

NEW PRODUCT NEWS

65 WATT HIGH FIDELITY OUTPUT TRANSFORMER BO-15

CHICAGO

Bulletin CT-47
7-60

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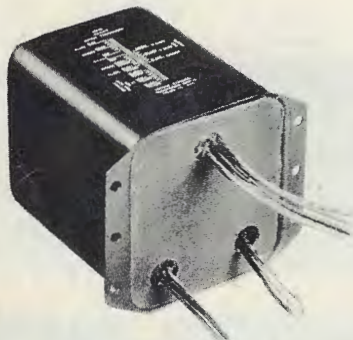
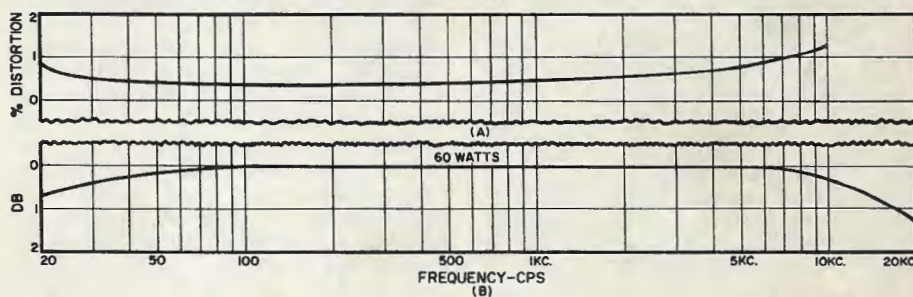
Featuring wide frequency response and extremely low harmonic and intermodulation distortion. In stock now, ready for immediate delivery.

CHICAGO Part No.	Applica- tion	Impedance	Operating Level	Output Tubes	Mounting		Dimensions			Mounting Centers	Weight in Lbs.	List Price
					Type	Size	Height	Width	Depth			
BO-15	Push-Pull Plates to Voice Coil	Pri. 4300 Ω CT (has screen grid taps and separ- ate cathode feedback wind- ing) Sec. 8/16 Ω	65 Watts	6550's EL34's KT88's	C	22	5 $\frac{5}{16}$ F	4 $\frac{1}{8}$	4 $\frac{1}{16}$	2 $\frac{1}{2}$ x 4 $\frac{3}{4}$	11.6	\$44.18

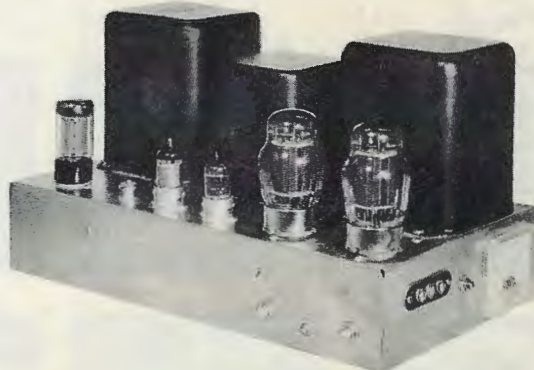
For construction information on a 40 watt or 60 watt amplifier using this unit, see the following article as reprinted from the August, 1960 issue of

ELECTRONICS WORLD

(A) Total harmonic distortion of the 60-watt amplifier at an output within ± 1 db of full output. (B) Power-response curve of the 60-watt version. Full-power response of the 40-watt version is just a little flatter at the frequency extremes.



