Electronic TUBES

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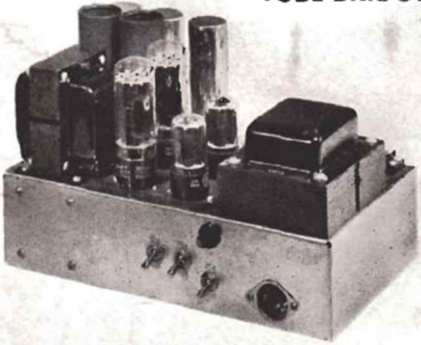
DUAL-VOLTAGE POWER SUPPLIES

TUBE BRIDGE



GERMANIUM FULL BRIDGE

GERMANIUM HALF BRIDGE

DUAL FULL WAVE

Need two high voltages for your medium power transmitter? Build a dual-voltage power supply from one of these circuits, tailored to the contents of your junk box, or from inexpensive television receiver replacement components.

—Lighthouse Larry

CONTENTS

DUAL-VOLTAGE POWER SUPPLIES

Preparation of a simple and stable 100-watt transmitter for the November–December, 1957 issue demanded an equally simple dual-voltage power supply. Our solution: Combine plentiful replacement-type components in bridge and full-wave rectifier circuits, smooth with a high-capacity filter, and package compactly in a corner of the transmitter cabinet.

—Lighthouse Larry

GENERAL CIRCUIT DETAILS

A majority of amateur transmitters in the medium power class (60 to 200 watts) require at least two different high voltages, usually about 300 volts for the oscillator and intermediate stages, and 600 to 750 volts for the power amplifier.

These voltages may be obtained by any of three means: A separate power supply for each high voltage required; or single power supplies having either a transformer with a tapped high-voltage winding feeding separate full-wave rectifiers; or a single bridge rectifier with the lower DC voltage obtained from a center tap on the high-voltage winding. The two latter circuits will be described here.

As the simplified schematic diagram of a vacuum tube bridge rectifier in Fig. 1 shows, the cathodes of diode tubes A and B, connected to opposite ends of the high-voltage winding, each should be powered from a separate filament transformer having adequate insulation. In addition, a third filament transformer is required for diodes C and D, having their cathodes connected together. Thus, tube bridge rectifiers with directly heated cathodes have complex heater circuitry.

Development of rectifier tubes having separate cathodes electrically isolated from the heater has made possible tube bridge rectifiers with fewer filament transformers. Publication of the "Economy Power Supply" circuit[1] a few years ago suggested this innovation, in addition to more efficient utilization of replacement type radio and television receiver power transformers in dual-voltage power supplies. Type 6X5-GT indirectly-heated full-wave rectifier tubes were suggested for V_1 and V_2 in the original "Economy" type bridge circuit, shown in Fig. 2A. The 6X5-GT may be operated with the cathode 450 volts positive or negative with respect to the heater.

Since the DC output current rating of the 6X5-GT is only 70 milliamperes, connecting each pair of tube plates in parallel still limits the maximum output current of the original economy power supply to about 140 milliamperes. By substituting a pair of similar full-wave rectifier tubes, 6AX5-GT's, for the 6X5-GT's, the same circuit is capable of supplying up to 300 milliamperes total current when operated into a choke input filter with up to 700 volts AC applied to the bridge rectifier.

A single filament transformer, T_3, powers both tube heaters, but three precautions should be taken to keep the heater—cathode voltage on V_1 and V_2 within the rating. First, one side of the heater circuit should be connected to the center tap on the high-voltage transformer winding. Second, the high-voltage transformer, T_1, should not be turned on until the heaters of V_1 and V_2 reach operating temperature. Third, V_1 and V_2 should be hot before heater voltage is applied to V_3, the full-wave rectifier forming the other two legs of the bridge circuit.

In the circuit of Fig. 2A, V_1 and V_2 are heated by T_3 when the main power switch, S_1, is closed. Primary power for the high-voltage transformer, and the filament transformer for V_3, T_4, should be applied by closing S_2 at least 30 seconds later than S_1. If S_2 is closed immediately after S_1, a negative voltage will appear at the "HV/2" output terminal until the heaters of V_1 and V_2 warm up. Heater power for V_3 may be taken from T_1 if a suitable winding is available.

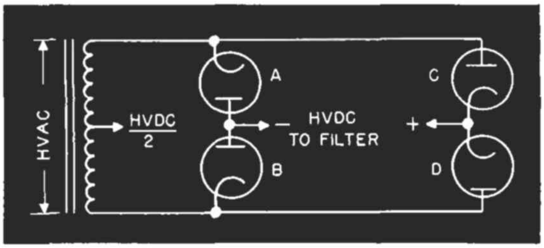


Fig. 1. Basic schematic diagram of a bridge rectifier circuit using four single diode tubes.

