

AMPLIFIER AND OSCILLATOR CIRCUITS (CONT'D)

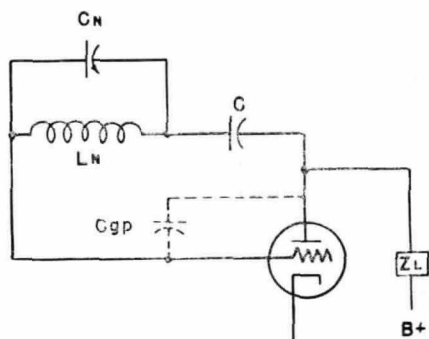
4. Neutralizing. One of the most serious problems encountered in the design of radio-frequency amplifiers employing triodes is the capacitive feedback of energy from plate to grid. It may be shown that the effect of this feedback is to increase tremendously the apparent input capacitance of the system. At optimum tuning, when the grid and plate voltage are exactly opposite in phase,

$$C_i = C_{gp} \left(1 + \frac{E_p}{E_g} \right)$$

Since the ratio, E_p/E_g , is not simply the μ of the tube, but is the actual gain of the amplifier, C becomes a function of the nature of the load, the tube bias, plate voltage, tuning, etc., and subject to so many variables that it becomes difficult to predict or control.

With a triode, no possible method of avoiding feedback exists, and neutralization must be used. This is accomplished by applying, to the grid circuit, a current equal in magnitude and opposite in phase to that flowing through C_{gp} .

An interesting form of neutralization is shown in Fig. 54. The circuit is adjusted so that the inductance reactance of L_n is equal to the capacitive reactance of C_{gp} and C_n together. Although L_n could be made adjustable to equal C_{gp} , variable reactors are difficult to build, and by making L_n slightly larger than needed, the easily controlled C_n can be added. Since the circuit formed by L_n and $C_{gp} + C_n$ are in resonance, the impedance is very nearly a maximum and the grid-plate current circulates only in the loop.

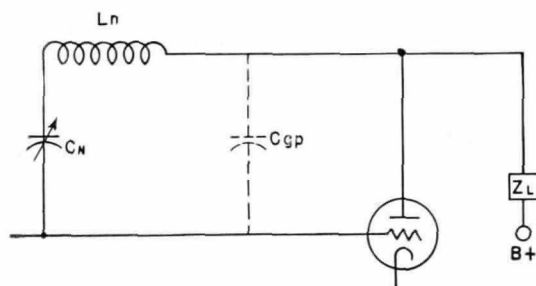


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Fig. 54—Neutralization Circuit for Triode Amplifier

When grid modulation is used, the circuit arrangement is as shown in Fig. 55. This arrangement is necessary to avoid phase shift at audio frequencies across the grid circuit but does not provide neutralization as good as the first circuit.



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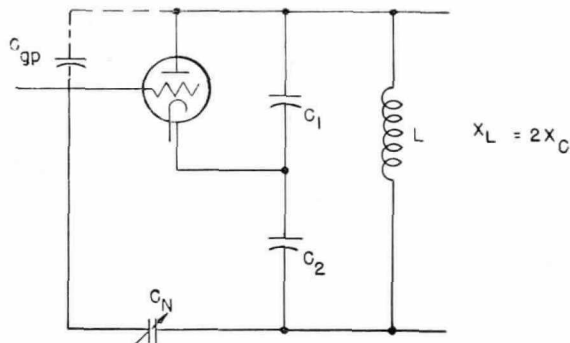
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Fig. 55—Neutralization for Circuit with Grid Modulation

A widely used neutralization is the so-called "built-out" circuit. The neutralizing current is fed back from a point having a voltage opposite in phase to the anode voltage, and the built-out circuit produces this voltage.

It is convenient to have this voltage roughly equal to the anode voltage, so that the neutralizing capacitor can be equal to the grid-plate capacitance. The circuit often takes the form of Fig. 56. It is important to remember these points concerning this circuit:

1. The currents through C_{gp} and C_n are not equal under ideal operating conditions since the voltage across C_{gp} is the arithmetic sum of the grid and plate voltage, while the voltage across C_n is their arithmetic difference. The components of current that are equal and opposite are due to the plate, the criterion for neutralization, but the components due to the grid are in phase, so that the input is capacitive.
2. C_2 acts in parallel with C_n to produce the total built-out reactance.
3. If the load is coupled to L , neutralization cannot be complete because of the phase shift introduced by the load. The load coupling must be separate from the neutralizing circuit.



