ELECTRON TUBES

RCA Application Note

AN - 139
March 15, 1949

Characteristics of Pentodes and Triodes in Mixer Service

This Note gives mixer information, including typical operating conditions and approximate characteristics, for a number of pentode and triode types.

The characteristics of a tube used as a mixer may be derived from the amplifier characteristics of that tube by application of Fourier analysis. Detailed analysis reveals, however, that satisfactory approximations of the mixer characteristics can be obtained by assuming simple proportionality relationships between the mixer characteristics and the amplifier characteristics which apply to the peak of the local-oscillator cycle.

In the preparation of the data given in the tabulations of mixer characteristics (Tables I, II, III, and IV), the following conditions were considered:

1. Pentode grid-No.2 voltages and triode plate voltages are chosen to permit the use of moderate oscillator injection voltages and, of course, to provide operating conditions within tube ratings.

2. The data are derived for peak values of oscillator voltage one volt less than the control-grid bias voltages. This condition may cause a small amount of grid current in some tubes, but the additional input conductance caused by the grid current is not important except at low frequencies. The majority of applications for pentode and triode mixers, at the present time, are at frequencies above forty megacycles.

3. For sharp-cutoff pentodes and triodes, the control-grid bias is chosen so that the plate current for zero oscillator voltage is reduced to about one-tenth the value observed at one-volt bias.

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4. For remote-cutoff pentodes, the control-grid bias is chosen so that the transconductance for zero oscillator voltage is reduced to about one-quarter the value observed at one-volt bias.

The proportionality factors applicable under the given conditions are as follows:

Mixer Characteristic	Derived from Amplifier Characteristic	Proportionality Factor* Sharp-Cutoff Triodes & Pentodes	Proportionality Factor* Remote-Cutoff Pentodes
Plate Current (i_b)	Peak Plate Current	0.30	0.45
Grid-No.2 Current (i_{c2})	Peak Grid-No.2 Current	0.30	0.45
Plate Conductance (g_p)	Peak Plate Conductance	0.40	0.40
Input Conductance (g_{in})	Peak Input Conductance	0.40	0.40
Average Transconductance (g_m)	Peak Transconductance	0.40	0.40
Conversion Transconductance (g_c)	Peak Transconductance	0.27	0.23

$$* \text{ Proportionality Factor} = \frac{\text{Mixer Characteristic}}{\text{Amplifier Characteristic}}$$

Use of the Tables

The operating conditions chosen for the tubes listed give approximately the maximum values of conversion transconductance obtainable with the stated grid-No.2 or plate voltage. Consequently, the values of conversion transconductance and input conductance shown may be used in the same manner as the transconductance and input-conductance data for rf amplifiers in calculating the stage gain, provided the required oscillator voltage is applied. The input conductance values, which are given for a frequency of 100 megacycles, may be assumed to vary directly with the square of the frequency. The average transconductance values may be used to calculate the gain with an if signal applied to the control grid, provided such a test can be made without materially changing the oscillator amplitude. The values of plate current and grid-No.2 current are useful for indicating when the correct oscillator voltage has been obtained.

The cathode resistor values listed will give approximately the indicated bias voltages when the oscillator voltage is applied. Deviations of ±10 per cent from these values can be tolerated; they will have little effect on tube performance.

In cases where difficulty is experienced in obtaining the required oscillator voltage, it is usually preferable to operate the pentode or triode mixer with reduced grid-No.2 or plate voltage. With high grid-No.2 or plate voltage and low oscillator voltage, the ratio of average transconductance to conversion transconductance is higher than necessary with the result that plate or grid-No.2 current is also high with respect to the conversion transconductance obtained. This condition leads to excessive input conductance and excessive noise. When the available oscillator voltage is limited, the grid-No.2 or plate voltage for sharp-cutoff tubes should be chosen so that as the oscillator voltage swings from its peak value to zero, the plate current varies over a range of 10 to 1. On the other hand, when the oscillator voltage is higher than the optimum value there is generally only a small loss in conversion transconductance.

Table I - Characteristics and Typical Operating Conditions for Remote-Cutoff Pentodes used as Mixer Tubes

	Tube Type					
	6SK7	6SG7	6BA6	6BJ6	9003	
Plate Voltage	250	250	250	250	250	volts
Grid-No.2 Voltage	100	150	125	125	100	volts
Grid-No.1 Voltage	-8.5	-4.5	-4.5	-4.5	-6.0	volts
Plate Current	6.1	7.4	7.6	6.1	5.0	ma
Grid-No.2 Current	1.2	2.7	2.9	2.2	2.0	ma
Cathode Resistor	1200	470	470	560	820	ohms
Peak Oscillator Voltage	7.5	3.5	3.5	3.5	5.0	volts
Input Conductance (100 Mc)	240	340	300	150	32	μmhos
Average Transconductance	980	2000	2000	1700	1000	μmhos
Conversion Transconductance	560	1150	1150	1000	580	μmhos

Table II - Characteristics and Typical Operating Conditions for Sharp-Cutoff Pentodes used as Mixer Tubes

	Tube Type									
	6SJ7	6SH7	6AC7	6AU6	6BH6	6AG5	12AW6	6AK5	9001	
Plate Voltage	250	250	250	250	250	250	250	180	250	volts
Grid-No.2 Voltage	125	150	150	150	150	150	150	120	100	volts
Grid-No.1 Voltage	-6.5	-4.0	-3.5	-3.5	-3.5	-3.5	-3.5	-4.0	-4.5	volts
Plate Current	2.9	3.3	6.3	3.2	2.2	3.3	3.3	4.1	1.6	ma
Grid-No.2 Current	0.8	1.2	1.5	1.3	0.9	0.9	0.9	1.3	0.6	ma
Cathode Resistor	1800	1000	470	810	1000	810	810	810	2200	ohms
Peak Oscillator Voltage	5.5	3.0	2.5	2.5	2.5	2.5	2.5	3.0	3.5	volts
Input Conductance (100 Mc)	300	260	1040	300	140	140	160	80	32	μmhos
Average Transconductance	1000	1960	5400	2100	1800	2100	2100	2900	800	μmhos
Conversion Transconductance	680	1300	3600	1400	1240	1430	1430	1940	540	μmhos