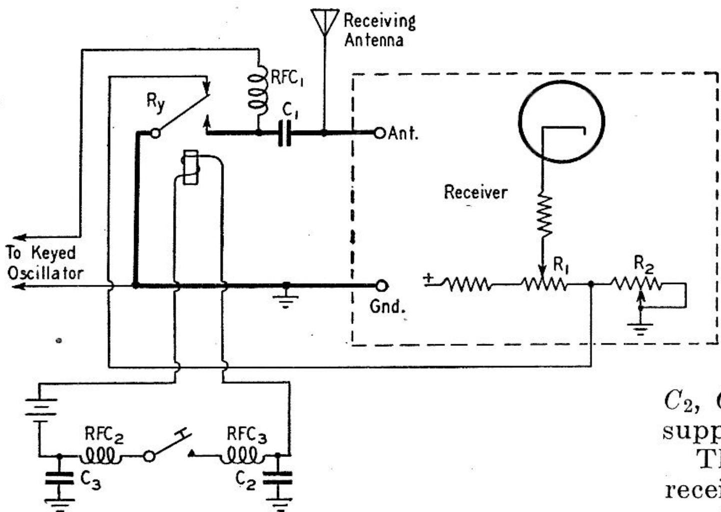


Fig. 8-16 — **Wiring diagram for smooth break-in operation. The leads shown as heavy lines should be kept as short as possible, for minimum pick-up of the transmitter signal.**

C_1, C_2, C_3 — 0.001 μfd.
R_1 — Receiver manual gain control.
R_2 — 5000- or 10,000-ohm wire-wound potentiometer.
RFC_1, RFC_2, RFC_3 — 2.5-mh. r.f. choke.
Ry — S.p.d.t. keying relay.

If a low-powered transmitter is used, it is often quite satisfactory to use no special equipment for break-in operation other than the separate receiving antenna, since the transmitter will not block the receiver too seriously. Even if the transmitter keys without clicks, some clicks will be heard when the receiver is tuned to the transmitter frequency because of overload in the receiver. An output limiter, as described in Chapter Five, will wash out these clicks and permit good break-in operation even on your transmitter frequency.

When powers above 25 or 50 watts are used, special treatment is required for quiet break-in on the transmitter frequency. A means should be provided for shorting the input of the receiver when the code characters are sent, and a means for reducing the gain of the receiver at the same time is often necessary. The system shown in Fig. 8-16 permits quiet break-in operation for higher-powered stations. It requires a simple operation on the receiver but otherwise is perfectly straightforward. R_1 is the regular receiver r.f. and i.f. gain control. The ground lead is lifted on this control and run to a rheostat, R_2, that goes to ground. A wire from the junction runs outside the receiver to the keying relay, R_y. When the key is up, the ground side of R_1 is connected to ground through the relay arm, and the receiver is in its normal operating condition. When the key is closed, the relay closes, which breaks the ground connection from R_1 and applies additional bias to the tubes in the receiver. This bias is controlled by R_2. When the relay closes, it also closes the circuit to the transmitter oscillator. C_2, C_3, RFC_2 and RFC_3 is a keying filter to suppress the clicks caused by the relay current.

The keying relay should be mounted on the receiver as close to the antenna terminals as possible, and the leads shown heavy in the diagram should be kept short, since long leads will allow too much signal to get through into the receiver. A good high-speed keying relay should be used. If a two-wire line is used from the receiving antenna, another r.f. choke, RFC_4, will be required. The revised portion of the schematic is shown in Fig. 8-17.

● A DE LUXE BREAK-IN SYSTEM

In many instances it is quite difficult to key an oscillator without clicks *and* chirps. Most oscillators will key without apparent chirp

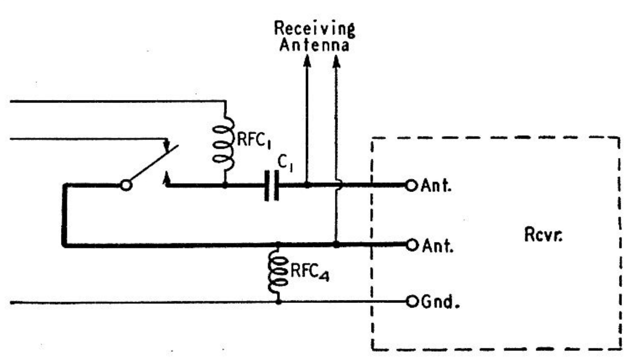


Fig. 8-17 — **Necessary circuit revision of Fig. 8-16 if a two-wire lead from the receiving antenna is used. RFC_4 is a 2.5-mh. r.f. choke — other values are the same as in Fig. 8-16.**

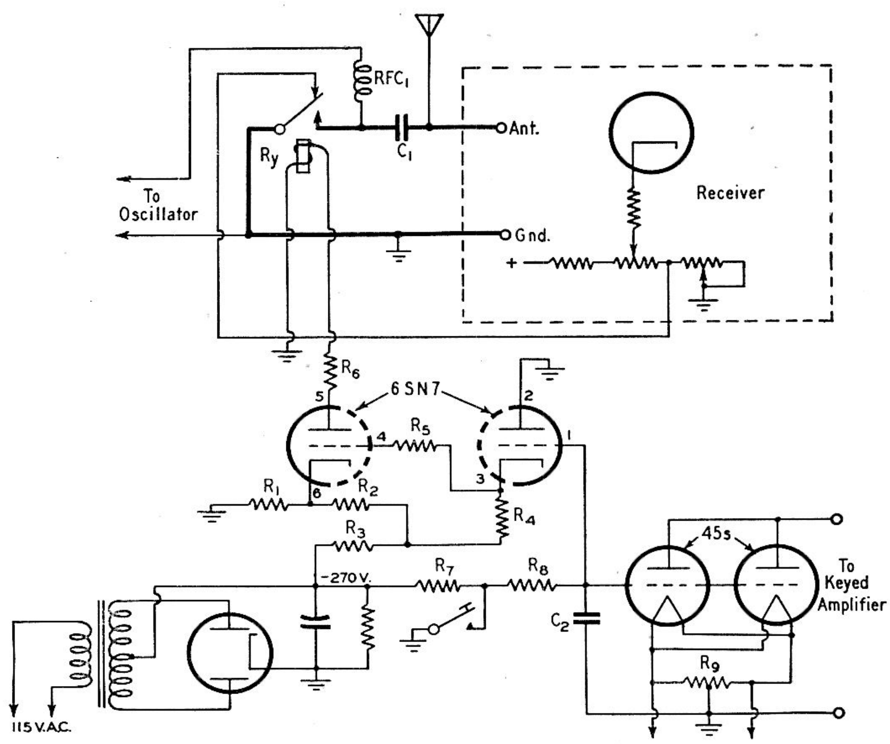


Fig. 8-18 — **A de luxe break-in system that holds the oscillator circuit closed (and the receiver input shorted) during a string of fast dots but opens between letters or words.**

C_1 — 0.001 μfd.
C_2 — 0.005 μfd.
R_1 — 20,000 ohms, 10 watts, wire-wound.
R_2 — 1800 ohms.
R_3 — 1500 ohms.
R_4, R_5 — 1.0 megohm.
R_6 — 4700 ohms.
R_7 — 6.8 megohm.
R_8 — 0.47 megohm.
R_9 — 50-ohm center-tapped resistor, 2 watts.
All resistors 1-watt composition unless otherwise noted.
RFC_1 — 2.5-mh. r.f. choke.
Ry — High-speed relay, 1400-ohm 18-volt coil (Stevens-Arnold Type 172 Millisec relay).

if the rise and decay times are made very short, but this introduces key clicks that cannot be avoided. The system shown in Fig. 8-18 avoids this trouble by turning on the oscillator quickly, keying an amplifier with a vacuum-tube keyer, and turning off the oscillator after the amplifier keying is finished. The oscillator is turned on and off without lag, but the resultant clicks are not passed through the transmitter. Actually, with keying speeds faster than about 15 w.p.m., the oscillator will stay turned on for a letter or even a word, but it turns off between words and allows the transmitting station to hear the "break" signal of the other station. It requires one tube more than the ordinary vacuum-tube keyer and a special high-speed relay.

As can be seen from Fig. 8-18, the circuit is a combination of the break-in system of Fig. 8-16 and the tube keyer of Fig. 8-9, with a 6SN7 tube and a few resistors added. Normally the left-hand portion of the 6SN7 is biased to a low value of plate current by the drop through R_2 (part of the bleeder $R_1R_2R_3$) and the relay is open. When the key is closed and C_2 starts to discharge, the right-hand portion of the 6SN7 draws current and this in turn puts a less-negative voltage on the grid of the left-hand portion. The tube draws current and the relay closes. The relay will stay closed until the negative voltage across C_2 is close to the supply voltage, and consequently a string of dots or dashes (which don't give C_2 a chance to charge to full negative) will keep the relay closed. In adjusting the system, R_2 controls the amount of idling current through the relay and R_6 determines the voltage across the relay. R_7, R_8 and C_2 are the normal resistors and condenser for the tube keyer. When adjusted properly, the relay will close without delay on the first dot and open quickly during the spaces between words or slower letters. When idling, the voltage across the relay should be one or two volts — with the key down it should be 18 volts.

The oscillator should be designed to key as fast as possible, which means that series resistances and shunt capacitances should be held to a minimum. Negative-plate-lead keying is slightly faster than cathode keying and should be used in the oscillator. The keyer tubes are connected in the cathode circuit of an amplifier following the oscillator, far enough removed in the circuit to avoid reaction on the oscillator.

ELECTRONIC KEYS

Electronic keys, as contrasted with mechanical automatic keys, use vacuum tubes (and possibly relays) to form automatic dashes as well as automatic dots. Full descriptions of such devices can be found in the following *QST* articles:

Beecher, "Electronic Keying," April, 1940.
Grammer, "Inexpensive Electronic Key," May, 1940.
Savage, "Improved Switching Arrangement for Simplified Electronic Key," March, 1942.
Gardner, "New Electronic-Key Circuits," March, 1944.
Wiley, "Simplifying the Electronic Key," July, 1944.
"Electronic Bug Movement," Feb., 1945.
Snyder, "Versatile Electronic Key," March, 1945; correction, page 82, May, 1945.
Beecher, "Better Electronic Keyer," August, 1945.
DeHart, "De luxe Electronic Key," Sept., 1946; correction, page 27, Jan., 1947.

Radiotelephony

To transmit intelligible speech by radio it is necessary to **modulate** the normally-constant output of the radio-frequency section of a transmitter. **Modulation,** defined in the most simple terms, is the process of varying the transmitter output in a desired fashion. In the case of radiotelephony, it means varying the radio-frequency output in a way that follows the spoken word.

The unmodulated r.f. output of the transmitter is called the **carrier**. In itself, the carrier conveys no information to the receiving operator — other than that the transmitting station is "on the air." It is only when the carrier is modulated that it becomes possible to transmit a message.

● METHODS OF MODULATION

The carrier as generated by the transmitter is a simple form of alternating current — practically a sine wave. As such, it has three "dimensions" that can be varied — its amplitude, its frequency, and its phase. Modulation can be applied successfully to any of the three.

In **amplitude modulation (AM)** the amplitude of the carrier is made to vary upward and downward, following similar variations in audio-frequency currents generated by a microphone. In this type of modulation the frequency and phase of the carrier are unaffected by the modulation. Amplitude modulation is today the most widely-used system in amateur stations.

In **frequency modulation (FM)** the frequency of the carrier is made to vary above and below the unmodulated carrier frequency, the frequency variations being made to follow the a.f. currents. The power output of the transmitter does not change in frequency modulation. The *phase* of the carrier does change, however, since frequency and phase are intimately related.

In **phase modulation (PM)** the phase of the carrier is advanced and retarded by the modulating audio-frequency current. The transmitter power does not vary with modulation, but the carrier frequency changes.

These definitions are quite broad, and detailed explanations of the three systems are given later in this chapter.

● SIDEBANDS

No matter what the method of modulation, the process of modulating a carrier sets up new groups of radio frequencies both above and below the frequency of the carrier itself. These new frequencies that accompany the modulation are called **side frequencies,** and the frequency bands occupied by a group of them when the modulating signal is complex (as it is with voice modulation) are called **sidebands.** Sidebands always appear on *both* sides of the carrier; the band higher than the carrier frequency is called the **upper sideband** and the band lower than the carrier frequency is called the **lower sideband.** The modulation (that is, the intelligence) in the signal is carried in the sidebands, not in the carrier itself.

The result of this is that a modulated signal occupies a group or band of frequencies **(channel)** rather than the single frequency of the carrier alone. Just how much of a frequency band (that is how wide a channel) is occupied depends upon the method of modulation and the frequency characteristics of the modulating signal itself.

A normal voice contains frequencies or tones ranging from perhaps a hundred cycles at the low end to several thousand cycles at the high end. Vowel sounds (*a, e, i, o, u*) are in general fairly low in frequency and contain most of the voice power. Consonants usually are characterized by higher frequencies, and the hissing sound of the letter "S" is particularly high up in the audio-frequency range. The timbre of a voice, or the thing that makes it possible for us to distinguish the voices of different individuals, results principally from overtones or harmonics. All these things add up to the fact that a fairly wide range of audio frequencies is needed for the accurate reproduction of a *particular* voice.

On the other hand, the frequency range required for good *intelligibility* is not nearly so wide as that needed for accurate reproduction or "fidelity." For the latter, an audio system that is "flat" — that is, has the same amplification at all frequencies — over the range up to about 10,000 cycles is required. But a system that "cuts off" above 2500 cycles — that is, has comparatively little output above that figure — will transmit everything that is necessary for *understandable* speech. The speech may sound a little less like the speaker's actual voice, but it will be thoroughly intelligible to the receiving operator.

This distinction between intelligibility and "quality" is extremely important. The *minimum* channel occupied by a 'phone transmitter, *no matter what the system of modulation,* is equal to *twice the highest audio frequency present in the modulation.* If audio frequencies up to 10,000 cycles are contained in the modulation, the channel will be at least twice 10,000 or 20,000 cycles (20 kc.) wide. But if there are no frequencies above 2500 cycles in the modulation, the channel will be only 5000 cycles (5 kc.) wide. In amateur bands where there is a great deal of congestion it is in everybody's interest that each transmitter should occupy no more than the minimum channel needed for transmitting *intelligible* speech. Taking up a wider frequency channel than that simply creates unnecessary interference.

Also, transmitting a wide range of audio frequencies in a congested band actually accomplishes nothing, insofar as "fidelity" is concerned; the receiving operator has to use so much receiver selectivity — in order to "copy" the signal at all — that the higher-frequency sidebands are rejected by the receiver. Those sidebands do, however, continue to interfere with stations operating on near-by carrier frequencies.

We have said that the *minimum* channel is equal to twice the highest audio frequency in the modulation. The actual channel occupied may be several times the minimum necessary channel-width. This depends on the system of modulation used, for one thing. For another, it depends on whether the system is operated properly or whether it is misadjusted. Improper operation of any sort invariably increases the channel-width. Since the amount of frequency space available for amateur operation is limited, no operator of an amateur 'phone station can avoid the obligation to confine his transmissions to the least possible space.

Amplitude Modulation

In amplitude modulation, as we have already stated, the amplitude or strength of the carrier is varied up and down from the unmodulated value. The several methods of making the carrier strength vary are discussed in a later section; for the moment let us look only at the end result that is the object of all the various amplitude-modulation systems.

In Fig. 9-1, the drawing at A shows the unmodulated r.f. carrier, assumed to be a sine wave of the desired radio frequency. The graph can be taken to represent either voltage or current, and each cycle has just the same height as the preceding and following ones.

In B, the carrier wave is assumed to be modulated by a signal having the shape shown in the small drawing above. The frequency of the modulating signal is much lower than the carrier frequency, so quite a large number of carrier cycles can occur during each cycle of the modulating signal. This is a necessary condition for good modulation, and always is the case in radiotelephony because the audio frequencies used are very low compared with the radio frequency of the carrier. (Actually, there would be very many times more r.f. cycles in each modulation cycle than are shown in the drawing; so many that it is impossible to make the drawing to actual scale.) When the modulating signal is "positive" (above its axis) the carrier amplitude is increased *above* its unmodulated amplitude; when the modulating signal is "negative" the carrier amplitude is *decreased.* Thus the carrier grows larger and smaller with the polarity and amplitude of the modulating signal.

The drawing at C shows what happens with a stronger modulating signal. In this case the strength of the modulation is such that on the "up" modulation the carrier amplitude is doubled at the instant the modulating signal reaches its positive peak. On the negative peak of the modulating signal the carrier amplitude just reaches zero; in other words, the carrier is "all used up."

Percentage of Modulation

When a modulated wave is detected in a receiver the sound that comes out of the loud-

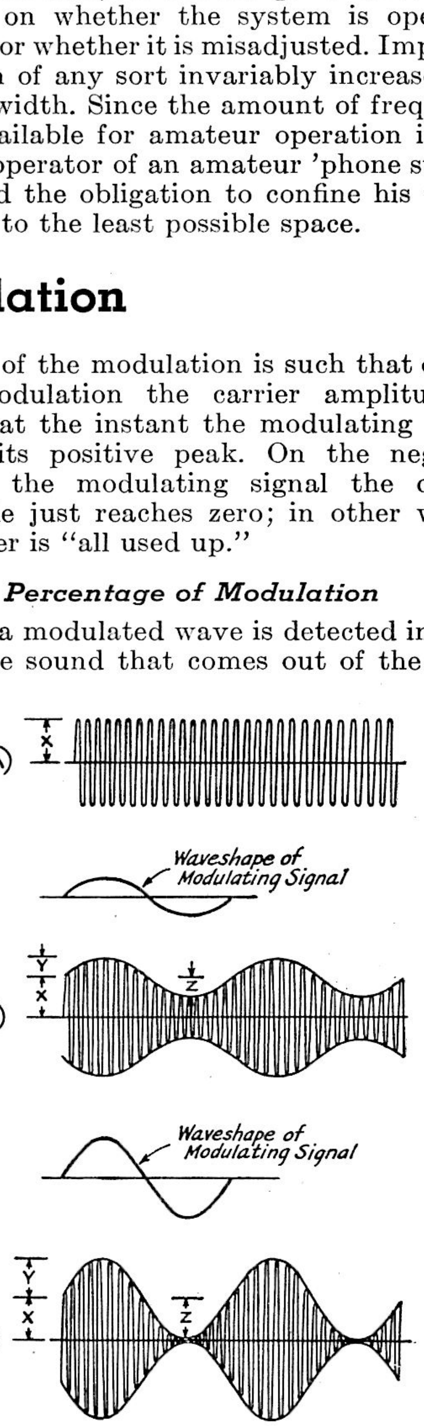


Fig. 9-1 — Graphical representation of (A) carrier unmodulated, (B) modulated 50%, (C) modulated 100%.

speaker or headset is caused by the modulation, not by the carrier. In other words, in detecting the signal the receiver eliminates the carrier and takes from it the modulating signal. The stronger the modulation, therefore, the greater is the useful receiver output. Obviously, it is desirable to make the modulation as strong or "heavy" as possible. A wave modulated as in Fig. 9-1C would produce considerably more useful signal than the one shown at B.

