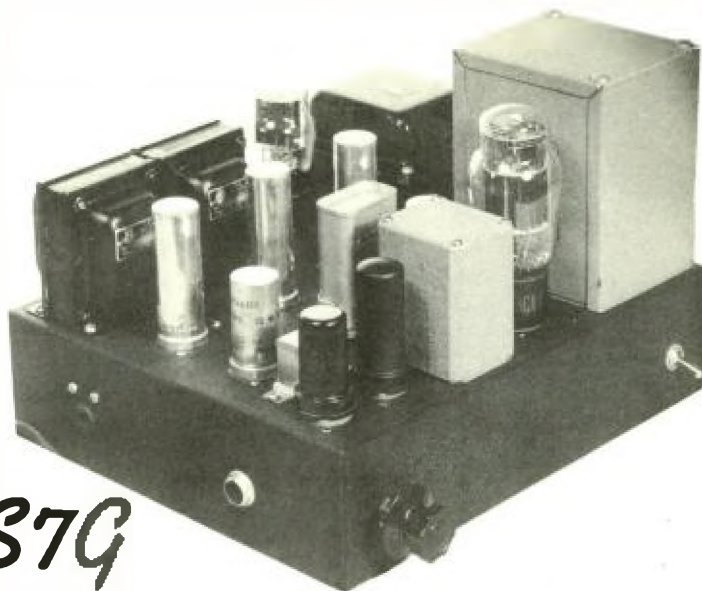


The high quality audio amplifier.

High Quality Amplifier with the 6AS7G



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Outstanding performance from an ultra-modern amplifier

ALTHOUGH not particularly new, the 6AS7G twin triode recently publicized by RCA as an audio output tube is an interesting device, and natural curiosity prompts the experimenter to use the tube in an amplifier to determine its capabilities. The 6AS7G, briefly, was originally designed with two principal uses in view—one being a high-current substitute for the usual 2A3 in tube-controlled voltage regulator circuits, and the other as a damper for the horizontal sweep circuits in television receivers where greater power is required than was previously obtainable with existing tubes. In this particular application, the requirement is for a short duty cycle, but one in which the current is relatively high. Recently, however, it has been given considerable attention as an audio amplifier.

Physically, the 6AS7G is a fascinating tube. In cross section, the elements resemble the sketch in Fig. 1, with each plate being composed of two separate and very deep channels, with the short dimension serving as the plate proper, the longer sides being used for heat dissipation. Above and below the element structure are the two radiators for the grids, also used to dissipate the heat. Compared with the 2A3, the 6AS7G is almost the equal of two of the former tubes. Plate dissipation for the 2A3 is 15 watts, whereas that for the 6AS7G is 13 watts per section, making a total of 26 watts for the tube. Thus it is seen to be useful as an output tube.

Advantages

There are a number of advantages to the 6AS7G which are not obtainable in any other output triode. In the first

place, it uses a heater-cathode construction, eliminating the problem of reducing hum from this source. The two sections of the tube are completely separate, permitting the use of separate cathode resistors to obtain grid bias, and making it a simple matter to balance plate currents in the two sections. The plate

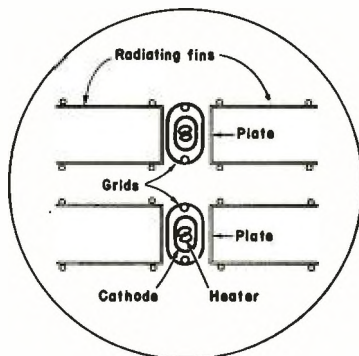


Fig. 1. Cross-section of element structure of the new 6AS7G, showing the unique plate construction with adequate area for heat radiation. Grid radiators are alternately above and below the element structure.

resistance is relatively low, being of the order of 670 ohms at the operating point selected. With this value of plate resistance and the high-current capability of the tube, the plate efficiency is seen to be high. The amplification factor of the tube is 2.1. When working into a 3000-ohm plate load, the effective output impedance of the amplifier—at a 16-ohm winding, for example—is 7.2 ohms, which provides a good damping

factor for an amplifier used to drive a loudspeaker.