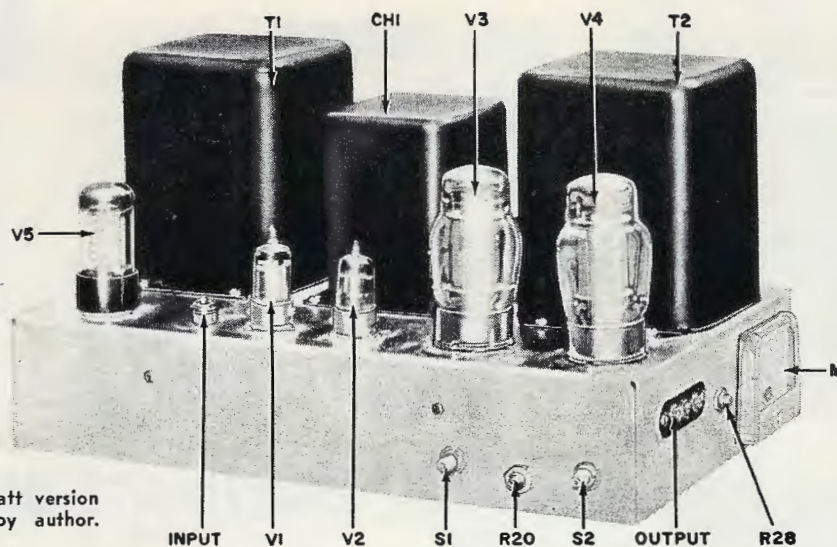
BO-15



40 WATT VERSION



CHICAGO STANDARD TRANSFORMER CORPORATION
3501 WEST ADDISON STREET
CHICAGO 18, ILLINOIS



Over-all view of the 40-watt version of hi-fi amplifier built by author.

40- or 60-Watt Hi-Fi Amplifier with Tertiary Feedback

By THOMAS F. BURROUGHS / Complete construction details on a stable, high-power audio amplifier with output-stage cathode feedback.

FOR years the most popular power amplifier circuit design was based on the famous "Williamson." Some of the factors leading to its popularity are its low distortion, simplicity, straightforward design, and the rising interest in high-fidelity reproduction. Even today a "Williamson" amplifier that is carefully constructed and tested with the speaker with which it is to be used will give top quality results.

Of late the trend in amplifier design has been toward higher power and, as the trend has developed, use of the "Ultra-Linear" output stage has grown with it. In this circuit the primary winding of the output transformer is tapped at approximately 40 per-cent of the primary turns. These taps are con-

nected to the screens of the output, thus providing the inherent advantages which have been adequately covered in the literature.

Some interest has been shown in tertiary feedback, which has been called "super Ultra-Linear." Up to this time, there have been very few circuits published using this type of feedback, but it is believed that its popularity will grow as more transformers become available. Some of the advantages of tertiary feedback are the lack of problems involving instability—which may occur when feedback is taken around three or four stages. In fact, an amplifier with tertiary feedback seems to be more tolerant of an over-all feedback loop. It is very effective

in reducing distortion and helps to lower the internal impedance of the amplifier.

While the distortion of present-day amplifiers is very low when measuring a sine wave, it is only of late that attention has centered on the stability of the amplifier. In a feedback amplifier instability will occur when the feedback becomes regenerative. This regeneration takes place when the phase shift reaches 180 degrees at some point where the gain of the amplifier has not dropped by an amount equal to the feedback. Sometimes instability will appear when a transient signal is fed to the amplifier. This transient instability is one of the reasons why an amplifier often shows up on test in-

