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Fixed Condensers in Radio Transmitters

By the Engineering Department, Aerovox Corporation

FIXED condensers are among the simplest of radio circuit components. Their basic construction is substantially the same as that of the 18th century Leyden jar, forerunner of all condensers. The manner in which they operate is easy to understand. But despite their freedom from complexity, fixed condensers perform numerous essential functions and are, as a result, liberally distributed throughout receiver and transmitter circuits.

In transmitter r.f. stages, and between these stages, fixed condensers serve the important purposes of by-passing, coupling, and blocking. They make possible the transfer of radio-frequency energy between circuit points, the removal of r.f. currents from certain parts of a circuit, and the separation of a.c. and d.c. components. Thus, the fixed condenser plays a trilateral role in the complicated process of transforming commercial a.c. power into radio waves.

Fixed condensers for transmitter r.f. circuits must be judiciously chosen with respect to *capacitance, voltage rating, current rating, dielectric, type of construction, casing, circuit function, and operating frequency* to insure efficient and economical transmitter operation. Many of the operative difficulties, such as parasitic oscillations, reduced excitation voltage and r.f. leakage, which arise in transmitter circuits may be traced to neglect of one or more of these items. Hence, it is apparent that numerous common disorders may be "designed out" of a transmitter in the beginning by properly selecting its fixed condensers.

In this article, we will endeavor to give practical rules whereby the proper fixed transmitting capacitor may be selected for each circuit position. And while concentration will be in the direction of the r.f. portion of the transmitter, we have not forgotten that fixed condensers play an important part in the audio-modulator channel. However, the rules for radio-frequency applications, as outlined, will apply with very slight modification to the a.f. stages as well, since the lone difference encountered is the reduced frequency of operation. The fixed capacitors employed in the power supply filter circuits will likewise not be dealt with in this paper, their action and the rules governing their application having been fully covered in other issues of the *Research Worker.*

Figure 1 shows a conventional three-stage transmitter circuit such as might be employed on amateur, commercial, and experimental frequencies between 1500 and 30,000 kc. This arrangement, using a single 75T tube in the output amplifier, is capable of delivering 200 watts of modulated or unmodulated r.f. power to a suitable antenna. There are fifteen separate fixed condensers in this circuit, acting to bypass r.f. currents, transfer r.f. energy from one stage to another, or to prevent the passage of direct currents. Each of these condensers is, in general, subject to different operating voltages, and the capacitance of each will be determined by its special purpose and the frequencies which it must pass. The minimum voltage and current rating of each will depend upon the maximum d.c. and r.f. voltages to which the condenser is subjected and upon the operating frequency. The functions of the various capacitors will be discussed first, and then the factors governing their characteristics will be presented.

BYPASS CONDENSERS

From the simplest viewpoint, the purpose of a bypass condenser is to *detour* r.f. or a.f. currents around a circuit or sub-circuit through which they must not flow, or in which they might encounter a large amount of resistance or impedance. In practice, such a circuit generally carries a d.c. component. Bypassing action is obtained through the ability of the condenser to block completely the d.c. component, while providing a comparatively low-impedance path for the alternating currents.

The commonest bypass capacitor is probably the cathode condenser, such

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200 Watts Output – C.W. or Phone

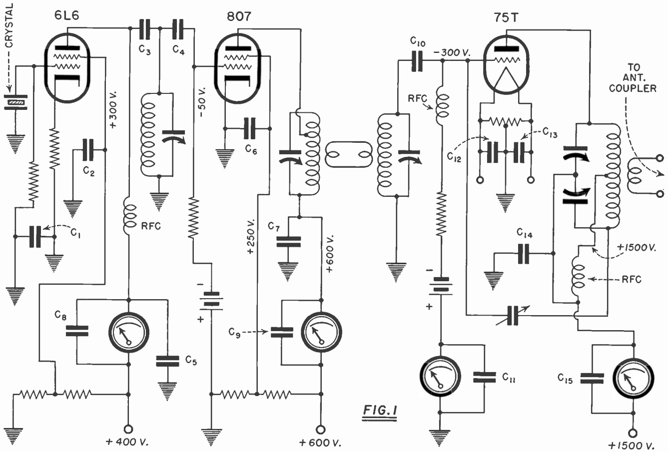

FIG. I

C_1—.01 mfd., 600 v.
C_2—.01 mfd., 600 v.
C_3—.001 mfd., 500 v.
C_4—.0001 mfd., 500 v.
C_5—.01 mfd., 1000 v.
C_6—.01 mfd., 600 v.
C_7—.01 mfd., 1000 v.
C_8—.002 mfd., 1000 v.