Design of the Amplifier

Proponents of high-quality reproduction are divided over the relative merits of triodes versus pentodes-with-feedback, but the current trend seems to be back (?) toward the use of triodes for the output tubes in the better apparatus. With this in mind, the 6AS7G was investigated, and since it appeared to have certain advantages over the other tubes of similar power output

TABLE 1
AUDIO AMPLIFIER SERVICE
Values are for each unit

Maximum Ratings, Design Center Values:			
PLATE VOLTAGE	.....	250 max.	volts
PLATE CURRENT	.....	125 max.	ma
PLATE DISSIPATION	.....	13 max.	watts
PEAK HEATER-CATHODE VOLTAGE			
Heater negative with respect to			
cathode	.....	300 max.	volts
Heater positive with respect to			
cathode	.....	300 max.	volts
Typical operation, Class A, push-pull amplifier.			
Unless otherwise specified, values are for both units.			
Plate	.....	200	250
			volts
Grid	.....	-90	-125
			volts
Cathode Resistor (per unit)	.....	1500	2500
			ohms
Peak AF grid to grid voltage	.....	180	250
			volts
Zero signal plate current	.....	120	100
			ma
Max. signal plate current	.....	128	106
			ma
Effective load resistance (plate to plate)	.....	4000	6000
			ohms
Total harmonic distortion (less than)	.....	4	4
			per cent
Max. signal power output	.....	11	13
			watts
Amplification Factor (per unit)	.....	2.0	2.0

*It is essential that precaution be taken in equipment design to prevent subjecting the tube to full load current of 250 ma before its cathodes have reached normal operating temperature. The cathodes require approximately 15 seconds to attain normal operating temperature. Unless this precaution is observed, the cathodes will be seriously damaged, if not completely ruined. In speech amplifier service, as indicated under typical operating conditions, the plate voltage may be applied simultaneously with the filament voltage.

capabilities, an amplifier was designed around it. This amplifier was designed on the basis of the highest fidelity of reproduction, and used broadcast quality transformers. It was not intended that any short cuts would be employed, but simply that a good, stable, reliable amplifier should result. The finished amplifier reasonably well justifies the time spent, since the performance comes up to the expectations.

The values published by RCA for typical operating conditions are shown in Table 1. This table indicates that the tube draws a high plate current, requires a high grid bias, and is operated with separate cathode resistors to develop this bias. The high bias also indicates a high signal voltage applied to the grids, which poses somewhat of a problem, as will be discussed later. Under the 200-volt condition, the plate dissipation is 12 watts per unit, which appears to be too

close to the maximum to provide a factor of safety. Therefore, a slightly higher bias voltage was chosen, in order to reduce the plate dissipation to 10 watts, as well as to reduce the plate current through the primary of the transformer to a more reasonable value.

Commencing the design, the output stage is considered first. A study of the typical operating conditions indicates a plate voltage of 200 and a bias of -95 volts, making a total of 300 volts, allowing for a 5-volt drop in the output transformer, which may be a trifle high. However, a supply voltage of 300 is practicable, and the amplifier is designed on that basis.

Using high quality transformers restricts the choice considerably, but two transformers of Audio Development Company manufacture appear to be suitable for this application. The Type 314C output transformer is equipped with a

primary for 3,000 or 5,000 ohms, and with secondary impedances of 600, 150, 16, 8, 4 and 2 ohms, which provides sufficient versatility for most uses. Since the 6AS7G should be operated with a relatively low resistance in the grid circuit for optimum performance, the coupling to the preceding stage should preferably be a transformer. Another reason for the use of a transformer is that it is difficult to obtain sufficient voltage swing from any existing tube in a resistance-coupled circuit unless the grid resistor is made large. Reference to tables in the tube handbook indicate that a 6AU6 would provide adequate grid swing as a resistance-coupled driver, but it seems rather ludicrous to employ two miniature tubes to drive a combined output tube. Furthermore, the added complication of a phase inverter is avoided by using a transformer.