The "depth" of the modulation is expressed as a percentage of the unmodulated carrier amplitude. In either B or C, Fig. 9-1, X represents the unmodulated carrier amplitude, Y is the maximum *increase* in amplitude on the modulation up-peak, and Z is the maximum *decrease* in amplitude on the modulation down-peak. Assuming that Y and Z are equal, then the *percentage of modulation* can be found by dividing either Y or Z by X and multiplying the result by 100. In the wave shown in Fig. 9-1C, Y and Z are both equal to X, so the wave is modulated 100 per cent. In case the modulation is not symmetrical (Y and Z not equal), the larger of the two should be used for calculating the percentage of modulation.

The outline of the modulated wave is called the **modulation envelope.** It is shown by the thin line outlining the patterns in Figs. 9-1 and 9-2.

Power in Modulated Wave

The amplitude values shown in Fig. 9-1 correspond to current or voltage, so the drawings may be taken to represent instantaneous values of either. Now power varies as the square of either the current or voltage (so long as the resistance in the circuit is unchanged), so at the peak of the modulation up-swing the instantaneous power in the wave of Fig. 9-1C is four times the unmodulated carrier power (because the current and voltage are doubled). At the peak of the down-swing the power is zero, since the amplitude is zero. With a sine-wave modulating signal, the *average* power in a 100-per-cent modulated wave is one and one-half times the value of unmodulated carrier power; that is, the power output of the transmitter increases 50 per cent with 100-per-cent modulation.

The complex waveform of speech does not contain as much power as there is in a pure tone or sine wave of the same peak amplitude. On the average, speech waveforms will contain only about half as much power as a sine wave, both having the same peak amplitude. The average power output of the transmitter therefore increases only about 25 per cent with 100-per-cent speech modulation. However, the *instantaneous* power output must quadruple on the peak of 100-per-cent modulation regardless of the modulating waveform. Therefore, the peak output-power capacity of the transmitter must be the same for any type of modulating signal.

Overmodulation

If the carrier is modulated more than 100 per cent, a condition such as is shown in Fig. 9-2 occurs. Not only does the peak amplitude exceed twice the carrier amplitude, but there actually may be a considerable period during which the output is entirely cut off. Therefore the modulated wave is distorted, and the modulation contains harmonics of the audio modulating frequency.

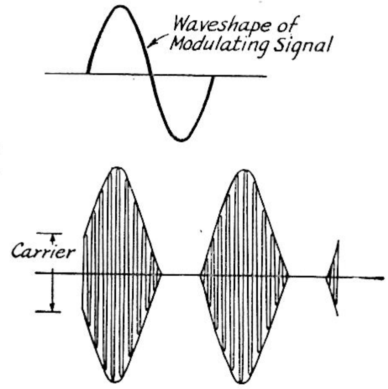


Fig. 9-2 — An overmodulated r.f. carrier wave.

The sharp "break" when the carrier is suddenly cut off on the modulation down-swing produces a type of distortion that contains a large number of harmonics. For example, it is easily possible for harmonics up to the fifth to be produced by a relatively small amount of overmodulation. If the modulating frequency is 2000 cycles, this means that the actual modulated wave will have sidebands not only at 2000 cycles, but also at 4000, 6000, 8000 and 10,000 cycles each side of the carrier frequency. The signal thus occupies five times the needed channel-width. It is obviously of first importance to prevent the modulation from exceeding 100 per cent, and thus prevent the generation of spurious sidebands — commonly called "splatter."

Carrier Requirements

For satisfactory amplitude modulation, the carrier *frequency* should be entirely unaffected by the application of modulation. If modulating the amplitude of the carrier also causes a change in the carrier frequency, the frequency will wobble back and forth with the modulation. This causes distortion and widens the channel taken by the signal. Thus unnecessary interference is caused to other transmissions. In practice, this undesirable frequency modulation is prevented by applying the modulation to an r.f. amplifier stage that is isolated from the frequency-controlling oscillator by a **buffer amplifier.** Amplitude modulation applied directly to an oscillator always is accompanied by frequency modulation. Under existing regulations amplitude modulation of an oscillator is permitted only on frequencies above 144 Mc. Below that frequency the regulations require that an amplitude-modulated transmitter be completely free from frequency modulation.

Plate Power Supply

The d.c. power supply for the plate or plates of the modulated amplifier must be well filtered; if it is not, the plate-supply ripple will modulate the carrier and cause annoying hum. To be substantially hum-free, the ripple voltage should not be more than about 1 per cent of the d.c. output voltage.

In amplitude modulation the plate current varies at an audio-frequency rate; in other words, an alternating current is superimposed on the d.c. plate current. The output filter condenser in the plate supply must have low reactance, at the lowest audio frequency in the modulation, if the transmitter is to modulate equally well at all audio frequencies. The condenser capacitance required depends on the ratio of d.c. plate current to plate voltage in the modulated amplifier. The requirements will be met satisfactorily if the capacitance of the output condenser is at least equal to

$$C = 25 \frac{I}{E}$$

where C = Capacitance of output condenser in μfd.
I = D.c. plate current of modulated amplifier in milliamperes
E = Plate voltage of modulated amplifier

Example: A modulated amplifier operates at 1250 volts and 275 ma. The capacitance of the output condenser in the plate-supply filter should be at least

$$C = 25 \frac{I}{E} = 25 \times \frac{275}{1250} = 25 \times 0.22 = 5.5 \mu\text{fd.}$$

Linearity

Up to the limit of 100-per-cent modulation, the amplitude of the r.f. output should be directly proportional to the amplitude of the modulating signal. Fig. 9-3 is a graph of an ideal **modulation characteristic,** or curve, showing the relationship between r.f. output amplitude and modulating-signal amplitude. The modulation swings the amplitude back and forth along the curve *A* as the modulating signal alternately swings positive and negative. Assuming that the negative peak of the modulating signal is just sufficient to reduce the carrier amplitude to zero (modulating signal equal to −1 in the drawing), the same modulating signal peak in the *positive* direction (+1) should cause the r.f. amplitude to reach twice its unmodulated-carrier value. The ideal modulation characteristic is a straight line, as shown by curve *A*. Such a modulation characteristic is perfectly **linear.**

A **nonlinear** characteristic is shown by curve *B*. The r.f. amplitude does not reach twice the unmodulated carrier amplitude when the modulating signal reaches its positive peak. A modulation characteristic of this type gives a modulation envelope that is "flattened" on the up-peak; in other words, the modulation envelope is not an exact reproduction of the modulating signal. It is therefore distorted and harmonics are generated, causing the transmitted signal to occupy a wider channel than is necessary. A nonlinear modulation characteristic can easily result when a transmitter is not properly designed or is misadjusted.

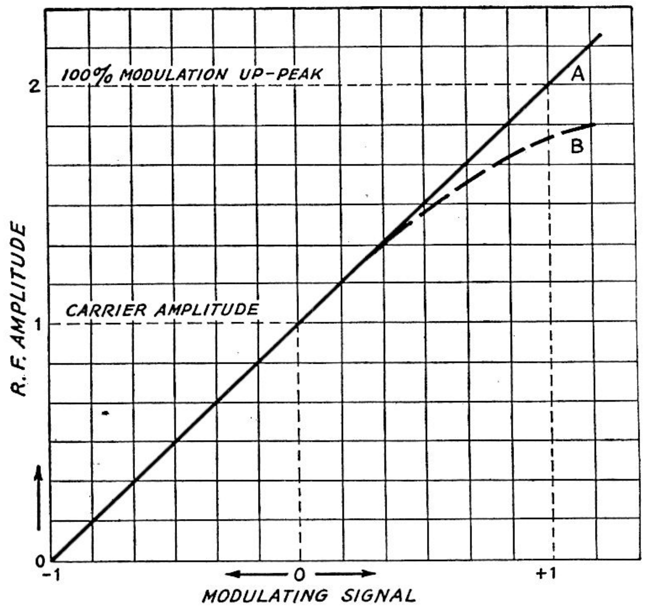


Fig. 9-3 — The modulation characteristic shows the relationship between the instantaneous amplitude of the r.f. output and the instantaneous amplitude of the modulating signal. The ideal characteristic is a straight line, as shown by curve *A*.

The **modulation capability** of the transmitter is the maximum percentage of modulation that is possible without objectionable distortion from nonlinearity. The maximum capability is 100 per cent on the down-peak but can be higher on the up-peak. The modulation capability should be as high as possible, so that the most effective signal can be transmitted for a given carrier power.

Types of Amplitude Modulation

The most widely-used amplitude-modulation system is that in which the modulating signal is applied in the plate circuit of a radio-frequency power amplifier **(plate modulation).** In a second type the audio signal is applied to a control grid **(grid-bias modulation).** A third system, involving variation of both plate and grid voltages, is called **cathode modulation.**

● PLATE MODULATION

The most popular system of amplitude modulation is plate modulation. It is the simplest to apply, gives the highest efficiency in the modulated amplifier, and is the easiest to adjust for proper operation.

Fig. 9-4 shows the most widely-used system of plate modulation. A balanced (push-pull Class A, Class AB or Class B) **modulator** is transformer-coupled to the plate circuit of the modulated r.f. amplifier. The audio-frequency power generated by the modulator is combined with the d.c. power in the modulated-amplifier plate circuit by transfer through the coupling transformer, *T*. For 100-per-cent modulation the audio-frequency output of the modulator and the turns ratio of the coupling transformer must be such that the voltage at the plate of the modulated amplifier varies between zero and twice the d.c. operating plate voltage, thus causing corresponding variations in the amplitude of the r.f. output.

As stated earlier, the average power output of the modulated stage must increase during modulation. The modulator must be capable of supplying to the modulated r.f. stage sine-wave audio power equal to 50 per cent of the d.c. plate input. For example, if the d.c. plate power input to the r.f. stage is 100 watts, the sine-wave audio power output of the modulator must be 50 watts.

Modulating Impedance; Linearity

The **modulating impedance,** or load resistance presented to the modulator by the modulated r.f. amplifier, is equal to

$$\frac{E_b}{I_p} \times 1000$$

where E_b = D.c. plate voltage
I_p = D.c. plate current (ma.)

E_b and I_p are measured without modulation.

The power output of the r.f. amplifier must vary as the square of the plate voltage (the r.f. voltage must be proportional to the applied plate voltage) in order for the modulation to be linear. This will be the case when the amplifier operates under Class C conditions. The linearity then depends upon having sufficient grid excitation and proper bias, and upon the adjustment of circuit constants to the proper values.

Adjustment of Plate-Modulated Amplifiers

The general operating conditions for Class C operation have been described in Chapter Six. The grid bias and grid current required for plate modulation usually are given in the operating data supplied by the tube manufacturer; in general, the bias should be such as to give an operating angle of about 120 degrees at carrier plate voltage, and the grid excitation should be great enough so that the amplifier's plate efficiency will stay constant when the plate voltage is varied over the range from zero to twice the unmodulated value. For best linearity, the grid bias should be obtained partly from a fixed source of about the cut-off value, and then supplemented by grid-leak bias to supply the remainder of the required operating bias.

The maximum permissible d.c. plate power input for 100-per-cent modulation is twice the sine-wave audio-frequency power output of the modulator. This input is obtained by varying the loading on the amplifier (keeping its tank circuit tuned to resonance) until the product of d.c. plate voltage and plate current is the desired power. The modulating impedance under these conditions must be transformed to the proper value for the modulator by using the correct output-transformer turns ratio. This point is considered in detail later in this chapter in the section on Class B modulator design.

Neutralization, when triodes are used, should be as nearly perfect as possible, since regeneration may cause nonlinearity. The amplifier also must be completely free from parasitic oscillations.

Although the *effective* value of power input increases with modulation, as described above, the *average* d.c. plate power input to a plate-modulated amplifier does not change. This is because each increase in plate voltage and plate current is balanced by an equivalent decrease in voltage and current on the next half-cycle of the modulating signal. The d.c. plate current to a properly-modulated amplifier is always constant, with or without modulation. On the other hand, an r.f. ammeter connected in the antenna or transmission line will show an increase in r.f. current with modulation.

Screen-Grid Amplifiers

Screen-grid tubes of the pentode or beam-tetrode type can be used as Class C plate-modulated amplifiers by applying the modulation to both the plate and screen grid. The usual method of feeding the screen grid with the necessary d.c. and modulation voltage is shown in Fig. 9-5. The dropping resistor, *R*, should be of the proper value to apply normal d.c. voltage to the screen under steady carrier

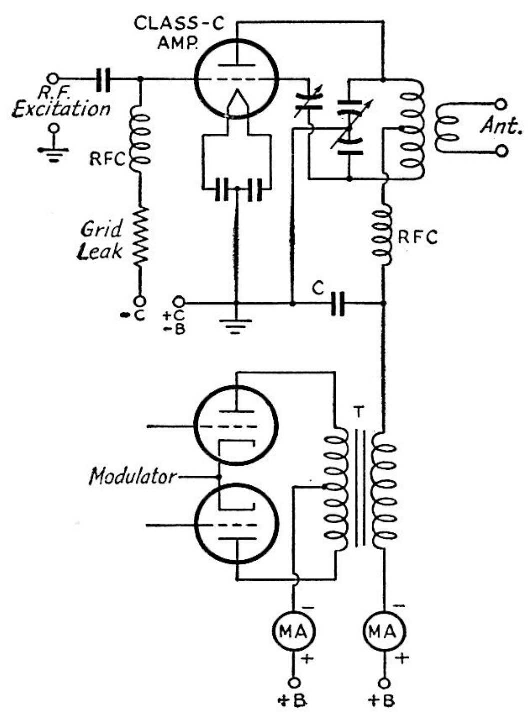


Fig. 9-4 — **Plate modulation of a Class C r.f. amplifier. The r.f. plate by-pass condenser, *C*, in the amplifier stage should have reasonably high reactance at audio frequencies. (See section on Class B modulators.)**

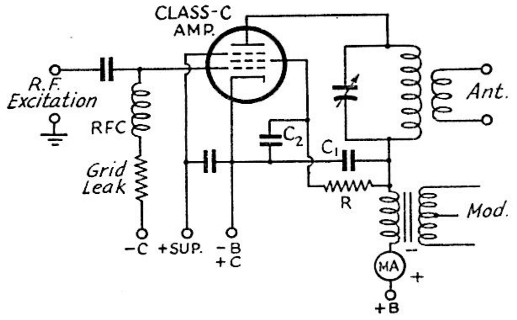


Fig. 9-5 — **Plate and screen modulation of a Class C r.f. amplifier using a pentode tube. The plate r.f. by-pass condenser, C_1, should have reasonably high reactance at all audio frequencies. (See section on Class B modulators.) The screen by-pass, C_2, should be 0.002 μfd. or less in the usual case.**

conditions. Its value can be calculated by taking the difference between plate and screen voltages and dividing it by the rated screen current.

The modulating impedance is found by dividing the d.c. plate voltage by the sum of the plate and screen currents. The plate voltage multiplied by the sum of the two currents gives the power input to be used as the basis for determining the audio power required from the modulator.

Modulation of the screen along with the plate is necessary because both elements affect the plate current in a power-type screen-grid tube, and a linear modulation characteristic cannot be obtained by modulating the plate alone. However, at least some types of beam tetrodes (the 4-250A and 4-125A, for example) can be modulated satisfactorily by applying the modulating power to the plate circuit alone, *provided* the screen is "floating" at audio frequencies — that is, is not grounded for a.f. but is connected to its d.c. supply through an audio impedance. The circuit is shown in Fig. 9-6. The choke coil L_1 is the audio impedance in the screen circuit; its inductance should be large enough to have a reactance (at the lowest desired audio frequency) that is not less than the impedance of the screen. The latter can be taken to be approximately equal to the d.c. screen voltage divided by the d.c. screen current.

Choke Coupling

Fig. 9-7 shows the circuit of the **choke-coupled** system of plate modulation. The d.c. plate power for both the modulator tube and modulated amplifier is furnished from a common source through the modulation choke, L. This choke must have high impedance, compared to the modulating impedance of the Class C amplifier, for audio frequencies. The modulator operates as a power amplifier with the plate circuit of the r.f. amplifier as its load, the audio output of the modulator being superimposed on the d.c. power supplied to the amplifier.

For 100-per-cent modulation, the audio voltage applied to the r.f. amplifier plate circuit across the choke, L, must have a peak value equal to the d.c. voltage on the modulated amplifier. To obtain this without distortion the r.f. amplifier must be operated at a *lower* d.c. plate voltage than the modulator. The extent of the voltage difference is determined by the type of modulator tube used. The necessary drop in voltage is provided by the resistor, R_1, which is by-passed for audio frequencies by the by-pass condenser, C_1.

This type of modulation seldom is used except in very low-power portable sets, because a Class A modulator is required. The output of a Class A modulator is very low compared to the power obtainable from a pair of tubes of the same size operated Class B, so only a small amount of r.f. power can be modulated.

● GRID-BIAS MODULATION

Fig. 9-8 is the diagram of a typical arrangement for grid-bias modulation. In this system, the secondary of an audio-frequency output transformer, the primary of which is connected in the plate circuit of the modulator tube, is connected in series with the grid-bias supply for the modulated amplifier. The audio voltage varies the grid bias, and thereby the power output of the r.f. stage. The r.f. stage is operated as a Class C amplifier.

In this system the plate voltage is constant, and the increase in power output with modulation is obtained by making both the plate current and plate efficiency vary with the mod-

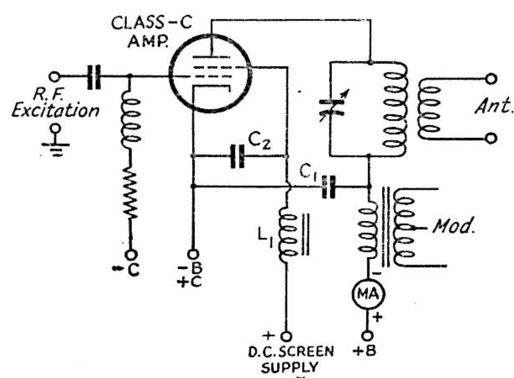


Fig. 9-6 — **Plate modulation of a beam tetrode, using an audio impedance in the screen circuit. The value of L_1 is discussed in the text. See Fig. 9-5 for data on by-pass capacitors C_1 and C_2.**

ulating signal. For 100-per-cent modulation, both plate current and efficiency must, at the peak of the modulation up-swing, be twice their carrier values. Thus at the modulation peak the power input is doubled, and since the plate efficiency also is doubled at the same instant the peak output power will be four times the carrier power. The maximum efficiency obtainable in practicable circuits is of the order of 70 to 80 per cent, so the carrier efficiency ordinarily cannot exceed about 35

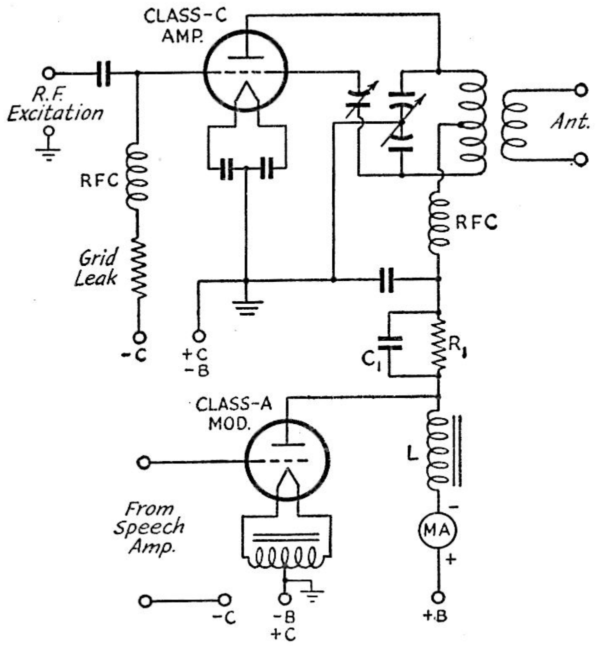


Fig. 9-7 — Choke-coupled plate modulation.

to 40 per cent. For a given r.f. tube, the carrier output is about one-fourth the power obtainable from the same tube plate-modulated.