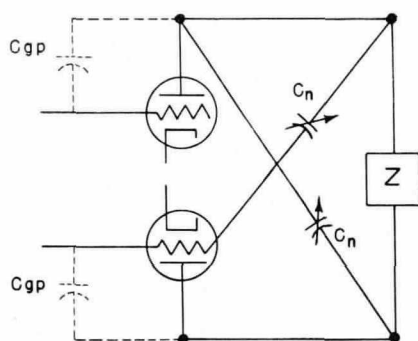
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Fig. 56—Built-out Neutralization Circuit

AMPLIFIER AND OSCILLATOR CIRCUITS (CONT'D)

It is apparent that neutralization is most easily accomplished with push-pull circuits. Here, the out-of-phase voltages are ready and waiting. A simple criss-cross network is added as in Fig. 57.

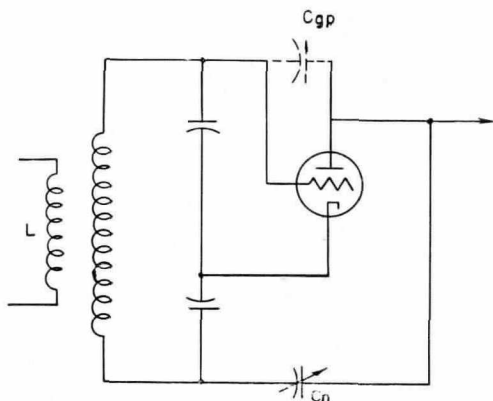


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Fig. 57—Criss-Cross Neutralization Circuit

The circuits shown in Fig. 58 and Fig. 59 have been used, but, while they give some of the desired effects during adjustment, they do not produce true neutralization. Ordinarily, excitation is applied with the plate voltage removed and C_n adjusted to give a minimum on a radio-frequency indicator. A good null is obtained when C_n is equal to C_{gp} . If, however, we consider an r-f voltage on the anode of Fig. 58, it is apparent that while this voltage will cause equal and opposite currents to flow through the capacitors, no net current flows in the grid inductance. The currents produce voltages across the grid capacitors which are in phase with the plate voltage. Since this is in phase opposition to the grid excitation, negative feedback is produced.

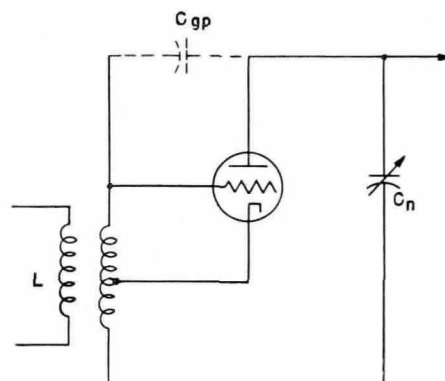


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Fig. 58—Imperfect Neutralization Circuit

On the build-out, the excitation voltage and feedback voltage are in phase. The apparent null indicates neutralization only so long as the system is in balance.



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Fig. 59—Another Circuit Employing Imperfect Neutralization

Two more circuits are shown in Fig. 60 and Fig. 61. Instead of a built-out circuit, phase reversal is obtained by using a transformer. Using the legend shown in the figure, the following relations may be used for the design:

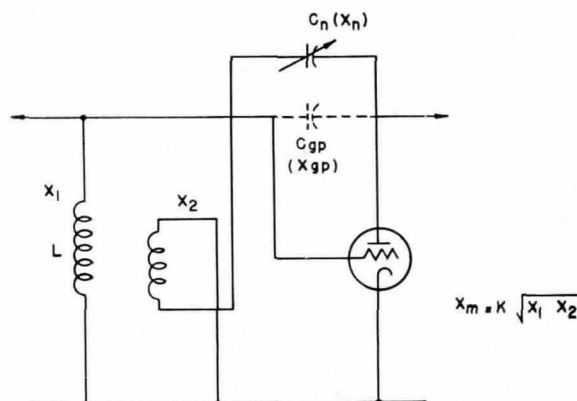
$$\frac{X_n}{X_{gp}} = \frac{K\sqrt{X_2 X_1}}{1 - X_2(1 - K^2)}$$

