ELECTRON TUBES

RCA Application Note

AN-173

High-Fidelity Audio Amplifiers Using RCA-6973 Beam Power Tubes

This Note describes the application of the new RCA-6973 beam power tube designed for use in the output stages of high-fidelity audio amplifiers. Two amplifier circuits are given: a moderate-cost circuit providing a power output of 15 watts at a total harmonic distortion of less than 0.4 per cent, and a low-cost circuit providing a power output of 10 watts at a total harmonic distortion of less than 0.5 per cent and 15 watts at less than 4 per cent distortion.

Characteristics of the RCA-6973

The 6973 is a high-perveance 9-pin miniature type having high power sensitivity, very low grid-No.2-current and heater-power requirements, and negligible grid emission. It is designed to provide linear operation over a wide range of power output and can deliver high power output at low distortion when operated at moderate plate voltage. Technical data for this tube, including Maximum Ratings and Typical Operation Values, are given in Table I. Values are given for operation in push-pull class AB_1 circuits using both the conventional pentode connection and the grid-No.2 feedback ("ultra-linear") connection.

Moderate-Cost Amplifier

Fig.1 shows the circuit of an amplifier using 6973's with fixed bias in the output stage, and the pentode and triode units of a 6U8-A in the input voltage amplifier and phase-splitter stages, respectively. This amplifier employs 20 db of inverse feedback between the speaker voice-coil winding and the input amplifier cathode, has no adjustments or critical components, and provides exceptionally fine performance at moderate cost. It can deliver a maximum-signal power output of 15 watts (actual power delivered to a resistive load) with less than 0.4 per cent total harmonic distortion (see Fig.2). Its frequency-response characteristic, shown in Fig.3, is flat over the entire audio spectrum, and down less than 2 db at 10 and 80,000 cycles per second. It has a sensi-

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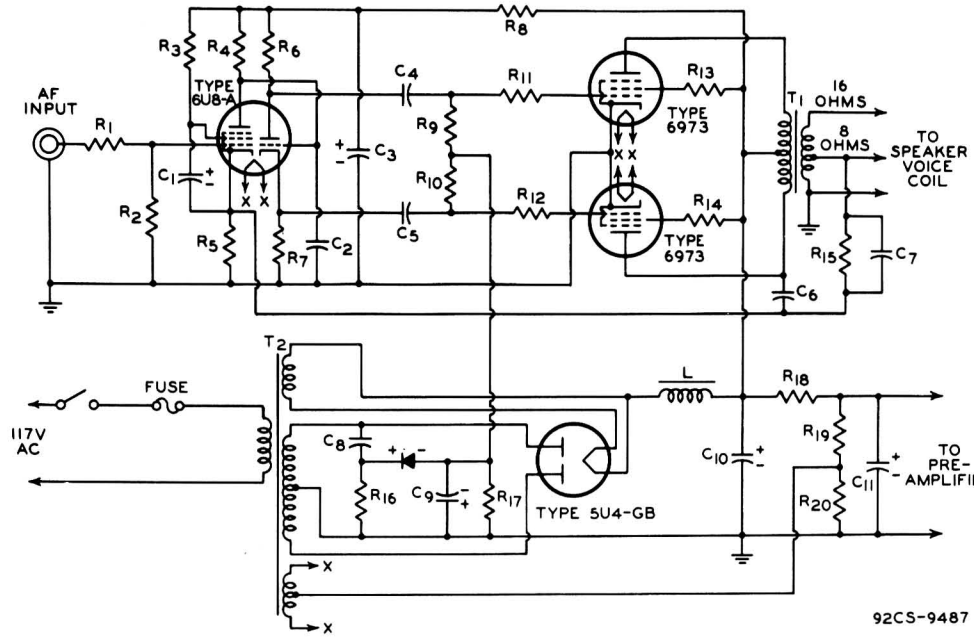
tivity of 1.2 volts RMS for full output, a damping factor of 12, and an extremely low noise level (combined hum and noise with input circuit open are 75 db below 15 watts).