Modulator Power

The increase in average carrier power with modulation is secured by varying the plate efficiency and d.c. plate input of the amplifier, so the modulator need supply only such power losses as may be occasioned by connecting it in the grid circuit. Since these are quite small, a modulator capable of only a few watts output will suffice.

The load on the modulator varies over the a.f. cycle as the rectified grid current of the modulated amplifier changes, so the modulator must have good voltage regulation. The purpose of the resistor *R* across the primary of the modulation transformer in Fig. 9-8 is to "swamp" such load changes by dissipating most of the audio power in the resistor. Generally, this resistor should be approximately equal to the load resistance required by the particular type of modulator tube used. The turns ratio of transformer *T* should be about 1-to-1 in most practical cases.

Grid-Bias Source

The change in instantaneous bias voltage with modulation causes the rectified grid current of the amplifier also to vary, the r.f. excitation being fixed. If the bias source has appreciable resistance, the change in grid current will cause a change in bias in a direction opposite to that caused by the modulation. It is necessary, therefore, to use a grid-bias source having low resistance, so that these bias variations will be negligible. Battery bias is satisfactory. If a rectified a.c. bias supply is used, the type having regulated output should be chosen (see Chapter Seven). Grid-leak bias for a grid-modulated amplifier is unsatisfactory, and its use should never be attempted.

Driver Regulation

The load on the r.f. driving stage varies with modulation, and a linear modulation characteristic cannot be obtained if the r.f. voltage from the driver does not stay constant with changes in load. Driver regulation (ability to maintain constant output voltage with changes in load) may be improved by using a driving stage having two or three times the power output necessary for excitation of the amplifier (which is less than the power required for ordinary Class C operation), and dissipating the extra power in a constant load such as a resistor. The variations caused by changes in load with modulation are thereby reduced because the variable load is only a fraction of the total load.

Operating Conditions

The d.c. plate input to the modulated amplifier, assuming a round figure of ⅓ (33 per cent) for the plate efficiency, should not exceed 1½ times the plate dissipation rating of the tube or tubes used in the modulated stage. On the modulation up-peaks the d.c. plate current doubles instantaneously but the d.c. plate voltage does not change. The problem, therefore, is to choose a set of operating conditions that will give normal Class C efficiency when the plate current is *twice* the carrier value.

Example: Two tubes having plate dissipation ratings of 55 watts each are to be used with grid-bias modulation. With plate modulation, the ratings are 1250 volts and 250 ma. for the two tubes, so the plate-voltage/plate-current ratio is

$$\frac{E\text{ (volts)}}{I\text{ (ma.)}} = \frac{1250}{250} = 5$$

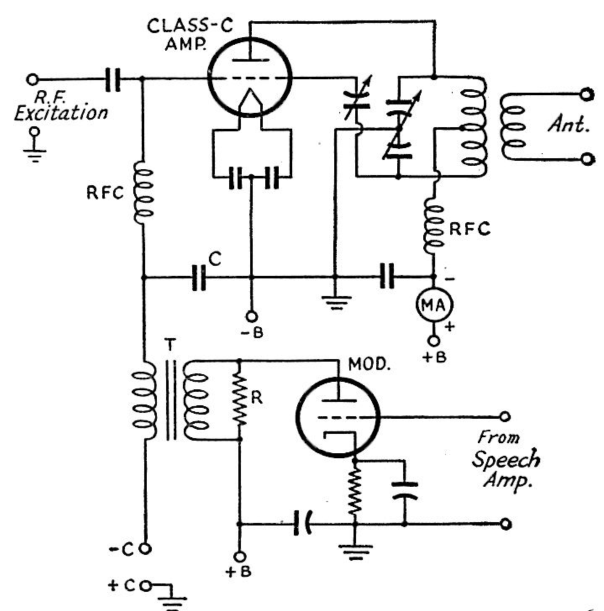


Fig. 9-8 — Grid-bias modulation of a Class C amplifier. The r.f. grid by-pass condenser, *C*, should have high reactance at audio frequencies (0.005 μfd. or less).

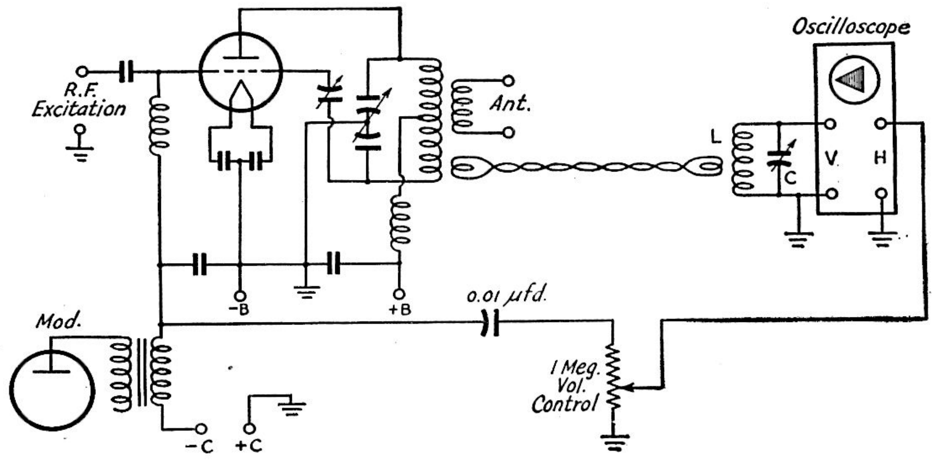


Fig. 9-9 — Adjustment set-up for grid-bias modulation. *L* and *C* should tune to the operating frequency, and may be coupled to the transmitter tank circuit through a twisted pair or other low-impedance line, using single-turn links at each end. The 0.01-μfd. blocking condenser that couples the audio voltage to the horizontal plates of the oscilloscope should have a voltage rating equal to about three times the grid bias.

With grid-bias modulation the maximum power input, at 33% efficiency, is

$P = 1.5 \times (2 \times 55) = 1.5 \times 110 = 165$ watts

The maximum recommended plate voltage for these tubes is 1500 volts. Using this figure, the plate current for the two tubes will be

$$I = \frac{P}{E} = \frac{165}{1500} = 0.11 \text{ amp.} = 110 \text{ ma.}$$

The plate-voltage/plate-current ratio at *twice* carrier plate current is

$$\frac{1500}{220} = 6.8$$

This is quite satisfactory. In this case it would be possible to use a lower plate voltage without having the plate-voltage/plate-current ratio drop to too low a value. At 1300 volts, for example, the ratio would be slightly over 5. However, at 1000 volts it would be only 3.

At 33% efficiency, the carrier output to be expected is 55 watts.

The tank-circuit L/C ratio should be chosen on the basis of *twice* the carrier plate current. In the example above, it would be based on a plate-voltage/plate-current ratio of 6.8. Note that if *carrier* conditions are used the ratio is 13.6, and a tank L/C ratio based on this figure would have a Q much too low for good coupling to the output circuit.

Since the amplifier operates in normal Class C fashion on the modulation up-peaks, the grid bias should be chosen for Class C operation at the plate voltage used. It may be higher if desired, but should never be lower. It is convenient to have an adjustable bias source for arriving at optimum operating conditions.

Adjustment

This type of modulated amplifier should be adjusted with the aid of an oscilloscope. The oscilloscope should be connected as shown in Fig. 9-9. A tone source for modulating the transmitter is a convenience, since a steady tone will give a steady pattern on the oscilloscope. A steady pattern is easier to study than one that flickers with voice modulation.

Having determined the permissible carrier plate current as previously described, apply r.f. excitation and plate voltage and, without modulation, adjust the plate loading to give the required plate current (keeping the plate tank circuit tuned to resonance). Next, apply modulation and increase the modulating signal until the modulation characteristic shows curvature (see later section in this chapter for use of the oscilloscope). If curvature occurs well below 100-per-cent modulation, the plate efficiency is too high. Increase the plate loading slightly and reduce the excitation to maintain the same plate current; then apply modulation and check the characteristic again. Continue this process until the characteristic is linear from the horizontal axis to twice the carrier amplitude. It is usually easier to obtain a more linear characteristic with high plate voltage and low current (carrier conditions) than with relatively low plate voltage and high plate current.

Suppressor Modulation

The circuit arrangement for suppressor-grid modulation of a pentode tube is shown in Fig. 9-10. The operating principles are the same as for grid-bias modulation. However, the r.f. excitation and modulating signals are applied to separate grids; this makes the system somewhat simpler to operate because best adjustment for proper excitation requirements and proper modulating-circuit requirements are more or less independent. The carrier plate efficiency is approximately the same as for grid-bias modulation, and the modulator power requirements are similarly small. With tubes having suitable suppressor-grid charac-

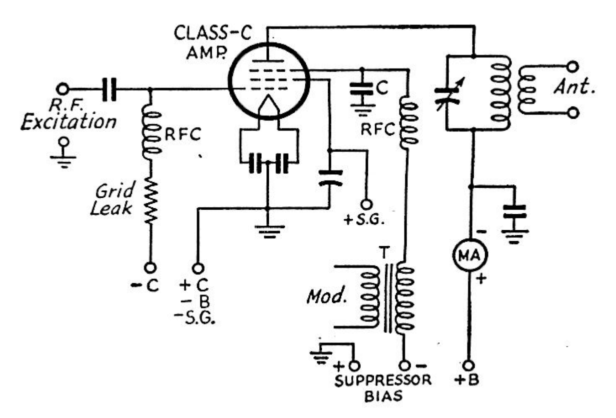


Fig. 9-10 — Suppressor-grid modulation of an r.f. amplifier using a pentode-type tube. The suppressor-grid r.f. by-pass condenser, *C*, should be the same as the grid by-pass condenser in grid-bias modulation (Fig. 9-8).

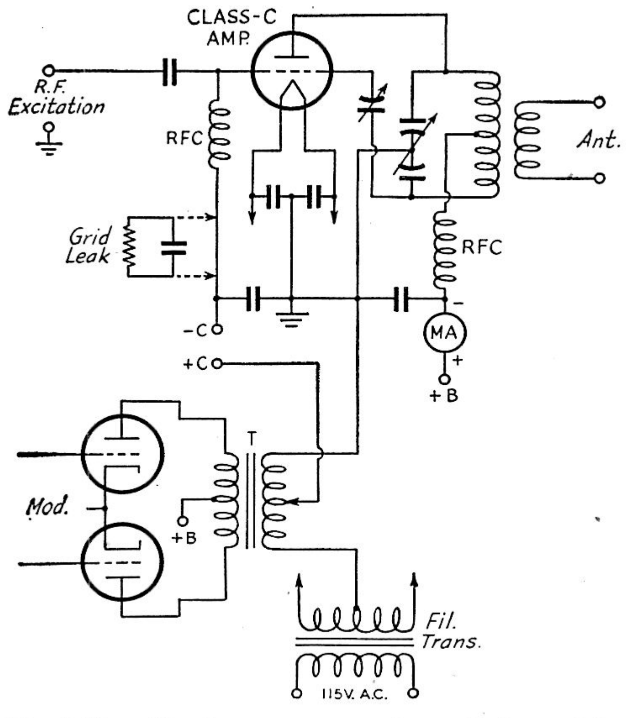


Fig. 9-11 — **Circuit arrangement for cathode modulation of a Class C r.f. amplifier.**

teristics, linear modulation up to practically 100 per cent can be obtained with negligible distortion.

The method of adjustment of this system is essentially the same as that described in the preceding paragraph.

CATHODE MODULATION

Circuit

The fundamental circuit for cathode or "center-tap" modulation is shown in Fig. 9-11. This type of modulation is a combination of the plate and grid-bias methods, and permits a carrier efficiency midway between the two. The audio power is introduced in the cathode circuit, and both grid bias and plate voltage vary during modulation.

Because part of the modulation is by the grid-bias method, the plate efficiency of the modulated amplifier must vary during modulation. The carrier efficiency therefore must be lower than the efficiency at the modulation peak. The required reduction in efficiency depends upon the proportion of grid modulation to plate modulation; the higher the percentage of plate modulation, the higher the permissible carrier efficiency, and vice versa. The audio power required from the modulator also varies with the percentage of plate modulation, being greater as this percentage is increased.

The way in which the various quantities vary is illustrated by the curves of Fig. 9-12. In these curves the performance of the cathode-modulated r.f. amplifier is plotted in terms of the tube ratings for plate-modulated telephony, with the percentage of plate modulation as a base. As the percentage of plate modulation is decreased, it is assumed that the grid-bias modulation is increased to make the over-all percentage of modulation reach 100 per cent. The limiting condition, 100-per-cent plate modulation and no grid-bias modulation, is at the right (A); pure grid-bias modulation is represented by the left-hand ordinate (B and C).

Example: Assume that the r.f. tube to be used has a 100% plate-modulation rating of 250 watts input and will give a carrier power output of 190 watts at that input. Cathode modulation with 40% plate modulation is to be used. From Fig. 9-12, the carrier efficiency will be 56% with 40% plate modulation, the permissible d.c. input will be 65% of the plate-modulation rating, and the r.f. output will be 48% of the plate-modulation rating. That is,

Power input $= 250 \times 0.65 = 162.5$ watts
Power output $= 190 \times 0.48 = 91.2$ watts

The required audio power, from the chart, is equal to 20% of the d.c. input to the modulated amplifier. Therefore

Audio power $= 162.5 \times 0.2 = 32.5$ watts

The modulator should supply a small amount of extra power to take care of losses in the grid circuit. These should not exceed four or five watts.

Modulating Impedance

The modulating impedance of a cathode-modulated amplifier is approximately equal to

$$m\frac{E_b}{I_b}$$

where m = Percentage of plate modulation (expressed as a decimal)
E_b = D.c. plate voltage on modulated amplifier
I_b = D.c. plate current of modulated amplifier

Example: Assume that the modulated amplifier in the example above is to operate at a plate

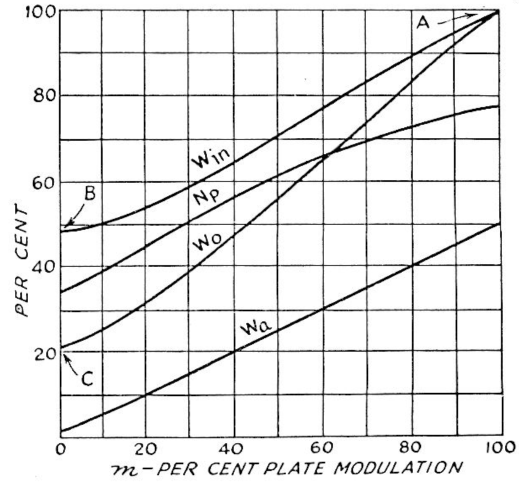


Fig. 9-12 — **Cathode-modulation performance curves, in terms of percentage of plate modulation plotted against percentage of Class C telephony tube ratings.**

W_{in} — D.c. plate input watts in terms of percentage of plate-modulation rating.
W_o — Carrier output watts in per cent of plate-modulation rating (based on plate efficiency of 77.5%).
W_a — Audio power in per cent of d.c. watts input.
N_p — Plate efficiency of the amplifier in percentage.

potential of 1250 volts. Then the d.c. plate current is

$$I = \frac{P}{E} = \frac{162.5}{1250} = 0.13 \text{ amp. (130 ma.)}$$

The modulating impedance is

$$m\frac{E_b}{I_b} = 0.4\frac{1250}{0.13} = 3846 \text{ ohms}$$

The modulating impedance is the load into which the modulator must work, just as in the case of pure plate modulation. This load must be matched to the load required by the modulator tubes by proper choice of the turns ratio of the modulation transformer.

Conditions for Linearity

R.f. excitation requirements for the cathode-modulated amplifier are midway between those for plate modulation and grid-bias modulation. More excitation is required as the percentage of plate modulation is increased. Grid bias should be considerably beyond cut-off; fixed bias from a supply having good voltage regulation is preferred, especially when the percentage of plate modulation is small and the amplifier is operating more nearly like a grid-bias modulated stage. At the higher percentages of plate modulation a combination of fixed and grid-leak bias can be used, since the variation in rectified grid current is smaller. The grid leak should be by-passed for audio frequencies. The percentage of grid modulation may be regulated by choice of a suitable tap on the modulation-transformer secondary.

The cathode circuit of the modulated stage must be independent of other stages in the transmitter. That is, when directly-heated tubes are modulated their filaments must be supplied from a separate transformer. The filament by-pass condensers should not be larger than about 0.002 μfd., to avoid by-passing the audio-frequency modulation.

Adjustment of Cathode-Modulated Amplifiers

In most respects, the adjustment procedure is similar to that for grid-bias modulation. The critical adjustments are antenna loading, grid bias, and excitation. The proportion of grid-bias to plate modulation will determine the operating conditions.

Adjustments should be made with the aid of an oscilloscope connected in the same way as for grid-bias modulation. With proper antenna loading and excitation, the normal wedge-shaped pattern will be obtained at 100-per-cent modulation. As in the case of grid-bias modulation, too-light antenna loading will cause flattening of the upward-peaks of modulation as also will too-high excitation. The cathode current will be practically constant with or without modulation when the proper operating conditions have been established.

Speech Equipment

In designing speech equipment it is necessary to "work from both ends." That is, we must know, simultaneously, (1) the amount of audio power the modulation system must furnish and (2) the output voltage developed by the microphone when it is spoken into from normal distance (a few inches) with ordinary loudness. It then becomes possible to choose the number and type of amplifier stages needed to generate the required audio power without overloading or distortion anywhere along the line.

The starting point is the microphone.

● MICROPHONES

In this age, no one needs an introduction to the microphone. However, there are several different types of them, considerably different in characteristics. Before considering the various types, it is necessary to define a few terms used in connection with microphones.

The **level** of a microphone is its electrical output for a given sound intensity. Level varies greatly with microphones of different basic types, and also varies between different models of the same type. The output is also greatly dependent on the character of the individual voice (that is, the audio frequencies present in the voice) and the distance of the speaker's lips from the microphone. It decreases approximately as the square of the distance. Because of these variables, only approximate values based on averages of "normal" speaking voices can be given. The values in the following paragraphs are based on close talking; that is, with the microphone about an inch from the speaker's lips.