If $X_n \gg X_2$ or if the coefficient of coupling approaches unity

$$\frac{X_n}{X_{gp}} = K\sqrt{\frac{X_2}{X_1}}$$

If $C_n = C_{gp}$, then

$$\frac{X_2}{X_1} = \frac{1}{K^2}$$

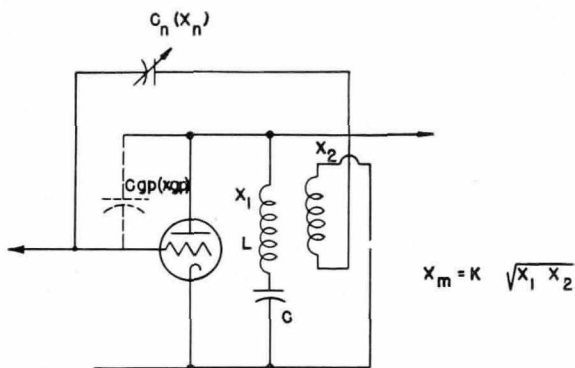


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Fig. 60—Hazeltine Grid-neutralization Circuit

Amplifier and Oscillator Circuits (Cont'd)



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Fig. 61—Hazeltine Plate-neutralization Circuit

5. Output Coupling. The problems involved in coupling an amplifier to a load such as an antenna are very similar to those of interstage coupling. Capacitive coupling can be used but is useless in the suppression of harmonics. Inductive coupling reduces the transfer of harmonics to the antenna and effectively isolates the load from the high d-c voltages of the final amplifier, and allows the use of transmission lines.

PARASITIC AND TUNING CONSIDERATIONS

Parasitic oscillations are a frequent and occasionally serious problem in the design of both audio and radio-frequency amplifiers. Although a good deal can be done to eliminate them in the design program, they sometimes appear in even the most carefully designed circuits.

Parasitics generally occur at frequencies somewhat higher than the operating frequency and without necessarily integral relation to that frequency. They are caused by various circuit components which in combination satisfy the conditions required for oscillation. As a rule, the tube capacitances form an important part of the resonant circuit. Besides representing a severe power loss, parasitics may be responsible for erratic and even intermittent operation, high distortion, flashover, and tube failure. They may take the form of continuous, self-sustained oscillations, or be triggered by various circuit transients.

The parasite can usually be located with a neon lamp or high frequency receiver; the latter method helps to fix the frequency of oscillation. Cures can be effected by careful analysis or by a trial and error method. Pass filters, series resistors, detuning of parasitic circuit, and rearrangement of layout and wiring may be necessary, singly or in combination. The series

resistors should be placed so as to present a severe load to the parasite circuit and little load to the amplifier itself. In parallel tube operation, series resistors isolating the tube grids and, possibly, low resistance radio-frequency chokes should be included as a matter of course in the design.

Multiple radio-frequency grounds should be avoided and the utmost simplicity maintained in the layout. Shunt fed grid and plate supplies should not be used together since the complex resonant combinations which result may cause serious parasiting. Tuning and loading taps, long leads, crowding of components and poor power supply filtering may also cause trouble.

TUNING CLASS C AMPLIFIERS

The first step in tuning a Class C amplifier is to obtain proper neutralization. Adjustment of the neutralizing circuit is made without plate voltage on the tube by applying grid excitation, and tuning for minimum radio-frequency voltage between plate and ground or minimum radio-frequency current in one of the output circuit elements. Another method is to adjust the neutralizing circuit so that no change in d-c grid current occurs as the plate circuit is tuned through its range. In low power amplifiers, a neon lamp near the plate circuit is an effective null indicator. If the load causes detuning of the circuit, the tank must be re-trimmed during the process.

The grid circuit is tuned to resonance as indicated by maximum grid current. If the rectified current is less than that recommended for the tube, the excitation, should be increased.

