King-Size Quarter Horse Power Stereo Amplifier

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Photographs by Edwin F. Meers

In this age of solid-state devices, it is unusual to find a constructor who still resorts to high-quality commercial practice to produce a high-power amplifier. This unit seemed to have sufficient merit to warrant the full treatment, and all seasoned audio buffs know that superb performance can still be obtained from vacuum tubes.

TRANSISTORS MAY BE HERE TO STAY, but tubes are not yet ready to be written off and placed in museums. The amplifier described here was designed and constructed to see just how far vacuum-tube design has progressed; it is a state-of-the-art device.

Before you read further, a word of caution: if you are interested in compact or miniaturized equipment, this is not for you. The amplifier and power supply are each built on 13- by 17-in. chassis, whose combined weight is over 80 lbs. The construction of the power supply (about 55 lbs.) required installation of a small hydraulic jack underneath the workbench to avoid sag and ultimate collapse of the bench. Those who look upon the amplifier marvel greatly; their awe is brought upon by the overall massiveness and, particularly, by the size of the power transformer which, by normal home standards is immense, although it would not hold a candle to some units in professional installations.

The basic amplifier circuit is, up to the output stages, an adaptation of a Genalex design, and a number of its features are deserving of further comment. First of all, the RC networks between C_3 and C_5 and R_{15} and R_{1}[illegible] are there for the purpose of rolling off response at both frequency extremes to avoid any tendency toward motorboating or high-frequency oscillation at the resonant frequency of the output transformer and associated circuitry. Incorporation of a driver stage between the phase-splitter and power-amplifier stages, in addition to supplying some needed gain, isolates the output stage from the shaping circuits and allows both output tubes to be driven by sources of the same impedance. Circuits which drive the output stage directly from the paraphase inverter may overload assymetrically, because, although in schematic form this type of inverter tends to look completely symmetrical, such is not at all the case. The top half of the inverter is a simple voltage amplifier with no voltage feedback, while the bottom (the half which is actually the inverter) is a voltage amplifier with sufficient feedback to reduce its gain to unity and its output impedance to a comparatively much lower value. Because of the large amount of drive needed for the output stage, the plates of the drivers are fed from the same 650-volt source as is the output stage. Very large coupling capacitors are used to the output stage to hold roll-off and consequent phase shift to a point well below the frequency determined by the earlier shaping networks.

The Power Supply

Aside from these few refinements the circuit is very straightforward, and this leads to ease of adjustment and a large stability margin, in addition to generally superior performance. One possible source of difficulty, however, was the large swing in plate current drawn by each output tube from 50 mA at zero signal to 150 mA at 100 watts output per channel. To accommodate this variation (equivalent to a total amplifier drain of about 250 mA idling and 650 mA at 200 watts out) we have used a silicon rectifier feeding a choke-input filter. The rectifier (Sarkes-Tarzian S5162) is meant as a tube replacement, and was the most economical way of meeting the current and peak-inverse-voltage requirements. (Strings of lower voltage diodes, with voltage equalizing rc networks would have cost about the same, and are a makeshift solution at best.) Those with a real aversion to solid-state components can use push-pull 5R4GY's in place of the silicon rectifier: this will reduce power output somewhat because of both larger initial voltage drop and poorer regulation. In addition, it will require redesign of the physical layout of the power supply since 5R4GY's cannot be expected to live very long underneath a chassis.

The power transformer and chokes are rated at 400 mA continuous output, which means that the power supply runs at a comfortably low temperature, even after many hours of operation. If you are testing the amplifier for maximum output, or running it at high power for any other purpose, replace the half-amp B-plus fuse with 1 amp for the duration of the test, and avoid driving it at sustained full power for more than 10 minutes or so. This does not mean that the power supply has an inadequate safety margin: quite the contrary, the amplifier is quite suited to fill your living room (or major league baseball park) with large amounts of sound for indefinite periods for a long time. When initially wiring the power supply, test the filament windings to make sure they are in phase rather than bucking by momentarily touching the red leads (*thick* ones, not the thin red high voltage leads) to the green; if you get a fat spark (only 6 volts here, no shock hazard) they are out of phase; reverse one set of leads and solder.