The **frequency response** or **fidelity** of a microphone is its relative ability to convert sounds of different frequencies into alternating current. With fixed sound intensity at the microphone, the electrical output may vary considerably as the sound frequency is varied. For understandable speech transmission only a limited frequency range is necessary, and intelligible speech can be obtained if the output of the microphone does not vary more than a few decibels at any frequency within a range of about 200 to 2500 cycles. When the variation expressed in terms of decibels is small between two frequency limits, the microphone is said to be **flat** between those limits.

Carbon Microphones

The **carbon microphone** consists of a metal diaphragm placed against an insulating cup containing loosely-packed carbon granules **(microphone button).** Current from a battery flows through the granules, the diaphragm be-

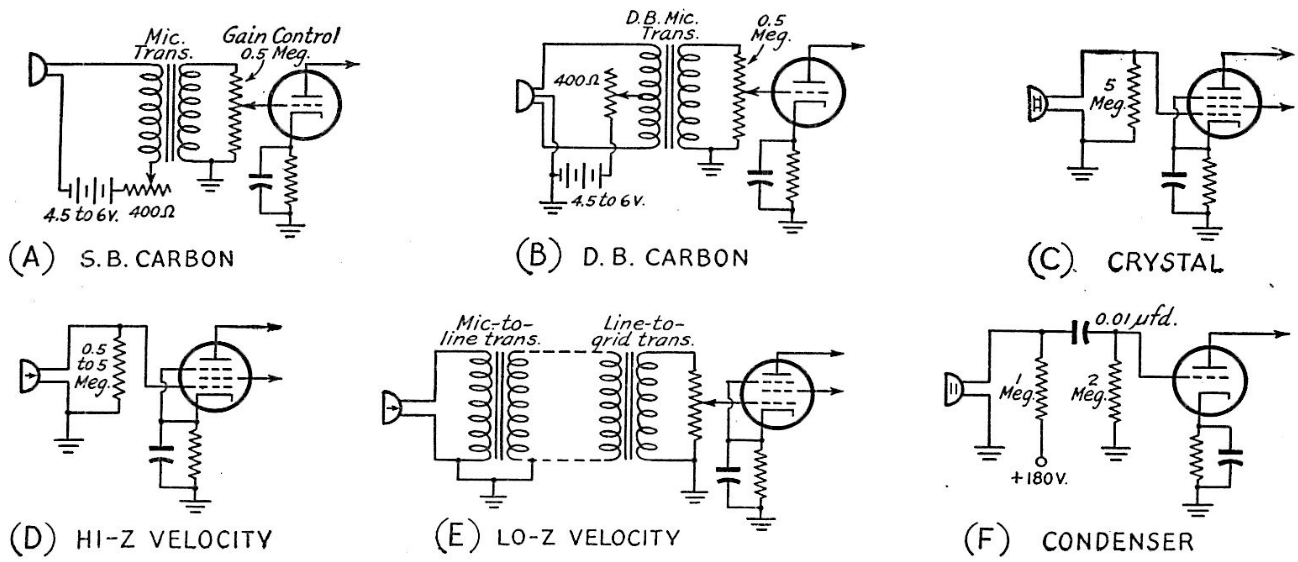


Fig. 9-13 — Speech input circuits for various types of microphones.

ing one connection and the metal backplate the other. Fig. 9-13A and B shows connections for **single- and double-button carbon microphones,** with a rheostat included in each circuit for adjusting the button current to the correct value as specified with each microphone. The primary of a transformer is connected in series with the battery and microphone.

As the diaphragm vibrates, its pressure on the granules alternately increases and decreases, causing a corresponding increase and decrease of current flow through the circuit, since the pressure changes the resistance of the mass of granules. The resulting change in the current flowing through the transformer primary causes an alternating voltage, of corresponding frequency and intensity, to be set up in the transformer secondary. In the double-button type the two buttons are in push-pull.

Good quality single-button carbon microphones give outputs ranging from 0.1 to 0.3 volt across 50 to 100 ohms; that is, across the primary winding of the microphone transformer. With the step-up of the transformer, a peak voltage of between 3 and 10 volts can be assumed to be available at the grid of the amplifier tube. The usual button current is 50 to 100 ma.

The level of good-quality double-button microphones is considerably less, ranging from 0.02 volt to 0.07 volt across 200 ohms. With this type of microphone and the usual push-pull input transformer, a peak voltage of 0.4 to 0.5 can be assumed available at the first speech-amplifier grid. The button current with this type of microphone ranges from 5 to 50 ma. per button. Double-button microphones have better frequency response and less distortion than the single-button type.

Crystal Microphones

The **crystal microphone** makes use of the piezoelectric properties of Rochelle salts crystals. This type of microphone requires no battery or transformer and can be connected directly to the grid of an amplifier tube. It is the most popular type of microphone among amateurs, for these reasons as well as the fact that it has good frequency response and is available in inexpensive models.

The "communications-type" crystal microphone uses a diaphragm mechanically coupled to a crystal. This type of construction gives good sensitivity and adequate frequency response for speech. In higher-fidelity types the sound acts directly on a pair of crystals cemented together, with plated electrodes. The level with the latter construction is considerably less. The input circuit for either model of crystal microphone is shown in Fig. 9-13C.

Although the level of crystal microphones varies with different models, an output of 0.03 volt or so is representative for communication types. The level is affected by the length of the cable connecting the microphone to the first amplifier stage; the above figure is for lengths of 6 or 7 feet. The frequency characteristic is unaffected by the cable, but the load resistance (amplifier grid resistor) does affect it; the lower frequencies are attenuated as the value of load resistance is lowered. A grid-resistor value of at least 1 megohm should be used for reasonably flat response, 5 megohms being a customary figure.

Velocity and Dynamic Microphones

In a **velocity** or "ribbon" **microphone,** the element acted upon by the sound waves is a thin corrugated metallic ribbon suspended between the poles of a magnet. When vibrating, the ribbon cuts the lines of force between the poles, first in one direction and then the other, thus generating an alternating voltage. The movement of the ribbon is proportional to the velocity of the air particles set in motion by the sound.

Velocity microphones are built in two types, high impedance and low impedance, the former being used in most applications. A high-impedance microphone can be directly connected to the grid of an amplifier tube, shunted by a resistance of 0.5 to 5 megohms (Fig. 9-13D). Low-impedance microphones are used when a long connecting cable (75 feet or more) must be employed. In such a case the output of the microphone is coupled to the first amplifier stage through a suitable step-up transformer, as shown in Fig. 9-13E.

The level of the velocity microphone is about 0.03 to 0.05 volt. This figure applies directly to the high-impedance type, and to the low-impedance type when the voltage is measured directly across the coupling-transformer secondary.

The **dynamic microphone** somewhat resembles a dynamic loudspeaker. A light weight voice coil is rigidly attached to a diaphragm, the coil being placed between the poles of a permanent magnet. Sound causes the diaphragm to vibrate, thus moving the coil back and forth between the magnet poles and generating an alternating voltage. The frequency of the generated voltage is proportional to the frequency of the sound waves and the amplitude is proportional to the sound pressure.

The dynamic microphone usually is built with high-impedance output, suitable for working directly into the grid of an amplifier tube. If the connecting cable must be unusually long, a low-impedance type should be used, with a step-up transformer at the end of the cable.

A small permanent-magnet 'speaker can be used as a dynamic microphone, although the fidelity is not as good as is obtainable with a properly-designed microphone.

Condenser Microphones

The **condenser microphone** consists of a two-plate capacitance, with one plate stationary. The other, which is separated from the first by about a thousandth of an inch, is a thin metal membrane serving as a diaphragm. This condenser is connected in series with a resistor and a d.c. voltage source, as shown in Fig. 9-13F. When sound waves cause the diaphragm to vibrate, the change in capacitance causes a small charging current to flow through the circuit. The resulting audio voltage that appears across the resistor is fed to the grid of the tube through the coupling condenser.

The output of condenser microphones varies with different models, the high-quality type being about one-hundredth to one-fiftieth as sensitive as the double-button carbon microphone. The first speech-amplifier stage must be built into the microphone, since the capacity of a connecting cable would impair both output and frequency range. Also, this "preamplifier" must be battery operated, because the microphone output is so low that the least hum would be objectionable. This is cumbersome, and the microphone itself is expensive in construction because of the high precision required. As a result, the condenser microphone finds little present-day application.

THE SPEECH AMPLIFIER

In common terminology, the audio-frequency amplifier stage that actually causes the r.f. carrier output to be varied is called the **modulator,** and all the amplifier stages preceding it comprise the **speech amplifier.** Depending on what sort of modulator is used, the speech amplifier may be called upon to deliver a power output ranging from practically zero (only voltage required) to 20 or 30 watts.

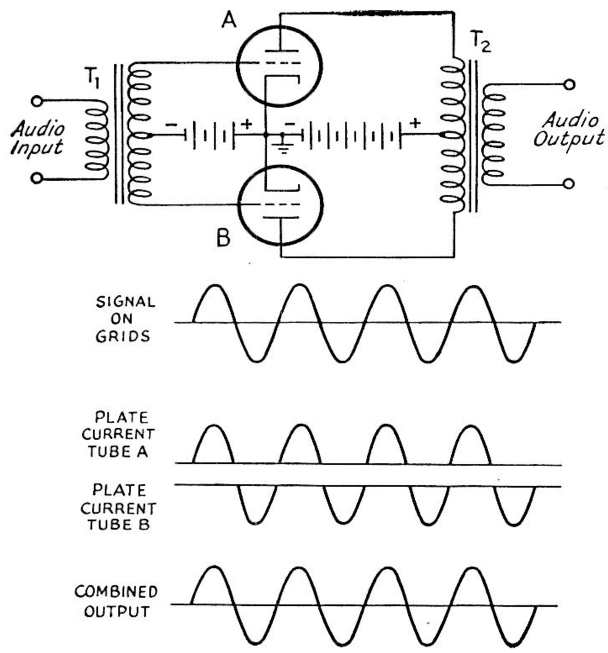


Fig. 9-14 — **Class B amplifier operation.**

Before starting the design of a speech amplifier, therefore, it is necessary to have selected a suitable modulator for the transmitter. This selection must be based on the power required to modulate the transmitter 100 per cent, and this power in turn depends on the type of modulation system selected, as already described. With the modulator picked out, its **driving-power** requirements (audio power required to excite the modulator to full output) can be determined from the tube tables in Chapter Twenty-Five. Generally speaking, it is advisable to choose a tube or tubes for the last stage of the speech amplifier that will be capable of developing at least 50 per cent more power than the rated driving power of the modulator. This will provide a factor of safety so that losses in coupling transformers, etc., will not upset the calculations. A "skimpy" driver, or one designed without a safety factor, usually cannot excite the modulator to full output without being itself overloaded. The inevitable result is speech distortion, generation of unnecessary sidebands, and a "broad" transmitter.

Audio-Amplifier Classifications

The description of amplification as outlined in Chapter Three covered only one — the simplest — way of operating an amplifier tube. There are several other ways of operating tubes to obtain higher power output and greater plate efficiency (ratio of useful power output to d.c. plate-power input).

Fig. 9-14 shows two tubes connected in a push-pull circuit. If the grid bias is set at the point where (when no signal is applied) the plate current is just cut off, then a signal can cause plate current to flow in either tube *only* when the signal voltage applied to that particular tube is positive. In the balanced grid circuit, the signal voltages on the grids of the two tubes always have opposite polarities; that is, when the signal swings the instantaneous voltage in the positive direction on the grid of tube *A*, it is at the same time swinging the grid of tube *B* more negative. On the next half-cycle the polarities reverse and the grid of tube *B* is more positive and that of tube *A* more negative. Since the fixed bias is just at the cut-off point, this means that plate current flows only in one tube at a time.

The graphs show the operation of such an amplifier. The plate current of tube *B* is drawn inverted to show that it flows in the opposite direction, through the primary of the output transformer, to the plate current of tube *A*. Thus each half of the output-transformer primary works alternately to induce a half-cycle of voltage in the secondary. In the secondary of T_2, the original waveform is restored. This type of operation is called **Class B amplification.**

The Class B amplifier is considerably more efficient than the Class A amplifier described in Chapter Three. As a matter of fact, the plate efficiency is in the neighborhood of 65 to 75 per cent, as compared to 20 to 30 per cent for a Class A power amplifier. Furthermore, the d.c. plate current of a Class B amplifier is proportional to the signal voltage on the grids, so the power input is small with small signals. The d.c. plate power input to a Class A amplifier is the same whether the signal is large, small, or absent altogether; therefore the maximum input that can be applied to a Class A amplifier is the rated plate dissipation of the tube or tubes. The result is that two tubes in a Class B amplifier can deliver approximately twelve times as much audio power as the same two tubes in a Class A amplifier.

A Class B amplifier usually is operated in such a way as to secure the maximum possible power output. This requires that the grids be driven positive with respect to the cathode during at least part of the cycle, so grid current flows and the grid circuit consumes power. While the power requirements are fairly low (as compared to the power output), the fact that the grids are positive during only *part* of the cycle means that the load on the driver stage varies in magnitude during the cycle; the effective load resistance is high when the grids are not drawing current and relatively low when they do take current. This must be allowed for when designing the driver. One essential is that the driver must be capable of delivering more power than actually is required by the Class B grids.

Certain types of tubes have been designed specifically for Class B service and can be operated without fixed or other form of grid bias ("zero-bias" tubes). The amplification factor is so high that the plate current is small without signal. Because there is no fixed bias, the grids start drawing current immediately whenever a signal is applied, so the grid-current flow is continuous throughout the cycle. This makes the load on the driver much more constant than is the case with tubes of lower μ biased to plate-current cut-off.

The amplifier that drives a Class B modulator usually is a **Class AB amplifier.** As the name indicates, this type of amplifier is operated midway between Class A and Class B conditions. A Class AB amplifier is a push-pull amplifier with higher bias than would be normal for pure Class A operation, but less than the cut-off bias required for Class B. At low signal levels the tubes operate practically as Class A amplifiers, and the plate current is the same with or without signal. At higher signal levels, the plate current of one tube is cut off during part of the *negative* cycle of the signal applied to its grid, and the plate current of the other tube rises with the signal. The plate current for the whole amplifier also rises above the no-signal level when a large signal is applied.

In a properly-designed Class AB amplifier the distortion is as low as with a Class A stage, but the efficiency and power output are considerably higher than with pure Class A operation. A Class AB amplifier can be operated either with or without driving the grids into the positive region. A **Class AB_1 amplifier** is one in which the grids are never positive with respect to the cathode; therefore, no driving power is required — only voltage. A **Class AB_2 amplifier** is one that has grid-current flow during part of the cycle, when the applied signal is large; it takes a small amount of driving power. The Class AB_2 amplifier will deliver somewhat more power (using the same tubes) but the Class AB_1 amplifier avoids the problem of designing a driver for it that will deliver power, without distortion, into a load of highly-variable resistance. It is advisable to use a Class AB_1 amplifier rather than the Class AB_2 type, whenever the circumstances permit.

Voltage Amplifiers

If the last stage in the speech amplifier is a Class AB_2 or Class B amplifier, the stage ahead of it must be capable of sufficient power output to drive it. However, if the last stage is a Class AB_1 or Class A amplifier the preceding stage can be simply a voltage amplifier.

From there on back to the microphone, all stages are voltage amplifiers. These are always operated Class A, not only to simplify the design by avoiding driving power, but because just as much *voltage* can be secured from a Class A amplifier as from any other type.

The important characteristics of a voltage amplifier are its **voltage gain,** maximum undistorted **output voltage,** and its **frequency response.** The voltage gain is the voltage-amplification ratio of the stage. The output voltage is the maximum a.f. voltage that can be secured from the stage without distortion; we cannot figure on any greater output voltage than this, no matter what the gain of the stage, without running into the overload region. The amplifier frequency response should be adequate for voice reproduction; this requirement is easily satisfied.

The voltage gain and maximum undistorted output voltage depend on the operating conditions of the amplifier. Data on the popular types of tubes used in speech amplifiers are given in Table 9-I, for resistance-coupled amplification. The output voltage is in terms of *peak* voltage rather than r.m.s.; this method of rating is preferable because it makes the rating independent of the waveform. The ratio of peak to r.m.s. voltage varies widely with different waveforms and, in general, is known accurately only for a sine wave. On the other hand, exceeding the peak value causes the amplifier to distort, so it is more useful to consider only peak values in working with amplifiers.

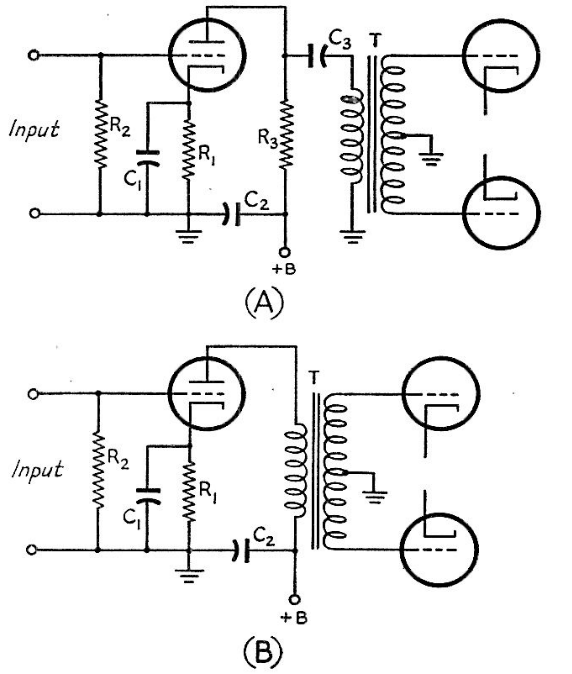


Fig. 9-16 — Transformer-coupled amplifier circuits for driving a push-pull amplifier. A is for resistance-transformer coupling; B, for transformer coupling. Designations correspond to those in Fig. 9-15. In A, values can be taken from Table 9-I. In B, the cathode resistor is calculated from the rated plate current and grid bias as given in the tube tables for the particular type of tube used.

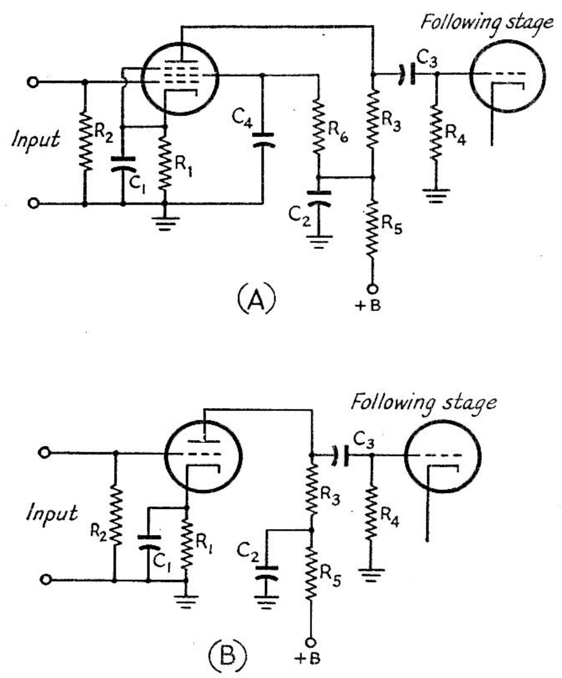


Fig. 9-15 — Resistance-coupled voltage-amplifier circuits. A, pentode; B, triode. Designations are as follows:

C_1 — Cathode-by-pass condenser.
C_2 — Plate by-pass condenser.
C_3 — Output coupling condenser (blocking condenser).
C_4 — Screen by-pass condenser.
R_1 — Cathode resistor.
R_2 — Grid resistor.
R_3 — Plate resistor.
R_4 — Next-stage grid resistor.
R_5 — Plate decoupling resistor.
R_6 — Screen resistor.