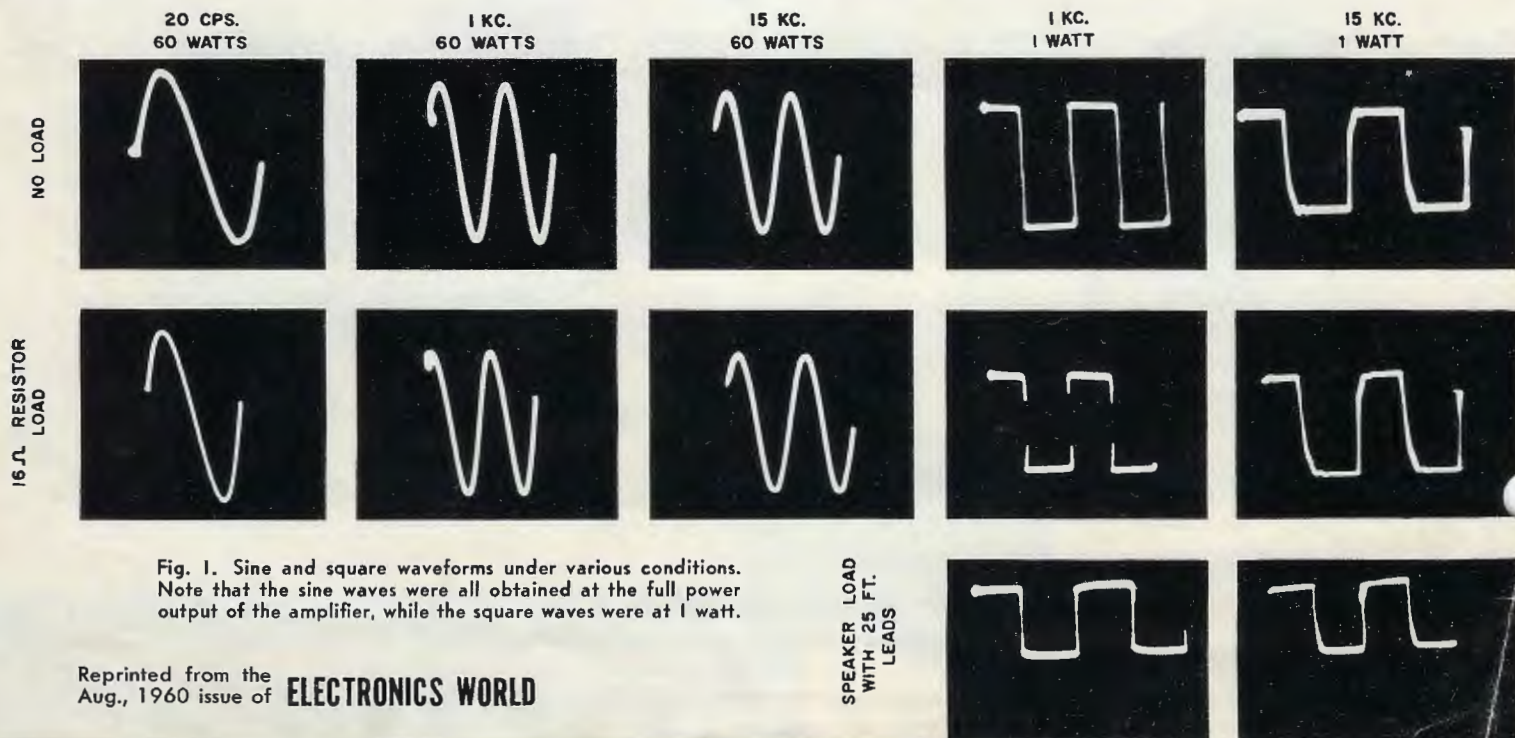


Fig. 1. Sine and square waveforms under various conditions. Note that the sine waves were all obtained at the full power output of the amplifier, while the square waves were at 1 watt.

struments a lot better than it actually sounds.

Circuit Used

The circuit of Fig. 2 is a very stable 40-watt amplifier (or a 60-watt amplifier with the higher voltage power supply in Fig. 4), using a new transformer made by *Chicago Standard Transformer Corp.*—the BO-15. This transformer was designed for 6550's, EL34's, or KT88's using screen taps plus 11 db of tertiary feedback in the output stage. There is also 12 db of feedback taken around the whole amplifier. Many configurations were tried and discarded for one reason or another before the present design was arrived at.

The first problem which arose was the high signal needed to drive the 6550's when using tertiary feedback. The required signal is 135 volts r.m.s. grid-to-grid. The need for this high signal arises because the voltage must be increased by the feedback factor in the output stage. This ruled out the use of a 6SN7 as a driver. The tube found best suited for this purpose was the 5687, a dual-triode used extensively in electronic computers. It is capable of exceptional output into the low impedance necessary when using fixed bias. When used in the *Mullard* circuit as a phase-splitter/driver, as it is here, it will deliver 180 volts r.m.s. grid-to-grid into a 50,000-ohm load. The out-

puts from the plates are almost perfectly balanced and the impedance looking back into the tube is the same. This stage is quite degenerative and very little distortion is introduced by it.

The EF86 is a low-noise pentode used as a voltage amplifier. This is direct-coupled to the phase-splitter/driver, thus eliminating some phase shift that would be introduced by a coupling capacitor.

Stability of the amplifier is very good under practically any type of load, as can be seen by the oscillograms of Fig. 1. Over 20 db more of over-all feedback could be added before instability in the form of ringing or motorboating sets in. If the amplifier is to be used

