HIGH-POWER williamson amplifier for HI-FI

50-watt unit uses 6550 output tubes and larger output transformer

By DAVID HAFLER*

THE need for high-powered amplifiers for home reproduction is being accepted by a rapidly growing minority of audio enthusiasts. Many still feel that "10 watts is enough," but the author is a member of the group which believes that power capabilities above 25 watts are required to attain maximum fidelity. Extended listening tests indicate that high-powered amplifiers of about 50 watts are *cleaner* than low-powered 10-watt units, particularly in the bass region.

One disadvantage of high-powered amplifiers has been their cost. Now it is practical to build a Williamson type amplifier that delivers 50 watts of clean power at a cost only $10 higher than either the 15-watt triode or 25-watt Ultra-Linear unit (assuming that top-grade transformers are used in these amplifiers). It is also feasible to convert existing Williamson amplifiers to high-powered use with a considerable improvement in listening quality. This is made possible by the Tung-Sol 6550 tube, now commercially available.

The 6550 is a ruggedized beam-power tetrode with a total plate and screen dissipation rating of over 40 watts. It is an efficient tube with high-power sensitivity that offers high quality and high power without corresponding high cost. Tung-Sol suggests several types of operation ranging from 28 watts in triode connection to 100 watts as a tetrode with 600 volts on the plate. The triode connection does not take full advantage of the power-output capabilities of the tube and the 100-watt circuit requires a complicated and expensive power supply.

Design considerations

Most Williamson amplifiers have power supplies which provide 425 to 450 volts at about 200 ma. These can be used with the 6550 operated with 450 volts on the plate and screen and 48 volts bias. The bias can be obtained from a 200-ohm cathode resistor adequately bypassed, but it is preferable to use fixed bias to make full use of the tube's capabilities. Fixed bias is obtained as shown in Fig. 1. An a.c. voltage divider consisting of a .05-μf capacitor and 47,000-ohm resistor is placed across half of the high-voltage secondary of the power transformer. Its output is fed to two small selenium rectifiers—connected in series for an adequate voltage rating—and filtered by the 40-μf electrolytic capacitor. The d.c. voltage divider consisting of the 10,000-ohm control and 15,000-ohm resistor proportions the voltage. The output bias is adjusted to the desired value with the BIAS control. To convert present amplifiers, the 10,000-ohm potentiometer can be inserted in the hole which previously held the bias balancing pot.

If the B plus voltage runs a full 450, for extra safety the conventional 5V4-G rectifier should be replaced with a 5U4-GB. This will lower the plate supply slightly (and keep it under 450 volts even if the line voltage is high) and will adequately handle the additional current drain of the 6550's which runs about 180 ma. It is not desirable to operate the 6550's with more than 450 volts, so the 5U4-GB is generally preferable.

The other basic change in circuitry lies in the output stage. The 6550's have the same basing arrangement as KT-66's or 5881's and, therefore, can be directly substituted. However, they require a different impedance match for optimum performance. This means that a different output transformer must be used. This is also necessary to handle the 50 watts which the converted circuit can provide.

Experiments with impedance matching showed that maximum power could be realized with a low plate-to-plate load of about 3,000 ohms and 40 volts bias. This condition resulted in excessive power dissipation in the tubes which could not be remedied by an increase in bias without a corresponding

