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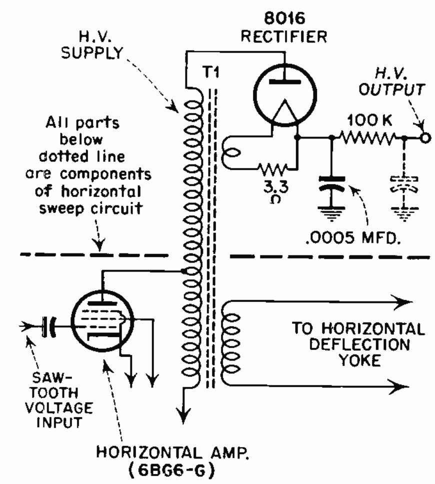
Cathode-Ray Tube High-Voltage Supplies

By the Engineering Department, Aerovox Corporation

THE widespread use of the cathode-ray tube in television viewers and in test instruments has occasioned the use of high-voltage, direct-current supplies of rather unconventional design. Such departures from the standard 60-cycle power supply are due to the special requirement of 'scope tubes for accelerating voltages ranging up to 30,000 volts at current drains less than one milliampere. The production of such voltages by line-frequency, iron-core transformers is impractical because the process of winding high-voltage secondaries with extremely fine wire is expensive. The problem of maintaining adequate insulation between the secondary and the other parts of the transformer is also troublesome. In addition, the network required to filter the low ripple-frequency is dangerous and bulky. For these reasons, the use of this type of supply for high potentials has been virtually superseded by the more modern high-frequency supplies.

There are three general types of special high-voltage, low-current supplies in common use for cathode-ray tube applications. In the order of popularity, they are;

(a) The Flyback, or "Kick" Supply.
(b) The Radio-Frequency Supply
(c) The Pulse-type Supply.



TYPICAL FLYBACK H.V. SUPPLY
FIG.1

Each of these types has special advantages with respect to the requirements of economy, efficiency, compactness, ease of construction, and lack of interference with other circuits. This paper will discuss the operating principles and relative advantages of each type.

The Flyback Supply

The high-potential supply most widely used in television sets having magnetic deflection systems is the horizontal return-sweep, or "flyback" supply. The popularity of this arrangement is due to the fact that it requires the least number of additional parts and it functions during the retrace period during which the picture-tube beam is blanked out. In this manner, the interference which may be caused in adjacent circuits is not visable in the television picture. This type of supply also requires no additional source of power, since it uses energy from a "transient" voltage in the horizontal sweep circuit which would otherwise be wasted.

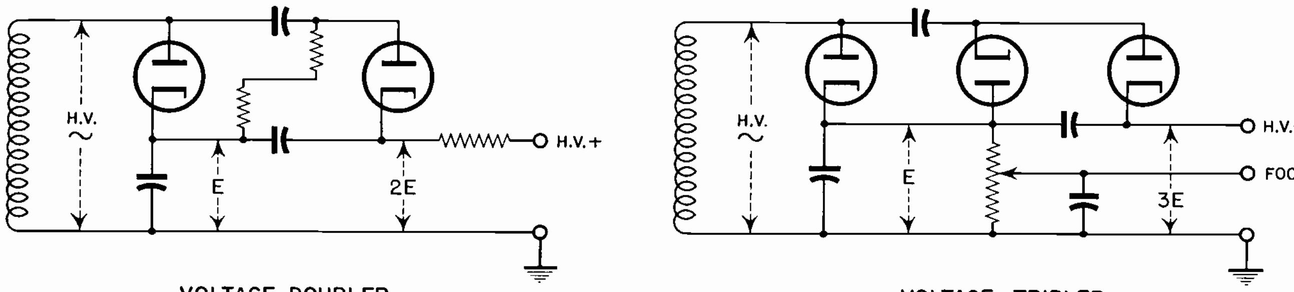
A typical high-voltage supply of the flyback, or "kick", variety is shown schematically in Fig. 1. This circuit makes use of the fact that a high-voltage pulse of short duration is developed across the primary winding of the horizontal deflection transformer during the flyback period of the saw-tooth current pulse which is generated in the plate circuit of the horizontal amplifier tube. The amplitude of this inductive voltage surge is expressed approximately by;

$$\text{Voltage } (e) = L \frac{di}{dt}$$

Where: L is the primary winding inductance.