Values for suitable tubes are given in Table 9-I. Values in the decoupling circuit, C_2R_5, are not critical. R_5 may be about 10% of R_3; an 8- or 10-μfd. electrolytic condenser is usually large enough at C_2.

Resistance Coupling

Resistance coupling generally is used in voltage-amplifier stages. It is relatively inexpensive, good frequency response can be secured, and there is little danger of hum pick-up from stray magnetic fields associated with heater wiring. It is the only type of coupling suitable for the output circuits of pentodes and high-μ triodes, because with transformers a sufficiently high load impedance cannot be obtained without considerable frequency distortion. Typical circuits are given in Fig. 9-15 and design data in Table 9-I.

Transformer Coupling

Transformer coupling between stages ordinarily is used only when power is to be transferred (in such a case resistance coupling is very inefficient), or when it is necessary to couple between a single-ended and a push-pull stage. Triodes having an amplification factor of 20 or less are used in transformer-coupled voltage amplifiers. With transformer coupling, tubes should be operated under the Class A conditions given in the tube tables in Chapter Twenty-Five.

Representative circuits for coupling single-ended to push-pull stages are shown in Fig. 9-16. The circuit at A combines resistance and transformer coupling, and may be used for exciting the grids of a Class A or AB_1 following

TABLE 9-I — RESISTANCE-COUPLED VOLTAGE-AMPLIFIER DATA

Data are given for a plate supply of 300 volts, departures of as much as 50 per cent from this supply voltage will not materially change the operating conditions or the voltage gain, but the output voltage will be in proportion to the new voltage. Voltage gain is measured at 400 cycles; condenser values given are based on 100-cycle cut-off. For increased low-frequency response, all condensers may be made larger than specified (cut-off frequency in inverse proportion to condenser values provided all are changed in the same proportion). A variation of 10 per cent in the values given has negligible effect on the performance.

	Plate Resistor Megohms	Next-Stage Grid Resistor Megohms	Screen Resistor Megohms	Cathode Resistor Ohms	Screen By-pass μfd.	Cathode By-pass μfd.	Blocking Condenser μfd.	Output Volts (Peak)[1]	Voltage Gain[2]
6SJ7	0.1	0.1	0.35	500	0.10	11.6	0.019	72	67
		0.25	0.37	530	0.09	10.9	0.016	96	98
		0.5	0.47	590	0.09	9.9	0.007	101	104
	0.25	0.25	0.89	850	0.07	8.5	0.011	79	139
		0.5	1.10	860	0.06	7.4	0.004	88	167
		1.0	1.18	910	0.06	6.9	0.003	98	185
	0.5	0.5	2.0	1300	0.06	6.0	0.004	64	200
		1.0	2.2	1410	0.05	5.8	0.002	79	238
		2.0	2.5	1530	0.04	5.2	0.0015	89	263
6J7, 7C7	0.1	0.1	0.44	500	0.07	8.5	0.02	55	61
		0.25	0.5	450	0.07	8.3	0.01	81	82
		0.5	0.53	600	0.06	8.0	0.006	96	94
	0.25	0.25	1.18	1100	0.04	5.5	0.008	81	104
		0.5	1.18	1200	0.04	5.4	0.005	104	140
		1.0	1.45	1300	0.05	5.8	0.005	110	185
	0.5	0.5	2.45	1700	0.04	4.2	0.005	75	161
		1.0	2.9	2200	0.04	4.1	0.003	97	200
		2.0	2.95	2300	0.04	4.0	0.0025	100	230
6AU6, 6SH7	0.1	0.1	0.2	500	0.13	18.0	0.019	76	109
		0.22	0.24	600	0.11	16.4	0.011	103	145
		0.47	0.26	700	0.11	15.3	0.006	129	168
	0.22	0.22	0.42	1000	0.1	12.4	0.009	92	164
		0.47	0.5	1000	0.098	12.0	0.007	108	230
		1.0	0.55	1100	0.09	11.0	0.003	122	262
	0.47	0.47	1.0	1800	0.075	8.0	0.0045	94	248
		1.0	1.1	1900	0.065	7.6	0.0028	105	318
		2.2	1.2	2100	0.06	7.3	0.0018	122	371
6AQ6, 6AT6, 6Q7, 6SL7GT (one triode)	0.1	0.1	—	1500	—	4.4	0.027	40	34
		0.22	—	1800	—	3.6	0.014	54	38
		0.47	—	2100	—	3.0	0.0065	63	41
	0.22	0.22	—	2600	—	2.5	0.013	51	42
		0.47	—	3200	—	1.9	0.0065	65	46
		1.0	—	3700	—	1.6	0.0035	77	48
	0.47	0.47	—	5200	—	1.2	0.006	61	48
		1.0	—	6300	—	1.0	0.0035	74	50
		2.2	—	7200	—	0.9	0.002	85	51
6F5, 6SF5, 7B4	0.1	0.1	—	1300	—	5.0	0.025	33	42
		0.25	—	1600	—	3.7	0.01	43	49
		0.5	—	1700	—	3.2	0.006	48	52
	0.25	0.25	—	2600	—	2.5	0.01	41	56
		0.5	—	3200	—	2.1	0.007	54	63
		1.0	—	3500	—	2.0	0.004	63	67
	0.5	0.5	—	4500	—	1.5	0.006	50	65
		1.0	—	5400	—	1.2	0.004	62	70
		2.0	—	6100	—	0.93	0.002	70	70
6SC7[3] (one triode)	0.1	0.1	—	750	—	—	0.033	35	29
		0.25	—	930	—	—	0.014	50	34
		0.5	—	1040	—	—	0.007	54	36
	0.25	0.25	—	1400	—	—	0.012	45	39
		0.5	—	1680	—	—	0.006	55	42
		1.0	—	1840	—	—	0.003	64	45
	0.5	0.5	—	2330	—	—	0.006	50	45
		1.0	—	2980	—	—	0.003	62	48
		2.0	—	3280	—	—	0.002	72	49
6J5, 7A4, 7N7, 6SN7GT (one triode)	0.05	0.05	—	1020	—	3.56	0.06	41	13
		0.1	—	1270	—	2.96	0.034	51	14
		0.25	—	1500	—	2.15	0.012	60	14
	0.1	0.1	—	1900	—	2.31	0.035	43	14
		0.25	—	2440	—	1.42	0.0125	56	14
		0.5	—	2700	—	1.2	0.0065	64	14
	0.25	0.25	—	4590	—	0.87	0.013	46	14
		0.5	—	5770	—	0.64	0.0075	57	14
		1.0	—	6950	—	0.54	0.004	64	14
6C4	0.047	0.047	—	870	—	4.1	0.065	38	12
		0.1	—	1200	—	3.0	0.034	52	12
		0.22	—	1500	—	2.4	0.016	68	12
	0.1	0.1	—	1900	—	1.9	0.032	44	12
		0.22	—	3000	—	1.3	0.016	68	12
		0.47	—	4000	—	1.1	0.007	80	12
	0.22	0.22	—	5300	—	0.9	0.015	57	12
		0.47	—	800	—	0.52	0.007	82	12
		1.0	—	11000	—	0.46	0.0035	92	12

[1] Voltage across next-stage grid resistor at grid-current point.
[2] At 5 volts r.m.s. output.
[3] Cathode-resistor values are for phase-inverter service.

stage. The resistance coupling is used to keep the d.c. plate current from flowing through the transformer primary, thereby preventing a reduction in primary inductance below its no-current value; this improves the low-frequency response. With low-μ triodes (6C5, 6J5, etc.), the gain is equal to that with resistance coupling multiplied by the secondary-to-primary turns ratio of the transformer.

In B the transformer primary is in series with the plate of the tube, and thus must carry the tube plate current. When the following amplifier operates without grid current, the voltage gain of the stage is practically equal to the μ of the tube multiplied by the transformer ratio. This circuit also is suitable for transferring power (within the capabilities of the tube) to a following Class AB_2 or Class B stage.

Phase Inversion

Push-pull output may be secured with resistance coupling by using an extra tube, as shown in Fig. 9-17. The extra tube is used purely to provide a 180-degree phase shift without additional gain. The outputs of the two tubes are then added to provide push-pull excitation for the following amplifier.

The circuit shown in Fig. 9-17 is known as the "self-balancing" type. The amplified voltage from V_1 appears across R_5 and R_7 in series. The drop across R_7 is applied to the grid of V_2, and the amplified voltage from V_2 appears across R_6 and R_7 in series. This voltage is 180 degrees out of phase with the voltage from V_1, thus giving push-pull output. The part that appears across R_7 therefore opposes the voltage from V_1 across R_7, thus reducing the signal applied to the grid of V_2. The negative feed-back so obtained tends to automatically regulate the voltage applied to the phase-inverter tube so that the output voltages from both tubes

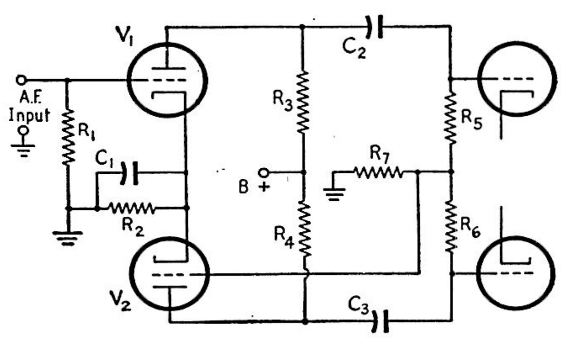


Fig. 9-17 — Self-balancing phase-inverter circuit. V_1 and V_2 may be a double triode such as the 6SN7GT or 6SL7GT.

R_1 — Grid resistor (1 meghom or less).
R_2 — Cathode resistor; use one-half value given in Table 9-I for tube and operating conditions chosen.
R_3, R_4 — Plate resistor; select from Table 9-I.
R_5, R_6 — Following-stage grid resistor (0.22 to 0.47 megohm).
R_7 — 0.22 megohm.
C_1 — 10-μfd. electrolytic.
C_2, C_3 — 0.01- to 0.1-μfd. paper.

are substantially equal — as they must be for distortionless reproduction. Other circuits usually require careful adjustment (preferably with the aid of an oscilloscope) for satisfactory operation. The self-balancing circuit also has the advantage of compensating for variations in the characteristics of the two tubes.

It is common practice to use a double triode when a phase inverter is to be built. This provides two identical tubes in one bulb, and saves space and cost.

Gain Control

A means for varying the over-all gain of the amplifier is a practical necessity. Without it, there would be no way to keep the final output down to the proper level for modulating the transmitter except to talk at just the right intensity. The common method of gain control is to adjust the value of a.c. voltage applied to the grid of one of the amplifiers by means of a voltage divider or potentiometer.

The gain-control potentiometer should be near the input end of the amplifier, at a point where the a.c. voltage level is so low that there is no danger of overloading in the stages ahead of the gain control. With carbon microphones the gain control may be placed directly across the microphone-transformer secondary. With other types of microphones, however, the gain control usually will affect the frequency response of the microphone when connected directly across it. The control therefore is usually placed in the grid circuit of the second stage.

● DESIGNING THE SPEECH AMPLIFIER

The steps in designing a speech amplifier are as follows:

1) Determine the power needed to modulate the transmitter and select the modulator. In the case of plate modulation, this will nearly always be a Class B amplifier. Select a suitable tube type and determine from the tube tables in Chapter Twenty-Five the driving power required.

2) As a safety factor, multiply the required driver power by at least 1.5.

3) Select a tube, or pair of tubes, that will deliver the power determined in the second step. This is the last speech-amplifier stage. Receiver-type power tubes can be used (beam tubes such as the 6L6 may be needed in some cases) so the receiving-tube tables in Chapter Twenty-Five may be consulted. (If the speech amplifier is to drive a Class B modulator, use a Class A or AB_1 amplifier if it will give enough power output. If the last speech-amplifier stage *has* to operate Class AB_2, use a medium-μ triode (such as the 6J5 or corresponding types) to drive it. In the extreme case of driving 6L6s to maximum output, two triodes should be used in push-pull in the driver. In either

case transformer coupling will have to be used, and transformer manufacturers' catalogs should be consulted for a suitable type.)

4) If the last speech-amplifier stage operates Class A or AB_1, it may be driven by a voltage amplifier. If the last stage is push-pull, the driver may be a single tube coupled through a transformer with a balanced secondary, or may be a dual-triode phase inverter. Determine the signal voltage required for full output from the last stage. If the last stage is a single-tube Class A amplifier, the peak signal is equal to the grid-bias voltage; if push-pull Class A, the peak signal voltage is equal to twice the grid bias; if Class AB_1, twice the bias voltage when fixed bias is used; if cathode bias is used, twice the bias figured from the cathode resistance and the no-signal plate current.

5) From Table 9-I, select a tube capable of giving the required output voltage and note its rated voltage gain. A phase inverter (using two tubes of the type selected) will have approximately twice the output voltage and twice the gain of one tube operating as an ordinary amplifier. If the driver is to be transformer-coupled to the last stage, select a medium-μ triode and calculate the gain and output voltage as previously described.

6) Divide the voltage required to drive the last stage by the gain of the preceding stage. This gives the peak voltage required at the grid of the next-to-the-last stage.

7) Find the output voltage, under ordinary conditions, of the microphone to be used. This information should be obtained from the manufacturer's catalog. If not available, the figures given in the section on microphones in this chapter will serve.

8) Divide the voltage found in (6) by the output voltage of the microphone. The result is the over-all gain required from the microphone to the grid of the next-to-the-last stage. To be on the safe side, double or triple this figure.

9) From Table 9-I, select a combination of tubes whose gains, when multiplied together, give approximately the figure arrived at in (8). These amplifiers will be used in cascade. In general, if high gain is required it is advisable to use a pentode for the first speech-amplifier stage, but it is *not* advisable to use a second pentode because of the possibility of feed-back and self-oscillation. In most cases a triode will give enough gain, as a second stage, to make up the total gain required. If not, a third stage, also a triode, may be used.

● SPEECH-AMPLIFIER CONSTRUCTION

Once a suitable circuit has been selected for a speech amplifier, the construction problem resolves itself into avoiding two difficulties — excessive hum, and unwanted feed-back. For reasonably humless operation, the hum voltage should not exceed about 1 per cent of the maximum audio output voltage — that is, the hum should be about 40 db. below the output level. Unwanted feed-back, if negative, will reduce the gain below the calculated value; if positive, is likely to cause self-oscillation or "howls." Feed-back can be minimized by isolating each stage with "decoupling" resistors and condensers, by avoiding layouts that bring the first and last stages near each other, and by shielding of "hot" points in the circuit, such as grid leads in low-level stages.

Speech-amplifier equipment, especially voltage amplifiers, should be constructed on metal chassis, with all wiring kept below the chassis to take advantage of the shielding afforded. Exposed leads, particularly to the grids of low-level high-gain tubes, are likely to pick up hum from the electrostatic field that usually exists in the vicinity of house wiring. Even with the chassis, additional shielding of the input circuit of the first tube in a high-gain amplifier usually is necessary. In addition, such circuits should be separated as much as possible from power-supply transformers and chokes and also from any audio transformers that operate at fairly-high power levels; this will minimize magnetic coupling to the grid circuit and thus reduce hum or audio-frequency feed-back. It is always a safe plan, although not an absolutely necessary one, to build the speech amplifier and its power supply as separate units.

If a low-level microphone such as the crystal type is used, the microphone, its connecting cable, and the plug or connector by which it is attached to the speech amplifier, all should be shielded. The microphone and cable usually are constructed with suitable shielding. The cable shield should be connected to the speech-amplifier chassis, and it is advisable — as well as usually necessary — to connect the chassis to a ground such as a water pipe.

Heater wiring should be kept as far as possible from grid leads, and either the center-tap or one side of the heater-transformer secondary winding should be connected to the chassis. If the center-tap is grounded, the heater leads to each tube should be twisted together to reduce the magnetic field from the heater current. With either type of connection, it is advisable to lay heater leads in the corner formed by a fold in the chassis, bringing them out from the corner to the tube socket by the shortest possible path.

In a high-gain amplifier it is sometimes helpful if the first tube has its grid connection brought out to a top cap rather than to a base pin; in the latter type the grid lead is exposed to the heater leads inside the tube and hence may pick up more hum. With the top-cap tubes, complete shielding of the grid lead and grid cap is a necessity.

When metal tubes are used, always ground the shell connection to the chassis. Glass tubes used in the low-level stages of high-gain amplifiers must be shielded; tube shields are obtainable for that purpose. It is a good plan to enclose the entire amplifier in a metal box, or at least provide it with a cane-metal cover, to avoid feed-back difficulties caused by the r.f. field of the transmitter; r.f. picked up on exposed wiring leads or tube elements causes overloading, distortion, and frequently oscillation.

When using paper condensers as by-passes, be sure that the terminal marked "outside foil" is connected to ground. This utilizes the outside foil of the condenser as a shield around the "hot" foil. When paper condensers are used as coupling condensers between stages, always connect the outside-foil terminal to the side of the circuit having the lowest impedance to ground. Usually, this will be the plate side rather than the following-grid side.

For low-power transmitters, it is often possible to construct the speech amplifier and modulator as a single unit. In high-power equipment the modulator (for plate modulation) takes up so much space that it is usually impracticable to build it on the same chassis with the speech amplifier. In the following section representative designs are given for combination units as well as for speech amplifiers alone.

The speech amplifiers described in the following pages are all designed for use with crystal microphones, since that type of microphone is the most popular. If a carbon microphone is to be used, the secondary of the transformer used with it may be connected directly to the gain control in any of the amplifier circuits given. The stage or stages of amplification preceding the gain control may be omitted in that case. An alternative method is to build the amplifier just as described and connect the carbon microphone as shown in Fig. 9-18. With this method of connection there is no need for a microphone transformer, because a speech amplifier designed for use with a crystal microphone has more than enough gain to compensate for the omission of the microphone transformer.