C_1: 2 μf, 450 v., electrolytic
C_2: 15 $\mu\mu$f, 400 v., mica or ceramic
C_3 C_{11}: 40 μf, 450 v., electrolytic
C_4 C_5: 0.1 μf, 600 v., paper
C_6: 6.8 $\mu\mu$f, 600 v., mica or ceramic
C_7: 180 $\mu\mu$f, 400 v., mica or ceramic
C_8: 0.02 μf, 600 v., paper
C_9: 100 μf, 50 v., electrolytic
C_{10}: 80 μf, 450 v., electrolytic
F: Fuse, 3 amperes, 150 volts
L: Filter choke, 3 henries, 160 ma., 75 ohms, Triad type C13X or equivalent
R_1: 10,000 ohms, 0.5 watt
R_2: 470,000 ohms, 0.5 watt
R_3: 820,000 ohms, 0.5 watt
R_4: 240,000 ohms, 0.5 watt
R_5: 680 ohms, 0.5 watt
R_6 R_7: 15,000 ohms ± 5%, 2 watts
R_8: 3900 ohms, 2 watts
R_9 R_{10}: 220,000 ohms, 0.5 watt
R_{11} R_{12}: 1000 ohms, 0.5 watt
R_{13} R_{14}: 100 ohms, 0.5 watt
R_{15}: 6800 ohms, 0.5 watt
R_{16}: 15,000 ohms, 1 watt
R_{17}: 68,000 ohms, 0.5 watt
R_{18}: 4700 ohms, 2 watts
R_{19}: 270,000 ohms, 1 watt
R_{20}: 47,000 ohms, 0.5 watt
SR: Selenium rectifier, 20 ma., 135 volts rms
T_1: Output transformer for matching speaker voice-coil impedance to 6600-ohm plate-to-plate tube load, Stancor type A8056 or equivalent
T_2: Power transformer, 360-0-360 volts rms, 120 ma., Stancor type PC 8410 or equivalent

Fig. 1 - Circuit of high-fidelity amplifier using RCA-6973's with fixed bias.

Fixed bias for the 6973's is obtained simply and inexpensively from a half-wave rectifier circuit supplied by a capacitance-resistance voltage divider across one side of the high-voltage winding. Capacitors C_2, C_6,

and C_7 are used to improve the stability of the amplifier at the higher audio frequencies. The values shown for these capacitors were chosen to match the characteristics of the Stancor Type A8056 output transformer,

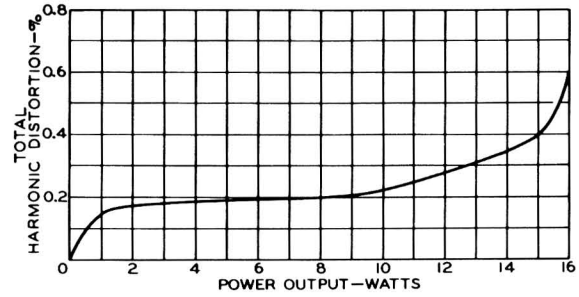


Fig. 2 - Total harmonic distortion produced by the amplifier shown in Fig. 1, as a function of power output.

and consequently, may require modification if a different transformer is used.

Low-Cost Amplifier

Fig. 4 shows the circuit of an amplifier using 6973's with cathode-resistor bias, and a 12AX7 as an input voltage amplifier and "floating

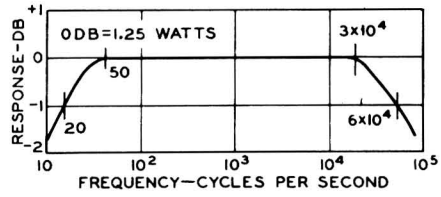


Fig. 3 - Frequency-response characteristic of the amplifier shown in Fig. 1.

