ELECTRON TUBES
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Use of the 6BA6 and 6BE6 Miniature Tubes in FM Receivers

The expanding requirements of modern receiver design have resulted in the development of several new tubes which may be used to advantage in both FM and standard broadcast bands. Two of these, the 6BA6 and the 6BE6, are new miniature tubes particularly suitable for the rf and converter positions of dual-purpose FM/AM receivers.

Description of the 6BA6

The 6BA6 is a high-frequency pentode in a miniature glass envelope. A sectional view of this tube is given in Fig.1. Some of the distinguishing features of the tube are noted here. A double-helical heater coil is used to minimize difficulties with hum. A reduction in microphonics is obtained by the inverted pinch-weld which is used in making the cathode assembly. This method of construction is accomplished by drawing an embossing on the cathode against the under side of the mica and pinching the portion of the sleeve above the mica. Because the cathode is free to slide in the bottom mica, it cannot become bowed due to expansion. In order to take maximum advantage of the coated area of the cathode, the control grid is formed to the shape of the cathode. This formed grid permits greater grid-to-cathode spacing for a given transconductance and, consequently, the possibility of grid-to-cathode shorts is reduced. In addition, the combination of a round cathode and a formed grid results in a rugged construction which also helps to reduce microphonics. The lateral wires of the control grid are silver plated in order to minimize variations in sensitivity at low signal levels. The use of copper-alloy side rods for control and screen grids provides maximum heat conduction for these electrodes. Because the plate area is small, the grid-to-plate capacitance, due in part to the internal shielding, is only 0.003 µµf. If an external shield is used, this value is reduced by approximately ten per cent. The total input and output capacitance is only 10.5 µµf. Input loading due to lead inductance is reduced because of the direct-through, short leads afforded by miniature tube construction. Under 250-volt operating conditions, the input resistance

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of the 6BA6 at 100 megacycles is approximately 1600 ohms and the transconductance is 4400 micromhos.

Description of the 6BE6

The 6BE6 is a single-ended, glass, miniature converter. It is equivalent in most characteristics to the 6SA7 and is similar in electrode arrangement (Fig.2). In construction, it is similar to the 6BA6 in that it has a formed oscillator (No.1) grid, an inverted and pinched cathode, copper-alloy side rods, a double-helical heater coil, and short stem leads. The formed grid utilizes the emitting surface of the cathode very efficiently and, therefore, provides a very high oscillator transconductance of 7250 micromhos. Under 250-volt operating conditions, the conversion transconductance is 475 micromhos.

Performance in the Frequency-Modulation Band

At high frequencies, tubes and their associated circuits are essentially inseparable. In order, therefore, to provide reliable and useful measurements, the circuit used must be a representative one. The FM test receiver of Fig.3 was employed because the mechanical arrangement and choice of component parts are based on contemporary good design practices and because it is representative of practical possibilities.

In this circuit, the converter is followed by an intermediate-frequency amplifier having two 6BA6 stages. The if system, which has a bandwidth of approximately 200 kilocycles centered at 10.7 megacycles, is terminated by a square-law, vacuum-tube voltmeter. The voltage gain from the first if grid to the voltmeter is 1750. The overall if gain, measured from the converter grid, is 18,000. The first if transformer is over-coupled in order to obtain a substantially uniform gain throughout the 200-kilocycle band. The second and third transformer are approximately critically coupled.

It is desirable, of course, to obtain performance data both with and without the rf stage. In either case, the signal is applied to the signal circuit through a 300-ohm resistor. The effects of induced oscillator voltage in the signal circuit, interaction between oscillator and signal circuits, and input loading can be observed with and without the rf stage. Likewise, the improvement in signal-to-noise ratio, selectivity, and image rejection due to the use of an rf stage can be ascertained. When the signal is applied (through 300 ohms) to the signal-grid (grid-No.3) circuit of the converter, the measured gain from the terminals of the signal generator to the first if grid is 5.5. The equivalent noise is 7 microvolts. For optimum performance, the signal grid is placed 1-1/2 turns from the ground end of a coil of 1-3/4 turns. The antenna connection is made at 1-1/4 turns on the same coil. The image rejection is 26 db.

When the 6BA6 rf stage is added and the circuit adjustments necessary for stable operation are made, the measured gain from the signal

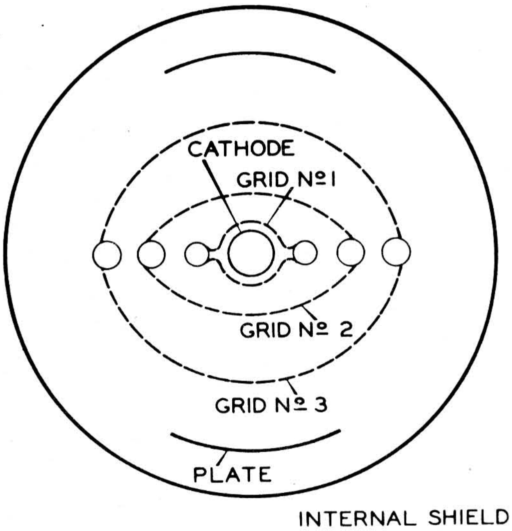


Fig. 1 - RCA-6BA6 Electrode Structure and Arrangement.