A single 5U4-GB or 5R4-GYA will suffice for V_3 with maximum current drains of 250 milliamperes or less. If sufficient heater power is available, two 5U4-GB, 5R4-GYA or 5V4-GA tubes may be connected in parallel to reduce the voltage drop through the tubes.

Choke input filters, as shown in Fig. 2B, are recommended for both the high-voltage and half-voltage outputs, even though the output DC voltage under full load will be about 10 percent lower than with a capacitor input filter. However, the peak current through the rectifiers is much lower with choke input.

Four 125-mfd, 450-volt electrolytic capacitors, C_1 to C_4, connected in a series—parallel circuit, are desirable for good dynamic voltage regulation, as described in "ABOUT POWER SUPPLIES" (See G-E HAM NEWS, January-February and March-April, 1954, Vol. 9, Nos. 1 and 2, for details). These capacitors, plus a single smoothing choke in each filter, reduce the AC ripple appearing on the output voltage to a fraction of one percent. Additional low-resistance filter chokes may be connected in series with L_1 to further reduce the resonant frequency of the filter circuit.

A simple circuit by which the primary voltage applied to T_1 may be adjusted also is shown in Fig. 2A. All heater windings on T_1 are connected in series (the windings should be in phase) and placed in series with the primary. The actual voltage on the primary will then be either higher or lower by the total voltage of the heater windings. A single-pole, double-throw switch, S_3, applies normal primary voltage with the switch arm as shown, or alternate primary voltage with the switch arm in the "up" position.

If single 6.3- and 5-volt windings are connected in series, the primary voltage can be changed to about 10 percent above and below normal. A 15 percent change either way will result from connecting one 5-volt and two 6.3-volt windings all in series. It is thus possible to boost the output voltage of a transformer high-voltage winding 50 to 80 volts if desired. Or, the high voltage can be reduced to a suitable value, if it is too high, by reversing the connections to the heater windings. However, the AC high voltage from T_1 should not exceed the rating of the rectifiers under any conditions.

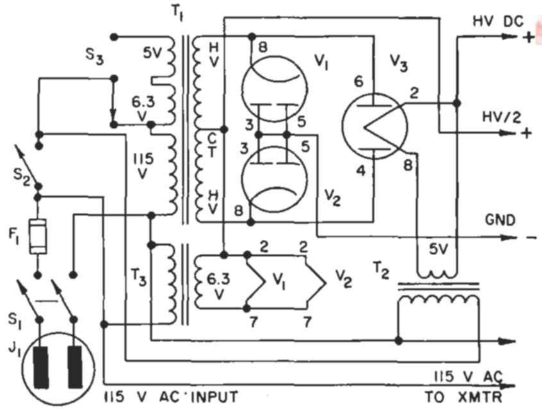


Fig. 2A. Schematic diagram of the "Economy" bridge rectifier circuit. Note that the heater supply winding for V_1 and V_2 is connected to the high-voltage-winding center tap.

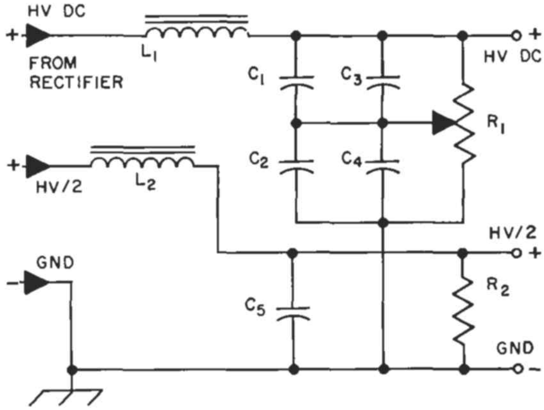


Fig. 2B. Schematic diagram of the dual choke input filter circuit recommended for use with all rectifier circuits described herein.

