A Design for Living—With Television

A High-Voltage Power Supply with Complete Safety Features

BY PHILIP ROSENBLATT,* W2AKF

In casting about for a suitable design for a television receiver power supply, it was discovered that the experimenter could escape oblivion when working around many commercial-, ham- and experimenter-built supplies only by being adroitly alert. Unless an "unconfined high voltage" law is passed before television's mass debut, Johnny Public and Willie Ham are likely to view angelic images when the back cover comes off the receiver.

The limitations of the present supplies were found to be:

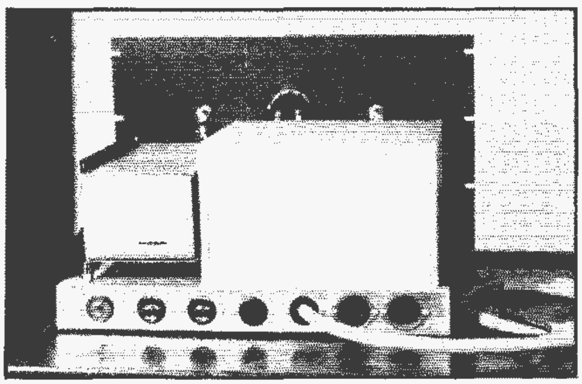
1. Danger of death by either direct contact with the high voltage (exposed high-voltage terminals placed tantalizingly convenient for one to kiss himself into heaven) or by injury contact, caused by the reflex action of the body after feeling the effects of corona from a high-voltage lead. The thought of thousands of volts anxious for liberation will cause almost anyone to spring up like a jack-in-the-box, with a very good chance of his coming in contact with a high-voltage terminal on the way. Some defend the breadboard arrangements of the tuned low-*C* supplies by comparing them to an automobile ignition system but, granting that the h.v. transformer possesses the worst regulation and that the filter condensers discharge rapidly because of their low capacity, the fact remains that high-voltage d.c. is decidedly lethal while the transient-type ignition voltage is not.

2. Severe ripple content above 1 ma. drain. Because most systems use half-wave rectification (which is four times as hard to filter as full-wave, at the same supply frequency), inductance or high resistance is required to complete a tuned filter with the low-capacity condensers used.

3. Poor regulation. Poor regulation results in voltage changes on the Kinescope elements when undergoing varying light excursions and defocusing caused by control-grid (screen intensity) adjustments, necessitating readjustments of the first anode voltage.

4. Fixed voltages. Impossible to adjust for different 'scopes if the filament and plate windings are wound on a single core.

5. Combined with other receiver components on a single chassis. This increases the danger of making adjustments on the less deadly parts.



The television power supply is built on a metal chassis for rack-and-panel mounting. An aluminum box completely houses all of the high-voltage gear, and it is impossible to remove the box without opening one or more of the interlocks. The white cord is the high-voltage cable; the plugs and sockets at the rear of the chassis are for 110-volt circuits.

The features a high-voltage supply should possess to meet present trends and future developments are:

1. Absolute safety under the most extreme absent-mindedness of the operator.

2. Self-contained, and *not* combined with other receiver parts.

3. Good regulation. By increasing the bleeder drain to about 3 ma., voltage flickers and their

Not everyone is going to build a television receiver, but everyone is interested in keeping high voltage where it belongs — away from the operator. That's why you'll find a number of good ideas in this story even if you aren't interested in television. If you *are* interested in television, the story is a "must."

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resultant varying screen light changes and control-grid and focusing adjustment interaction are practically eliminated.

4. Variable output. To accommodate tubes of all sizes, the voltage should be variable between 100 and 6000 volts.

5. Negligible ripple up to the rectifier tube current limit. For a full-wave system the d.c. output is twice the limit of a single tube, and for the voltage-doubling system the rectified current cannot exceed that of a single tube. Either method safely supplies 5 ma., and the ripple at this current and 6000 volts is 0.2%.

6. Simple voltage-indicating meter for the entire output range.

These requirements are met by the power supply to be described.

Circuit Details

Reference to Fig. 1 shows that the wiring diagram of the supply is not unusual, except possibly in the inclusion of a large number of interlock switches. These switches are placed at various points throughout the power supply and Kinescope chassis, making it impossible to get at a high-voltage lead without disconnecting the primary of the h.v. transformer. Provision is included for using a G-R 170-watt Variac (Type 200-B) to control the output voltage of the supply. This permits a fine control of the voltage, and is also used to bring the voltage up from zero each time the set is turned on, a good practice which tends to lengthen the life of the rectifier tubes. The Variac is set at zero, Sw_2 is thrown, and the Variac is adjusted until the output voltage is up to the desired value as indicated by the meter M. If the voltage isn't brought up in this manner, the filter condensers appear as practically a direct short when the full voltage is first applied, and the rectifier tubes take quite a licking until the condensers are charged.

