AN ECONOMY AUDIO AMPLIFIER

By

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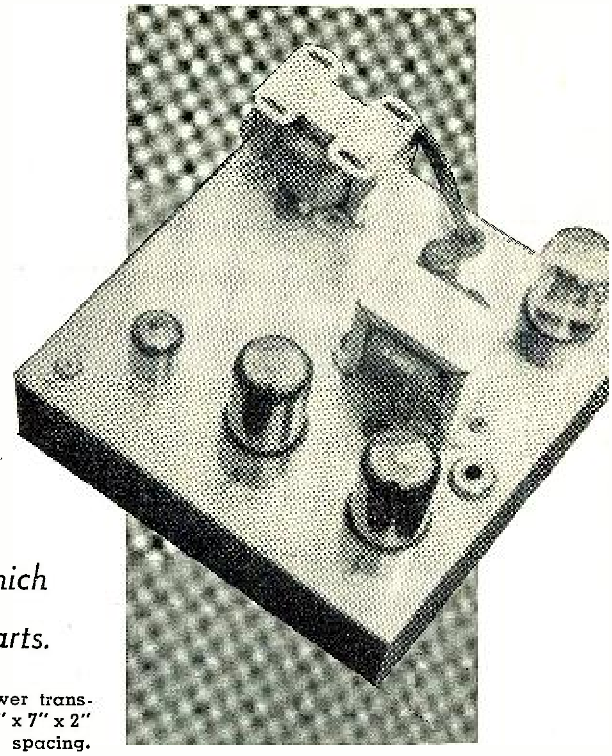
Details on a simplified "Williamson"-type unit which can be built from inexpensive and non-critical parts.



Top chassis view of the "power transformerless" amplifier. The 7" x 7" x 2" chassis permits correct parts spacing.

HERE is a compact, low-cost amplifier that will give surprisingly good results. As the total power input is approximately 30 watts, this amplifier can be operated for hours with a minimum of wasteful heat dissipation and at low operating cost.

Sufficient gain is available to operate from a crystal-type phono pickup or from an AM or FM tuner. The amplifier was designed and built by the author for use with a crystal-type pickup to enable the junior member of the household to play children's records.

It was decided to build the "best" little amplifier that the "state of the art" would permit at minimum initial cost and minimum operating expense. It was assumed at the outset that the young operator would, at times, leave the player on for long periods of time.

A power transformer was deemed unnecessary and it was decided to design around the "a.c.-d.c." or "power transformerless" type of hookup. Since good quality was a prime requisite (along with low cost), the Williamson amplifier circuit was studied and compared with typical a.c.-d.c. audio amplifier circuits. Several tube combinations were checked in the tube manuals with the final product being built as shown in the circuit diagram of Fig. 1.

This amplifier was based upon the use of a 35L6 beam power tube as a triode-connected, class A operated amplifier. Power output for triodes in push-pull can be calculated by using the formula:

$$\text{Power output} = (I_{max} \times E_o)/5$$

For an operating plate potential (E_o) of 200 volts, I_{max} equals 125 ma. Substituting 200 for E_o and .125 for I_{max}, a power output of 5 watts is obtained.

The proper plate-to-plate load resistance for triodes in push-pull can be determined from the formula:

$$\text{Plate-to-plate load} = 4(E_o - .6\ E_o)/I_{max}$$

Substituting 200 for E_o and .125 for I_{max}, a plate-to-plate load resistance of 2560 ohms is obtained.

The grid bias for class A operation is equal to one-half the grid bias for plate current cut-off with a plate potential equal to 1.4 times E_o. For a 35L6 triode-connected at a plate potential of 280 volts (1.4 $\times$ E_o) cut-off bias equals minus 50 volts. One-half this value equals minus 25 volts. Under operating conditions of a plate potential of 200 volts positive and a grid bias of 25 volts negative, a triode 35L6 will draw a plate current of approximately 25 ma. The plate dssipation (grid #2 connected to plate) will be equal to 200 $\times$ .025 or approximately 5 watts for each tube. This value of plate dissipation is well under the maximum rated plate dissipation for this type of tube which indicates that long tube life may be expected.