Since the power transformer has no bias winding, a separate transformer is used for the bias supply. Any isolation transformer will do as long as

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it can deliver about 15 mA; the exact output voltage is not critical since it is adjustable at each tube. If you can't locate a packaged bridge rectifier, just about any four silicon or selenium diodes will work just as well.

Figure 1 is the top view of the amplifier: each channel is on one side of the chassis, with the common components (meter and switch) in the center. Hidden behind the output transformers are the output terminal strips. The male octal power connecter is on the far side of the chassis, the hum balance control on the near side. The two other capped potentiometers (between the 6SN7's and pairs of KT88's are the a.c. balance controls. *Figure* 2 shows what the amplifier looks like underneath. There are plenty of components used in the input stages, but the large chassis leaves plenty of room. Just make sure nothing is touching that isn't supposed to touch. The locations of the meter and switch are obvious. The four large capacitors are the coupling to the output stage; the balance controls are between them. The four bias pots are on the other side of the output tube sockets. Two buss bars are used, to which all grounds are connected; they are tied together and grounded to *one* of the input sockets; this is the only chassis ground.

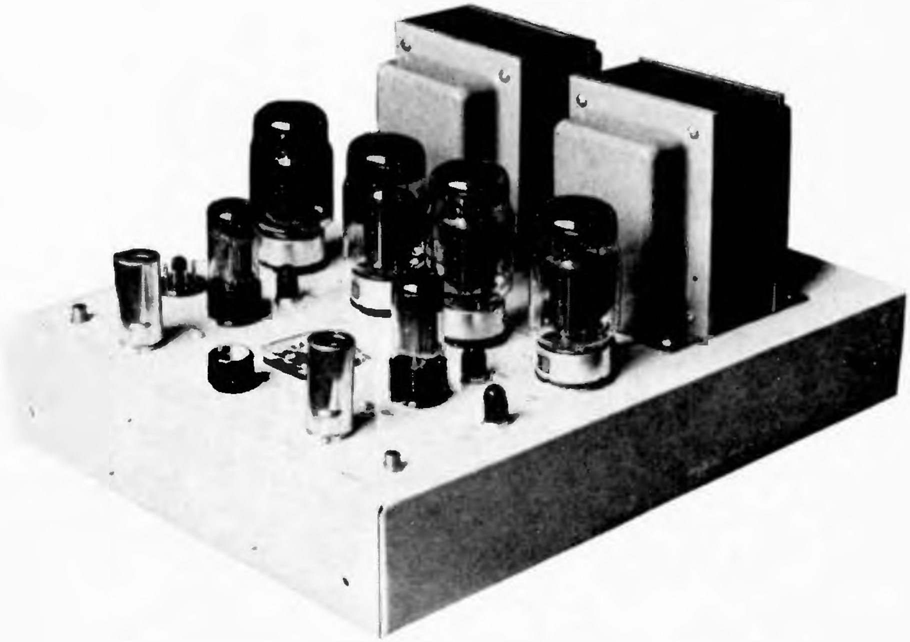

Fig. 1. Top view of the amplifier.

The top of the power supply is shown in *Fig*. 3; the only components here are the power transformer and chokes, the octal power connecter, and the line cord. More is to be seen underneath (*Fig*. 4). On the lower right are the components of the bias supply: transformer and (partly hidden) R_8, R_7, C_7, and C_8. The B-plus rectifier is mounted on an angle; there is no need to put it on top of the chassis since its life is indefinite. Underneath the rectifier is the high-voltage fuse, underneath the fuse are all of the resistors and capacitors in the high-voltage circuit.