Since some voltage step-up is desired

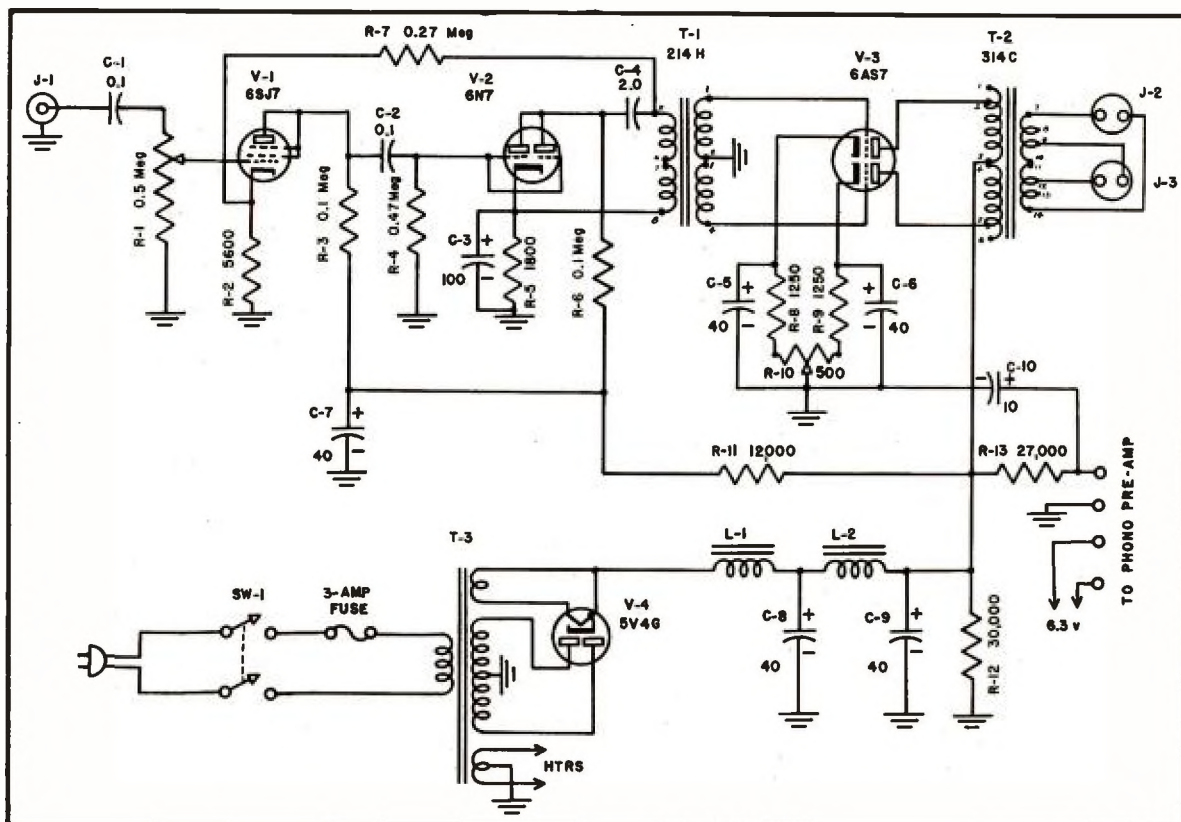


Fig. 2. Schematic of 6AS7G amplifier, showing provision for furnishing plate and filament power to external pre-amplifier.

- C₁—0.1 μ f, 600-volt, tubular
- C₂—0.1 μ f, 600-volt, Aerovox 618B
- C₃—100 μ f, 25-volt, CD UP4AJ23
- C₄—2.0 μ f, 600-volt, CD TJU-6010
- C₅, C₆—40-40 μ f, 150-volt, CD UP4415
- C₇, C₈, C₉—40 μ f, 450 volt, CD UP4045
- C₁₀—10 μ f, 450 volt, CD BR1045
- J₁—input jack, Amphenol 80C
- J₂—600-ohm output jack, Amphenol 80PC 2F
- J₃—8-ohm output jack, Amphenol 80PC2F

- L₁, L₂—7.0 H, 140 ma choke, Stancor C-1421
- R₁—0.5 meg. volume control, IRC D13-133
- R₂—5,600 ohms, 1 watt
- R₃, R₄—0.1 meg, 1 watt
- R₅—0.47 meg, 1 watt
- R₆—1,800 ohms, 1 watt
- R₇—0.27 meg 1 watt
- R₈, R₉—1,250 ohms, Ohmite 10 W, Brown Devil
- R₁₀—500-ohm wirewound potentiometer