It is important to remember that the tuning of an amplifier is a step by step process, and that any one adjustment may entail resetting of other circuit components.

AMPLITUDE MODULATORS

Some typical amplitude modulation circuits are shown in Fig. 62 through 66. Fig. 62 is the Heising constant-current circuit for plate modulation. The polarity of induced voltages in the reactor due to the audio drive applied to the modulator tends to maintain constant supply current. As modulator current increases, the radio-frequency amplifier current drops and the radio-frequency carrier amplitude is reduced. The purpose of the dropping resistor R is to limit the amplifier voltage so that 100 per cent modulation can be achieved. C serves as low-impedance by-pass capacitor around R for the audio-signal current.

AMPLITUDE MODULATORS (CONT'D)

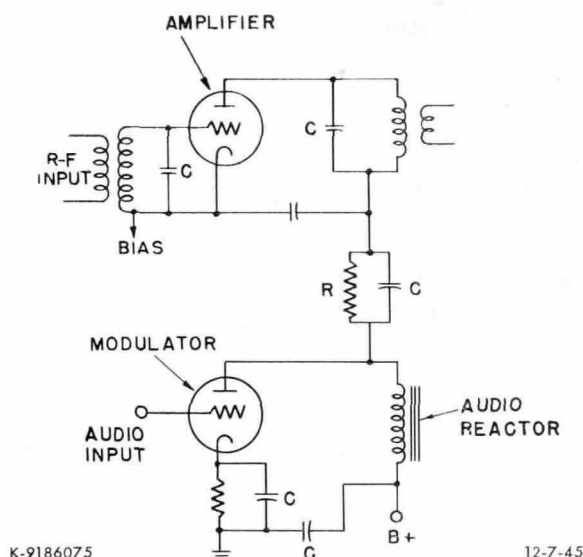


Fig. 62—Heising Constant Current Circuit or Plate Modulation

Fig. 63 employs a transformer rather than a reactor. It may be driven by a Class A, Class B, or Class AB amplifier. The audio signal is superimposed upon the plate supply as a series voltage. When the impedances of the modulator and radio-frequency tube plate circuits are properly matched, 100 per cent modulation with low distortion can be accomplished.

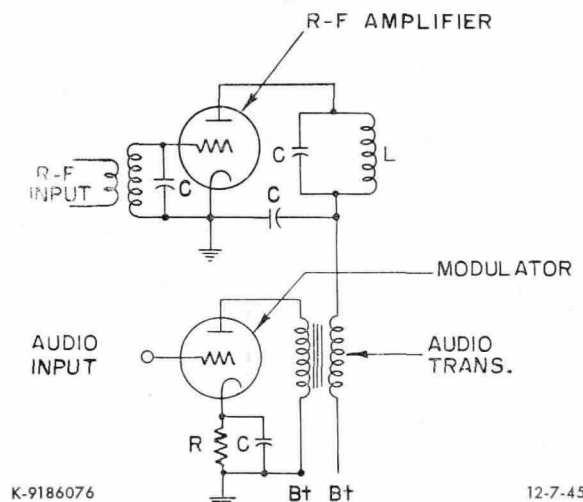


Fig. 63—Modulator Employing Transformer

Fig. 64 shows a grid modulation circuit. The bias of the radio-frequency amplifier is varied at the audio rate with consequent variation in the radio-frequency envelope. The advantage of the system is that it takes very little audio driving power, but, since operating conditions must be carefully chosen and maintained, the circuit is difficult to use.

Suppressor modulation, Fig. 65, involves the introduction of the audio component in series with the suppressor bias. As with grid modulation,

tion, driving power is small, but the circuit is critical and tends to distort at high modulation levels.