$\frac{di}{dt}$ is the time rate of change of current or the slope of the current saw-tooth.

Thus, it is seen that the amplitude of the voltage "kick" developed depends



VOLTAGE DOUBLER FIG. 2 VOLTAGE TRIPLER

upon the inductance of the transformer primary winding and the rapidity with which the current flowing through it is changing. Since the current in the transformer builds up during the sweep period of about 57 microseconds, and collapses rapidly during the flyback time of approximately 7 microseconds, the rate of current change, and hence the induced voltage, is more than eight times greater during the retrace period. This inductive voltage "kick" is further stepped-up by a third winding on the horizontal deflection transformer which is connected with the primary to form an auto transformer. In addition to the high-voltage rectifier and filter circuit shown in Fig. 1, this special horizontal deflection transformer having a *tertiary* winding for the high-voltage supply is the only extra component needed for the flyback supply, since all other parts are standard components of the horizontal deflection system. The transformer, T1 in Fig. 1, is of special pulse-transformer construction. The windings are assembled on a core built up of very thin laminations or a special low-loss molded iron powder core.

The Rectifier and Filter Circuit

The type of high-voltage rectifier and direct-current filter used with the flyback supply is also practically standard for the other types of high-potential supplies to be discussed. For this reason, these components will be discussed in some detail here.

To rectify the high-voltage alternating or pulse wave, a specially designed diode rectifier tube is almost universally used. This tube, designated the 1B3-GT/8016, is rated at 33 kilovolts maximum peak inverse voltage. Maximum diode current is rated at 2.2 milliamperes. The special low-drain filament requires only 1.2 volts at 200 milliamperes for heating. This low filament power consumption feature of the 8016 rectifier, (less than one-quarter watt) enables the tube to be heated directly from the source of high-frequency energy. The filament circuit is inductively coupled to the high-voltage step-up transformer by means of a one- or two-turn link, as indicated in Fig. 1. A 3.3 ohm resistor is sometimes used in series with the filament circuit to protect the tube from burnout in case of over-coupling. The low-voltage link coupling feature of the 8016 facilitates isolating the rectifier filament circuit, which is operated at full output voltage above ground.

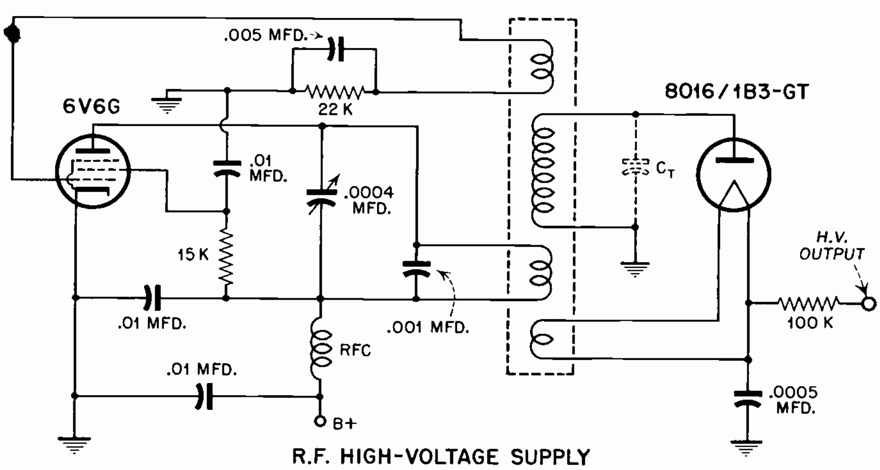
The design of the smoothing filter used with all modern types of high-frequency supplies is greatly simplified because of the low current requirement and the high ripple-frequency used. In the "kick" and the pulse-type supplies, the operating frequency is the same as the horizontal sweep frequency of 15,750 c.p.s. In the r.f. supply, the frequency of operating is usually above 50 kc. When such high-frequency waves are rectified, the resulting high ripple-frequency can be filtered by relatively small filter components. The high capacity filter capacitors and heavy iron-core chokes necessary in the usual 60-cycle filter section are replaced by a simple high-frequency filter consisting of a 500-microfarad condenser and a low-wattage resistor. The output capacitance of this filter, shown by dotted lines in Fig. 1, frequently consists only of the conductor-to-shield capacity of the high-voltage output cable.