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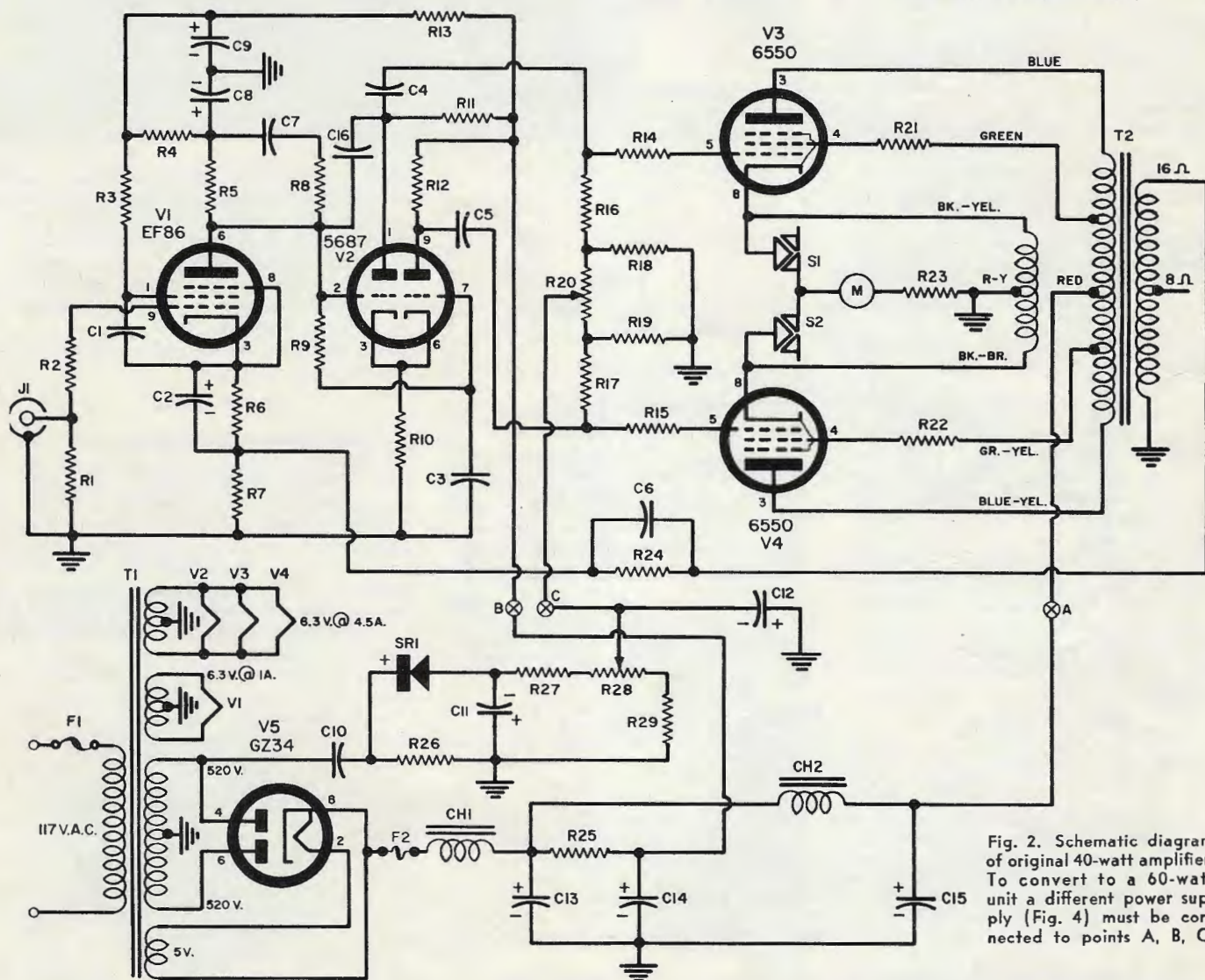


Fig. 2. Schematic diagram of original 40-watt amplifier. To convert to a 60-watt unit a different power supply (Fig. 4) must be connected to points A, B, C.

R₁, R₂—1 megohm, 1/2 w. res.
R₃—3300 ohm, 1 w. res.
R₄—330,000 ohm, 1 w. res.
R₅, R₆, R₇, R₈—47,000 ohm, 1 w. res.
R₉—1800 ohm, 1 w. res.
R₁₀—510 ohm, 1 w. res.
R₁₁—4700 ohm, 1 w. res.
R₁₂—8000 ohm, 4 w. carbon res. (see text)
R₁₃—25,000 ohm, 4 w. carbon res. (see text)
R₁₄—30,000 ohm, 4 w. carbon res. (see text)
R₁₅—180,000 ohm, 1 w. res.
R₁₆, R₁₇, R₁₈—1000 ohm, 1/2 w. res.
R₁₉, R₂₀—100,000 ohm, 1 w. res.
R₂₁, R₂₂—10,000 ohm pot
R₂₃—680 ohm, 1/2 w. res. (see text)
R₂₄—2200 ohm, 1 w. res.
R₂₅—600 ohm, 2 w. res.