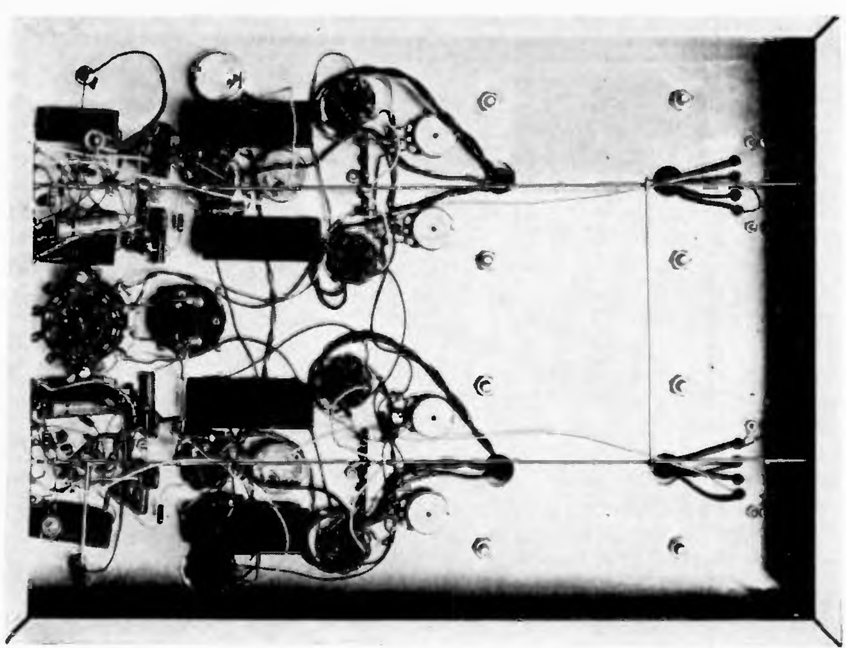

Fig. 2. Under-chassis view of the amplifier shows relatively neat construction.

The output of the power supply is fed to an octal socket; a matching cable is used to deliver power to the amplifier. Hook-up is by means of a 6-conductor cable. Since the total filament drain is over 8 amperes, the two wires carrying filament current should be at least #18; the others can be #22. We used Belden 8446, whose #22 conductors are rated at only 200 volts, but as in other applications, we have had no difficulty with insulation breakdown at many times this rating. Perhaps lacing six single, well insulated wires might be a more elegant solution; in any case keep the length to no more than is necessary.

Testing and Operation

Before connecting the amplifier to the power supply, make a preliminary resistance check from pins 2, 3, 5, 6, and 8 of the male octal power connector on the *amplifier* to ground. Pins 2 and 3 should be wide open

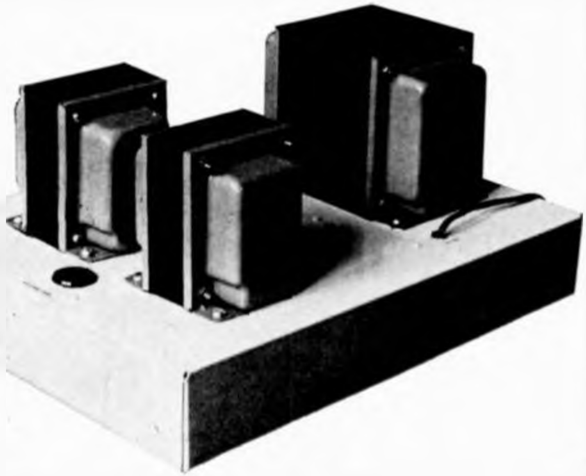 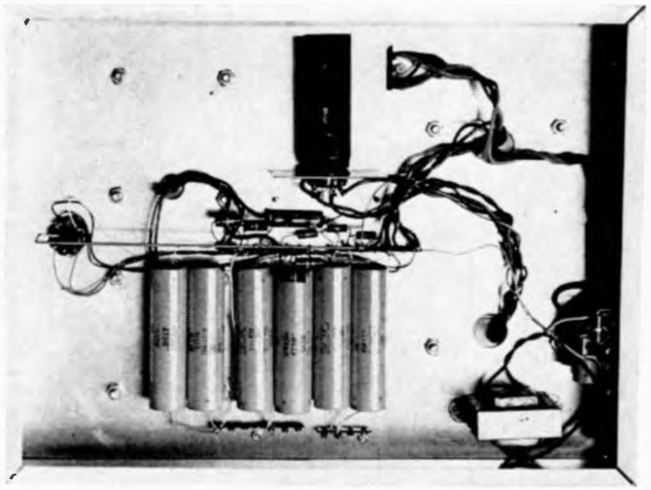

Fig. 3 (left). Top view of the massive power supply, which weighs in at about 55 lbs. Fig. 4 (right). Underside of the power supply chasis is similarly neat and uncluttered.