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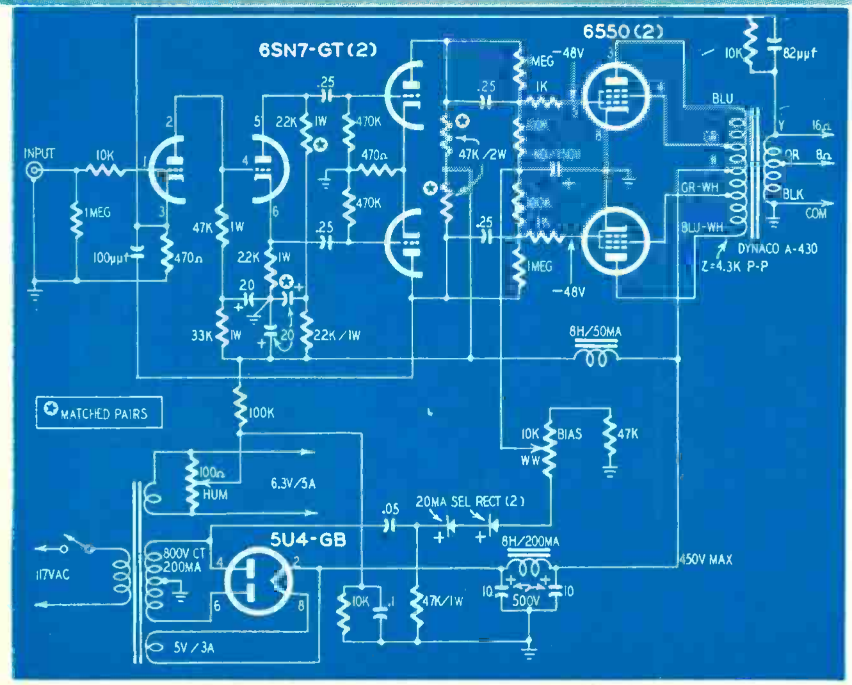
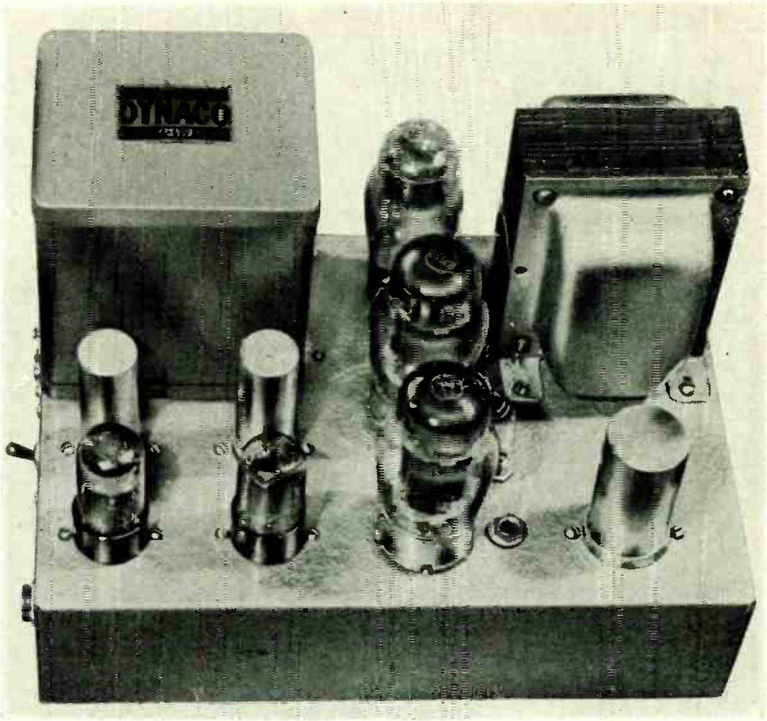
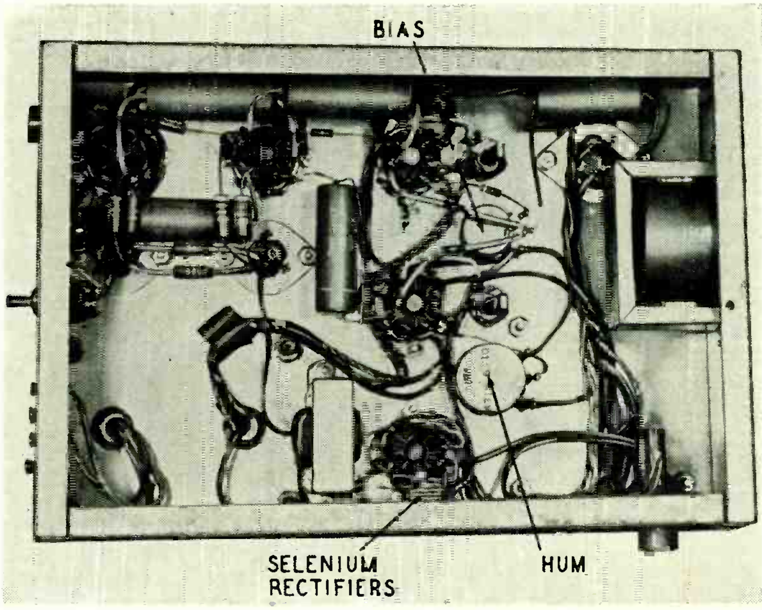


Fig. 1—Schematic diagram of the 50-watt modified Williamson amplifier.



Top view of the Ultra-Linear amplifier after conversion to 50-watt output.



Underchassis view after conversion. The jacks are for metering plate current.

increase in nonlinearity. Maximum linearity is attained with a plate-to-plate load between 4,000 and 4,500 ohms and 48 volts bias. This reduces maximum power from about 56 to 52 watts (depending on the supply voltages) but cuts the distortion below the 50-watt range to about one-half of what it is with the lower primary impedance.

On the basis of these considerations a transformer was designed with 4,300-ohm primary impedance and a *continuous* 50-watt rating for all frequencies from 20 cycles to 20 kc. This unit, the Dynaco A-430, has a bandwidth of from 6 cycles to over 60 kc ±1 db to minimize phase shift over a band far in excess of the audio spectrum. Other transformers of comparable specification can be used if their design permits a satisfactory margin of stability under feedback conditions.