Because of the low storage capacity of this filter design, the high-frequency supply is much less dangerous to operating personnel than a line-frequency supply using a "brute force" filter.

Voltage doubling and tripling arrangements are frequently resorted to in high-frequency supplies to obtain higher potentials, or to provide convenient taps for intermediate voltages. Fig. 2 illustrates some representative voltage-multiplying circuits. It will be noted that the techniques used are similar to those practiced with conventional line-frequency power supplies. See AEROVOX RESEARCH WORKER, February, 1941.

The Radio-Frequency Supply

The basic circuit of the radio-frequency type of high-voltage supply is shown in Fig. 3. In this arrangement, the r.f. output voltage of a class C self-excited oscillator is transformed to a very high value by a tightly coupled, double-tuned, step-up transformer. Since the frequency of operation may be between 50 to 200 kilocycles per second, the voltage step-up is accomplished by a light-



R.F. HIGH-VOLTAGE SUPPLY
FIG. 3

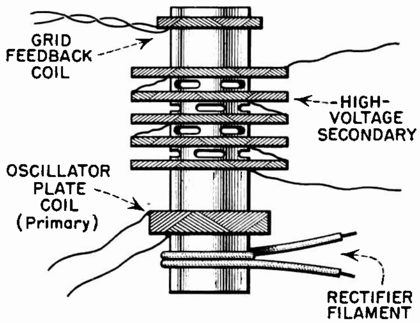
weight, economical, air-wound transformer.

The power oscillator usually consists of a beam pentode of the 6V6 or 6L6 type, used in a tuned-plate, grid-feedback circuit. Class C operation is used for high efficiency. Anode voltage ranging from 250 to 400 volts d.c. is applied to the oscillator tube, depending on the type used and the high-voltage value required. In applications where accelerating potentials as high as 27,000 volts are required for projection television kinescopes, two or more oscillator tubes as large as the type 807 may be operated in parallel.

The step-up transformer which couples the r.f. oscillator to the rectifier and filter circuit is designed to fulfill several special requirements. It must be sufficiently insulated between the primary and secondary windings to windstand the full output voltage and yet these windings must be tightly coupled to provide efficient energy transfer. It must dissipate considerable heat and must be designed to minimize stray current leakage. The secondary winding must have a high Q when resonated at the operating frequency with the distributed capacity of the wiring and rectifier tube. Windings for the rectifier filament and grid-feedback "tickler" must also be provided.

Fig. 4 shows a typical r.f. supply transformer design. The coil form is usually of thin-walled, impregnated bakelite tubing of low power factor. To decrease leakage currents between windings, and to facilitate the free circulation of air for cooling, a series of long circumferential slots is made in the coil form, as shown in Fig. 4. The primary, secondary, and grid-tickler windings are wound with Litz wire to minimize losses. The high-voltage secondary is made up of universal-wound "pies", spaced sufficiently to prevent corona discharge between them.

The overall efficiency of the r.f. oscillator type of high-voltage supply is between 25 and 45 percent.