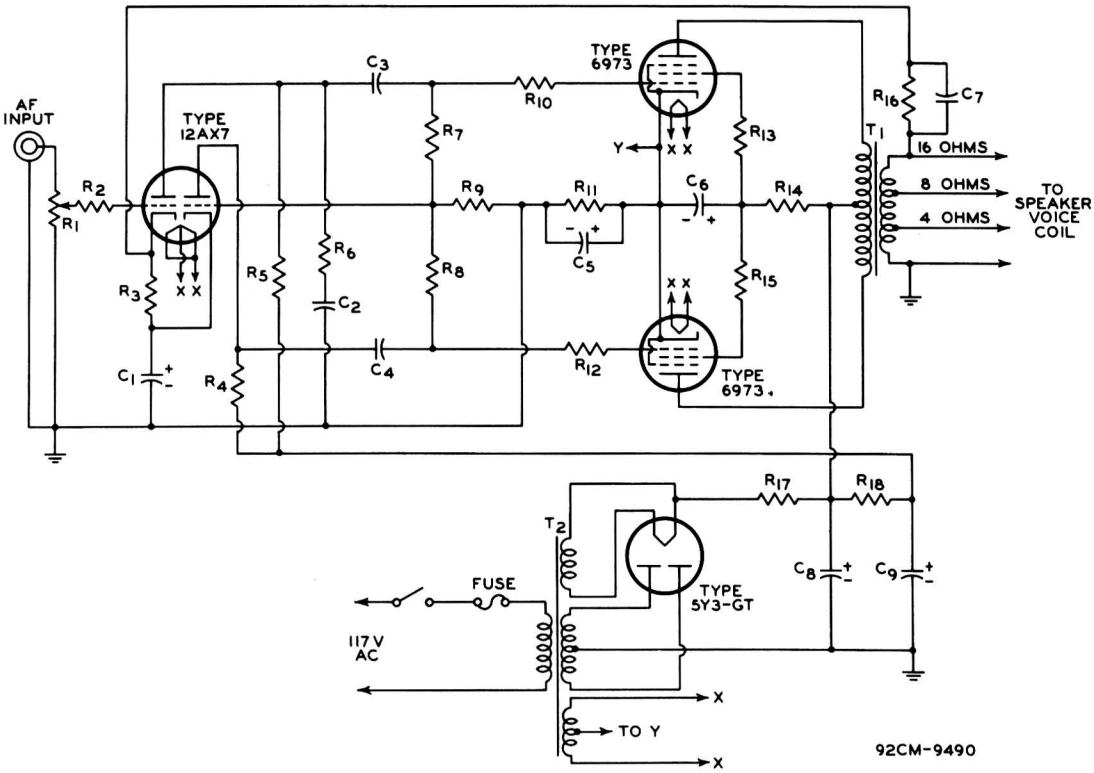
paraphase" phase inverter. It requires substantially fewer components than the amplifier shown in Fig. 1, employs approximately 14 db of overall inverse feedback, and provides very good performance at low cost. This amplifier can deliver a maximum-signal power output of 10 watts (actual power delivered to a resistive load) with less than 0.5 per cent distortion, and 14 watts with only 1.5 per cent distortion (see Fig. 5). It has very good frequency-response characteristics (see Fig. 6), and a sensitivity of 1.7 volts RMS for full (15 watts) output. Combined hum and noise level input circuit open are 75 db below 15 watts. The values used for the stabilizing components (R_6, C_2, and C_7) were chosen to match the characteristics of the Triad Type S31A output transformer.

The feedback connections for both amplifiers should be made between the points shown in the circuit diagrams, regardless of the taps used for the speaker connections.