PARTS LIST

C_1—C_5—125-mfd, 450-volt electrolytic (Sprague TVL-1760).
F_1—Small cartridge fuse and holder (3-ampere fuse for power supplies with up to 200 ma output, 5-ampere fuse for over 200 ma).
D—Semiconductor rectifiers (See TABLE I).
J_1—2-prong male chassis power receptacle.
J_2—Female high-voltage connector.
L_1—8 to 20-henry, 200 to 500-ma smoothing choke, with 1600-volt insulation.
L_2—20-henry, 50-ma smoothing choke.
R_1—50,000-ohm, 50-watt adjustable resistor.
R_2—25,000-ohm, 25-watt resistor.
S_1—Double pole, single throw 3-ampere toggle switch.
S_2—Single pole, single throw 3-ampere toggle switch.
S_3—Single pole, double throw 3-ampere toggle switch.
S_4—2-pole, 3-position 3-ampere selector switch.
T_1, T_7, T_8—Replacement type radio or television receiver power transformer, approximately 700 volts, center-tapped, at 150–350-ma DC output, 5-volt and 6.3-volt heater windings.
T_2, T_9, T_{10}—5-volt, 3-ampere transformer, 115-volt primary.
T_3—6.3-volt, 3-ampere transformer, 115-volt primary.
T_4, T_6—Replacement type television receiver power transformer, up to 750 volts, center-tapped, at up to 400-ma DC output, 5-volt and 6.3-volt heater windings.
T_5—5-volt filament transformer; 3 amperes for one 5U4-GB; 6 amperes for two 5U4-GB's, 115-volt primary.
V_1, V_2—G-E 6AX5-GT full-wave rectifier tubes.
V_3—V_6—G-E 5R4-GYA, 5U4-GB, or 5V4-GA full-wave rectifier tubes (see text).
V_7—G-E 5R4-GYA or 5U4-GB full-wave rectifier tubes (see text).

By substituting the alternate primary circuit for T_1 shown in Fig. 3, any of three primary voltages may be selected. The center position on S_4 applies normal line voltage to T_1; the HIGH position connects the heater windings to add to the line voltage; and the LOW position reverses the heater windings and thus subtracts from the line voltage.

The primary voltage switching circuits and high-voltage filter circuit are recommended for the other rectifier circuits which follow. Of course, pilot lights, relay control circuits, cabinet safety interlock circuits, indicating meters, output voltage regulators and other extra features may be added as desired. Only the basic circuitry has been shown here.

The maximum output current rating given replacement type power transformers by most manufacturers apply for these conditions: One, continuous operation; two, a full-wave rectifier circuit; and three, a capacitor input filter. For intermittent amateur type operation, approximately the same output current (and nearly twice the output power) can be drawn from the same transformer without excessive heating under the following conditions: First, operating into a bridge rectifier which more efficiently utilizes the high-voltage winding; and second, a choke input filter which reduces the peak current and power loss in the high-voltage winding as compared with a capacitor input filter.

It is a fairly simple matter to add the additional components to a good full-wave power supply to convert it to a bridge rectifier circuit and thus considerably increase the total DC output power obtainable from the supply. The only chassis-top space needed is for the two 6AX5-GT rectifier tubes. The extra filament transformer (T_3) and metal can or tubular type electrolytic capacitors (C_1 and C_3) can be located beneath the chassis.

SEMICONDUCTOR BRIDGE RECTIFIERS

Recent developments in the field of semiconductors have resulted in the marketing of highly efficient, moderate cost germanium, silicon and selenium rectifiers. Even though the maximum ratings usually apply to half and full-wave rectifier circuits, several identical semiconductor rectifiers can be connected into a bridge rectifier circuit. In a bridge circuit, the peak inverse voltage across each leg will be only half as much as in a half or full-wave rectifier for a given DC output

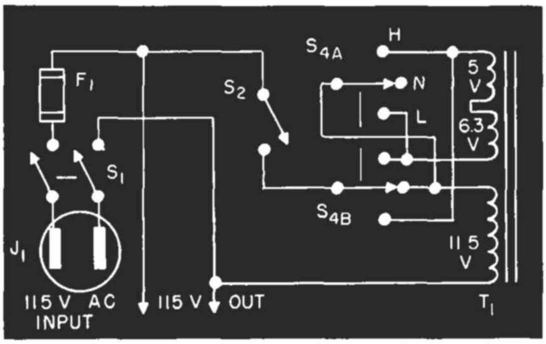


Fig. 3. Optional transformer primary voltage switching circuit. Additional heater windings may be added in series if available. All windings should be in phase.

[1]Grammer, "More Effective Utilization of the Small Power Transformer," QST, November, 1952, page 18.

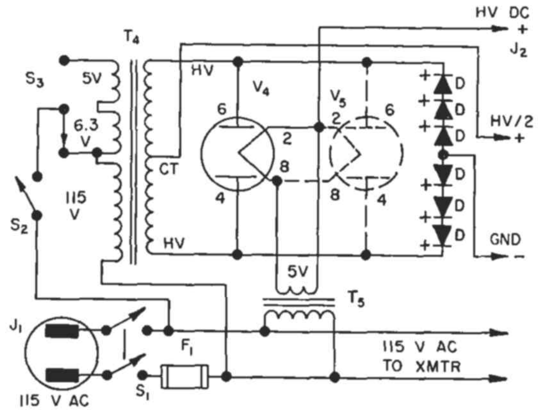


Fig. 4. Schematic diagram of a bridge rectifier converted from a full-wave rectifier by adding three series-connected semiconductor rectifiers in each leg. The optional rectifier tube, V_5, should be included to handle maximum current drains between 275 and 550 milliamperes.