The circuit (Fig. 1) uses a screen tap to provide d.c. for the screens of the 6550's and a small degree of screen loading. Since the primary impedance was selected to furnish optimum linearity, the screen tap was not used for this purpose but to reduce the internal impedance of the tubes and provide suitable damping. The damping factor of the complete amplifier, after applying inverse feedback, is over 20—greater than normally found in high-fidelity equipment of this power bracket.

The final variation in the design from the original is a change in the phase characteristics to provide additional stability at both high and low frequencies. The lack of adequate stability was one of the serious weaknesses in quality of the basic Williamson design. Many of these amplifiers, whether home designed, kit assembled or commercially produced, had a tendency to motorboat at low frequencies or to oscillate above audibility when used on a loudspeaker load. They measured well on a resistive load but their listening performance was frequently marred by this instability under listening conditions.

The 0.25-μf capacitors connected to the grids of the 6550's are bridged by 1-megohm resistors. At the very lowest frequencies, these reverse the phase shift introduced by the coupling capacitors, so the stage is direct-coupled for very low frequencies while capacitively coupled for higher frequencies. This reverse phase shift compensates some of the phase shift due to the 0.25-μf coupling capacitors preceding the 6SN7-GT driver. The d.c. voltage reaching the grids through the 1-megohm resistors is compensated by adjusting the bias control.

Thus, the amplifier phase shift at certain low frequencies is due solely to the phase shift in the output transformer since the phase shifts due to the R-C networks are opposite in sign and cancel. The frequencies at which this effect takes place are in the 1- to 2-cycle range where the circuit would otherwise approach 180° of phase shift with a tendency to motorboat when shock-excited. This type of phase correction eliminates *all* traces of low-frequency instability.

High-frequency phase correction is made by the capacitor across the feedback resistor and the capacitive internal feedback loop connected to the first cathode. This feedback loop is effective primarily at ultrasonic frequencies. The capacitor and feedback loop prevent ultrasonic oscillation or serious ringing whether the amplifier is used with resistive load, speaker load or open-circuited. In short, it is stable under any condition in which it would normally be used.

The underchassis photo shows the location of many components of our Williamson-type amplifier. The small filter choke next to the selenium rectifiers is not used in all models. The two jacks, used for metering output cathode currents, are not shown on the diagram.

Performance

The maximum power capability of the amplifier is determined largely by the effectiveness of the power supply. With the average supply used in Williamson amplifiers a power output slightly over 50 watts can be attained before the intermodulation distortion reaches 1% (based on 60 and 6,000 cycles mixed 4 to 1). If a power supply of better regulation is used, such as a pair of 5V4-G's in parallel with a choke-input filter, the power capability is increased to over 60 watts.

The distortion curve (Fig. 2) is based on a unit using a conventional 200-ma power supply with a single 5U4-GB rectifier. The combination gives less than the permissible 450 plate volts and at high output the B plus drops to about 400 volts. Even with these limitations, the distortion characteristics are excellent. At 35 watts, the IM distortion is still below 0.2%. At lower levels, distortion is below 0.1%. These figures are in sharp contrast to high-power amplifiers which depend on class-AB_2 or -B operation—either of these types of operation create minimum low-level distortion components of 0.25% or even higher.

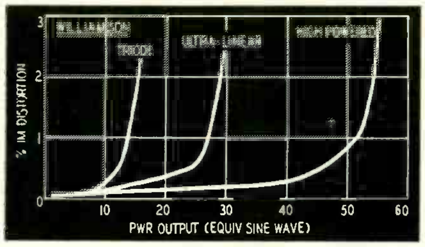


Fig. 2—Amplifier distortion curve.

Frequency response of the Williamson type circuit is generally outstanding and far in excess of the customary audio spectrum. The high-powered Williamson arrangement does not impair this and response is extended smoothly from below 10 cycles to over 100 kc with minor frequency discrimination. The peaks which normally indicate instability in many circuits are completely eliminated and the smooth extended bandpass permits excellent square-wave transmission from 20 cycles to 20 kc.

The power rating of the output transformer permits full power at all audio frequencies without visible distortion or attenuation of the waveform as viewed on a scope. Many power ratings indicate that amplifier *response* is flat at rated power but they ignore *distortion* at frequency extremes. In this design high-powered response is essentially distortion-free, indicating that the intermodulation products *must* be small for *any* combination of frequencies within the 20-cycle to 20-kc spectrum.