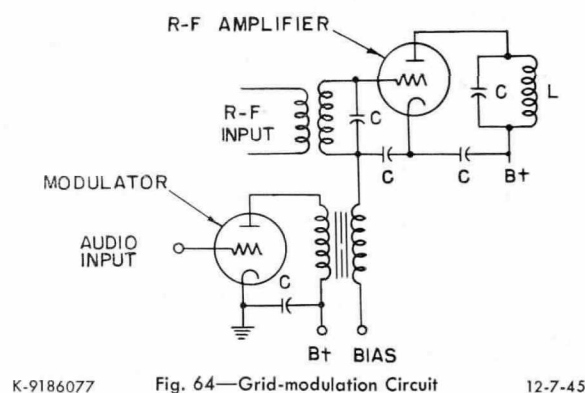


Fig. 64—Grid-modulation Circuit

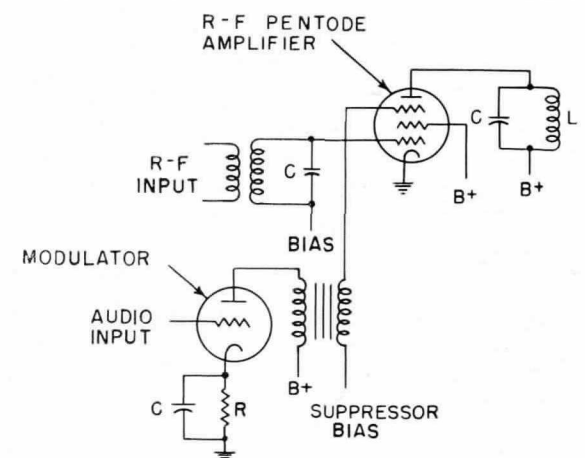


Fig. 65—Suppressor-modulation Circuit

The cathode modulator, shown in Fig. 66, gives a combination of both grid and plate modulation since both the effective grid bias and the plate voltage are varied. The amount of grid modulation is generally kept small to improve carrier efficiency by adjustment of the grid leak resistance and positioning of the grid return on the tapped secondary of the modulation transformer.

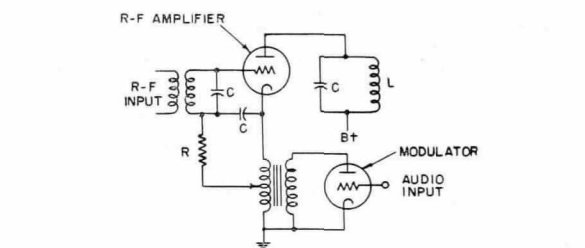


Fig. 66—Cathode-modulation Circuit

In general, the plate modulated amplifier provides the highest operating efficiency, about 70 to 80 per cent. Grid modulated stages rarely have efficiencies greater than about 35 per cent. The cathode-modulated amplifier, since it represents a combination of plate and grid modulation, normally is operated at about 55 per cent.

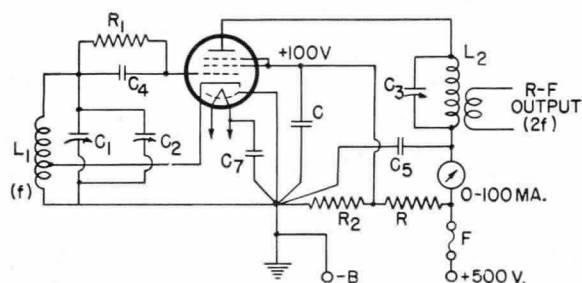
TYPICAL CIRCUITS

Fig. 67 through 73 shown on this page are selected to illustrate a few circuits commonly used in typical transmitting applications.

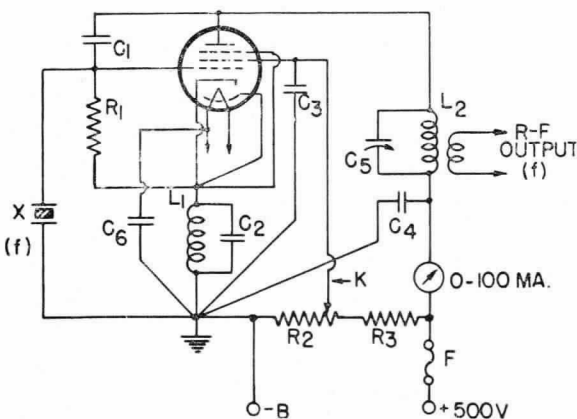
In general the diagrams of Fig. 67 through 73 are conventional circuits which experience has proven to be dependable and practicable.

The designer may find it desirable in certain applications to use a part of one circuit in combination with other circuits or portions of circuits to meet the requirements of a particular design.