- R₁₁—12,000 ohms, 2 watts
- R₁₂—30,000 ohms, Ohmite 10 W, Brown Devil
- R₁₃—27,000 ohms, 1 watt
- T₁—Audio Development Co. 214H, 10,000/80,000 interstage
- T₂—Audio Development Co. 314C, 3,000-5,000/600-16-4, output
- T₃—400/0/400 at 200 ma; 5 v at 4 amps; 6.3 v at 5.5 amps, Stancor P-6165

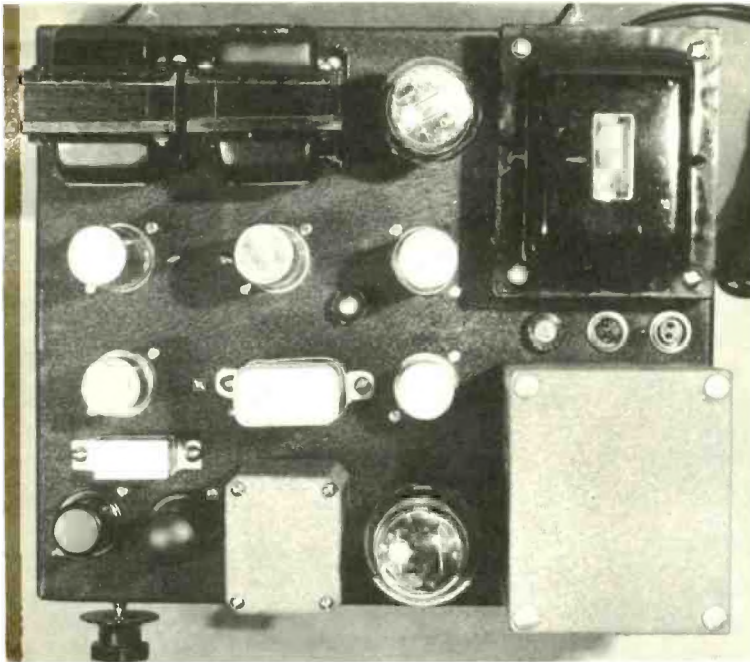


Fig. 3. Top view of amplifier, showing placement of parts. Note simplicity of arrangement. Capacitor above interstage transformer is C_1 , used in shunt feed circuit. Note use of inverted can capacitor for coupling between 6SJ7 and 6N7, shown directly above the two tubes.

from the interstage transformer, the 214H was selected. This transformer has an impedance ratio of 10,000 to 80,000, resulting in a voltage gain of 2.83. The peak grid-to-grid swing is—with the bias chosen—190 volts, or an rms swing of 138 volts. This requires a signal at the plate of the driver tube of $138/2.83$, or 49 volts, a value which is readily obtainable from triodes of the 6J5 type. However, an equal amount is obtainable from the 6N7 with ease, and with approximately twice the voltage gain in the tube. The 6N7, with the two sections in parallel, is often used as a driver tube since it is capable of furnishing rather a large amount of power. Although the 6AS7G is operating strictly Class A, some power is to be dissipated in the feedback circuit, used to improve the characteristics of the driver, which is the hardest-worked tube in this combination.

Relatively little total gain was required from the amplifier, so it was considered suitable to use a triode as the first stage. In order that the gain could be increased readily by the simple change to a pentode connection, the 6SJ7 was selected. With this tube lineup, the total gain of the amplifier, without any feedback, was calculated at 68 db. Planning on 20 db of feedback, a net gain of 48 would result, which is still more than sufficient for a "main" amplifier.

Power Supply

The power supply is conventional, using a choke input and two sections for adequate hum filtering. One of the

requirements of the 6AS7G is that the plate voltage should not be applied until the cathodes have attained normal operating temperature. This requirement is waived in speech amplifier service where the bias is obtained from cathode resistors, but since it is of some importance in certain applications, it is considered

desirable to limit the application of the plate voltage to some extent by using a 5V4G as the rectifier tube. This tube may be operated with up to 500 volts on each plate for choke-input filters, and is eminently suitable for this purpose.