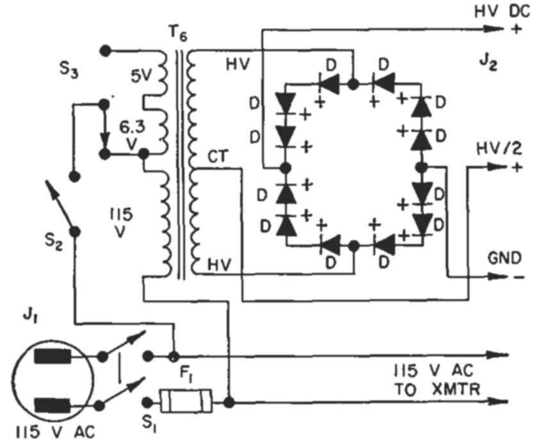


Fig. 5. Schematic diagram of a semiconductor bridge rectifier having three rectifier cells in each leg.

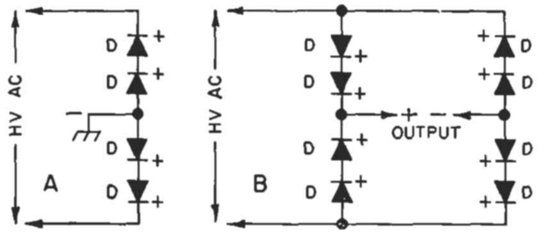


Fig. 6. Schematic diagrams showing (A) four and (B) eight rectifier cells used in half and full semiconductor bridge circuits in Figs. 4 and 5, respectively.

TABLE I—SEMICONDUCTOR RECTIFIER DATA

Rectifier	Ckt. Fig.	Quant. Rect.	Max. AC Input V.	Max. DC Current
1N93	4	6	660 V.	300 MA.
1N93	5	12	660 V.	300 MA.
1N153	4	6	660 V.	550 MA.
1N153	5	12	660 V.	1000 MA.
1N158	6A	4	810 V.	550 MA.
1N158	6B	8	810 V.	1000 MA.
1N539	6A	4	840 V.	550 MA.
1N539	6B	8	840 V.	1500 MA.
1N540	6A	4	1120 V.	550 MA.
1N540	6B	8	1120 V.	1500 MA.
300-MA Selen. Rect.	4	6	990 V.	500 MA.
	5	12	990 V.	500 MA.
	6A	4	660 V.	500 MA.
	6B	8	660 V.	500 MA.

voltage. Thus, each rectifier in a bridge circuit will withstand nearly twice the rated AC voltage without exceeding the peak inverse voltage rating.

Series-connected semiconductor rectifiers can be employed in the place of rectifier tubes in the two added legs in the previously described "Economy" bridge circuit, as shown in Fig. 4. This arrangement is adaptable to a power supply in which the extra filament transformer winding is not readily available.

The DC high voltage is taken from the heater circuit of V_4, and approximately half this voltage will be delivered from the center tap on the high-voltage winding, formerly connected to ground in the full-wave circuit. The lower voltage is rectified by the two strings of semiconductor rectifiers operating in a full-wave circuit. An additional full-wave rectifier tube, V_5, may be connected in parallel with V_4 to reduce the tube voltage drop if the additional heater power is available from T_5.

A bridge circuit in a new dual-voltage power supply can employ semiconductor rectifiers in all four legs. This circuit, shown in Fig. 5, also is suitable when an existing power supply is being rebuilt. Three series-connected rectifier cells are shown in each leg of these circuits. Only two rectifiers per leg may be necessary for certain operating conditions, as shown in the circuits of Fig. 6A and 6B.

Table I shows the maximum recommended operating voltages and currents for several popular semiconductor rectifiers in the aforementioned circuits. The 550-milliampere rating shown for the combination tube and semiconductor rectifier circuits is the maximum current that two 5U4-GB tubes in parallel will deliver. Note that the 1N158, 1N539 and 1N540 rectifiers are capable of handling far more current than the average power transformer will deliver.

A bridge rectifier made from replacement type selenium rectifiers costs less than a comparable germanium or silicon bridge, but the full-load voltage drop is about four times higher. Also, the temperature of the air surrounding selenium rectifiers should be kept below 115 degrees Fahrenheit. Germanium and silicon rectifiers are rated for normal operation in temperatures up to 130 degrees. In addition, the silicon rectifiers will operate at much higher temperatures with reduced current output.

TWO-TRANSFORMER DUAL FULL-WAVE RECTIFIER

The high-voltage windings of two similar power transformers may be connected in series, instead of in parallel, and used in a power supply having separate full-wave tube rectifiers for the full and half DC output voltages. As shown in Fig. 7, the midpoint between the windings becomes the negative output voltage connection. The center taps of the two windings are connected to one full-wave rectifier, V_6, and the outer ends feed the other full-wave rectifier, V_7. The windings must be in phase, otherwise there will be practically no DC output voltage from either rectifier.