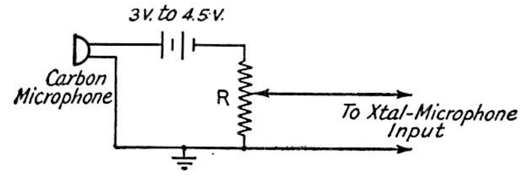


Fig. 9-18 — **Input connections for using a carbon microphone with a high-gain speech amplifier, omitting the usual microphone transformer. *R* is a 100-ohm potentiometer, wire-wound. The arm should be set at the point that gives normal output from the amplifier when the amplifier gain control is set at 1/3 to 1/2 full scale.**

Speech Amplifier with Push-Pull Triode Output

The speech amplifier shown in Fig. 9-19 is a general-purpose unit of conventional design, suitable either as a driver for a medium-power Class B modulator or as a grid-bias modulator. As shown in the circuit diagram, Fig. 9-20, it has a pentode first stage using a 6SJ7, a medium-μ triode second stage (6J5) followed by a 6SL7 phase inverter, and a pair of 6B4Gs in push-pull as Class AB_1 output amplifiers. The power supply for the unit is included on the same chassis. The measured power output is approximately 8 watts from the output-transformer secondary. A tone control is provided to reduce the response of the amplifier above about 2500 cycles.

The speech section occupies the left-hand side of the chassis and the power-supply section the right. Controls along the front chassis edge are the tone-control switch, S_1, gain control, R_5, microphone connector, "B" switch, S_3, and a.c. switch, S_2. The 6SJ7 is behind the microphone connector on the chassis, and the 6J5 is to its left, near the gain control. The 6SL7 phase inverter and 6B4G output tubes are located behind the 6J5.

At the right, the power transformer is at the rear of the chassis, the 5Y3GT rectifier in front, and the first filter choke, L_1, is to the left of the rectifier tube. The output transformer is at the rear center of the chassis.

The bottom view shows the cathode resistor, R_{17}, for the 6B4Gs at the lower right, together with its

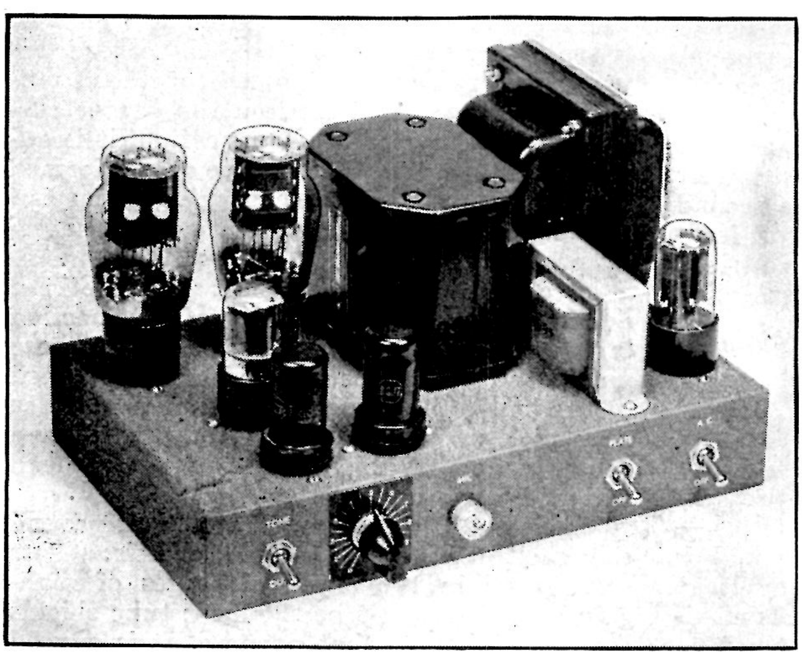


Fig. 9-19 — **This amplifier uses 6B4Gs (equivalent to 6A3s) as output tubes and will deliver 8 watts of undistorted power. It is complete with power supply on a 7 × 11 × 2-inch chassis.**

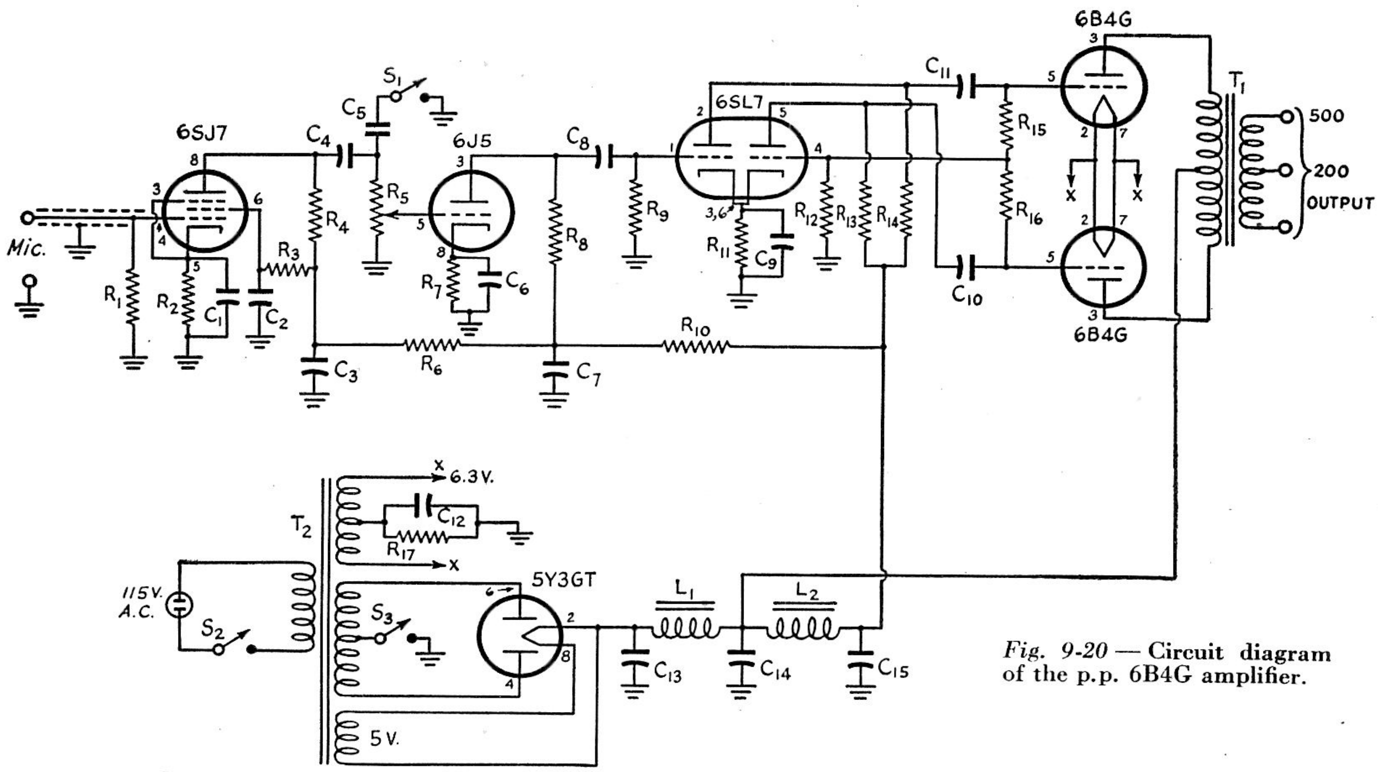


Fig. 9-20 — **Circuit diagram of the p.p. 6B4G amplifier.**

C_1, C_6, C_9 — 20-μfd. 25-volt electrolytic.
C_2 — 0.1-μfd. 400-volt paper.
C_3, C_7, C_{13}, C_{14}, C_{15} — 10-μfd. 450-volt electrolytic.
C_4, C_8, C_{10}, C_{11} — 0.01-μfd. 600-volt paper.
C_5 — 0.001-μfd. 500-volt mica.
C_{12} — 50-μfd. 100-volt electrolytic.
R_1 — 1 megohm, ½ watt.
R_2, R_7 — 1500 ohms, ½ watt.
R_3 — 1.5 megohms, ½ watt.
R_4, R_{12}, R_{13}, R_{14}, R_{15}, R_{16} — 0.22 megohm, ½ watt.
R_5 — 0.5-megohm volume control.
R_6 — 47,000 ohms, ½ watt.
R_8 — 82,000 ohms, ½ watt.
R_9 — 0.47 megohm, ½ watt.
R_{10} — 10,000 ohms, 1 watt.
R_{11} — 1500 ohms, 1 watt.
R_{17} — 750 ohms, 10 watts.
L_1 — 8-hy. 160-ma. filter choke (UTC R-20).
L_2 — 10-hy. 35-ma. filter choke (UTC R-55).
S_1, S_2, S_3 — S.p.s.t. toggle.
T_1 — Output transformer, p.p. plates (5000 ohms) to line (UTC PA-16).
T_2 — 700 volts c.t., 110 ma.; 5 volts, 3 amp.; 6.3 volts, 4.5 amp. (Stancor P-4080).

by-pass condenser, C_{12}. Just above is the second filter choke, L_2. The filter condensers, C_{13}, C_{14} and C_{15}, are the larger tubular units located to the left. The resistors and condensers associated with individual stages are grouped about the appropriate tube sockets. The terminals of the output transformer, T_1, project through a cut-out in the chassis, and secondary leads are brought out to a terminal strip.

A shielded lead should be used from the microphone connector to the grid prong on the 6SJ7 socket, but there are otherwise no special constructional precautions to observe other than those mentioned in the section on general considerations in speech-amplifier construction.

The output transformer shown in the photographs is designed for working into a 500- or 200-ohm line. This type of transformer may be used when the speech amplifier is located at some distance from the Class B modulator or other unit it is to drive. If desired, a Class B input transformer can be substituted at T_1. In that case, the leads to the modulator-tube grids should be shielded as a precaution against hum or r.f. pick-up. The transformer selected should be designed for working from a 5000-ohm plate-to-plate load to the grids of the modulator tubes selected. The amplifier has ample gain for communications-type crystal microphones.

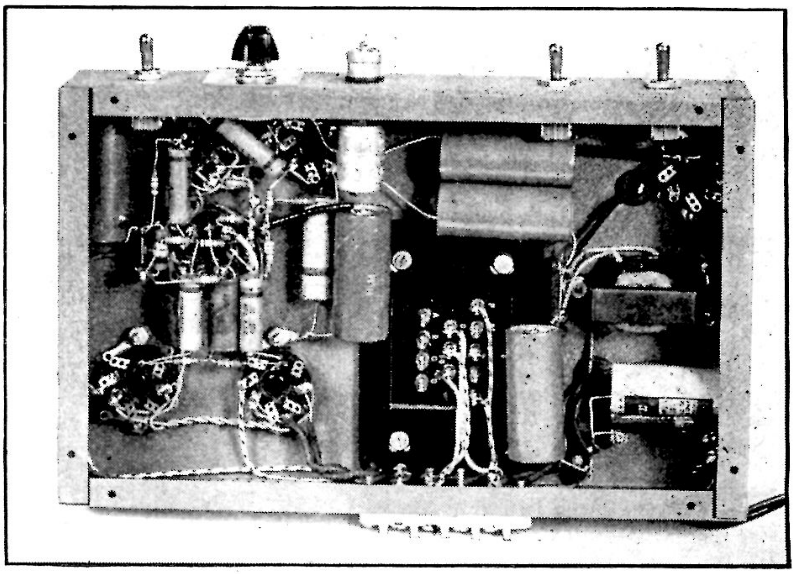


Fig. 9-21 — **Bottom view of the push-pull 6B4G amplifier. Output-transformer terminals are brought out to a connection strip on the rear edge of the chassis.**

Speech Amplifiers with Output Limiting

It is obviously desirable to modulate the transmitter as completely as possible — without, of course, overmodulating and setting up spurious sidebands. However, it is difficult to maintain constant voice intensity when speaking into the microphone. To overcome this variable output level, it is possible to use automatic gain control that follows the *average* (not instantaneous) variations in speech amplitude. This can be done by rectifying and filtering some of the audio output and applying the rectified and filtered d.c. to a control electrode in an early stage in the amplifier.

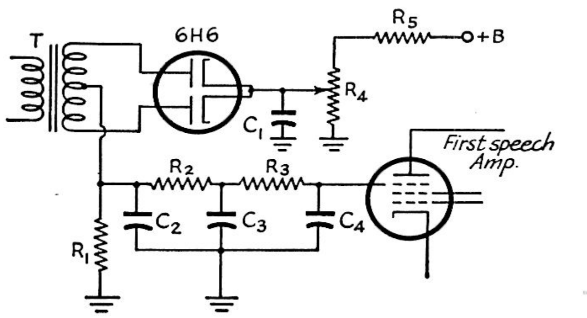


Fig. 9-22 — Speech-amplifier output-limiting circuit. C_1, C_2, C_3, C_4 — 0.1-μfd. R_1, R_2, R_3 — 0.22 megohm. R_4 — 25,000-ohm pot. R_5 — 0.1 megohm. T — See text.

A practical circuit for this purpose is shown in Fig. 9-22. The rectifier must be connected, through the transformer, to a tube capable of delivering some power output (a small part of the output of the power stage may be used) or else a separate power amplifier for the rectifier circuit alone may have its grid connected in parallel with that of the last voltage amplifier.

Resistor R_4, in series with R_5 across the plate supply, provides an adjustable positive bias on the rectifier cathodes. This prevents the limiting action from beginning until a desired microphone input level is reached. R_2, R_3, C_2, C_3 and C_4 filter the audio frequencies from the rectified output. The output of the rectifier may be connected to the suppressor grid of a pentode first stage of the speech amplifier.

A step-down transformer with a turns ratio such as to give about 50 volts when its primary is connected to the output circuit of the power stage should be used. If a transformer having a center-tapped secondary is not available, a half-wave rectifier may be used instead of the full-wave circuit shown, but it will be harder to get satisfactory filtering.

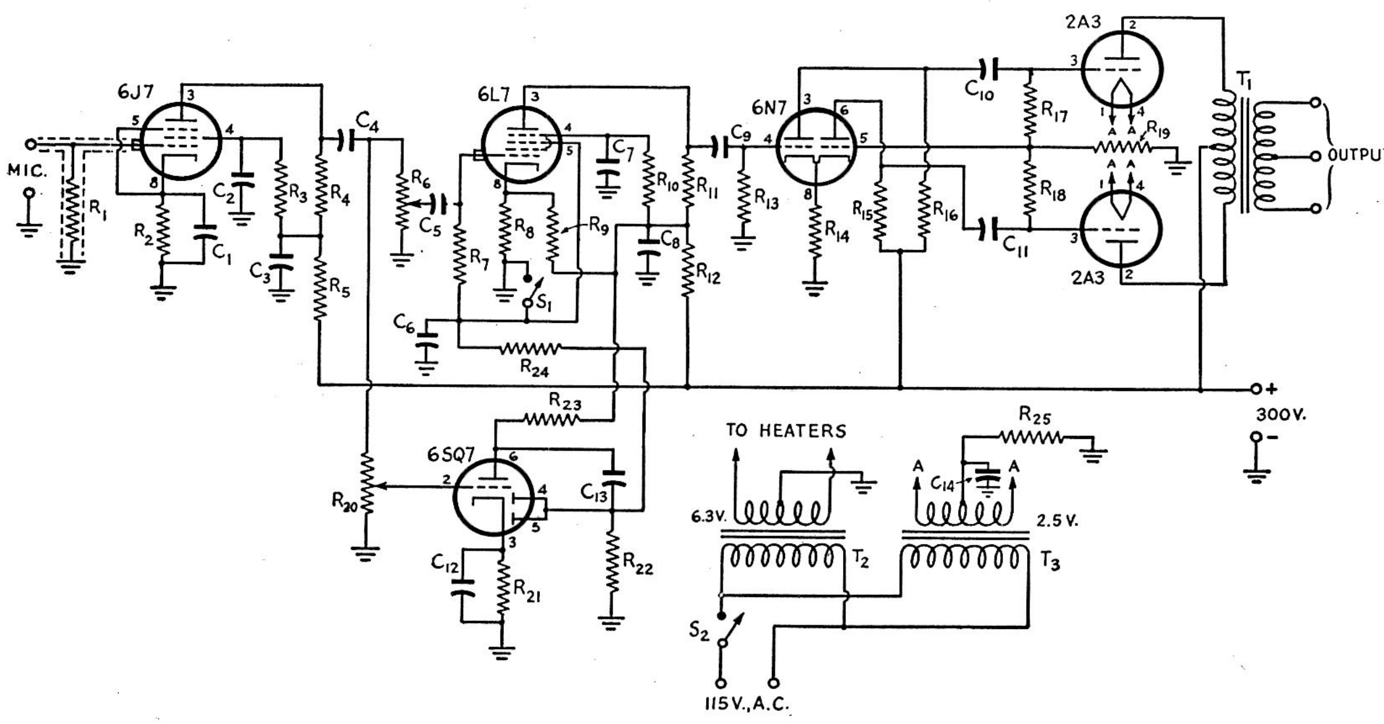


Fig. 9-23 — Circuit diagram of the Class-A 2A3 volume-compression speech amplifier.

C_1, C_{12} — 10-μfd. 50-volt electrolytic.
C_2, C_4, C_5, C_6, C_9, C_{10}, C_{11}, C_{13} — 0.1-μfd. 400-volt paper.
C_8, C_8 — 8-μfd. 450-volt electrolytic.
C_7 — 0.5-μfd. 400-volt paper.
C_{14} — 50-μfd. 100-volt electrolytic.
R_1 — 4.7 megohms, ½ watt.
R_2, R_8 — 1200 ohms, ½ watt.
R_3, R_7 — 2.2 megohms, ½ watt.
R_4, R_{13}, R_{22}, R_{24} — 0.47 megohm, ½ watt.
R_5 — 47,000 ohms, ½ watt.
R_6, R_{20} — 0.5-megohm variable.
R_9 — 0.22 megohm, 1 watt.
R_{10}, R_{11}, R_{23} — 0.1 megohm, ½ watt.
R_{12} — 10,000 ohms, ½ watt.
R_{14} — 1500 ohms, ½ watt.
R_{15}, R_{16} — 0.1 megohm, 1 watt.
R_{17}, R_{18}, R_{19} — 0.22 megohm, ½ watt.
R_{21} — 4700 ohms, ½ watt.
R_{25} — 750 ohms, 10 watts.
S_1, S_2 — S.p.s.t. switch.
T_1 — Output transformer to match p.p. 2A3s to Class B grids.
T_2 — Filament transformer, 6.3 volts, 2 amperes.
T_3 — Filament transformer, 2.5 volts, 5 amperes.

Volume-Limiting Circuit

Fig. 9-23 is the circuit diagram of a complete speech amplifier using a slightly different volume-limiting circuit than that given in Fig. 9-22. It has sufficient gain for working from a crystal microphone and has a power output (6 watts or more, depending upon the efficiency of the output transformer) sufficient to drive a Class B modulator to an output of about 250 watts. The automatic gain-control circuit uses a separate amplifier and rectifier combined in one tube, a 6SQ7. The rectified output of this circuit is filtered and applied to the Nos. 1 and 3 grids of a pentagrid amplifier tube, thereby varying its gain in inverse proportion to the signal strength. With proper adjustment, an average increase in modulation level of about 7 db. can be secured without exceeding 100-per-cent modulation on peaks.

The amplifier proper consists of a 6J7 first stage followed by a 6L7 amplifier-compressor. The 2A3 grids are driven by a 6N7 self-balancing phase inverter. The operation of the 2A3s is Class AB_1, without grid current.