(infinite resistance), pin 5 about 10K and pins 6 and 8 varying from 100 ohms to zero as the hum balance control is rotated. When measuring from pin 5, turn all four bias controls from one end of rotation to the other and make sure this has no effect on the resistance to ground at pin 5. Failure to make this check cost us a KT88: a sliver of wire caught under one of the bias pots removed all bias from that tube, and before we could get to the power cord, completely stripped the cathode of the tube. Any such short would show up as a resistance variation in the above check.

Assuming that the amplifier checks out, plug in the power supply with the amplifier not yet connected (the dimming of lights is normal) and measure the output voltages (B-plus should be about 700 volts with no load). If everything is normal, unplug the power supply and connect it to the amplifier. With the 12AX7's and 6SN7's in their sockets (no output tubes yet) plug the power supply in again and make sure the tubes light up. If you want to make plate voltage checks here, keep in mind that they will be a bit higher than normal. Connect a signal generator to one of the inputs (about 1 kHz) and adjust it for about 20 volts at pin 5 of either of the output tubes of that amplifier. Now adjust R_{21} so that the signal will be the same at pin 5 for both output tubes. Repeat the adjustment for the other amplifier; we used caps on the balance controls since this is a semi-permanent adjustment which cannot be checked on the meter.

Now connect each side of the amplifier to a dummy load (or a common load to the paralleled outputs), turn each bias control fully *negative* (CCW in our amplifier) and plug in the output tubes. To check output tube current, we used a 100 mA meter with a switch which inserts the meter into any one cathode circuit or cuts it out of the circuit. If you see no purpose in building into the amplifier a meter which will be used rarely, make some other provision for measuring cathode current (such as closed-circuit phone jacks). In any case, with the controls supplying full bias, the tubes should draw little or no current. After they have warmed up, slowly adjust each bias pot for 50 mA cathode current. Since they interact, go back and adjust each pot a couple of times until all of the tubes are drawing the same 50mA. After about 10 hours of operation, repeat the adjustments to compensate for initial aging.

Before connecting the amplifier to your speaker system check each side with a voltmeter (dummy load attached) to make sure it is not oscillating; should you have made a wiring error causing the feedback phase to be reversed, the amplifier would be producing about 160 watts of oscillation which you will want to correct before it sends your speaker up in smoke.

Adjustment of the amplifier is now completed. If you have the test equipment, you might want to trim balance controls R_{21} for minimum IM distortion; adjustment for equal output is sufficient for anything less than laboratory measurement uses.

Performance

Frequency response, power output, and other data are given in *Figs.* 7 and 8. No distortion measurements are given since these have been shown (by transistor research, to a great extent) to have little to do with sound quality. Suffice to say that square waves at 1 kHz and 10 kHz are closer to the original than those coming out of any other amplifier we have seen. 20 Hz square waves show a great deal of tilt because of subsonic rolloff and high-frequency square waves are rounded because of the high-frequency rolloff. Note the large difference between maximum output before clipping and absolute maximum output in