The diagram shows four heater windings all connected in series to provide a greater adjustment in the primary voltage than is possible with two or three heater windings on a single transformer. All windings should be in phase.

A 5U4-GB, 5V4-GA, or 5Y3-GT full-wave rectifier is suitable for the moderate current usually drawn from the lower output voltage tap. A 5U4-GB may be used for V_7 only when the full secondary voltage of each transformer is below 550 volts. A 5R4-GYA full-wave rectifier at V_7 can be operated with up to 950 volts per transformer.

Even for intermittent amateur service, the total current drain from both DC output voltage taps should not exceed the rated current of each transformer by more than 40 percent. The voltage regulation of this circuit is not as good as with a single power transformer, because the rectified current flows through the high-voltage windings only in one direction and tends to saturate the transformer cores at high current drains.

CONSTRUCTION DETAILS

The test model power supplies shown on the front page, and in the top views, Fig. 8, were constructed on 7 x 12 x 3-inch-deep aluminum chassis (Bud AC-408). When power transformers and chokes weighing more than 10 pounds each are used, a steel chassis is advisable, even though it is harder to cut and drill. The heavy components were placed at opposite ends of the chassis mainly to balance the weight load, with the rectifiers between them. The chassis size and parts placement may be changed to suit the equipment which the supply is to power.

The electrolytic capacitors should not be crowded against components which radiate considerable heat, such as the tubes. Capacitors C_1 and C_3 in the filter circuit diagram, Fig. 2B, were mounted on the insulating fiber mounting plates furnished with the capacitors. Since the metal cans of these capacitors are several hundred volts positive with respect to the chassis, fiber insulating sleeves should be placed over them. Holes 1½ inches in diameter were cut in the chassis for these capacitors to prevent the mounting lugs from shorting to the chassis.

Filament transformers, small filter chokes, bleeder resistors and other small parts are mounted under the chassis wherever convenient. The wiring is run along the chassis corners and between components, then laced into a cable upon completion. External connections are made through suitable plugs and terminal strips. A high-voltage type connector is recommended for the full DC output voltage.

Semiconductor rectifiers should be mounted atop the chassis, rather than under it, to allow adequate circulation of air around them. Rectifiers having insulated mounting feet may be fastened directly to the chassis in one or two rows. Small rectifiers having only leads can be mounted on a terminal board like that shown in Fig. 9. Connecting leads to the rectifiers are run up through rubber-grommeted holes in the chassis.

Another mounting method is recommended for selenium rectifiers in the half and full bridge circuits,

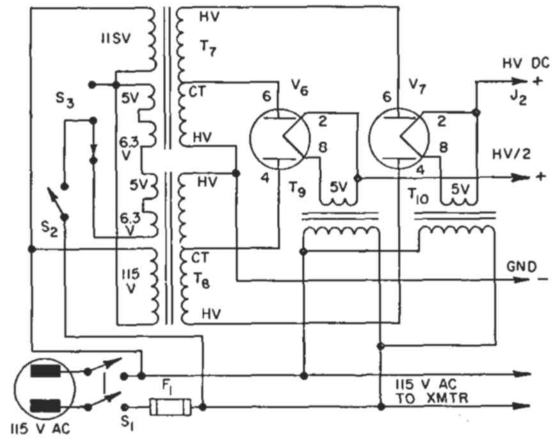


Fig. 7. Schematic diagram of a dual full-wave rectifier circuit using high-voltage windings of two replacement type power transformers in series. Extra "spaghetti" insulating tubing should be slipped over the transformer high-voltage leads to guard against insulation breakdown.