C_9—.002 mfd., 1000 v.
C_{10}—.0005 mfd., 600 v.
C_{11}—.002 mfd., 600 v.
C_{12}—.01 mfd., 600 v.
C_{13}—.01 mfd., 600 v.
C_{14}—.001 mfd., 5000 v.
C_{15}—.002 mfd., 5000 v.

Constants suitable for amateur and experimental frequencies between 1700 and 30,000 kc. Between 30,000 kc. and 60,000 kc. it is advisable to reduce coupling and blocking capacitances.

BYPASS—C_1, C_2, C_5, C_6, C_7, C_{12}, C_{13}, C_{14}
SPECIAL METER BYPASS—C_8, C_9, C_{11}, C_{15}
COUPLING—C_3
BLOCKING—C_4, C_{10}

as C_1 in Figure 1, which acts to conduct the a.c. component of tube plate current around the cathode bias resistor to ground. Since this condenser is to provide a low-impedance path for an alternating current, its capacitance must be such that its reactance will be low at the a.c. frequency. Reactance varies inversely with frequency, therefore low-capacity condensers will be most suitable for bypassing r.f. circuits in a transmitter; high-capacity ones for a.f. circuits—or circuits in which an audio component appears.

Very high voltages are not usually encountered in tube cathode circuits, so the d.c. operating voltage rating of the cathode bypass condenser need not be so high as that of other bypass condensers associated with the high-voltage plate and screen circuits. But the cathode bypass condenser must be capable of carrying the r.f. or a.f. *current* which would normally flow through a condenser of its capacitance in the tube cathode circuit at the operating frequency. Manufacturers' rating tables list the maximum safe r.f. current for definite condenser types at various common operating frequencies. The actual current through the condenser may be measured under operating conditions by one of two methods: by inserting a thermoammeter of suitable sensitivity in series with the condenser, or by reading the a.c. voltage appearing across the condenser with an isolated vacuum-tube voltmeter and calculating the current therefrom by Ohm's Law for a.c.

The tube-screen condenser, such as C_2 and C_6 (Figure 1), is another well-known type of bypass capacitor. This condenser places the screen electrode effectively at ground r.f. potential and must be capable of operating safely at the d.c. screen voltage. Like the cathode condenser, the screen capacitor must have low reactance at the operating frequency. The tube manufacturer usually specifies the value of capacitance which is most effective with a particular type of tetrode, pentode, or beam power transmitting tube.

The plate-circuit bypass condenser (C_5, C_7, and C_{14} in Figure 1) connects the tuned circuit, or "plate tank", to the tube cathode, with respect to r.f. currents. Thus, it provides a radio-frequency return circuit from plate tank to cathode without short-circuiting the high-level d.c. plate voltage to ground. Good plate bypass condensers are essential to proper operation of a radio-frequency transmitter stage.

Plate bypass condensers should be rated to operate at 2 times the d.c. voltage that will be applied to them by the plate-circuit power supply in a telegraph transmitter, and 4 times the d.c. voltage when they are employed in the modulated stage of a radiotelephone transmitter. Their actual capacitance should afford low reactance at the transmitter frequency, or the frequency of the stage in which they are inserted.

Although leakage has not much effect on bypassing efficiency, a good grade mica condenser will be superior to paper types in cathode, screen, and plate applications. The tubular type condensers should be particularly avoided in high-frequency transmitters, since their inductive effect introduces a number of circuit disorders.

As in the case of the cathode bypass capacitor, the plate- or screen-circuit condenser must be capable of handling the current which will flow through it in its circuit position at the operating frequency. The current rating will vary with the frequency and capacitance, and the product of the reactance (at the operating frequency) and the current must never exceed the working voltage of the condenser.

An added refinement to any transmitter is the employment of meter bypass condensers, such as C_8, C_9, C_{11}, and C_{15}. These serve to detour r.f. currents around the meters where they might cause severe damage or complete burnout of the delicate d'Arsonval movements. The same factors which govern the selection of the other condensers just described apply likewise to meter bypass condensers.

In the elimination of a.c. line-hum components from the transmitted carrier wave, the electrical center of the tube filament circuit is grounded through an appropriate center-tapped resistor, such as shown with the 75T final amplifier tube in Figure 1. This method is quite effective. However, the resistor introduces a considerable amount of impedance to the flow of r.f. currents from the tube filament to ground; and to offset this undesirable effect, filament bypass condensers (C_{12} and C_{13}) are connected from each filament leg to ground to provide a low-impedance r.f. path. The capacitance of filament bypass condensers should never exceed .01 mfd. and their voltage rating may safely be approximately one-half of the d.c. plate voltage applied to the tube.

