

New High-Gain Tubes For IF-Amplifier and Limiter Stages Of FM Tuners

This Note discusses the application of a new family of pentode tubes in the if-amplifier and limiter circuits of FM tuners. The characteristics of the tubes are compared with both the circuit requirements and the characteristics of other popular if-amplifier tubes. In addition, FM tuners having two and three if-limiter stages using the new family of tubes are described.

General Considerations

The operational requirements for FM stereo tuners are more severe than those specified for monaural tuners. A stereo tuner should have improved quieting sensitivity because of the substantially poorer signal-to-noise ratio associated with the greater over-all bandwidth desired in the FCC-approved stereo system. The RCA types 6HR6, 19HR6, 6HS6, and 19HS6 were developed to satisfy these more severe stereo requirements, as well as to improve monaural reception.

In a broad sense, these tubes are useful in any rf or if amplifier requiring high transconductance and low grid-No.1-to-plate capacitance. In particular, they can be advantageously applied to systems which use relatively low impedances in the grid-No.1 and plate circuits. They are especially suitable for use in such applications as FM if amplifiers and TV sound if amplifiers.

FM IF-Amplifier Requirements

A tube designed for use in FM if-amplifier circuits should have the following characteristics: (1) high transconductance, (2) low grid-No.1-to-plate capacitance, (3) high ratio of transconductance to grid-No.1-to-plate capacitance, (4) high plate resistance, and (5) relatively low supply-current requirements.

The ratio of transconductance to grid-No.1-to-plate capacitance is one of the more significant factors determining the suitability of a pentode for use in relatively narrow-bandwidth if-amplifier circuits. Although high transconductance can permit high gain in an if-amplifier stage, the transconductance is usable only if the stage is stable. If only the tube is considered, the grid-No.1-to-plate capacitance is the principal factor responsible for instability, and the usable transconductance of a pentode for radio circuits can be considered to be a function of this capacitance. The choice of a tube for FM if-amplifier service, therefore, depends primarily on the levels of transconductance and grid-No.1-to-plate



capacitance and the ratio between the two characteristics. In addition, the plate resistance should be sufficiently high to avoid loading the circuit.

Characteristics of New RCA Tubes

The 6HR6, 19HR6, 6HS6, and 19HS6 are very-high-transconductance pentodes having grid-No.1-to-plate capacitances considerably below 0.01 picofarad. The 6HS6 and 19HS6 are sharp-cutoff pentodes, and the 6HR6 and 19HR6 are semiremote-cutoff pentodes. The 19HR6 and 19HS6 use 150-milliampere heaters having controlled warmup time for series-string operation. The characteristics of the 6HR6 and 6HS6 are compared with those of several other popular if-amplifier tubes in Table I. Although higher levels of transconductance can be obtained from the 6HR6 and 6HS6 by the use of higher grid-No.2 voltages, the tubes usually operate more efficiently at lower levels.

Tube Type	Plate Volts	Grid-No.2 Volts	Plate and Grid-No.2 Ma.	Transconductance (μ mhos)	Plate Resistance (megohms)	Max. Grid-No.1-to-Plate Capacitance (pf)	Ratio of Transconductance to Grid-No.1-to-Plate Capacitance ($\times 10^{11}$)
Sharp-Cutoff Pentodes							
6HS6	150	75	11.6	9500	0.5	0.006	15.85
6AU6A	250	150	14.9	5200	1.0	0.0035	14.85
6CB6	125	125	16.7	8000	0.28	0.015*	5.3
Remote-Cutoff Pentodes							
6HR6	200	115	17.5	8500	0.5	0.006	14.2
6BA6	250	100	15.2	4400	1.0	0.0035	12.6
6BZ6	125	125	17.6	8000	0.26	0.015*	5.3

* With external shield.

Table I - Static Characteristics of IF-Amplifier Tubes.

Limiter Stages

A typical limiter circuit is shown in Fig.1. In most limiter stages, tubes are operated at reduced plate and grid-No.2 voltages to provide limiting at low signal levels. A typical value for plate and grid-No.2 voltages is 50 volts. Table II shows that the transconductance of the 6AU6A at this voltage is only slightly more than half the value listed in Table I. If an unbypassed cathode resistor is used to minimize the detuning effect caused by variations in grid-No.1 bias, as shown by the dashed lines in Fig.1, transconductance is reduced even further. Actual transconductance levels of the 6AU6A in typical limiter circuits, therefore, are considerably below the value shown in Table I.