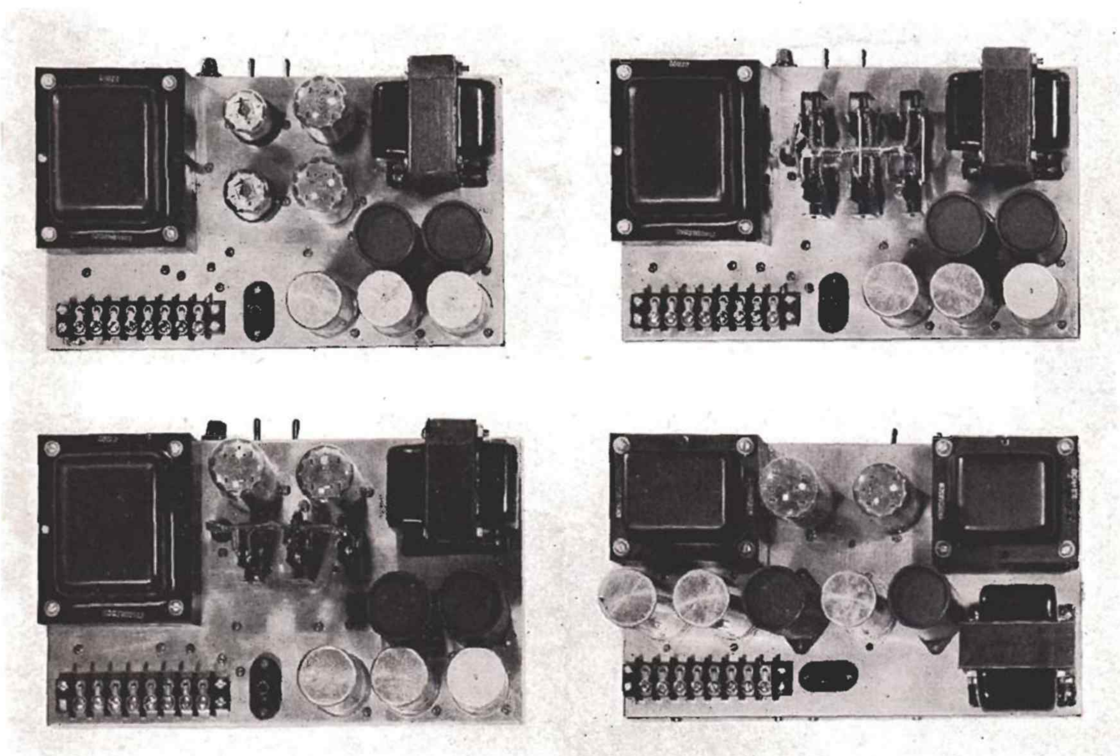


Fig. 8. Top views of the four types of power supplies shown on the cover. Note that the rectifiers are placed well away from the filter capacitors. Chassis size and layout may be varied to suit space requirements.

Figs. 4 and 5. The thin fiber tubes through which the rectifier fastening screws pass may not withstand the voltages involved, so four rows of three rectifiers each were fastened to the 5 x 5 x ¼-inch-thick laminated insulating board (Textolite or bakelite), shown in Fig. 10. The bottom edge of this board was drilled and tapped for fastening screws which run up through the chassis. A perforated metal shield should be placed over both germanium and selenium rectifiers to prevent curious fingers from touching dangerous voltages!

OPERATION

Power supplies do not have to be tuned up or otherwise adjusted, but a wiring check is advisable before applying power for the first time. After turning on the AC power, both DC output voltages without a load, and with full load, should be checked. These may be raised or lowered by adjusting the transformer primary voltage, as previously outlined.

Output voltage tests were conducted on all power supply circuits to obtain the comparative voltage regulation figures shown in Table II. When testing each power supply, the primary voltage was adjusted so that the high-voltage winding always delivered 700 volts AC regardless of the output current load. The figures thus will help determine the output voltage that can be expected from each type of rectifier when operated from a transformer having other than 700 volts AC output.

Other tests were run with the power supplies delivering twice the output current at which the power transformers were rated in full-wave rectifier service. After an hour of this torture, no components overheated to the extent that they smoked or showed other signs of failure.

These tests, plus hundreds of hours of use in transmitters, offer proof that these simple power supplies made from low-cost components will "deliver the goods" in your 60 to 200-watt transmitter.

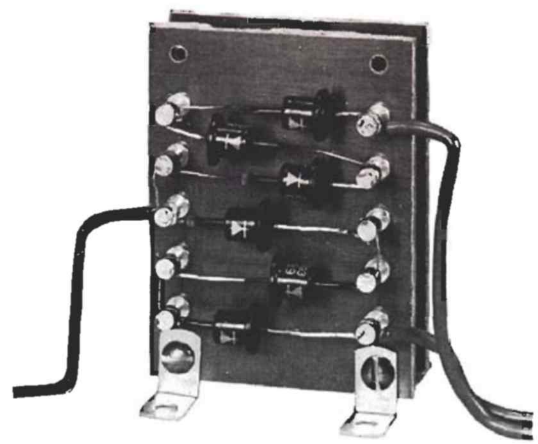


Fig. 9. View showing a suggested mounting arrangement for a group of lead-mounted germanium or silicon rectifiers on terminal boards. The boards were fastened together with bolts and spacers, then mounted on the chassis with small angle brackets.