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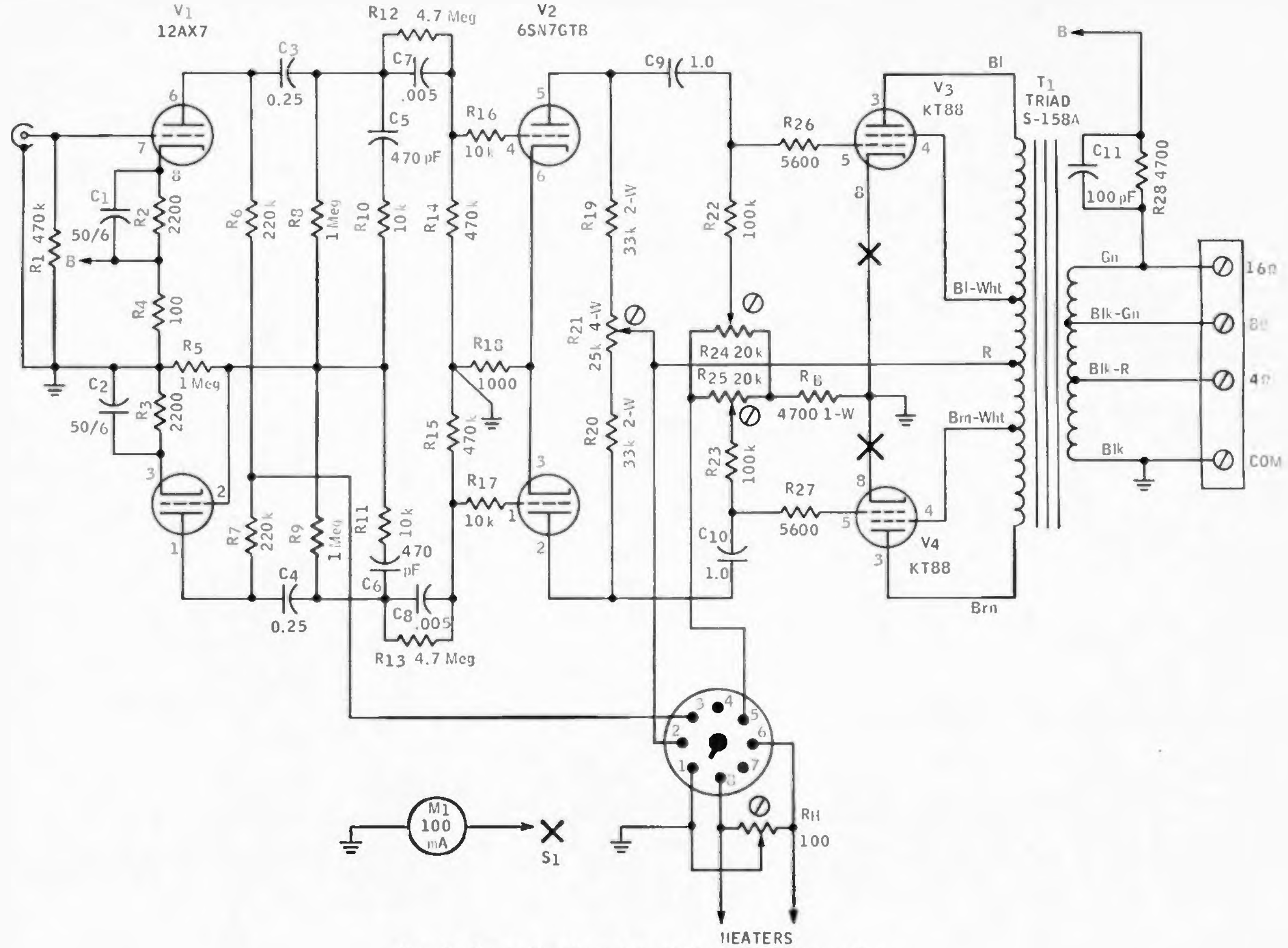

Fig. 5. Over-all schematic of the amplifier section.

both the single channel and combined measurements. This is indicative of the symmetrical, gradual clipping which turns sine waves almost into square waves before sides are deformed. Maximum power without audible distortion is about 100 watts. music power about 115 watts (each channel) and total peaks in the half-kilowatt region. Frequency response is dead flat throughout the spectrum, another 15 dB of feedback will produce neither oscillation nor detectable sound improvement, the noise is inaudible, the gain very high (input gain controls may be needed in some applications), and the damping factor (remember that?) good for most speakers. The amplifier has been tested into a capacitive load approximating an electrostatic speaker and shows no signs of instability or sound degradation.

A word of caution: if you have never experimented with anything this big, be very careful about plugging and unplugging leads. An open ground could easily mean 160 watts at 60 Hz fed to your speaker. Also,