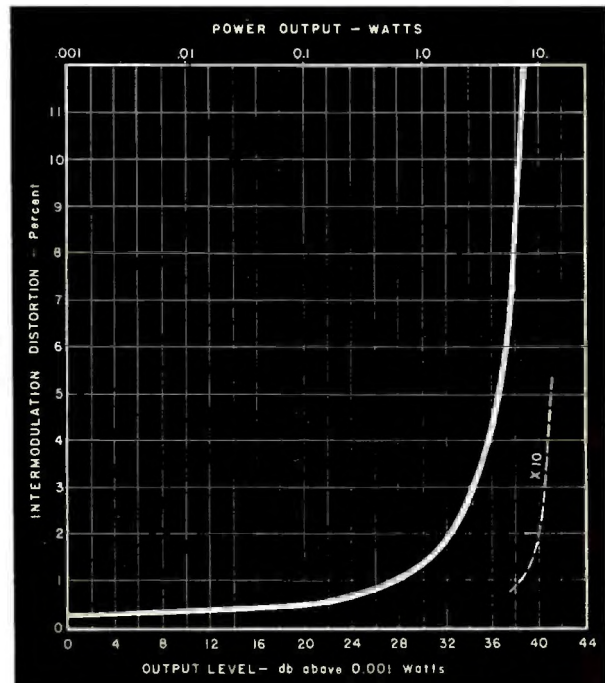
Desiring an amplifier suitable for continuous operation with adequate reserve to keep heating to a minimum, the power transformer selected is designed to furnish 200 ma at 400 volts each side of center tap, 5 volts at 4 amps for the rectifier heater, and 6.3 volts at 5.5 amps for the amplifier heaters. The 5V4G requires but 2 amps, and the tube complement of the amplifier draws 3.6 amps, which means that the entire power supply is "coasting."

Balancing Plate Currents

Returning to the output stage, some provision is desired for balancing the plate currents of the two sections of the 6AS7G, so instead of using separate resistors of equal value, each being 1500 ohms, it was decided to employ two 1250-ohm resistors, connecting to the ends of a 500-ohm potentiometer with the arm grounded. This arrangement provides sufficient control to balance the plate currents. Each cathode is by-passed with a 40- μ f, 150-volt electrolytic capacitor, a dual unit being used to conserve space.

The plate load resistor for the 6N7 is 0.1 meg, being coupled to the primary of the interstage transformer by a 2.0- μ f 600-volt oil-filled capacitor. At this same point the feedback resistor is connected, providing the isolation for both circuits with the same capacitor. The

Fig. 6. Intermodulation distortion curves at various output levels.



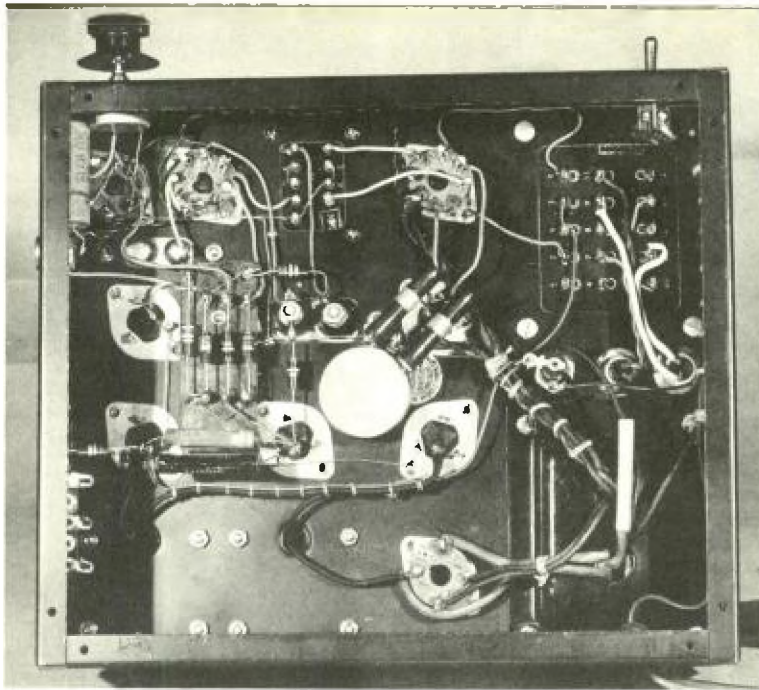


Fig. 4. Under-chassis view of amplifier.

cathode of the 6N7 is by-passed with a 100- μ f, 25-volt capacitor. The feedback resistor connects to the unby-passed cathode of the 6SJ7. The complete schematic is shown in Fig. 2, with the arrangement of parts both above and below the chassis shown in Figs. 3 and 4.