An exception to this generalization occurs in the inexpensive two-stage if/limiter table radio. The second if-amplifier stage of such receivers performs the function of a limiter when the input signal is large. In this case, however, the tube is usually operated with relatively high plate and grid-No.2 voltages (perhaps 100 volts) because high transconductance is necessary to obtain the high gain required from this stage.

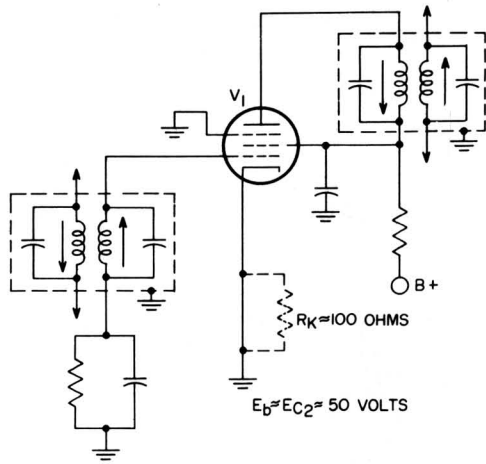
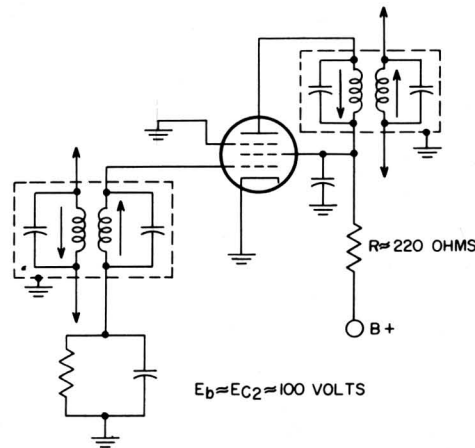


Fig. 1 - Typical limiter circuit.

These voltages are generally obtained directly from the B+ supply, as shown in Fig. 2, with only sufficient resistance for adequate decoupling of the stage.

Fig. 2 - IF/limiter stage used in two-stage table radio.



When the 6HS6 is operated at the conditions shown in Fig. 1, its transconductance is still relatively high. As a result, it can provide in this circuit the higher gain generally associated only with the circuit of Fig. 2. Table II compares the characteristics of the 6HS6 and the 6AU6A at the conditions used in the limiter circuits of Figs. 1 and 2. The 6HS6 has higher transconductance in the circuit of Fig. 1 than the 6AU6A in the circuit of Fig. 2, and almost comparable transconductance even when an unbypassed cathode resistor is used.

Circuit	Plate and Grid-No. 2 Volts	Grid-No. 1 Resistor (megohms)	Unbypassed Cathode Resistor (ohms)	Transconductance (μ mhos)	
				6AU6A	6HS6
Fig. 2	100	0.47	none	4300	10000
Fig. 1	50	0.47	none	2700	6400
Fig. 1	50	0.47	100	1850	3300
Fig. 1	100	0.47	100	2500	3900

Table II - Effect of Circuit Changes on Transconductance.



Although the cutoff characteristic of the 6HS6 is slightly less sharp than that of the 6AU6A at equal grid-No.2 voltages, the use of lower grid-No.2 voltages provides the sharper cutoff desired. Table III shows the relationship between grid-No.2 voltage, transconductance, and grid-No.1 cutoff voltage for the 6HS6 and the 6AU6A. When the plate and grid-No.2 voltages are reduced from 50 to 40 volts, the 6HS6 has the same cutoff point as the 6AU6A at 50 volts, with almost twice as much transconductance.

Tube Type	Plate and Grid-No.2 Volts	Transconductance (μ hos)	Grid-No.1 Cutoff Volts* ($I_b = 10 \mu a$)
6AU6A	50	2700	-2.6
6HS6	50	6400	-3.0
6HS6	40	5300	-2.6
6HS6	21	2700	-1.85

*Grid-No.1 resistor = 470,000 ohms.