The amount of compression is controlled by the potentiometer, R_{20}, in the grid circuit of the 6SQ7. A switch, S_1, is provided to short-circuit the rectified output of the compressor when normal amplification is required.

Adjustment of the compressor control is rather critical. First set R_{20} at zero and adjust the gain control, R_6, for full modulation with the particular microphone used. Then advance the compressor control until the amplifier just "cuts off" (output decreases to a low value) on peaks. When this point is reached, back off the compressor control until the cut-off effect is gone but an obvious decrease in gain follows each peak.

Because of the necessity for filtering out the audio-frequency component in the rectifier output, there will be a slight delay (amounting to a fraction of a second) before the decrease in gain "catches up" with the peak. This is caused by the time constant of the circuit, and so is unavoidable.

When a satisfactory setting is secured, as indicated by good speech quality with a definite reduction in gain on peaks, the gain control, R_6, should be advanced to give full output with normal operation. Too much volume compression, indicated by the cut-off effect following each peak, is definitely undesirable, and the object of adjustment of the compressor control should be to use as much compression as possible without danger of overcompression.

Speech Clipping and Filtering

Earlier in this chapter it was pointed out that with sine-wave 100-per-cent modulation the average power increases to 150 per cent of the unmodulated carrier power, but that in speech waveforms the average power content is considerably less than in a sine wave, when both waveforms have the same *peak* amplitude. Nevertheless, it is the peak conditions that count in modulation. This is shown in the drawings of Fig. 9-24. The upper drawing, A, represents a sine wave having a maximum amplitude that just modulates a given transmitter 100 per cent. The same maximum amplitude will modulate the same transmitter 100 per cent regardless of the waveform of the modulating signal. The speech wave at B, therefore, also represents 100-per-cent modulation.

In the speech wave, 100-per-cent modulation is reached only on occasional peaks. The *average* modulation is obviously much lower. But if the gain is increased to raise the average modulation level, the transmitter will immediately be overmodulated on the peaks, with the result that splatter-producing sidebands will be generated.

Now suppose that the amplitude of the wave shown at B is increased so that its power is comparable to — or even higher than — the power in a sine wave, but that everything above the 100-per-cent modulation mark is cut off. We then have a wave such as is shown at C, which is the wave at B increased in amplitude but with its peaks "clipped." This signal will not modulate the transmitter more than 100 per cent, but the voice power will be several times as great. The wave is not exactly like the one at B, so the result will not sound exactly like the original. However, such clipping can be used to secure a worth-while increase in modulation

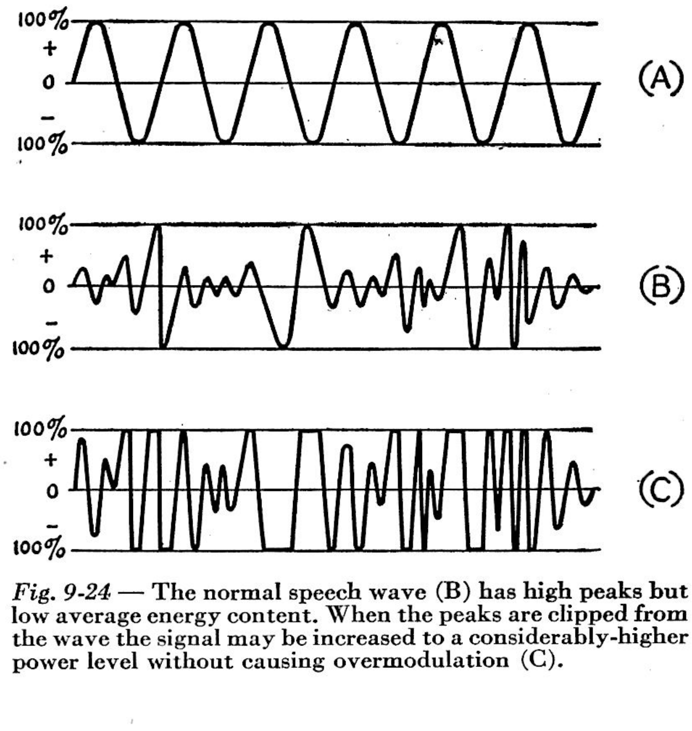


Fig. 9-24 — The normal speech wave (B) has high peaks but low average energy content. When the peaks are clipped from the wave the signal may be increased to a considerably-higher power level without causing overmodulation (C).

power without sacrificing *intelligibility*. The clipping can be done in the speech amplifier, and once the system is properly adjusted *it will be impossible to overmodulate the transmitter* no matter how much gain is used ahead of the clipper — because the clipper will hold the maximum output amplitude to the same value no matter what the amplitude of the signal applied to it.

But by itself the clipper is not enough. Although the clipping takes place in the audio system, the signal applied to the modulated r.f. amplifier has practically the same waveshape that the modulation envelope *would have had* if the signal were unclipped and the transmitter were badly overmodulated. In other words, clipping generates the same high-order harmonics that overmodulation does. So far as the end effect is concerned, it does not matter whether the distortion takes place in the audio system or in the modulated amplifier; both cause splatter. It is therefore necessary to prevent the higher audio frequencies from reaching the modulator. In other words, the frequencies above those needed for intelligible speech must be filtered out, *after* clipping and *before* modulation. The filter required for this purpose should have relatively little attenuation at frequencies below about 2500 cycles, but very great attenuation for all frequencies above 3000 cycles.

It is possible to use as much as 25 db. of clipping before intelligibility is lost; that is, if the original peak amplitude is 10 volts, the signal can be clipped to such an extent that the resulting maximum amplitude is less than one volt. If the original 10-volt signal represented the amplitude that caused 100-per-cent modulation on peaks, the clipped and filtered signal can then be amplified up to the same 10-volt peak level for modulating the transmitter, with a very considerable increase in modulation power. The price to be paid for the increased voice power is loss in naturalness.

Before drastic clipping can be used, the speech signal must be amplified up to 10 times more than is necessary for normal modulation. Also, the hum and noise must be much lower than the tolerable level in ordinary amplification, because the noise in the output of the amplifier increases in proportion to the gain. These factors need not be given so much attention if the clipper-filter is used chiefly as a means for preventing *occasional* overmodulation, and not primarily to obtain more modulation power.

A CLIPPER-FILTER SPEECH AMPLIFIER

The amplifier shown in Fig. 9-25 has a usable output of about 4 watts (sine wave) and includes a clipper-filter for increasing the effectiveness of the modulator and for confining the channel-width to the frequencies needed for intelligible speech. The output stage uses a 6V6 with negative feed-back; this reduces the effective plate resistance of the tube to a low value. The unit therefore can be used to drive a Class B modulator that does not require more than 4 watts on the grids. It can also be used as a complete modulator unit for grid-bias modulation.

As shown in the circuit diagram, Fig. 9-26, the first tube is a 6SJ7. The second stage is one section of a 6SL7GT. With S_3 thrown to the left-hand position, the output of this stage is connected to the grid of a 6J5, which in turn drives the 6V6. Under these conditions the amplifier operates conventionally and has fairly wide frequency response. With S_3 thrown to the right, the output of the first 6SL7GT section is fed to the 6AL5 clipper, and the clipped output is then fed to the grid of the second section of the 6SL7GT. The output of this tube goes through a low-pass filter and thence through a second gain control, R_{15}, to the grid of the 6J5. Thus the clipper-filter feature can be used or not as desired.

The first two stages are resistance-coupled amplifiers following ordinary practice. In the last stage, use is made of the center-tap on the primary of the output transformer to obtain feed-back voltage that is applied to the grid of the 6V6 through the plate resistor, R_{18}, of the 6J5. If a different type of transformer is used, not having a center-tap, a voltage divider can be connected across the primary to obtain the feed-back voltage, as

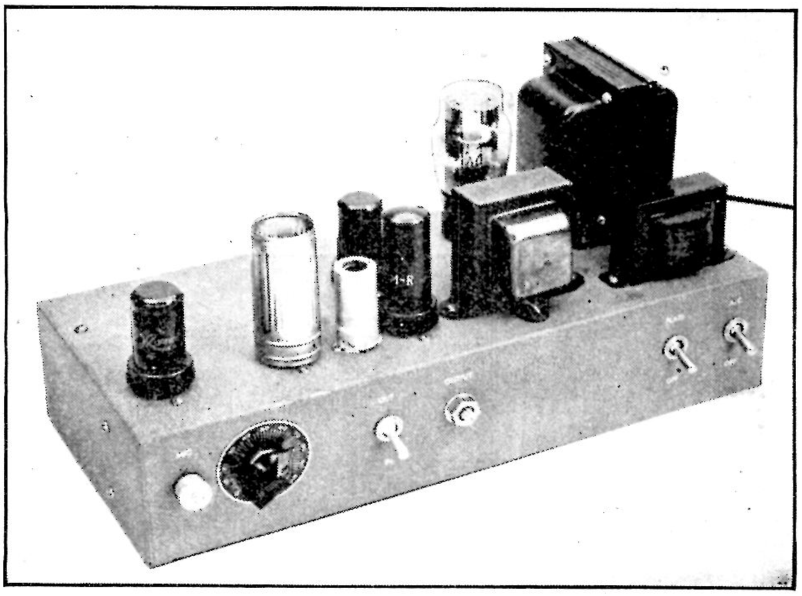


Fig. 9-25 — **A 4-watt output amplifier with speech clipping and filtering. It uses a 6V6 output tube with negative feed-back, and has its power supply on the same chassis.**

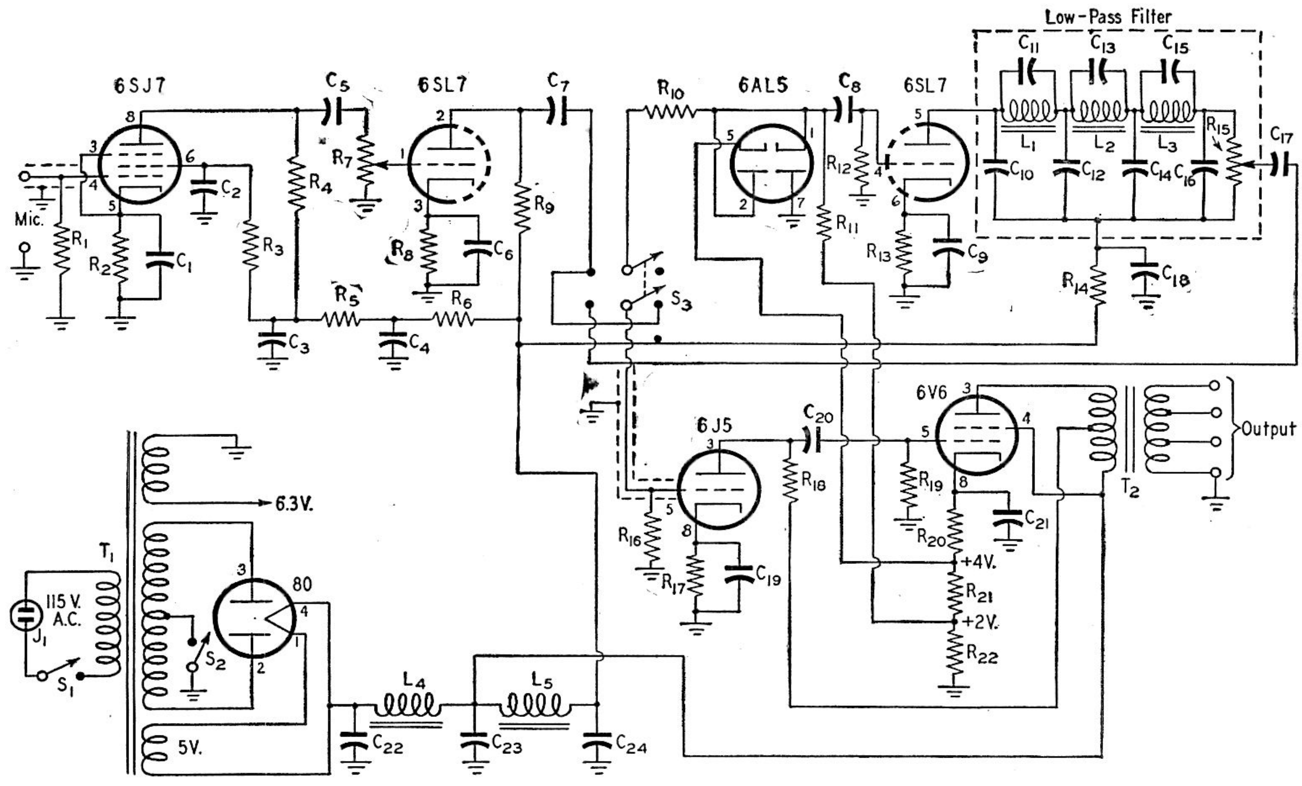


Fig. 9-26 — Circuit diagram of the clipper-filter speech amplifier.

C_1, C_6, C_9, C_{19} — 10-μfd. 25-volt electrolytic.
C_2 — 0.1-μfd. 400-volt paper.
C_3, C_4, C_{18}, C_{22}, C_{23} — 8-μfd. 450-volt electrolytic.
C_5, C_7, C_8, C_{17}, C_{20} — 0.01-μfd. 600-volt paper.
C_{10}, C_{11}, C_{13} — 0.015-μfd. paper.
C_{12} — 0.03-μfd. paper.
C_{14} — 0.05-μfd. paper.
C_{15} — 0.003-μfd. mica.
C_{16} — 0.06-μfd. paper.
C_{21} — 50-μfd. 50-volt electrolytic.
C_{24} — 16-μfd. 450-volt electrolytic.
R_1 — 1 megohm, ½ watt.
R_2, R_{13} — 1000 ohms, ½ watt.
R_3 — 1.2 megohms, ½ watt.
R_4 — 0.22 megohm, ½ watt.
R_5, R_{10} — 47,000 ohms, ½ watt.
R_6 — 0.1 megohm, ½ watt.
R_7 — 2-megohm volume control.
R_8 — 3300 ohms, ½ watt.
R_9, R_{12}, R_{19} — 0.47 megohm, ½ watt.
R_{11} — 0.15 megohm, ½ watt.
R_{14} — 10,000 ohms, 1 watt.
R_{15} — 2000-ohm wire-wound volume control.
R_{16} — 0.33 megohm, ½ watt.
R_{17} — 1500 ohms, ½ watt.
R_{18} — 82,000 ohms, ½ watt.
R_{20} — 150 ohms, 10 watts.
R_{21}, R_{22} — 39 ohms, 2 watts.
L_1, L_2, L_3 — 125 mh.
L_4 — 10 henrys, 60 ma.
L_5 — 10 henrys, 35 ma.
J_1 — 115-v. a.c. connector.
S_1, S_2 — S.p.s.t. toggle.
S_3 — D.p.d.t. toggle.
T_1 — Power transformer, 350 volts each side c.t., 70 ma.; 5 volts, 2 amp.; 6.3 volts, 3 amp. (Stancor P-4078).
T_2 — Output transformer, 5000 ohms (total primary) to line or voice coil.

described in the section on negative feed-back in this chapter.

The amplifier has its own power supply, as shown in the diagram and photographs.

Clipper-Filter Considerations

The clipper circuit resembles those used for noise limiting in receivers, as described in Chapter Five. It uses two diodes, one to clip positive and the other to clip negative peaks, in shunt with a load resistor, R_{11}. The diodes are biased so that they are nonconducting (and therefore have no effect on the signal) until the signal amplitude reaches about 2 volts. When the amplitude rises above 2 volts, signal current flows through the diodes. When conducting, the diode resistance is low compared to the resistance of R_{11}, and also compared to the series resistor R_{10}. Under these conditions, all of the voltage in excess of the 2-volt bias appears as a voltage drop in R_{10} (and in the plate resistance of the preceding stage), with the result that the voltage across R_{11} cannot exceed 2 volts.

For convenience, the bias for the diodes is taken from the cathode resistor of the 6V6 by a voltage-dividing arrangement. As shown in Fig. 9-26, the plate of one diode is connected to ground, R_{11} is returned to a point 2 volts above ground, and the cathode of the second diode is returned to a point 4 volts above ground. This makes the plate of each diode 2 volts negative with respect to its own cathode.

The filter shown in Fig. 9-27 is constructed of standard components, the chokes being 125-mh. units usually sold as r.f. chokes. The design of a filter using this value of inductance requires a fairly high capacitance and a low value of load resistance. The constants listed give a sharp cut-off between 2500 and 3000 cycles, with very large attenuation (averaging

45 db. below the response at 1000 cycles) at all frequencies above 3000 cycles. However, the low value of load or terminating resistor, 2000 ohms, greatly decreases the voltage amplification of the 6SL7GT section as compared to what could be obtained with a normal load. The over-all gain with R_{15} at maximum is about the same as with S_3 in the "normal-amplifier" position, despite the extra stage, when the input signal is below the clipping level. Once clipping begins, of course, the output voltage cannot rise above the clipping level no matter how high the amplitude of the input signal.

Construction

The amplifier is built on a 6 × 14 × 3-inch chassis. The input end of the speech amplifier is at the left end and the power supply is at the right. A shield is placed over the 6SL7GT to prevent hum pick-up and to protect the tube from r.f. fields from the transmitter. The 6AL5 is between the 6SL7GT and the 6V6. The 6J5 is just to the rear of the 6V6, and the output transformer, T_2, is to its right. Along the front edge of the chassis are the microphone connector; gain control, R_7; clipper-filter switch, S_3; the "output" control, R_{15}; and — at the far right — the "B" voltage and a.c. toggle switches.

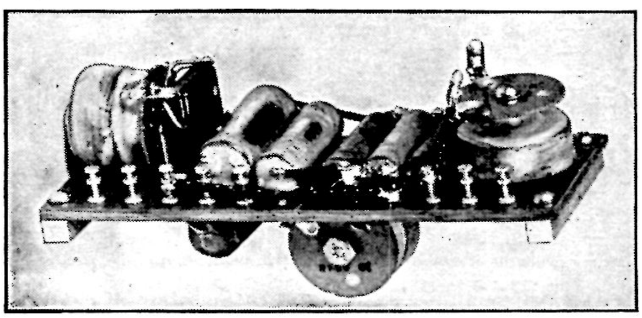


Fig. 9-27 — **The low-pass filter is assembled as a unit on its own mounting board. Readily-available parts are used throughout.**

The low-pass filter is built as a unit on a 2 × 5-inch mounting board, as shown in Fig. 9-27. The coils are kept well separated and are mounted so that their axes are all at right angles. This prevents magnetic coupling between them, and is essential to good filter performance. In other respects the placement of parts in the filter is not critical. If the proper values of capacitance are not at hand, they can be made up by connecting smaller units in parallel (a 0.01-μfd. paper and 0.005-μfd. mica can be paralleled to make 0.015 μfd., for example). The filter unit occupies the upper right-hand corner in the bottom-view photograph, Fig. 9-28.