The meter M is used as a voltmeter, since the output voltage can readily be determined from the value of current indicated and the value of resistance in series. The effective resistance in series with the milliammeter consists of the series combination of R_1 and R_2 in parallel with the voltage divider used at the Kinescope. The current drawn by the Kinescope is quite small and can be neglected. The resistor R_3 across the milliammeter has no practical effect on the accuracy of the meter, and serves to keep the negative terminal of the supply grounded in the event that the meter opens. There is not much danger of the meter opening, however, since the regulation of the rectifier tubes and the resistance of the transformer secondary limits the current to about 30 ma.

Both sides of the a.c. line are broken by all manual and interlocking switches to insure absolute safety should one of the line leads become grounded accidentally.

Construction

A large partitioned can on the 12- by 17- by 2-inch chassis houses all of the high-voltage accessories, and everything beneath the chassis is at

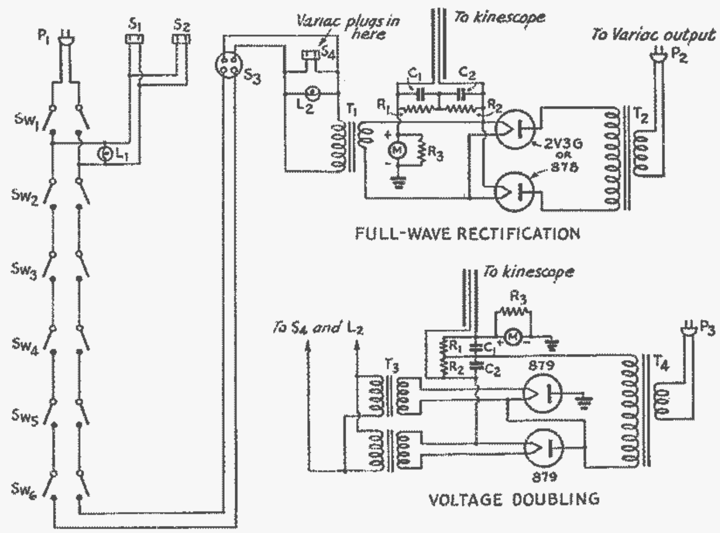
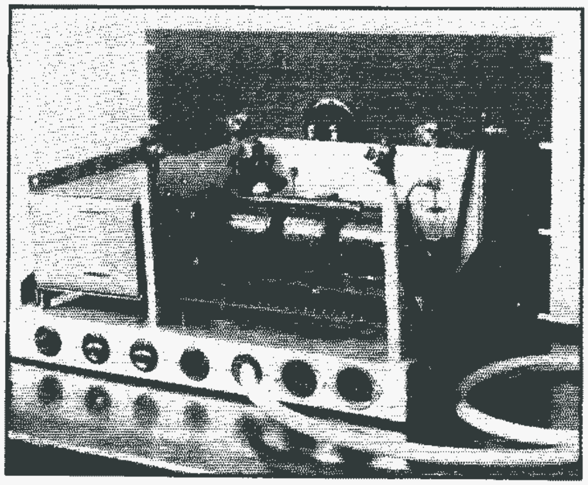


Fig. 1 — **Wiring diagram of the h.v. power supply, showing both full-wave and voltage-doubling connections.**

C_1, C_2 — 4-μfd., 3000-volt (G.E. 23F44).
P_1, P_2 — Line plug (Amphenol 61-M1).
S_1, S_2, S_4 — Socket (Amphenol 61-F1).
S_3 — 4-prong socket for interlocks on Kinescope chassis (Amphenol RS4-Am).
Sw_1 — D.p.d.t. 15-ampere, 120-volt main switch (Cutler-Hammer).
Sw_2 — D.p.d.t. high-voltage panel-operated primary circuit switch (Cutler-Hammer).
Sw_3, Sw_4, Sw_5, Sw_6 — D.p.d.t. momentary-on button-type depressor switch (H & H).
R_1, R_2 — 6 megohms each, made of eight 0.75-megohm 1-watt resistors (IRC).
R_3 — 150 ohms, 2-watt (IRC BT-2).
T_1 — 2.5-volt, 10-ampere filament transformer, 10,000-volt insulation (UTC S-57).
T_2 — Neon-sign transformer, 4500 volts each side of grounded center tap. Altered (see text and Fig. 3).
T_3 — Two 2.5-volt, 10-ampere filament windings, 10,000-volt insulation (UTC S-71).
T_4 — Neon transformer, 3000 volts total. If winding is grounded to frame at any point, frame must be mounted above chassis on insulators. Altered (see text and Fig. 3).
M — 0–10 ma. milliammeter.
L_1, L_2 — 120-volt, 6-watt candelabra-based pilot lamps (G.E.).