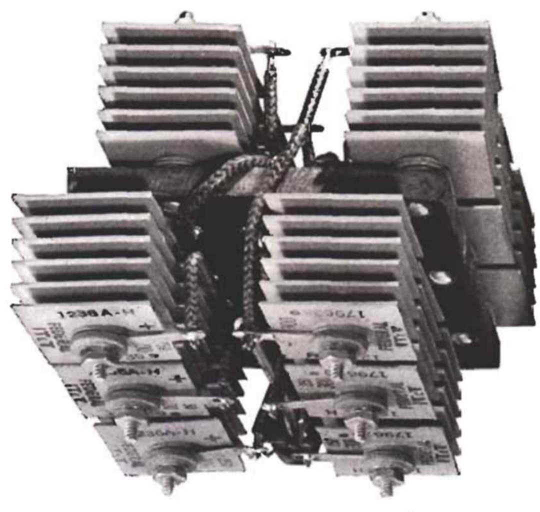
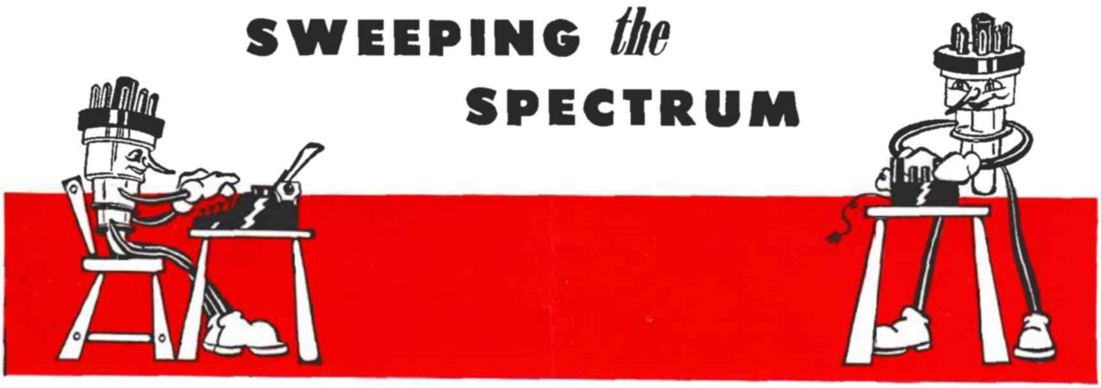


Fig. 10. Detail view of the suggested mounting method for the twelve selenium rectifiers. This assembly fits into the same area occupied by the other types of rectifiers shown in the top views.

TABLE II—POWER SUPPLY OUTPUT VOLTAGE MEASUREMENTS

POWER SUPPLY			OUTPUT—HV DC TERMINAL			OUTPUT-HV DC/2 TERM. WITH 50-MA LOAD AS LOAD IS VARIED ON HV DC TERM.		
CIRCUIT	FIG.	RECTIFIERS	NO LOAD	100-MA LOAD	200-MA LOAD	NO LOAD	100-MA LOAD	200-MA LOAD
TUBE BRIDGE	2A.	1—5U4-GB 2—6AX5-GT	720V.	580V.	550V.	300V.	260V.	240V.
TUBE BRIDGE	2A.	2—5U4-GB 2—6AX5-GT	725V.	590V.	560V.	300V.	260V.	240V.
COMBINATION BRIDGE	4.	1—5U4-GB 4—1N158	720V.	600V.	570V.	310V.	300V.	290V.
COMBINATION BRIDGE	4.	2—5U4-GB 4—1N158	725V.	605V.	575V.	310V.	300V.	290V.
GERMANIUM BRIDGE	6.	8—1N158	740V.	650V.	640V.	310V.	305V.	300V.
SELENIUM BRIDGE	6.	12—300-ma Selenium Rect.	735V.	630V.	610V.	305V.	280V.	265V.
TWO-XFMR FULL WAVE	9.	1—5U4-GB 1—5R4-GYA	725V.	580V.	520V.	290V.	275V.	265V.

SWEEPING *the* SPECTRUM



nominate your candidates now

1957 EDISON RADIO AMATEUR AWARD

The 1957 Edison Award once more will honor a radio amateur who has rendered outstanding public service. Since only names submitted by letter will be considered for the Award, your participation and support are essential. Start now to choose a suitable candidate! The rules below will help you prepare your nominating letter.

WHO IS ELIGIBLE. Any man or woman holding a radio amateur's license issued by the F.C.C., Washington, D. C., who in 1957 performed a meritorious public service in behalf of an individual or group. The service must have been performed while the candidate was pursuing his hobby as an amateur within the continental limits of the United States.

WINNER OF THE AWARD will receive the Edison Award trophy in a public ceremony in Washington, D. C. Expenses of his trip to that city will be paid.

$500 GIFT. Winner will be presented with a check for this amount in recognition of the public service he has rendered.

WHO CAN NOMINATE. Any individual, club, or association familiar with the service performed.

HOW TO NOMINATE. Include in a letter a *full description* of the public service performed, the candidate's name, mailing address and amateur call letters. In addition, any other information (newspaper clippings, photographs, commendation documents, etc.) which will assist the judges in evaluating your nominee's public service is welcomed, and will be returned following the judging, upon request.