R₂₆—25,000 ohm, 10 w. wirewound res.
R₂₇—560 ohm, 1 w. res.
R₂₈—27,000 ohm, 1 w. res.
C₁—0.05 μf., 400 v. capacitor
C₂—50 μf., 25 v. elec. capacitor
C₃—25 μf., 400 v. capacitor
C₄, C₅—5 μf., 600 v. capacitor
C₆, C₇—50 μf. ceramic capacitor
C₈, C₉—40 μf., 350 v. elec. capacitor
C₁₀—0.04 μf., 1000 v. capacitor
C₁₁, C₁₂—50 μf., 150 v. elec. capacitor
C₁₃, C₁₄, C₁₅—40 μf., 500 v. elec. capacitor
C₁₆—25 μf. ceramic capacitor
T₁—Power trans. 520-0-520 v. @ 200 ma.; 6.3 v. @ 4.5 amps.; 6.3 v. @ 1 amp.; 5 v. @ 3 amps. (Chicago Standard PCR-200 or equiv.)

T₂—Output trans. 4300 ohms c.t., with screen taps and cathode feedback winding; 8, 16 ohms sec.; 65 watts (Chicago Standard BO-15 or equiv.)
CH₁—8 hy., 200 ma. filter choke (Chicago Standard RC8200 or equiv.)
CH₂—2 hy., 200 ma., 60 ohms d.c. or less filter choke (Stancor C-2325 or equiv.)
SR₁—20 ma., 130 v. selenium rectifier
F₁—2 amp. fuse
F₂—225 ma. fuse
S₁, S₂—S.p.s.t. push-button switch, normally open
M—1 ma. d.c. meter
J₁—Phono jack
V₁—EF86 tube
V₂—5687 tube
V₃, V₄—6550 tube

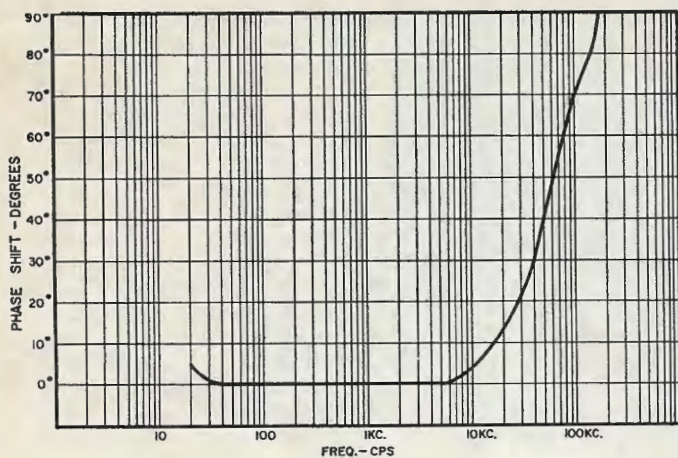


Fig. 3. Phase characteristics of the high-fidelity amplifier as measured between frequencies of 20 cps and 200 kc. by author.

Under-chassis view of the home-built unit showing the use of a ground bus, laced wiring, and the terminal board construction. ▶