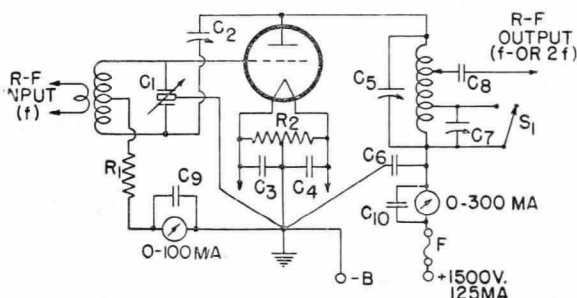
Specific tube type numbers are not indicated on the diagrams as the choice of a particular transmitting triode, tetrode or pentode will depend upon the power output desired, operating frequency, size, cost and other design considerations.



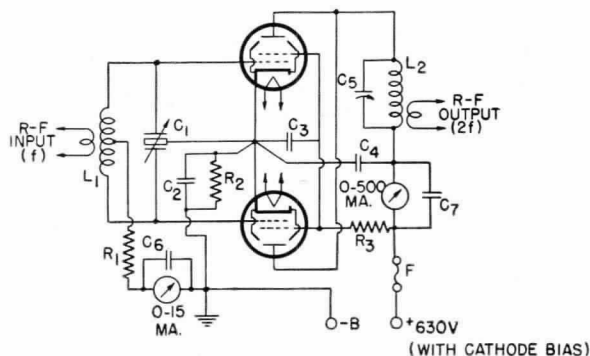
K-9186149 Fig. 67—Electron-Coupled Oscillator 1-9-46



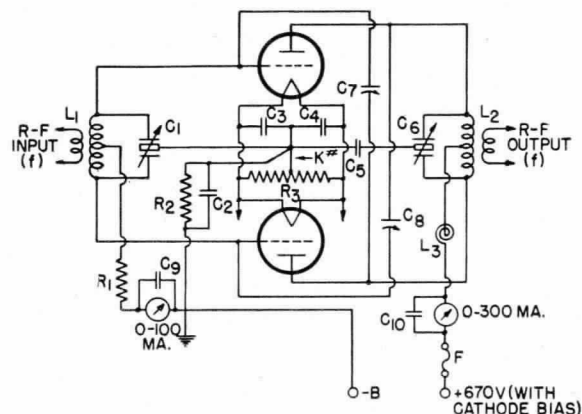
K-9186146 Fig. 68—Reinartz Crystal Oscillator 1-9-46



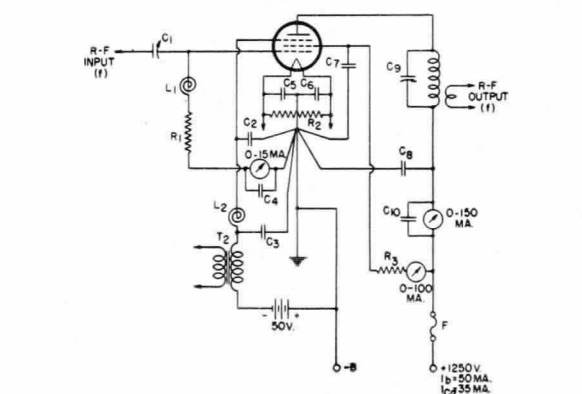
K-9186148 Fig. 69—Frequency Doubler or R-F Power Amplifier (Class C Telegraphy) 1-9-46



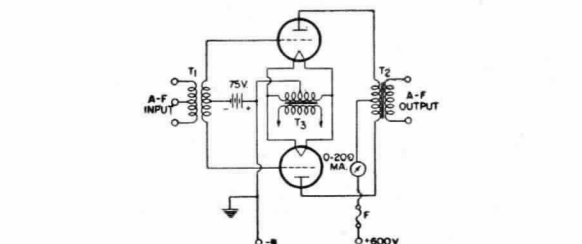
K-9186144 Fig. 70—Push-Pull Frequency Doubler of High Efficiency 1-9-46



K-9186147 Fig. 71—Push-Pull Class C R-F Amplifier for C-W Telegraphy 1-9-46



K-9186143 Fig. 72—Suppressor-modulated Pentode R-F Power Amplifier 1-9-46



K-9186145 Fig. 73—Class B Modulator 1-9-46

INSTALLATION AND OPERATION

CONVECTION-COOLED TYPES

INSTALLATION

Mechanical

Mountings must be of good quality and should be so installed as to minimize danger from impact. If the set is subject to vibration, a shock-absorbing suspension must be employed.