The plate dissipation for the two output tubes will be approximately 10 watts. With a calculated power output of 5 watts, it can be seen that the plate circuit efficiency of beam power tubes triode-connected and operating in class A at comparatively high plate voltage is surprisingly high. This may be an important consideration in the design of the new commercial amplifiers using beam power tubes in the output stages as triode-connected class A power amplifiers (807, KT66, etc.).

A d.c. supply of 225 volts will be necessary to obtain the 200 volts of plate potential and the 25 volts of cathode bias. A voltage doubler is used with a half-wave vacuum rectifier type 35Z5GT and a 100 ma. selenium rectifier. One side of the a.c. supply is common to the negative side of the d.c. supply. This is desirable in order to minimize hum difficulties in high gain audio amplifiers. In this amplifier the 12AU7 heater is on the side of the a.c. supply which is common to the d.c. supply negative. The two 35L6GT electron tubes are next, in series with the half-wave rectifier 35Z5GT at the other end of the a.c. supply. The heaters of the four tubes in series equal 117.6 volts at .15 ampere; an efficient transformerless heater hookup.

At this point it should be noted that the half-wave vacuum rectifier has a potential difference of approximately 120 volts d.c. between the heater and cathode. This type of tube is rated at a maximum peak heater-to-cathode voltage of 350 volts and should idle along with a heater-to-cathode potential difference of 120 volts d.c. The resistor, R_8, functions as a voltage dropping resistor so that a "B" and "C" supply voltage of 225 volts is obtained with a load current of approximately 55 ma. R_8 also functions as a surge-limiting resistor for the selenium rectifier.

The potential across C_7 builds up gradually as the cathode in the half-wave vacuum tube rectifier comes up to operating temperature. In this manner the full operating plate voltage is applied to the amplifier tubes when they have reached operating heater temperature. This will insure maximum useful cathode emission life.

Negative feedback is employed from the voice coil back to the cathode circuit of the input section of the 12AU7. Approximately 60 per-cent of the input-stage cathode resistor is bypassed by condenser C_1. The negative feedback voltage is developed across the unbypassed section of the first-stage cathode resistor. This was done in order to obtain maximum gain in the input stage with maximum negative feedback in the three-stage feedback loop. The feedback resistor, R_{13}, has a value of 2700 ohms and has been determined on a basis of negative feedback over the three stages, resulting in a gain reduction of 9 db at 400 cycles when the output is terminated in an 8-ohm load. The unbypassed section of the input amplifier cathode resistor provides a gain reduction of 1 db at 400 cycles. This results in a total of 10 db of negative feedback, 9 db over a three-stage loop (including the output transformer) and 1 db over a one-stage loop.

The output transformer should have an impedance ratio of 3000: 8. The primary winding should have a centertap for push-pull operation. A *Stancor* Type A-3852 universal output transformer or its equivalent will be adequate. When using the A-3852 transformer observe the connections as shown on the circuit diagram. When using other audio output transformers positive feedback may be obtained if the feedback voltage differs by 180 degrees. When turning the amplifier on for the first time, if oscillation is experienced reverse the two plate leads to the 35L6GT tubes.

Although this transformer is rated at 4000 ohms primary impedance, the performance was entirely satisfactory as used. It is possible that the constructor can find a stock transformer to give the exact match if a more accurate match is desired.

In the event that a speaker with other than an 8-ohm impedance is used, the eight ohm tap should still be used for the feedback. The proper taps to match the speaker used should still be connected to the speaker.

The phase inverter is of the split-load type, R_6 and R_9 being matched resistors. Out-of-phase drive voltage for the push-pull grids is obtained from the plate and cathode of the driver stage.

The amplifier was built on a 7" x 7" aluminum chassis which measured 2" high. The input stage is at one corner of the chassis away from the rectifier tube in order to minimize hum pickup. Shielding the 12AU7 was found to be unnecessary. An *RCA* type of phono jack is mounted close to the 12AU7 input grid. This jack is mounted in such a way that it is insulated from the chassis. As one side of the a.c. supply is common to the input grid-return circuit and d.c. negative, a.c.-d.c. precautions should be observed.