The final and most important test of an amplifier is the listening test. The 6550 passes this with flying colors and has amazed many who felt that there was no more room for improvement of audio power amplifiers. The high power capacity provides clean sound through the heaviest passages. Some muddiness which had been attributed to the program material vanished when the high-powered amplifier was substituted for a 25-watt Ultra-Linear amplifier.

The improved sound quality is due in part to the extra power handling; in part to the wide stability margin. This insures instantaneous recovery on percussive sounds and translucent, smooth listening on high-frequency string and wind instruments. Small transient sounds such as tambourines assume a different spatial perspective, possibly because the low phase shift does not disturb the harmonic pattern of complex nonrepetitive tones. The total effect is greater naturalness and less impression of reproduced sound. END

Parts for high-power amplifier

Resistors: 2—470, 2—1,000, 3—10,000, 1—39,000, 3—100,000, 2—470,000 ohms, 3—1 megohm, ½ watt; 3—22,000, 1—33.000, 2—47,000, 1 watt; 2—47,000, 2 watts; 1—100-ohm potentiometer; 1—10,000-ohm potentiometer.

Capacitors: 1—50, 1—82 µµf, mica; 1—.05, 1—0.1, 4—0.25 µf, 400 volts; 2—10 µf, 500 volts, electrolytic; 1—20 µf, 150 volts, 3—20 µf, 450 volts, electrolytic.

Tubes: 2—6SN7-GT, 2—6550, 1—5U4-GB.

Transformers and chokes: 1—output transformer, primary impedance 4,300 ohms plate to plate, secondary impedance 8 and 16 ohms (Dynaco A-430 or equivalent. Acrosound's TO 330 is a very close equivalent; Stancor is bringing out an equivalent for use with 6550's.); 1—power transformer, 800 volts ct @ 200 ma, 5 volts @ 3 amps, 6.3 volts @ 5 amps; 1—choke, 8 henries @ 200 ma; 1—choke, 8 henries @ 50 ma.

Miscellaneous: 2—selenium rectifiers, 20 ma; 5—octal sockets; 1—line cord; 1—input jack; 1—output terminal.

SOUND SELLING

By ROBERT E. RIDDLE

HERE is a copy of a letter—the signature has been changed—that recently came to my attention:

"Sir,

Could you, of Midland Engineering Company, fix me up with an unusual method of advertising my business?

I have signs of every description, both inside and outside, as well as display ads in the newspaper. I want a permanent, cheap means of advertising.

Respectfully,

Richard Roe"

The writer didn't say what kind of business he was running or its location. I was about to file it in the wastebasket, when the clock on the next desk started tolling the time. Then it hit me! Why not a chiming clock that could be heard over a wide area?

One of the fellows plays an electric guitar in the company dance band. Fortunately this happened to be their day to rehearse.

I removed the pickup from the guitar, fastened it to the side of the clock, plugged in the amplifier, turned the amplifier volume on full and sat back.

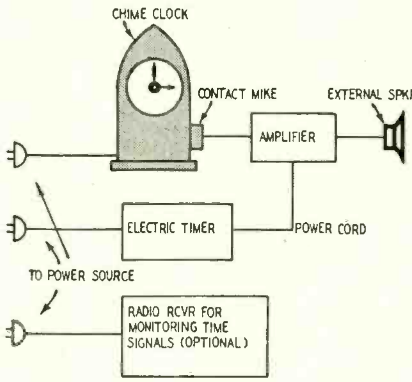
It wasn't long coming. Instead of the soft mellow chime, there was the thunderous roar of a gigantic gong. Turning the gain down I again restored the soft mellow chime, but with enough volume so that it could be heard over a radius of several blocks.

I had the technicians rig up a similar unit (see diagram) and install it on the front of the department store next door. At the end of a week the manager told us that business that week was a good 40% over the same period a year ago.

The only modification we made in the unit was to use outside speaker horns and hook the amplifier to a time clock that shut it off at a few minutes past midnight and on again about five in the morning.

To get the correct time we used a shortwave radio tuned to WWV at 2.5, 5, 10, 15 and 20 mc, and set the chime clock by this at least once a day.

WWV may be identified by a tone signal and a beat, similar to the ticking of a clock. Every 4 minutes the tone stops and a message is sent out in Morse code, a voice announces the time, another message in code follows, then the tone returns on the exact 5-minute mark on the clock at the U. S. Bureau of Standards' Naval Observatory at Washington, D. C. All time is given in Eastern standard time. Compute the time by subtracting one, two or three hours, depending on which time zone you happen to live in.



If you don't want to go to the expense of getting a shortwave radio you can get the correct time by calling your local Western Union office, telephone company or railroad station.

Remember, when you broadcast the time, people want the *right* time, not just any time. Inaccurate time will reflect on your business as much as if you had given shoddy service or sold inferior merchandise. END