As constructed, the gain of the amplifier without feedback is 67 db, measured from an unterminated 500-ohm gainset, or an actual gain of 61 db. With 26.7 db of feedback, the gain reduces to 34.3 db, without a transformer at the input.

Increasing Gain

If more gain is desired, the first stage may be changed to the pentode connection, with an increase in gain of approximately 20 db, and a 600/50,000 input transformer will give nearly 20 db more. Referring to the schematic of Fig. 5, it will be noted that the changes necessary to convert the first stage to a pentode are relatively simple—only one resistor is changed, and one resistor and one capacitor are added. Changing the value of the cathode resistor from 5,600 ohms to 680 ohms automatically compensates for the difference in gain for the two tubes with respect to the feedback connection, and provides approximately the same amount of feedback—in db of gain reduction—when using the same resistor for R7.

Performance

With the design considerations outlined, the amplifier was constructed as

shown, and then tested to determine how well the 6AS7G tube performed. The principal information required of an output stage is the maximum power output, and the output at a stated percentage of harmonic distortion, usually 5 per cent. Modern engineering and testing standards require information as to the intermodulation distortion in addition to the above. It is generally accepted that an amplifier designed for high-quality reproduction must be capable of

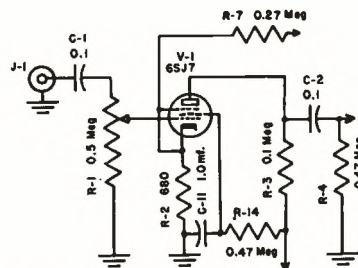


Fig. 5. Schematic of changes to circuit of V₁ when used as a pentode for increase of approximately 20 db in gain. Only required changes are in cathode resistor R₂ from 5,600 ohms to 680 ohms, and addition of R₁₄ and C₁₁. No change is necessary in feedback resistor, R₇.

furnishing sufficient output power at a harmonic distortion of less than 1 per cent to be completely satisfactory, and that the intermodulation distortion should be under 2.5 per cent for optimum performance.

This amplifier underwent the necessary tests, and the results are gratifying. The power output at 20 per cent intermodulation distortion, equivalent to 5 per cent harmonic distortion, was measured at 9.5 watts, and at 4 per cent intermodulation distortion (1% harmonic distortion approximately) 3 watts. The intermodulation distortion at 5 watts output is 6.3 per cent, and at 1 watt, 1.3 per cent. This indicates that the performance of the amplifier is satisfactory for the highest quality requirements for home or monitoring applications, using efficient speaker systems where the power requirements are not as severe as in public address systems.

One of the principal advantages of the 6AS7G shows up in the measurement of hum, this value being -45 dbm. When compared to the conventional 2A3 amplifier, this is somewhat better, and it should be noted that no special precautions were taken to minimize hum, nor were any of the "tricks" used. The measured gain is 34.3 db with feedback, and since the frequency response is flat within 0.5 db from 20 to 15,000 cps, it is not considered necessary to reproduce the curve. Intermodulation distortion curves are shown in Fig. 6. At 1 watt output, the output impedance at the 600-ohm winding is 258 ohms; at the 16-ohm winding, it is proportionately less than 8 ohms which provides excellent damping for a loudspeaker.

Conclusions

Tests of this amplifier indicate that the 6AS7G is an ideal substitute for a pair of 2A3s or 6B4Gs in the output stage of a quality amplifier. The low voltage and high current requirements of the tube reduce possibility of failure in filter capacitors, especially when electrolytic units are used, and the simplicity of the amplifier makes it ideal for applications where continuous service is required. Although phase inverter circuits are considerably less expensive than high-quality transformers, there is one thing to be said in favor of the transformer—once installed, it may be depended upon for years of service, and its characteristics are not dependent upon the gain of a tube or the constancy of a resistor. When shunt-fed circuits are used, there is little chance of burning out the primary (unless the coupling capacitor fails) and no trouble need ever be anticipated with a good transformer. The characteristics of a transformer-coupled amplifier may be counted on to be constant as long as the unit is in use.

The use of the 6AS7G in quality amplifier service definitely indicates a trend toward simple, reliable design, and if operated at reasonable plate dissipation, the tube should give continued satisfaction.