TYPICAL R.F. SUPPLY
TRANSFORMER CONSTRUCTION
FIG.4

Its principle disadvantage lies in the fact that sufficient harmonic radiation is sometimes present to cause interference with other circuits. Complete shielding and supply-lead filtering is therefore necessary.

The Pulse-Type Supply

Although not enjoying the wide useage of the high-voltage supply types discussed above, the pulse-type supply is used in some applications. Like the flyback supply, the pulse generated is synchronized to occur during the blanking period of the horizontal sweep cycle, so that minimum radiation interference is caused in television sets. In common with the r.f. supply, it has the disadvantage of requiring additional component parts and power, but can be used for cathode-ray tubes having electrostatic deflection.

The circuit arrangement of the pulse-type high-potential supply is illustrated in Fig. 5. The essential parts consist of; a blocking oscillator pulse generator, a pulse amplifier stage, a step-up pulse transformer, and a rectifier-filter section similar to those used with supplies of the r.f. and "kick" types. As in the "kick" supply, the amplitude of the high voltage developed is dependent upon the rapid change of current flowing in the pulse transformer inductance during the pulse.

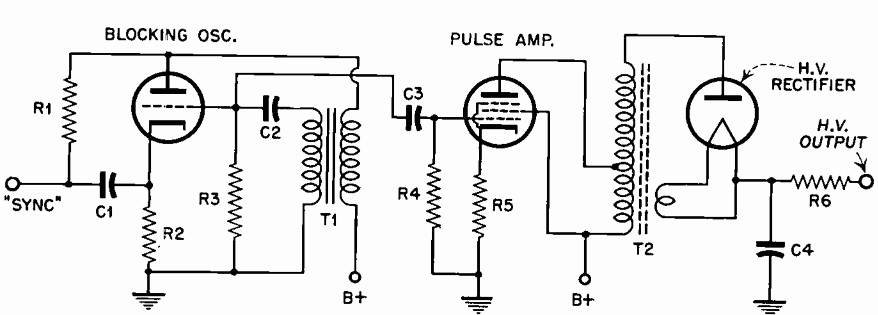
The pulse generated by the blocking oscillator is usually synchronized with the horizontal sweep so that it occurs during the 7 microsecond retrace period. Synchronization is effected by injecting horizontal sweep voltage into the blocking oscillator circuit at the point marked "Sync" in Fig. 5. The synchronizing voltage permits oscillation of the blocking oscillator, which is held normally inoperative by a bias voltage developed across the cathode resistor, R2. In addition to preventing picture tube "hash" by restricting the high-voltage pulse to the "dark", retrace period of the sweep, this system of synchronization also protects the kinescope from screen burning by holding the high-voltage supply inactive in case of sweep failure.

Service Notes

In performing any operation on active high-voltage supply circuits, it must be remembered that LETHAL VOLTAGES ARE PRESENT! Although the poor over-load regulation of the high-frequency types renders them much less dangerous than the older 60-cycle supplies, direct contact with the voltages developed is extremely painful and can be fatal. Therefore, due caution should be exercised.

The trouble most frequently encountered with high-potential supplies is corona discharge from the high-voltage portion of the circuit. Corona, identified by a blue glow or brush discharge around the parts effected, caused erratic output voltage with attendant poor picture brilliance. It is caused by high voltage gradients between adjacent parts, resulting in ionization of the surrounding air. To reduce corona effects, commercial supplies are designed with all components and conductors having large radius contours, since sharp corners or points aggrevate corona discharge. For this reason, when working on high-voltage sources, care should be taken to avoid introducing high gradient points such as rough, sharp solder joints or sharp bends in wiring.

Actual current leakage on the surface or through insulation material is another problem in cathode-ray tube supplies. This effect tends to load the supply excessively and frequently results in complete breakdown and carbonization of the leakage path. In such cases, replacement of the defective part is the only effective remedy. Leakage can be reduced by preventing the formation of greasy, dusty films on the surfaces of insulating material.



PULSE-TYPE H.V. SUPPLY
FIG.5