Other Applications

Because of its high grid-No. 2 voltage rating, the 6973 is particularly suitable for use in grid-No. 2-feedback ("ultra-linear") type amplifier

circuits. In this type of circuit the screen grid of each 6973 is connected to a tap on the plate winding of the output transformer and contributes a portion of the useful power output. A class AB_1 amplifier



C_1: 50 μf, 10 v., electrolytic
C_2: 680 $\mu\mu$f, 400 v., mica or ceramic
C_3 C_4: 0.1 μf, 600 v., paper
C_5: 50 μf, 50 v., electrolytic
C_6: 30 μf, 450 v., electrolytic
C_7: 1000 $\mu\mu$f, 400 v., mica or ceramic
C_8 C_9: 40 μf, 450 v., electrolytic
Fuse: 2 amps, 150 v.
R_1: Volume control, 500,000-ohm potentiometer, audio taper
R_2: 10,000 ohms, 0.5 watt
R_3: 100 ohms, 0.5 watt
R_4: 120,000 ohms, 0.5 watt
R_5: 100,000 ohms, 0.5 watt
R_6: 4700 ohms, 0.5 watt
R_7: 220,000 ohms, 0.5 watt
R_8: 270,000 ohms, 0.5 watt
R_9: 47,000 ohms, 0.5 watt
R_{10} R_{12} R_{16}: 1000 ohms, 0.5 watt
R_{11}: 240 ohms, 2 watts
R_{13} R_{15}: 47 ohms, 0.5 watt
R_{14}: 3300 ohms, 0.5 watt
R_{17}: 68 ohms, 0.5 watt
R_{18}: 3900 ohms, 1 watt
T_1: Output transformer for matching speaker voice coil impedance to 8000-ohm plate-to-plate tube load, Triad type S31A or equivalent
T_2: Power transformer, 300-0-300 volts rms, 120 ma, Thordarson type T22R05 or equivalent

Fig. 4 - Circuit of high-fidelity amplifier using RCA-6973's with cathode-resistor bias.

stage using the grid-No.2-feedback connection, has substantially lower output impedance and better regulation under varying load conditions than one using the conventional pentode connection. A disadvantage,

however, is the higher cost of the output transformer required. Examples of the performance obtainable from the 6973 in grid-No.2-feedback circuits are given in Table I.

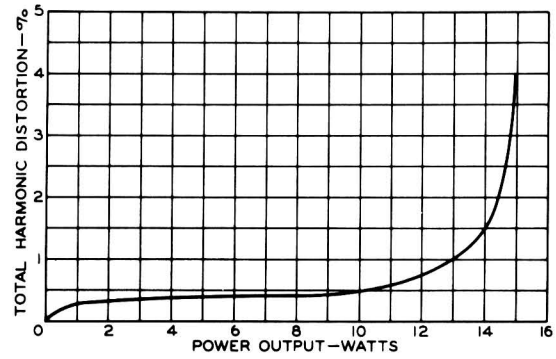


Fig.5 - Total harmonic distortion produced by the amplifier shown in Fig.4, as a function of power output.

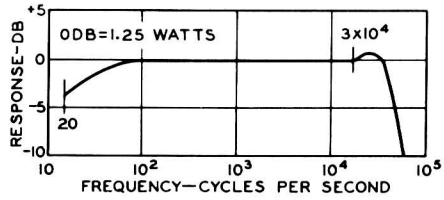


Fig.6 - Frequency-response characteristic of the amplifier shown in Fig.4.

Table I - General Technical Data for the RCA-6973 Beam Power Tube

Heater, for Unipotential Cathode:		
Voltage (AC or DC)	6.3	volts
Current	0.45	amp
Direct Interelectrode Capacitances (Without external shield):		
Grid No.1 to plate	0.7 max.	μμf
Grid No.1 to cathode & grid No.3, grid No.2, and heater	8	μμf
Plate to cathode & grid No.3, grid No.2 and heater	8.5	μμf

PUSH-PULL AF POWER AMPLIFIER - Class AB_1†

Pentode Connection

Maximum Ratings, *Design-Center Values:*

PLATE VOLTAGE	400	max.	volts
GRID-No.2 (SCREEN-GRID) VOLTAGE	300	max.	volts
PLATE DISSIPATION	12	max.	watts
GRID-No.2 INPUT	2	max.	watts
PEAK HEATER-CATHODE VOLTAGE:			
Heater negative with respect to cathode	200	max.	volts
Heater positive with respect to cathode	200▲	max.	volts
BULB TEMPERATURE (At hottest point on bulb surface)	250	max.	°C