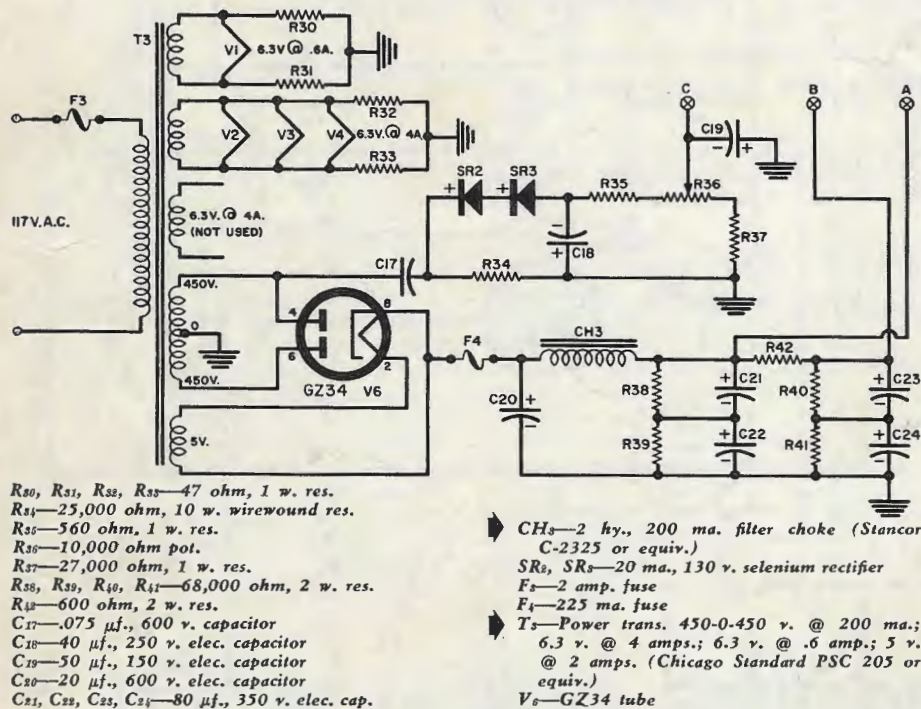
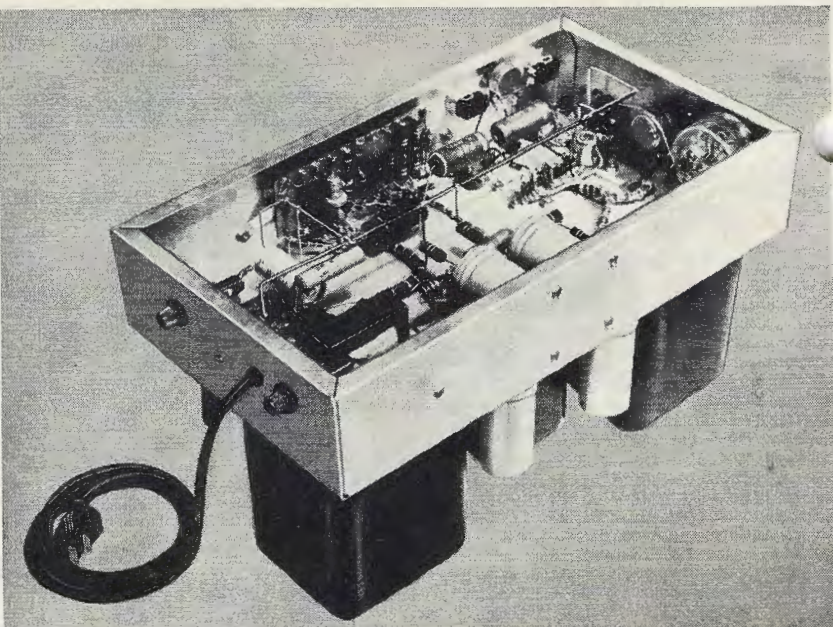
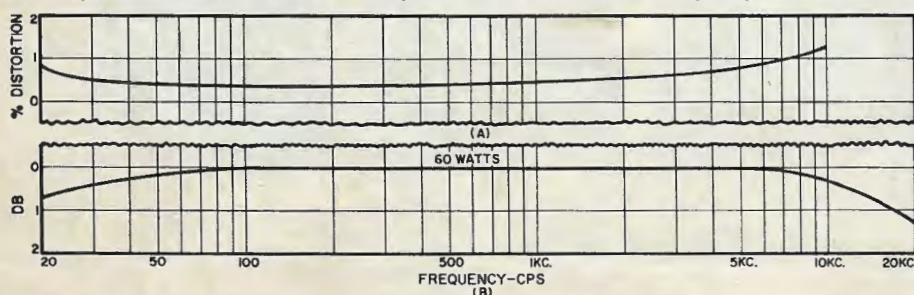


Fig. 4. Circuit of the capacitor-input power supply used to obtain the higher voltage necessary for the 60-watt version of the amplifier. Filter capacitors are series-connected and bleeder resistors are used to equalize voltage drops. Because of this arrangement, the negative terminals (usually the cans) of C_{21} and C_{23} must be insulated from the chassis and these capacitors must be separate units. Also for safety they should be mounted beneath the chassis. The 47-ohm resistors across the 6.3-volt heater windings are required since the windings are not center-tapped.