Your letter of nomination must be postmarked not later than January 3, 1958. Mail it to Edison Award Committee, General Electric Company, Owensboro, Kentucky.

BASIS FOR JUDGING. All entries will be reviewed by a group of distinguished and impartial judges. Their decisions will be based on (1) the greatest benefit to an individual or group, (2) the amount of ingenuity and sacrifice displayed in performing the service.

Winner of the award will be announced on or before Thomas A. Edison's birthday, February 11, 1958. Employees of the General Electric Company may nominate candidates for the Edison Radio Amateur Award, but are not permitted to receive the Award.

JUDGES WILL BE: E. Roland Harriman, Chairman, The American National Red Cross; Rosel H. Hyde, Commissioner, Federal Communications Commission; and Goodwin L. Dosland, President, American Radio Relay League.

⁂ ⁂ ⁂

We have received numerous requests for simplified circuit diagrams of the 100-watt Mobile Power Supply (see G-E HAM NEWS, July-August, 1957) without the output voltage switching, and with only the 450-volt DC output. Send a postal card requesting a copy if you are interested.

1957 ALL-AMERICAN AWARDS

General Electric has announced the establishment of a new nation-wide program of public service awards for television service technicians.

Entitled the "1957 All-American Awards," the program will bring national recognition to eleven television service technicians who have performed outstanding community service. Each winner will receive a handsome trophy and a $500 check for use in a public service activity or charity of his preference.

Under the program, eleven top service technicians will be chosen on the basis of their good citizenship. Only nominations submitted by letter to the Award committee administering the program will be considered. The winners will be chosen from among the nominees by a panel of distinguished judges who will base their decisions on benefit derived from the winners' public service activities during the two-year period ending September 30, 1957. Decision of the judges will be final.

Typical examples of community service to which television service technicians might apply their specialized knowledge are: repairing TV sets without charge in children's hospitals, teaching disabled veterans how to service electronic equipment, guiding and instructing Boy Scouts and other youth groups in elementary electronics, or assisting with civil defense communications activities.

The award rules require only that a letter of nomination be addressed to the All-American Awards Committee, General Electric Company, Owensboro, Kentucky, containing the name and address of the nominee and a full description of the public service he has performed. Nominations may be submitted by any individual, club or association. To qualify for this first year's All-American Awards, nominating letters must be postmarked on or before October 19, 1957.

Judges who will select the winners are Ed Sullivan, noted columnist and television master of ceremonies; Herman Hickman, television sportscaster; Wendell Barnes, administrator, U.S. Small Business Administration; and Wendell Ford, 1956–57 president, National Junior Chamber of Commerce.

Announcement of winners will be made in December.

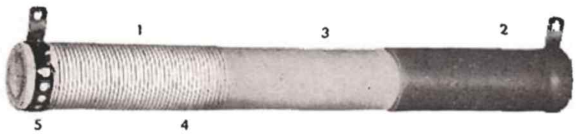
⁂ ⁂ ⁂

PARASITICS

The case of the missing "0"—in Fig. 12, page 8 of the July–August, 1957 issue of G-E HAM NEWS (Vol. 12, No. 4), the current balancing resistors in the mobile tube heater circuits should have been 10 ohms instead of 1 ohm.

—*Lighthouse Larry*

VITREOUS ENAMELED WIRE-WOUND STOCK RESISTORS



Features:

General Electric Vitreous Enameled resistors are made in fixed and slide-wire types, as follows. Fixed resistors, from 5 to 200 watts, standard resistance values from 1 to 250,000 ohms; slide-wire resistors, 10 to 200 watts, 1 to 100,000 ohms. See catalog at your authorized G-E tube distributor for complete listing. Copies also are available from Lighthouse Larry.

Replace that burned-out bleeder resistor in your high-voltage power supply with a new G-E resistor. Remember—an open bleeder resistor is an extremely dangerous shock hazard!

Install them for the many voltage dropping and current limiting applications in the radio shack. Quality construction and high 300-degree Centigrade maximum temperature rating permits operation of these resistors in confined under-chassis locations without developing hot spots which can cause failure of ordinary resistors.

1. LOW-TEMPERATURE-COEFFICIENT WIRE—resistance remains nearly constant as temperature changes, assuring stable operation.
2. VITREOUS ENAMEL COATING—kiln fired for resistance to adverse atmospheric conditions. Each strand of resistance wire is entirely encased in enamel, virtually eliminating resistor burnouts caused by "hot spots."
3. CERAMIC BODY—high dielectric strength and low porosity to withstand extreme temperature variations without weakening.
4. PRECISION WINDING—resistance wire wound on body smoothly and evenly for uniform operating characteristics.
5. WELDED TERMINALS—spot-welded around core for permanent fit and added strength. Positive connections assured by silver-soldering resistance wire to terminals.

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