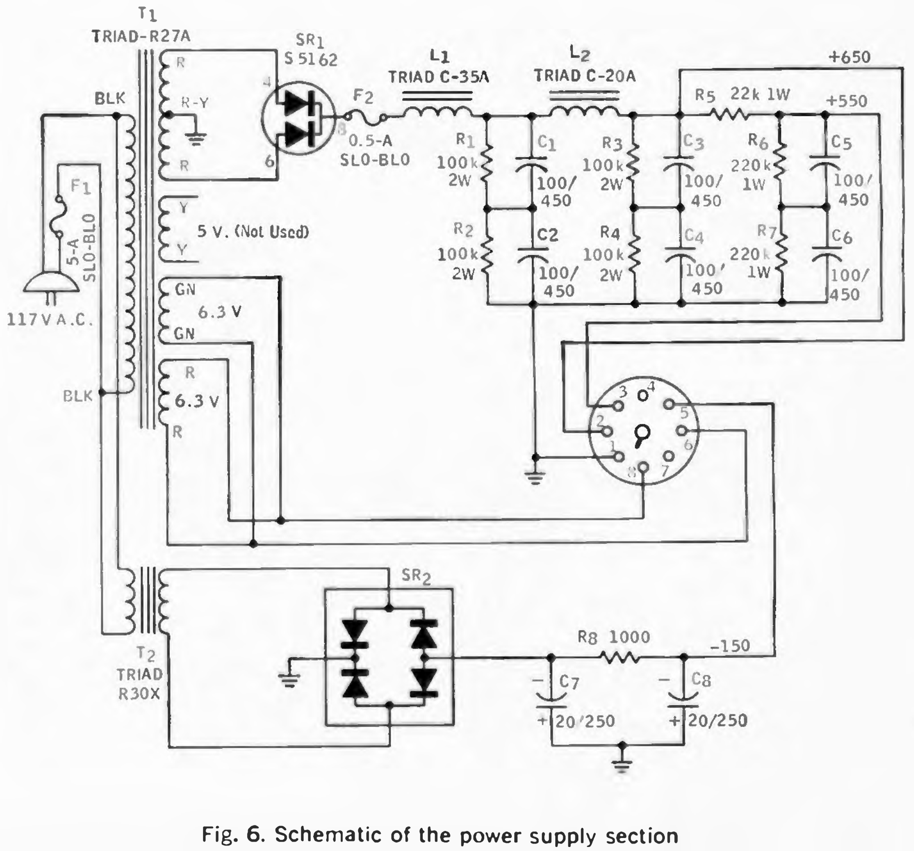

Fig. 6. Schematic of the power supply section

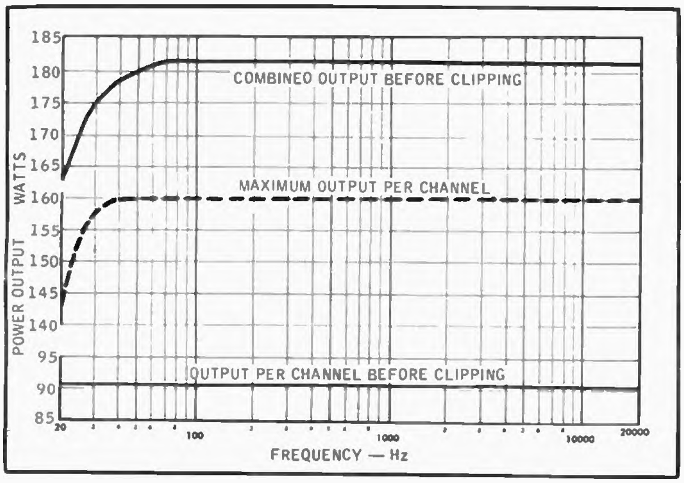

Fig. 7. Curves of output of each individual section before clipping, and of both sections together, along with maximum output per channel, all vs. frequency.

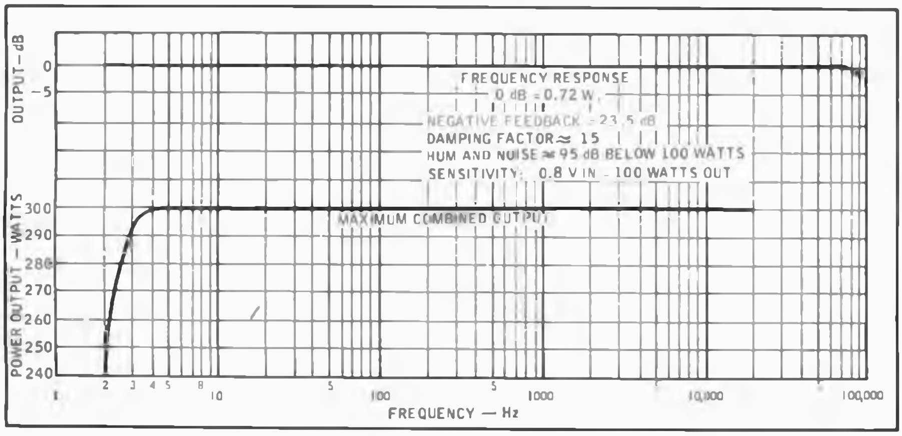

Fig. 8. Frequency response curves for 0.72 watts per channel, and for maximum combined output of both channels.

switching clicks may contain so much energy that they may cause your house lights to flicker. This does not mean oscillation, it simply means that the amplifier can reproduce a sharp thump fed into it at the equivalent of manv watts of power. If you have chronically noisy switches on your preamp, you might consider a subsonic filter.