COUPLING CONDENSERS

Coupling condensers are used to transfer radio-frequency energy from one point to another, such as between the output circuit of one stage and the input circuit of another. The particular technique of energy transfer by condensers is termed *capacitive coupling* by transmitter engineers.

Figure 2 illustrates capacitive coupling as commonly employed between two r.f. stages in a transmitter. The coupling condenser, C, is connected directly between the plate of one tube, V_1 and the grid of the succeeding tube, V_2. A low-impedance path is thus provided for r.f. used to excite the grid of V_2, while the latter is isolated from the V_1 plate voltage, E_1.

In such an arrangement, the condenser actually conducts all of the r.f. current it is able to from the first stage to the second and must be rated to carry this current safely at the operating frequency. In addition, the condenser is subject to the d.c. plate voltage, E_1, of the first tube, and the d.c. grid voltage, E_2, of the second, which are effectively in series with each other. The d.c. operating voltage of the coupling condenser, then, must be better than the sum of these two voltages. For safe operation, the rating should be from 50% to 100% greater than the voltage sum.

The coupling condenser must have exceedingly high leakage resistance and introduce few losses, requirements that at once dictate the use of mica as a dielectric. It must be well protected from moisture, therefore well sealed in a low-loss insulating material.

The capacitance of the coupling condenser, which must be of such value as to provide low reactance at the operating frequency, will depend directly upon the latter. At the frequencies allocated for amateur, commercial, and experimental short-wave services this will generally be between .0001 and .002 mfd. while in ultra-high-frequency applications the capacitance will more suitably be of the order of .00005 mfd.

The coupling condenser provides a convenient and simple means of excitation control when this feature is desired, since varying its capacitance, and correspondingly its reactance, at a given operating frequency will cause corresponding variations in the r.f. driving voltage applied through it to the grid of a succeeding tube. In fact, the proper amount of "grid drive" for a given tube may be obtained easily through this expedient by raising or lowering the coupling capacitance in appropriate steps.

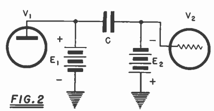

FIG. 2

Note that plate voltage, E_1, and grid voltage, E_2, act in series against coupling condenser, C.

BLOCKING CONDENSERS

The blocking condenser, as the name implies, is used wherever it is desired to obstruct the flow of direct current through a circuit carrying r.f. or a.f. currents. C_4 and C_{10} in Figure 1 are examples of blocking condenser applications.

The plate circuit of the crystal oscillator tube, 6L6, is *parallel fed;* i.e., the d.c. plate potential is applied through a radio-frequency choke instead of through the plate tank. And in order to prevent a resultant short-circuit of the plate supply through the grounded tank circuit, the *blocking* condenser, C_4, is interposed between the plate electrode and the tank. R.F. currents have no difficulty, however, in flowing from the plate to the tank circuit, or vice versa.

The grid circuit of the final amplifier is similarly parallel fed, and the blocking condenser, C_{10}, prevents a short circuit of the 75T grid bias voltage through the grounded grid tank circuit.

It is evident that the blocking condenser, in its function of separating a.c. and d.c. components, closely resembles the coupling condenser.

The factors influencing the values of capacitance, d.c. operating voltage rating, and permissible r.f. current for the blocking condenser are identical with those stated for the various types of bypass and coupling condensers and need no repetition.

Blocking condensers are becoming more widely known with the increasing popularity of parallel-fed transmitter circuits. The outstanding advantages of the parallel-fed over the series-fed circuit, responsible for its present adoption, are (1) the removal of dangerously high d.c. voltages from the tank tuning condenser, and (2) the permissible reduction in size and cost of the tuning condenser. To the blocking condenser may be accredited these important advantages.

CASING

Fixed condensers employed in transmitter r.f. stages should be of the hermetically-sealed type of construction, provided with short terminals, and physically as small as the required ratings will permit. In high-frequency applications, low-loss bakelite casing is recommended over all other types.

In order to prevent flashovers and to keep losses and stray capacitances at a minimum, metal casings should be avoided. Accommodations for mounting the high-voltage condensers firmly on the transmitter chassis are particularly desirable.

Special flat, bakelite-cased, meter bypass condensers are available with brackets for mounting directly to the screw terminals of the meter.