Typical Operation with Fixed Bias:

Values are for 2 tubes

Plate Voltage	250	350	400	volts
Grid-No.2 Voltage	250	280	290	volts
Grid-No.1 (Control-Grid) Voltage°	-15	-22	-25	volts
Peak AF Grid-No.1 to Grid-No.1 Voltage	30	44	50	volts
Zero-Signal Plate Current	92	58	50	ma
Max.-Signal Plate Current	105	106	107	ma
Zero-Signal Grid-No.2 Current	7	3.5	2.5	ma
Max.-Signal Grid-No.2 Current	16	14	13.7	ma
Effective Load Resistance (Plate to plate)	8000	7500	8000	ohms
Total Harmonic Distortion	2	1.5	2	%
Max.-Signal Power Output	12.5	20	24	watts

Typical Operation with Cathode Bias:

Values are for 2 tubes

Plate Supply Voltage	300	310	volts
Grid-No.2 Supply Voltage	300	310	volts
Cathode-Bias Resistor	230	270	ohms
Peak AF Grid-No.1 to Grid-No.1 Voltage	48	55	volts
Zero-Signal Plate Current	80	77	ma
Max.-Signal Plate Current	96	92	ma
Zero-Signal Grid-No.2 Current	6	5	ma
Max.-Signal Grid-No.2 Current	14	14	ma
Effective Load Resistance (Plate to plate)	5500	6000	ohms
Total Harmonic Distortion	2	4	%
Max.-Signal Power Output	15	17	watts

Maximum Circuit Values:°

Grid-No.1-Circuit Resistance:		
For fixed-bias operation	0.5 max.	megohm
For cathode-bias operation	1 max.	megohm

PUSH-PULL AF POWER AMPLIFIER - Class AB_1†

Grid No. 2 of Each Tube Connected to Tap on Plate Winding of Output Transformer

Maximum Ratings, *Design-Center Values:*

PLATE AND GRID-No. 2 SUPPLY VOLTAGE	375	max.	volts
PLATE DISSIPATION	12	max.	watts
GRID-No. 2 INPUT	1.75	max.	watts
PEAK HEATER-CATHODE VOLTAGE:			
Heater negative with respect to cathode	200	max.	volts
Heater positive with respect to cathode	200▲	max.	volts
BULB TEMPERATURE (At hottest point on bulb surface)	200	max.	°C

Typical Operation:

Values are for 2 tubes

	Fixed Bias	*Cathode Bias*	
Plate Supply Voltage	375	370	volts
Grid-No. 2 Supply Voltage	*	#	volts
Grid-No. 1 (Control-Grid) Voltage°	33.5	-	volts
Cathode-Bias Resistor		355	ohms
Peak AF Grid-No. 1 to Grid-No. 1 Voltage	67	62	volts
Zero-Signal Cathode Current	62	74	ma
Max.-Signal Cathode Current	95	84	ma
Effective Load Resistance (Plate to plate)	12500	13000	ohms
Total Harmonic Distortion	1.5	1.2	%
Max.-Signal Power Output	18.5	15	watts

Maximum Circuit Values:°

Grid-No. 1-Circuit Resistance:			
For fixed-bias operation	0.5	max.	megohm
For cathode-bias operation	1	max.	megohm

† Subscript 1 indicates that grid-No. 1 current does not flow during any part of the input cycle.

▲ The dc component must not exceed 100 volts.

° The type of input coupling network used should not introduce too much resistance in the grid-No. 1 circuit. Transformer or impedance-coupling devices are recommended.

* Obtained from taps on the primary winding of the output transformer. The taps are located on each side of the center tap (B+) so as to apply 50 per cent of the plate signal voltage to grid No. 2 of each output tube.

\# Obtained from taps on the primary winding of the output transformer. The taps are located on each side of the center tap (B+) so as to supply 43 per cent of the plate signal voltage to grid No. 2 of each output tube.