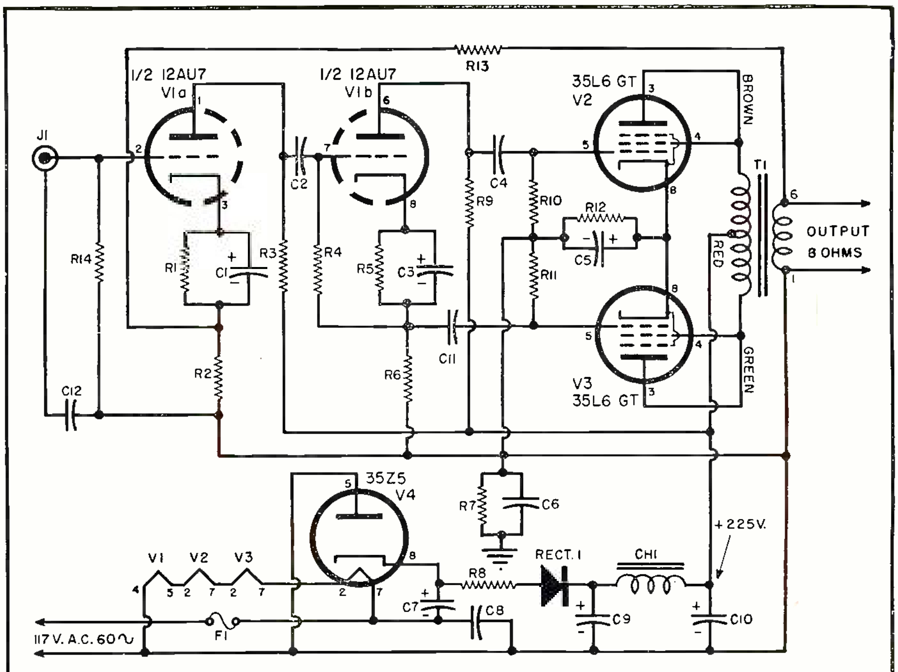
The ground side of the input jack is isolated from the a.c. line by means of condenser C_{12} but there is still enough voltage present at the jack to cause a slight shock when the line plug is inserted incorrectly.

If the amplifier is enclosed in a wooden or other non-conducting cabinet, there is little possibility of shock regardless of which way the line plug is inserted.

A 12" PM speaker having an 8-ohm voice coil impedance is used with the amplifier. No volume control was incorporated in the amplifier as this control is adjacent to the pickup arm, or is in the tuner. Likewise, no "on-off" switch was incorporated in the amplifier.

In the event that a volume control is wanted at the amplifier itself, R_4 may be made the control by substituting a one megohm pot. The arm of the pot. should go to the grid of V_{1b}.

An "on-off" switch can be inserted in the a.c. line, just to the left of the heater string.



R_1—8200 ohm, 1 w. res.
R_2—5600 ohm, 1 w. res.
R_3, R_7—220,000 ohm, 1 w. res.
R_4, R_{14}—1 megohm, 1 w. res.
R_5—10,000 ohm, 1 w. res.
R_6, R_9—100,000 ohm, 1 w. res.
R_8—50 ohm, 2 w. res.
R_{10}, R_{11}—470.000 ohm, 1 w. res.
R_{12}—450 ohm, 5 w. wirewound res.
R_{13}—2700 ohm, 1 w. res.
C_1, C_3—50 μfd., 25 v. elec. cond.
C_2, C_4, C_6, C_{11}, C_{12}—.1 μfd., 600 v. cond.
C_5—50 μfd., 50 v. elec. cond.
C_7, C_9—40 μfd., 450 v. elec. cond.
C_8—.05 μfd., 600 v. cond.
C_{10}—16 μfd., 450 v. elec. cond.
T_1—Output trans. 4000 ohms-to-8 ohms (Stancor Type A-3852 or equiv.)
CH_1—5 to 10 hy. filter choke, 75 to 100 ma. capacity (Stancor C-1355 or equiv.)
Rect. $_1$—100 ma. selenium rectifier
F_1—1 amp. fuse with holder (Type AGC)
J_1—RCA phono-type jack
V_1—12AU7 tube
V_2, V_3—35L6GT tube
V_4—35Z5 tube

Fig. 1. Circuit diagram of the "economy" amplifier. No power transformer is required.

REFERENCES

RCA Tube Manuals
Fleming, Lawrence: "Quality Amplifier for TV Sound," Radio & Television News, May, 1951
Fidelman, David: "Audio Simplified" (Part 6), Radio & Television News, February, 1952

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Under chassis view of the amplifier. A 7" x 7" x 2" chassis houses all parts.