Table III - Effect of Grid-No.2-Voltage Changes on Transconductance and Cutoff Characteristics.

IF Stages

Most if-amplifier tubes operate with cathode bias. In many cases, it is desirable to use an unbypassed cathode resistor to minimize the detuning effect caused by variations in input capacitance as a result of changing grid-No.1 bias. A major factor contributing to this change in input capacitance is the variation in the space-charge density about the No.1 grid.

If stable operation is assumed, the use of an unbypassed cathode resistor reduces gain appreciably from that obtained with a bypassed resistor. This reduction in gain is caused by the substantial decrease in transconductance. The 6HR6 and 6HS6, however, provide about the same level of transconductance with an unbypassed cathode resistor that the 6BA6 and 6AU6A provide with a bypassed cathode resistor. Values of transconductance for the 6HR6, 6HS6, 6BA6, and 6AU6A at bypassed and unbypassed conditions are shown in Table IV.

Prior to the introduction of the 6HR6 and 6HS6, it was difficult to obtain stable operation in FM if-amplifier stages with very-high-transconductance tubes because of high grid-No.1-to-plate capacitances. High-transconductance operation of the 6HR6 and 6HS6 was not investigated because suitable FM if transformers were not available.

FM Receivers Using Two and Three IF/Limiter Stages

FM receivers using the 6HR6 and 6HS6 in two and three if/limiter stages have been developed to compare performance with late-model commer-

Tube Type	Cathode Bypass Capacitor	Transconductance* (μ hos)
6BA6	Yes	3800
6AU6A	Yes	4300
6BA6	No	2500
6AU6A	No	2600
6HR6	No	3700
6HS6	No	4000

* Plate and grid-No.2 volts = 100; cathode resistor = 100 ohms.

Table IV - Effect of Cathode Bypass Capacitor on Transconductance.



cial table radios and tuners. The schematics of the if/limiter stages for these developmental systems are shown in Figs. 3 and 4, respectively.

The two-stage circuit shown in Fig. 3 had improved sensitivity for 30 db of quieting, higher gain (or better volume sensitivity), and limiting at much lower signal levels than comparable commercial sets. Performance data for this developmental system are given in Table V. Further improvements in volume sensitivity and limiting can be obtained by use of a higher-gain tuner than the 35-db tuner indicated.

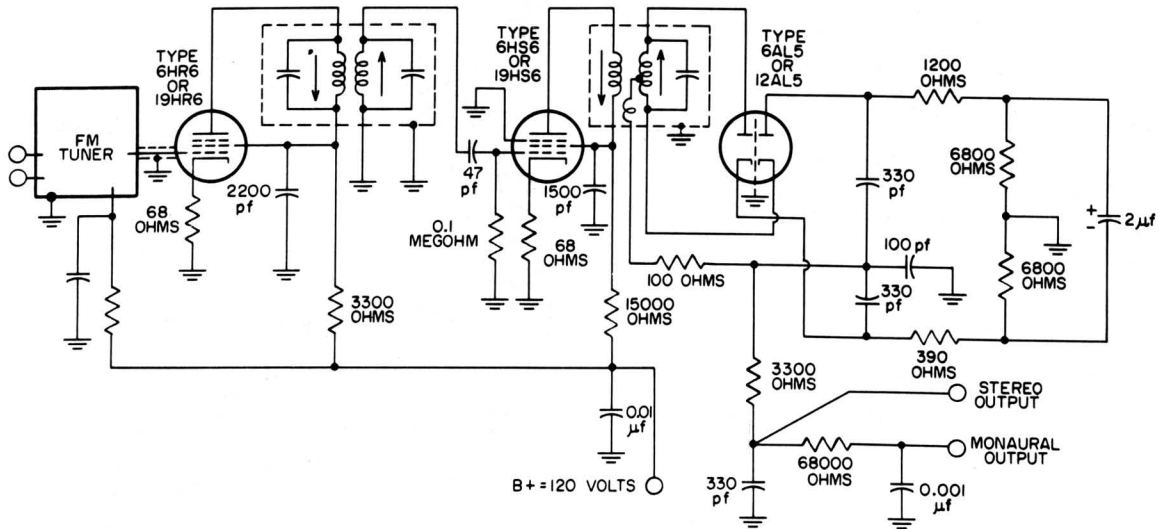


Fig. 3 - Two-stage if/limiter circuit for FM tuner.