Cooling

All apparatus should be arranged to allow free circulation of air around the tube. The bulb becomes very hot during operation and, therefore, should neither come in contact with any metallic object nor be subjected to drops or spray of liquid.

Sets using more than one tube should provide adequate spacing between tubes so that adjacent portions of the bulbs do not operate appreciably hotter than the other sections.

Electrical

To avoid danger of corona discharge, all wires and connections should be made to allow several inches of free space around the tube. For tubes using a metal base, the metal shell must not be connected to any part of the circuit.

The filament should be operated preferably from an a-c source, although a d-c supply may be used. The filament voltmeter should be connected to indicate the voltage at the filament terminals. The filament supply should be designed to allow operation at rated filament voltage. The filament transformer shall have good regulation and should be designed for at least thirty per cent above rated filament wattage.

Thoriated-tungsten filaments should be operated at eighty per cent of normal filament voltage during stand-by periods of less than two hours and shut down entirely for longer periods. However, for small tubes of less than 250 watts plate dissipation rating the filament voltage may be removed for stand-by periods greater than 15 minutes. There should be no reduction of filament voltage for periods of less than five minutes. The filament voltage may be reduced to eighty per cent during periods greater than five minutes if desired.

Oxide-coated filaments or cathode heaters should be operated at normal filament voltage during stand-by periods. If the stand-by periods exceed two hours the filament current may be shut off.

Overheating by severe overload may decrease filament emission. Unless the overload has liberated a large amount of gas, the activity of the filament usually can be restored by operating the filament at rated voltage for ten minutes or more with no voltage on the plate or grid. This process may be accelerated by increasing the filament voltage to 20 per cent above the normal value (not higher) for a few minutes.

The grid-circuit and plate-circuit return leads should be connected to the center tap of the filament-transformer secondary. When d-c filament excitation is used, the return leads from the grid and plate circuits should be connected to the negative filament terminal.

The circuits should be arranged to prevent parasitic oscillations so that the tube will not be subjected to excessive voltages and current.

An ammeter in the plate circuit of each tube should be connected so that the direct-plate current may be checked regularly.

The plate circuit should be provided with a protective device such as a fuse or relay in order to prevent overheating caused by improper circuit adjustments or overloading. This device should remove the plate voltage instantly if the direct-plate current reaches a value 50 per cent above normal.

In rating transmitting tubes, certain values are given as maximum; that is, the values beyond which it is unsafe to go from the viewpoint of life and performance. In order not to exceed the maximum ratings, changes in plate and filament voltage caused by line-voltage fluctuation, load variation, and manufacturing variation of the associated apparatus must be determined. Then, an average value of plate voltage should be chosen so that under the usual operating conditions the maximum ratings will not be exceeded.

IN TRYING OUT A NEW CIRCUIT OR WHEN ADJUSTMENTS ARE BEING MADE, THE PLATE VOLTAGE SHOULD BE REDUCED IN ORDER TO PREVENT DAMAGE TO THE TUBE OR ASSOCIATED APPARATUS IN CASE THE ADJUSTMENTS ARE INCORRECT.

OPERATION

General

Maximum ratings and typical operating conditions for each recommended class of service are given on the Description and Rating Sheet covering the individual type of tube. The typical values given must not be considered as ratings, because the tube may be used at any suitable conditions within the maximum ratings.

Class A Audio-frequency Amplifier or Modulator

Grid bias for this type of service may be obtained from a separate voltage source or by means of a self-biasing resistor shunted by a filter network to avoid degenerative effects at the low audio-frequencies. When several tubes are operated in parallel, it is necessary to make provision for individual adjustment of grid bias to insure that the plate dissipation of any tube does not exceed the maximum value. This may be accomplished by means of a tapped C battery or, if self bias is used, by means of a variable cathode resistor for each tube. When the self-