Sockets of all rectifier tubes must be raised above chassis and thoroughly insulated.



A view of the supply with the metal box partially removed shows the interlock switches at the four corners of the box. Note that the filter-condenser terminals project inside the protective box.

line-voltage potential only. The can measures 6 by 8 by 10 inches and is made by sliding the pieces of aluminum into four 6-inch high aluminum corner posts bolted to the chassis. Brass angles might also be used to hold the sides together, if the aluminum corner posts are not available. The cover is made of 18-gauge aluminum which can be fastened to the box by bolts. Push-button type switches are mounted at each of the top four corners of the box so that the minute the cover plate is loosened at least one of the switches opens, cutting the primary voltage from the transformer. By the time the cover plate has been removed, the condensers are completely discharged and there is no chance of shock. The high-voltage filter condensers are mounted outside the can, with their terminals extending inside the can.

The high-voltage cable is homemade and can be handled without corona discharges and fear, since the outer copper braid is at ground potential through the milliammeter. Construction of the cable is shown in Fig. 3 — the necessary length of 7-mm. high-tension ignition cable is slipped into a length of copper braid cut 3 inches shorter than the wire. A length of 3/8-inch inside diameter rubber tubing is slipped over this assembly to keep the meter from shorting to ground and to improve the cable's appearance. No removable plugs for the cable are provided, because if either end of the cable were withdrawn accidentally the safety features would be partially nullified. Both ends of the cable are firmly attached to terminals by their respective posts with sufficient insulation all around.

The safety features of these supplies derive around the constructional details of the high-voltage cabinet, the bleeder equalizing the load across the two condensers and the momentary-contact power line break switches. A condenser-discharging mechanism was not included because of its bulk and expense, because it was felt that the operator cannot possibly get into the box while the current is on or the condensers charged, but one might be added as a refinement. However, when one tries to get into the box, even under the extreme case of no bleeder load attached to the h.v. lead and the socket to the 'scope chassis (S_3) deliberately shorted, the following occurs: Upon releasing any one of the first top cover screws the momentary-on switch under that corner will spring open and disconnect the a.c. line to the high-voltage transformer. The condensers C_1 and C_2 immediately start discharging through resistors R_1 and R_2 (quite rapidly if the bleeder load is connected), and at least 10 seconds have elapsed after their complete discharge before the other three screws can be taken out and the cover removed. By then, everything is dead — except the operator! Trying to operate the supply by depressing all safety switches simultaneously by hand is rather futile. It is important that the cover be of thin material in order to flex suffi-

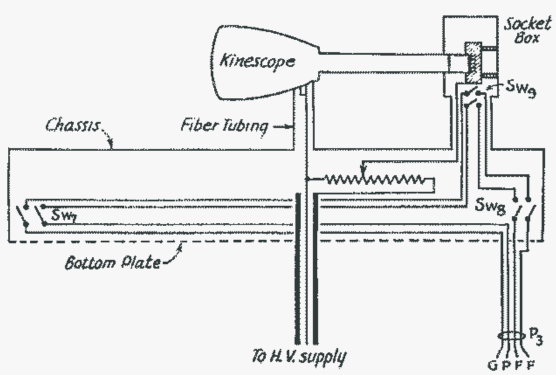


Fig. 2 — Sketch of Kinescope mounting construction. The 'scope socket is housed in a 4-inch by 4-inch by 2-inch steel box (Par-Metal MC-442), and further protection from high voltage is obtained from three interlocks mounted at various points on the chassis (Sw_7, Sw_8, Sw_9).

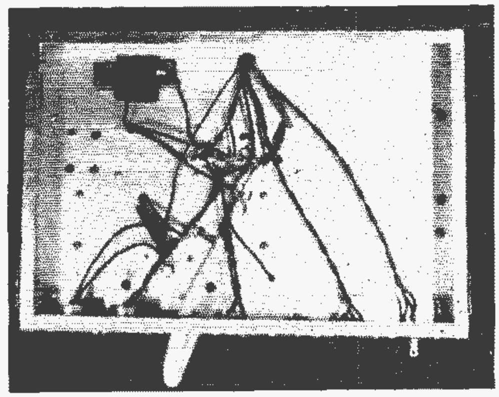
P_3 — 4-prong plug for 'scope chassis interlock (Amphenol PM4).