Rationale

Why, to sum things up, does one go out of one's way to listen to an amplifier whose only claim to fame seems to be the great gobs of power it can produce, an amplifier whose flat frequency response, low noise, and high gain can be duplicated by most of the commercial units on the market today, an amplifier which is hardly easy on the back muscles and which, if mistreated, may vent its rage by destroying any speaker made in a fraction of a second?

The reason is sound. For pure sound quality, this amplifier sounds noticeably better than anything we have ever heard. Using it in place of a respected 70-watter elicited immediate comments from listeners. Not only is it exceptionally clean at normal levels, but the feeling of completely unlimited power handling capacity is a new experience. We invariably listen to the amplifier at considerably higher levels than before, but it is a new type of loudness, absolutely free of listener fatigue and truly approaching live sound. This is an amplifier which can be relied upon never to call attention to itself (sonically, at least) no matter what it is called upon to do; it will always be a strong link in the chain or sound reproduction.

We would like to thank Calvert Electronics, Inc., Sarkes Tarzian, Inc., the Triad Distributor Division, and Mr. Frederic Feingold for their invaluable assistance in this project. Æ

Parts List

Amplifier—2 of each component unless otherwise specified

C_1, C_2	50 μF, 6V, electrolitic, Sprague TE 1100
C_3, C_4	0.25 μF, 600 V, paper, Sprague 6TM-P25
C_5, C_6	470 pF, Sprague 47192
C_7, C_8	.005 μF, paper, Sprague 6TM-D50
C_9, C_{10}	1.0 μF, paper, Sprague 6TM-M1
C_{11}	100 pF, ceramic, Sprague 10TCC-T10
M_1	100 mA meter, 1 only, optional
R_1, R_{14}, R_{15}	470 k ohms, ½ watt (All resistors 5%)
R_2, R_3	2200 ohms, 1 watt
R_4	100 ohms, ½ watt
R_5, R_8, R_9	1 megohm, ½ watt
R_6, R_7	220 k ohms, ½ watt
R_{10}, R_{11}	10,000 ohms, ½ watt
R_{16}, R_{17}	
R_{12}, R_{13}	4.7 megohms, ½ watt
R_{18}	1000 ohms, ½ watt
R_{19}, R_{20}	33,000 ohms, ½ watt
R_{21}	25,000-hm, 4-watt potentiometer
R_{22} R_{23}	100 k orms, ½ watt
R_{24}, R_{25}	20,000-ohm potentiometer
R_{26}, R_{27}	5600 ohms, ½ watt
R_{28}	4700 ohms, ½ watt
R_b	4700 ohms, 1 watt (1 only, common to both channels)
R_h	100-ohm potentiometer (1 only)
S_1	Meter switch, Mallory 1400L (1 only, optional)
T_1	100-W, tapped screen, 4500-ohm output transformer, Triad S-158-A)
V_1	12AX7
V_2	6SN7GTB
V_3, V_4	KT88
	Chassis, jacks, sockets, hardware, etc.
	Power supply
$C_1, C_2, C_3, C_4, C_5, C_6$	100 μF, 450-V electrolite, Sprague 1718
C_7, C_8	20 μF, 250-V, electrolytic, Sprague 1508
F_1	5-A, Slo-Blo fuse
F_2	0.5-A, Slo-Blo fuse
L_1	Triad C-35A swinging choke, 20-4 Hy, 40-400 mA.
L_2	Triad C-20A choke, 6 Hy, 400 mA.
R_1, R_2, R_3, R_4	100 k ohms, 2-watts (All 10%
R_5	22,000 ohms, 1 watt
R_6, R_7	220 k ohms, ½ watt
R_8	1000 ohms, ½ watt
SR_1	tube-replacement type silicon rectifier, Sarkes Tarzian S5162
SR_2	Bridge-type silicon rectifier
T_1	Triad R-27A
T_2	Triad R-30X
	Chassis, line cord, fuse mountings, power cable, hardware, etc.