Rated Tuner Gain.	35 db
Peak Separation of Detector	440 kc
IF Bandwidth from Grid No. 1 of First IF Amplifier (6 db down).	300 kc
Quieting Sensitivity:	
20 db Signal-to-Noise Ratio	2.8 μ v
30 db Signal-to-Noise Ratio	4.1 μ v
RF Input to Tuner for Output at Ratio Detector of 0.1 volt.	19 μ v
Limiting:	
1 db Down from Maximum Output at Ratio Detector	250 μ v

Table V - Performance Data for Two-Stage Circuit Shown in Fig. 3.

The three-stage circuit shown in Fig. 4 also had higher if gain than comparable commercial receivers. This higher gain helped to compensate for the lower gain of some of the relatively low-noise tuners, and thus resulted in improved over-all performance. Data for this developmental system are given in Table VI.

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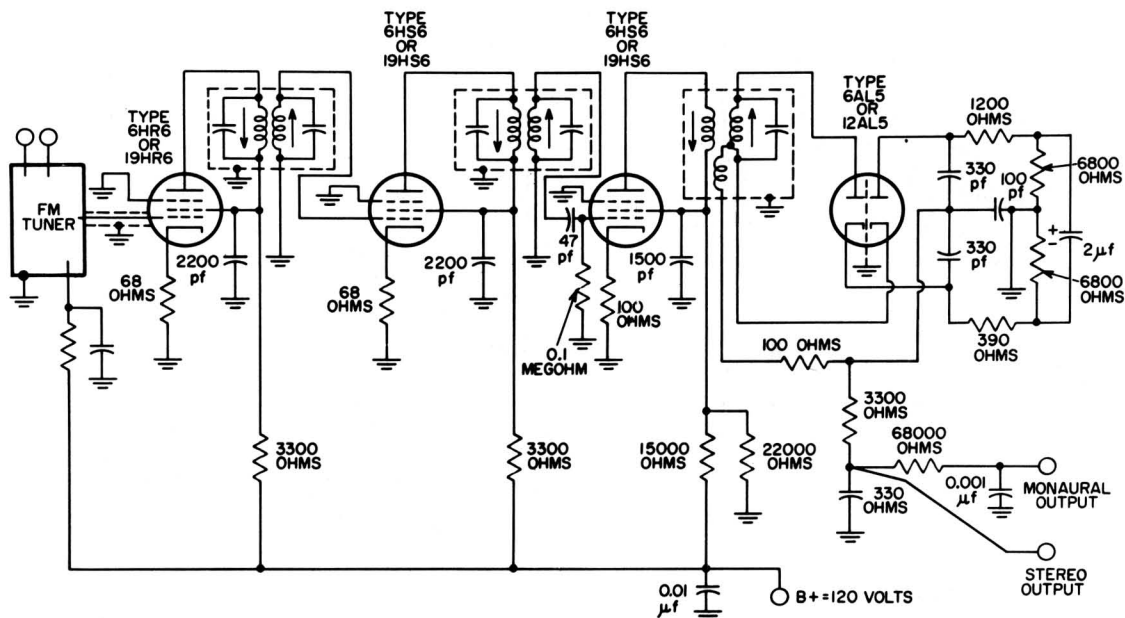


Fig.4 - Three-stage if/limiter circuit for FM tuner.

Rated Tuner Gain.	35 db
Peak Separation of Detector	405 kc
IF Bandwidth from Grid No.1 of First IF Amplifier (6 db down).	220 kc
Quieting Sensitivity:	
20 db Signal-to-Noise Ratio	1.8 μ v
30 db Signal-to-Noise Ratio	2.6 μ v
IF Input to Grid No.1 of First IF Amplifier for Output at Ratio Detector of 0.1 volt.	
	60 μ v
Limiting:	
1 db Down from Maximum Output at Ratio Detector	5.3 μ v

Table VI - Performance Data for Three-Stage Circuit Shown in Fig.4.