Sw_7, Sw_8, Sw_9 — D.p.d.t. momentary-on button-type depressor switch (H & H).

ciently upon the removal of only one screw for the depressor switch to spring up and open. Under no circumstances should the cover be hinged at one end. The time-consuming removal of the four corner screws provides the necessary decay period for the condensers.

The other end of the high-tension lead is protected by line-breaking switches installed diagonally across the bottom of the Kinescope chassis and at the Kinescope tube socket enclosure (Fig. 2). Thus when the bottom plate of the Kinescope chassis or the back cover of the socket enclosure is removed the supply will turn off and protect the operator.

No strict recommendations can be made for protecting oneself from the only other dangerous, although infrequently disturbed, places. These are the second anode nub and the focusing anode connection on the base of the 'scope. On the RCA 1803-P4, 1804-P4, 1800, 1801 and physically-similar tubes of other manufacturers, excellent protection can be obtained by shaping a piece of 1½-inch diameter bakelite or hard rubber tubing to conform with the tube surface at the second-anode nub, with the other end cut flush to lie in the center of the chassis hole through which the h.v. lead is brought to the nub. The focusing anode supply is protected by an interlock switch in the socket enclosure (see Fig. 2). Further to protect the operator, the chassis supporting the 'scope has a steel cabinet fitted over it.

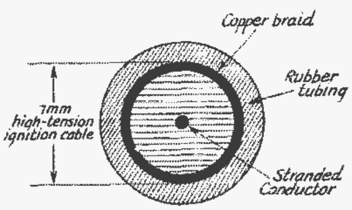


The only wires underneath the chassis are ones carrying the 110-volt current, with the exception of the well-insulated high-voltage cable.

The neon-sign transformer for the full-wave rectifier (T_2) is rated at 9000 volts overall, with a short-circuit current of 18 ma. The transformer used in the voltage-doubling circuit (T_4) is rated at 3000 volts, 18 ma. The secondary on this latter transformer cannot be grounded anywhere but, if the secondary is grounded (usually from center-tap to frame), the entire transformer can be mounted on 1-inch stand-off insulators. The primary is adequately insulated for this service. The transformers can be bought very cheaply from owners of old neon signs and the only modification necessary is to remove the magnetic shunts with a hacksaw (see Fig. 3). Not much can be done with the transformers that are enclosed in compound, but they can be used if the primary voltage is increased about 15%.

A comparison of the full-wave and voltage-doubling systems is given in Table I. Both supplies provide the easily-filtered 120-cycle output but, for all practical purposes, the voltage-doubling system is preferable. Series condensers were used in the output of the full-wave system because a 6000-volt 2-μfd. condenser costs 2½ times as much as the two 3000-volt 4-μfd. units.

During months of trouble-free operation, we have never even felt a corona discharge from the equipment. It's quite a relief to be able to work unafraid around such deadly voltages.



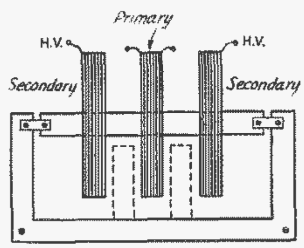


Fig. 3 — A cross-section of the high-voltage cable (at left) shows how it is made by slipping copper braid over a length of 7-mm. ignition cable and then slipping rubber tubing over the copper braid.

A neon-sign transformer is modified for use in the power supply by sawing out the magnetic shunts (shown by dotted lines) as shown at the right. If the secondary is grounded to the frame, the frame must be insulated from the chassis in the voltage-doubling application.

TABLE I

Both methods based on 6000 volts, at 5 ma. output with 0.2% ripple

Advantages	*Disadvantages*
Full Wave	
Single filament winding. Somewhat better regulation above 5-ma. drains. Twice the rectified current available that each single tube alone provides.	High inverse peak voltages. Total secondary voltage impressed across each tube on non-conduction cycles is about 13,000 volts.
Voltage Doubler	
High voltage secondary has to supply only slightly more than one-half the peak a.c. voltage for 2 times the rectified d.c. output.	Two separate filament windings required, insulated from each other and ground for 10,000 volts.
Low inverse-peak voltage of about 4500 volts across tubes on non-conduction cycles.	Rectified current cannot exceed the ratings of a single tube.