Fig. 5. (A) Total harmonic distortion of the 60-watt amplifier at an output within ± 1 db of full output. (B) Power-response curve of the 60-watter. Full-power response of the 40-watt version is just a little flatter at the frequency extremes.



with a highly capacitive load, such as an electrostatic speaker and a woofer calling for a low damping factor, it might be advantageous to omit R_{24} and C_{19} . This leaves out the over-all feedback loop, but there will still be 11 db of feedback in the output stage where it is most needed. This will give a lower damping factor and an amplifier that is very sensitive.

Construction

Construction of the amplifier is fairly standard, being built on a single $8\frac{1}{2} \times 15 \times 3$ " chassis. Most of the parts are mounted on a terminal strip to facilitate testing and easy access. All signal-carrying leads, including the feedback loop, were kept as short as possible. A ground bus was used and connected to the chassis at one point.

In the top chassis view of the amplifier you will notice a meter mounted on the side panel, with push-buttons by each output tube for balancing the current in the output stage. The meter is connected so as to read the voltage drop across the tertiary winding. A 1-ma. meter is used and R_{23} selected so that with 100 ma. flowing through the tertiary winding the meter will read full-scale. In this way the tertiary winding acts as the meter shunt. The value of R_{23} will vary, depending on the d.c. resistance of the tertiary winding and the meter used. This was an extra "frill" on the original amplifier but can be very handy if you have an old meter in the junk box that can be utilized.

The parts list calls for some 4-watt carbon resistors. The 8000-ohm unit was made up of two 16,000-ohm, 2-watt resistors in parallel. The 25,000-ohm unit is 12,000- and 13,000-ohm, 2-watt resistors in series while the 30,000 ohms is made up of two 15,000-ohm, 2-watt resistors, also in series.

All of the parts are conservatively rated and should give long, trouble-free performance. The "B+" supply bus was fused to prevent damage to the

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6550's if anything goes wrong with the bias supply. An RC voltage divider was used to obtain the bias voltage. It is a simple, yet effective, method of obtaining the desired voltage and one that dissipates very little heat. A choke-input power supply was chosen for the 40-watt version because of its excellent voltage regulation as compared to a capacitor input. With a swing in current from 165 to 220 ma., the d.c. voltage will drop less than 20 volts. In the case of the 60-watt version, capacitor input was used to get the higher voltage needed for the extra 2 db of power output.

The bias adjustment (R_{23}) should be such as to produce a cathode current for each output tube of about 75 ma. for the 40-watt amplifier and about 55 ma. for the 60-watt version. The balancing pot (R_{20}) should be adjusted for equal currents in both output tubes.

When connecting the output transformer, careful attention should be paid to the color coding of the primary leads. When the winding is connected properly, it will take approximately 70 volts r.m.s. on the grids of the 6550's for 60 watts of output. When the over-all feedback loop is connected, the output should drop by some 12 db. If motor-boating or oscillation occur, you can correct the phasing by reversing the transformer leads or transposing the connections of the coupling capacitors at the driver.

A word might be said here about how the amplifier sounds, since the final word on any amplifier is whether it pleases the ear and sounds good after prolonged listening sessions. The highs sound clean and the instruments well delineated. The bass is solid and well damped. A large measure of the quality obtained with this circuit should be attributed to the outstanding characteristics of the output transformer and its ability to reproduce full output over such a wide frequency range. —30—

D. C. VOLTAGES

PIN	1	2	3	4	5	6	7	8	9
V_1	110	—	2.5	—	—	82	—	2.5	—
V_2	240	76	92	—	—	92	82	—	250
V_3, V_4	—	—	410	410	—48	—	—	.5	—

Table 1. Voltages measured by author in 40-watt unit. Voltages in 60-watt version are fairly similar except for somewhat higher "B-plus" and bias on tubes V_3, V_4 .

Table 2. Important specs of both versions.

	40 watts	60 watts
Output Sensitivity	.7 volt for full output	1 volt for full output
Response	Down .1 db at 20 cps; down .5 db at 20,000 cps (at 40 watts)	Down .7 db at 20 cps; down 1.3 db at 20,000 cps (at 60 watts)
Feedback	12 db over-all 11 db tertiary	12 db over-all 11 db tertiary
Feedback Stability Margin	20 db	20 db
Damping Factor	10	10