Particular care should be taken to reduce hum. The 6SJ7 grid lead must be shielded, and the heater wiring in the vicinity of the first two tubes should be kept in the corners of the chassis except where it is necessary to bring the ungrounded wire out to the socket terminal. It is worth while to try reversing the heater connections on the 6SJ7 to reduce hum. Reducing the gain at the lower frequencies also will reduce the hum in the output, and this may be done by decreasing the capacitance of C_5 and C_7 to 0.002 μfd. instead of the 0.01 μfd. specified.

The output transformer, T_2, in this unit is a low-impedance output type, with 500- and 200-ohm line taps as well as taps for a 'speaker voice coil. A Class B driver transformer can be substituted, if desired, or a 1-to-1 transformer can be used for grid-bias modulation.

Adjusting the Clipper-Filter Amplifier

The good effect of the low-pass filter in eliminating splatter can be entirely nullified if the amplifier stages following the filter can introduce appreciable distortion. That is a primary reason for the use of negative feedback in the output stage of the amplifier described. Amplifier stages following the unit must be operated well within their capabilities; in particular, the Class B output transformer (if a Class B modulator is to be driven) should be shunted by condensers to reduce the high-frequency response as described in the section on Class B modulators.

The setting of R_{15} is most important. It is most easily done with the aid of an oscilloscope (one having a linear sweep) and an audio oscillator, using the test set-up shown in the section on testing of speech equipment. Use a resistance load on the output transformer to reflect the proper load resistance (5000 ohms) at the plate of the 6V6. First set R_{15} at about ¼ the resistance from the ground end, switch in the clipper-filter, and apply a 500-cycle sine-wave signal to the microphone input. Increase the signal amplitude until clipping starts, as shown by flattening of both the negative and positive peaks of the wave. To check whether the clipping is taking place in the clipper or in the following amplifiers, throw S_3 to the "normal" or "out" position; the waveshape should return to normal. If it does not, return S_3 to the "in" position and reduce the setting of R_{15} until it does. Then reduce the amplifier gain by means of R_7 until the signal is just below the clipping level. At this point the signal should be a sine wave. Increase R_{15}, without touching R_7, until the wave starts to become distorted, *and then* reduce the setting of R_{15} until the distortion just disappears.

Next, change the input-signal frequency to 2000 cycles, without changing the signal level. Slowly increase R_7 while observing the pattern. At this frequency it should be almost impossible to get anything except a sine wave through the filter, so if distortion appears it is the result of overloading in the amplifiers *following* the filter. Reduce the setting of R_{15} until the distortion disappears, even when R_7 is set at maximum and the maximum available signal

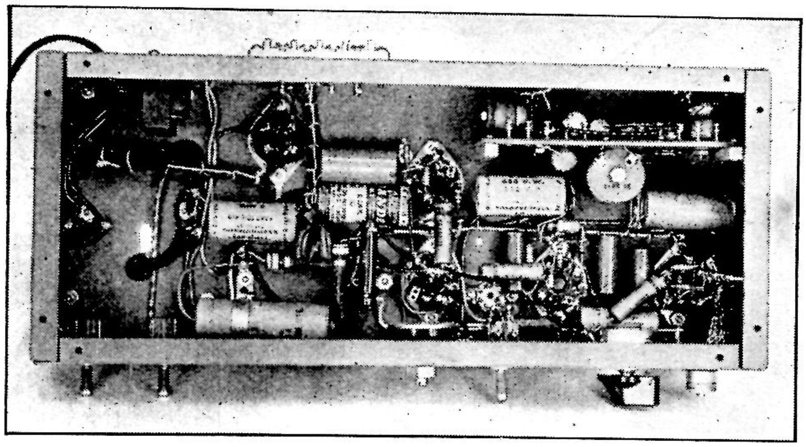


Fig. 9-28 — Bottom view of the clipper-filter speech amplifier. Resistors and condensers are grouped around the sockets to which they connect.

from the audio oscillator is applied to the amplifier. The position of R_{15} should be marked at this point and the marked setting should never be exceeded.

To find the *operating* setting of R_{15}, leave the audio-oscillator signal amplitude at the value just under the clipping level and set up the complete transmitter for a modulation check, using the oscilloscope to give the trapezoidal pattern. With the Class C amplifier and modulator running, find the setting of R_{15} (keeping the audio signal just under the clipping level) that just gives 100-per-cent modulation. This setting should be below the maximum setting of R_{15} as previously determined; if it is not, the driver and modulator are not capable of modulating the transmitter 100 per cent and must be redesigned — or the Class C amplifier input must be lowered. Assuming a satisfactory setting is found, connect a microphone to the amplifier and set the amplifier gain control, R_7, so that the transmitter is modulated 100 per cent. Observe the pattern closely at different settings of R_7 to see if it is possible to overmodulate. If overmodulation does not occur at any setting of R_7, the transmitter is ready for operation and R_{15} may be locked in position; it need never be touched subsequently. If some overmodulation does occur, R_{15} should be backed off until it disappears and then locked.

In the absence of an oscilloscope the other methods of checking distortion described in the section on speech-amplifier testing may be used. The object is to prevent any distortion in all stages following the filter, so that when the clipping level is exceeded the following stages will still be working within their capabilities.

As a final check, the signal should be monitored by another station a short distance away. A receiver with a sharp crystal filter is needed for this purpose. The signal input to the receiver should be kept low enough (by using a small antenna) so that there is no danger of overloading any stage of the receiver. When the transmitter is modulated 100 per cent by a tone of about 2500 cycles, the receiving operator should be able to find only one pair of sidebands, each 2500 cycles from the carrier, even when the speech-amplifier gain control (R_7, not R_{15}) is set well beyond the level at which 100-per-cent modulation is reached. If additional sidebands are in evidence there may be distortion in the modulator (use condensers across the modulation transformer to cut high-frequency response), or the low-pass filter in the speech amplifier may not be properly built.

6L6 Modulators for Low-Power Transmitters

Plate modulation for transmitters operating at final-stage plate power inputs up to 75 or 80 watts can be provided at relatively small cost by using Class AB 6L6s as modulators. The combined speech amplifier and modulator shown in Fig. 9-29 uses the 6L6s as Class AB_2 amplifiers and has an output (from the transformer secondary) of about 40 watts. The input amplifier is a 6J7 (a 6SJ7 can be substituted if a single-ended tube is preferred to the type with the top grid cap). It is resistance-coupled to a 6J5 second amplifier, and the 6J5 is in turn coupled through a transformer to a pair of 6J5s in push-pull. These two tubes supply the power necessary to drive the 6L6s into the grid-current region. (A 6SN7GT can be substituted for the pair of 6J5s in the push-pull stage if desired; no changes in circuit constants will be necessary.)

The amplifier is built on a 6 × 14 × 3-inch chassis. The photographs show the arrangement of parts. About the only constructional precaution that must be observed is to use a short lead from the microphone socket (a jack may be used instead of the screw-on type) and to shield the entire input circuit to the grid of the 6J7. This shielding is necessary to reduce hum pick-up. In this amplifier the 6J7 grid resistor, R_1, is enclosed along with the input jack in a National Type JS-1 jack shield, and a shielded lead is run from the jack shield to the grid of the 6J7. A metal slip-on shield covers the grid cap of the tube. The amplifier has more than enough gain for typical crystal microphones.

This unit may be used to plate-modulate 80 watts input to an r.f. amplifier. For cathode modulation, the input that can be modulated

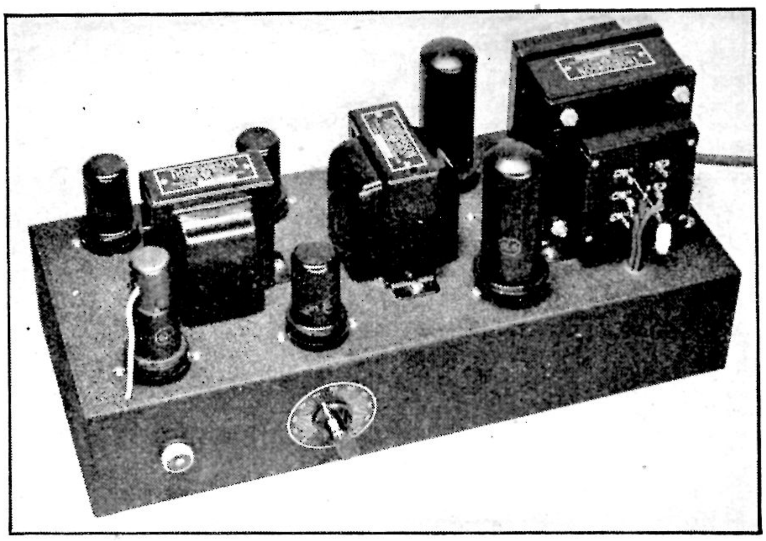


Fig. 9-29 — A 40-watt speech amplifier or modulator of inexpensive construction. The 6J7 and first 6J5 are at the front, near the microphone socket and volume control, respectively. T_1 is behind them, and the push-pull 6J5s are at the rear of the chassis behind T_1. T_2, in the center, the push-pull 6L6s, and T_3 follow in order to the right.

will depend upon the type of operation chosen, as described earlier. For instance, with 55-per-cent plate efficiency in the r.f. stage the input may be of the order of 200 watts, making an allowance for the small amount of audio power taken by the grid circuit. The output transformer shown in the photograph is a universal Class B output type suitable for coupling to a plate-modulated amplifier; other types may be substituted if the r.f. amplifier is to be cathode-modulated. Whatever the type of service, the output-transformer turns

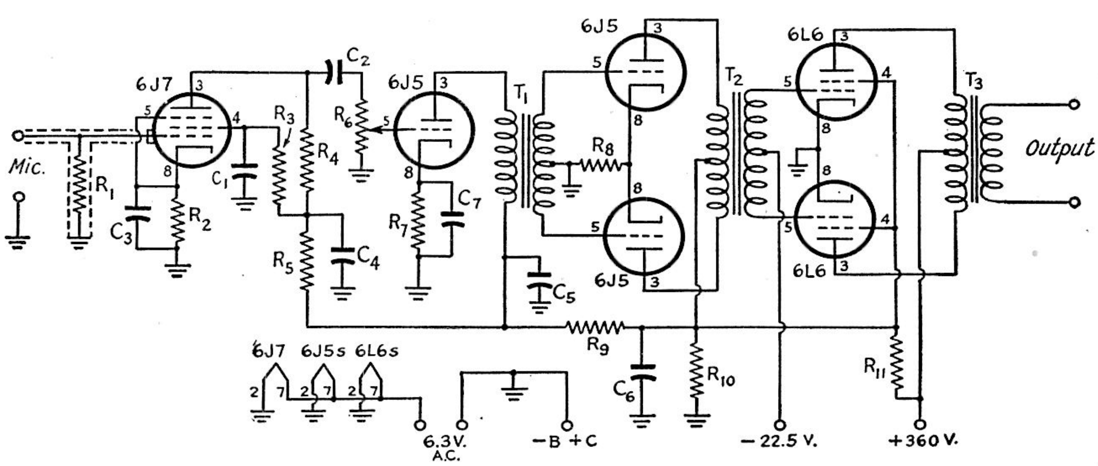


Fig. 9-30 — **Circuit diagram of the Class AB2 push-pull-6L6 40-watt-output speech amplifier or modulator.**

C_1 — 0.1-μfd. 200-volt paper.
C_2 — 0.01-μfd. 400-volt paper.
C_3, C_7 — 20-μfd. 50-volt electrolytic.
C_4, C_5, C_6 — 8-μfd. 450-volt electrolytic.
R_1 — 4.7 megohms, ½ watt.
R_2 — 1500 ohms, ½ watt.
R_3 — 1.5 megohms, ½ watt.
R_4 — 0.22 megohm, ½ watt.
R_5 — 47,000 ohms, ½ watt.
R_6 — 1-megohm volume control.
R_7 — 1500 ohms, 1 watt.
R_8 — 750 ohms, 1 watt.
R_9 — 12,000 ohms, 1 watt.
R_{10} — 20,000 ohms, 25 watts.
R_{11} — 1500 ohms, 10 watts.
T_1 — Interstage audio, single plate to p.p. grids, 3:1 ratio (Thordarson T-57A41).
T_2 — Driver transformer, p.p. 6J5s to 6L6s, Class AB_2 (Thordarson T-84D59).
T_3 — Output transformer, type depending on requirements. A multitap modulation transformer (Thordarson T-19M15) is shown.

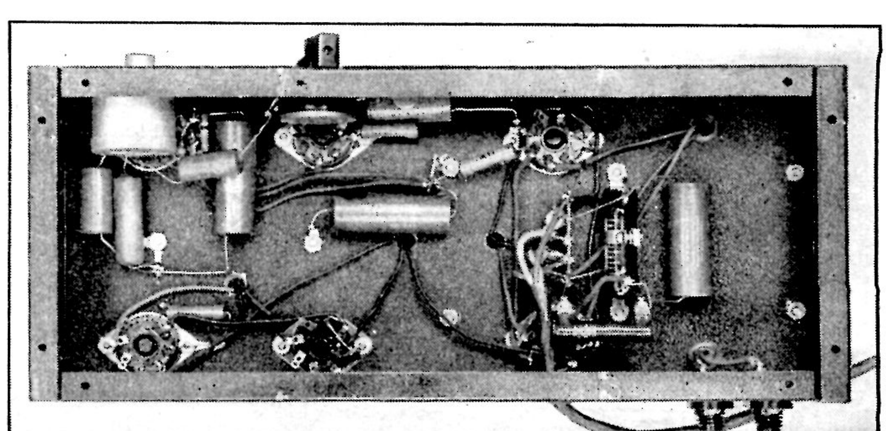


Fig. 9-31 — Underneath the chassis of the 40-watt speech amplifier-modulator.

ratio should be chosen to couple properly between 3800 ohms (the plate-to-plate load required by the 6L6s) and the modulating impedance of the r.f. amplifier.

The power supply should have good voltage regulation, since the total "B" current varies from approximately 140 ma. with no signal to 265 ma. at full output. A heavy-duty choke-input plate supply should be used; general design data will be found in Chapter Seven. Heater requirements are 6.3 volts at 3 amperes. Bias for the 6L6 stage can be supplied conveniently by a 22.5-volt "B"-battery block; a small-sized unit will be satisfactory.

Fig. 9-32 is the circuit of a speech amplifier and modulator that has an output of approximately 20 watts. This circuit also uses 6L6s as output tubes, but the amplifier operates Class AB_1 and thus requires no driving power. Aside from the fact that there is one less voltage-amplifier stage than in the 40-watt unit, the same general construction may be followed. The first two stages are identical in circuit with the first two stages in the 40-watt amplifier, and the same constructional precautions should be observed with respect to shielding the grid circuit of the first tube. This amplifier can be used to plate-modulate an input of 40 watts to the r.f. amplifier. It is necessary, of course, to choose the proper output-transformer turns ratio to couple the modulator and modulated amplifier. The output stage of the unit is designed to work into a plate-to-plate load of 9000 ohms.

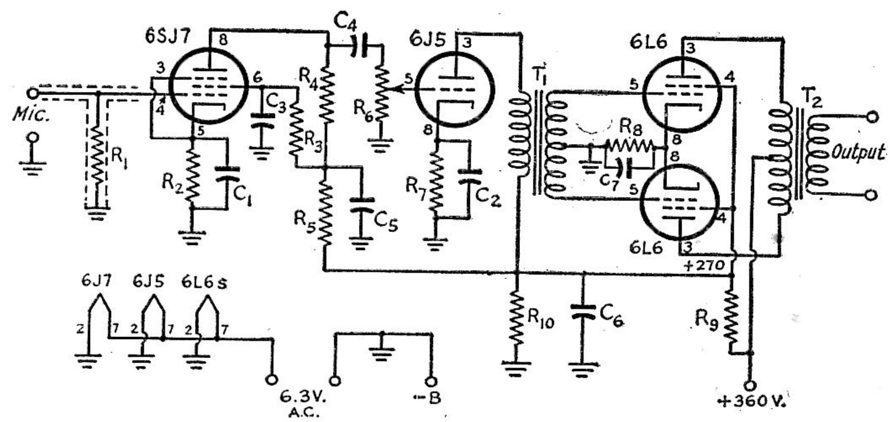


Fig. 9-32 — Circuit diagram of the low-cost speech amplifier or modulator capable of power outputs up to 20 watts.

C_1, C_2 — 20-μfd. 50-volt electrolytic.
C_3 — 0.1-μfd. 200-volt paper.
C_4 — 0.01-μfd. 400-volt paper.
C_5, C_6 — 8-μfd. 450-volt electrolytic.
C_7 — 50-μfd. 50-volt electrolytic.
R_1 — 4.7 megohms, ½ watt.
R_2 — 1500 ohms, ½ watt.
R_3 — 1.5 megohms, ½ watt.
R_4 — 0.22 megohm, ½ watt.
R_5 — 47,000 ohms, ½ watt.
R_6 — 1-megohm volume control.
R_7 — 1500 ohms, 1 watt.
R_8 — 250 ohms, 10 watts.
R_9 — 2000 ohms, 10 watts.
R_{10} — 20,000 ohms, 25 watts.
T_1 — Interstage audio transformer, single plate to p.p. grids, ratio 3:1 (Thordarson T-57A41).
T_2 — Output transformer, type depending on requirements. A multitap transformer (Thordarson T-19M14) is shown in photos.

For the maximum power output of 20 watts, the plate supply for the amplifier must deliver 145 ma. at 360 volts. A condenser-input supply of ordinary design (Chapter Seven) may be used. The total plate current is approximately 120 ma. with no signal and 145 ma. at full output. If a power output of no more than 12 or 13 watts is needed, R_9 and R_{10} may be left out of the circuit and all tubes fed directly from a "B" supply giving approximately 175 ma. at 270 volts.

An 807 Modulator and Speech Amplifier

The combined speech amplifier and modulator unit shown in Fig. 9-33 is simple and inexpensive in design and, with the exception of the plate supply for the modulator tubes, is contained on a chassis measuring 3 × 8 × 17 inches. With a 750-volt plate supply, it is capable of a tube output of 120 watts, or enough to plate-modulate a Class C stage with 200 watts input, allowing for moderate losses in the modulation transformer. The output tubes, 807s, will develop this amount of audio power when operated as Class AB_2 amplifiers, but require only a small amount of grid driving power.

As shown in Fig. 9-34 the first tube in the speech amplifier is a 6J7 (a 6SJ7 may be substituted). A 6SN7GT is used in the second stage, one section serving as a voltage amplifier and the other as a phase inverter of the self-balancing type. The gain control for the amplifier is in the grid circuit of the first half of the tube. The third tube, also a 6SN7GT, is a push-pull amplifier, transformer-coupled to the grids of the 807s.

A power supply for the three tubes preceding the 807s is built on the same chassis. Voltage for the 807 screens is taken from this same supply. The negative return of the supply goes to the chassis through the adjustable arm of potentiometer R_{17}, which is connected in series with the bleeder resistor, R_{16}. The voltage developed in the section of R_{17} below the adjustable arm is negative with respect to chassis, and is used to provide fixed bias for the 807s. C_{11} is connected across this section of R_{17} to by-pass any a.f. current that might flow through the resistor. A separate filament transformer is provided for the 807 heaters, since the total heater power required by all the tubes in the amplifier is somewhat in ex-