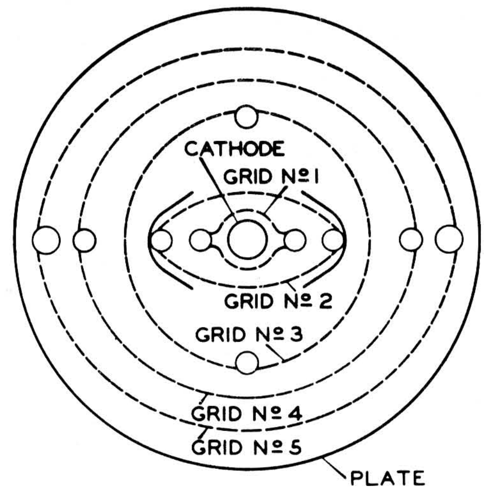
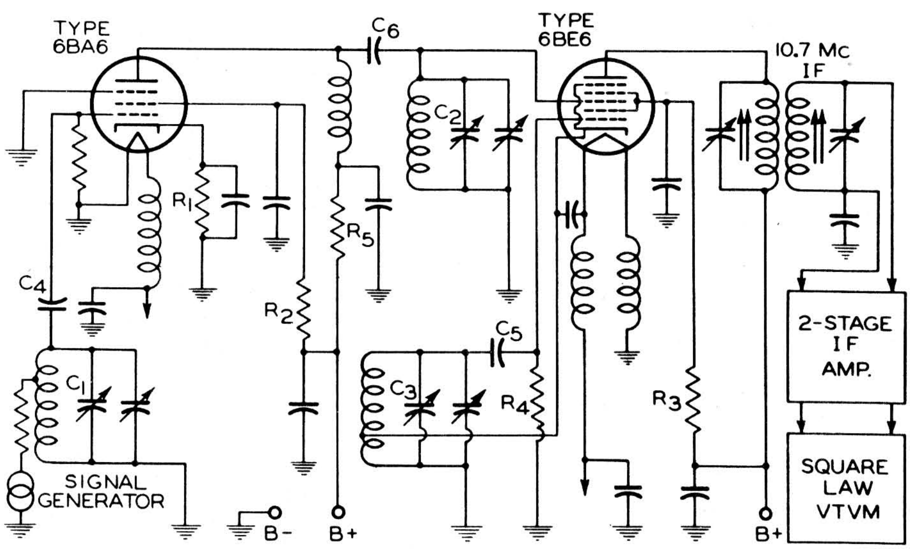


Fig. 2 - RCA-6BE6 Electrode Structure and Arrangement.



C_1 C_2 C_3 = Ganged Tuning Capacitor 7.5 - 18 $\mu\mu$f

C_4 C_5 = 22 $\mu\mu$f

C_6 = 100 $\mu\mu$f

C_7 = 33 $\mu\mu$f

C_8 to C_{15} = 1000 $\mu\mu$f

C_{16} C_{17} C_{18} = Trimmer Capacitor 1.5 - 7.0 $\mu\mu$f

R_1 = 68 ohms

R_2 = 40000 ohms

R_3 = 22000 ohms

R_4 = 20000 ohms

R_5 = 150 ohms

L_1 L_2 L_3 = 0.1 μh approx. 1-3/4 turns of No. 14 tinned copper wire; coil diameter, 3/4"; spacing between turns, 1/2 coil diam.

L_4 L_5 L_6 L_7 = 26 turns of No. 16 enameled wire close wound on a 3/8" mandrel

Fig. 3 - Typical Self-Excited Converter Circuit for 6BE6 with 6BA6 RF Stage. For Operation at 88 to 108 Megacycles.

generator to the first if grid is 70. The equivalent noise is approximately 5.8 microvolts, or 17 db above the thermal noise of the 300-ohm resistor. Noise-free reception may properly be assumed when the signal is at least three or four times as great as the equivalent noise. The receiver will have satisfactory performance, consequently, when the input signal is 25 microvolts. Addition of the rf stage increases the image rejection from 26 db to 55 db.

It is natural for the oscillator frequency to undergo a fractional percentage drift during the warm-up period. This drift is due to a slight change in effective capacitance (Δc) of the oscillator LC circuit. As no compensation for this change is provided in the circuit, it is of interest to determine the amount of change (Δc) in oscillator-circuit capacitance as a function of time for the 6BE6 alone. This test was made by placing the cold 6BE6 in operation in the receiver which had already been warmed up. Because a ceramic type of socket was employed, the effect of its temperature change on frequency drift was negligible. As the values of Fig.4 (Δc versus time) were obtained in this manner, they apply almost wholly to the tube itself.

Method of Circuit Adjustment

The adjustment of pentagrid converter circuits operating at high frequencies is complicated by the fact that there is an appreciable amount of coupling and interaction between the oscillator and signal-grid circuits. In addition, negative admittance across the signal-grid circuit causes appreciable regeneration. Parasitic oscillations, too, may occur when the signal-grid circuit is improperly adjusted. Use of the following procedure, however, will result in correct circuit adjustment with a minimum of difficulty.

1. Connect the signal grid of the converter to ground, adjust the cathode tap of the oscillator for maximum oscillator-grid current, and then vary the oscillator inductance and the size of the fixed capacitance to furnish the desired amounts of frequency variation with the tuning capacitor used.

2. Apply the if signal directly to the signal grid of the converter and adjust the first if transformer for desired response.

3. Apply the rf signal directly to the signal grid of the converter and adjust the cathode tap for maximum gain. It should be necessary to move the cathode tap only slightly lower than the previous position for maximum oscillator-grid current. The conversion gain under this condition with an if transformer impedance of 12,000 ohms should be approximately six.

4. Place the signal-grid coil back in the circuit by connecting the grid to a tap approximately one turn from the top of the coil. Connect the signal generator through a 300-ohm resistor to a tap on the grid coil of the converter approximately one turn from the bottom. Adjust the values of inductance and fixed capacitance so that tracking is obtained throughout the band. The tuning of the signal-grid circuit of the converter will affect the loading of the

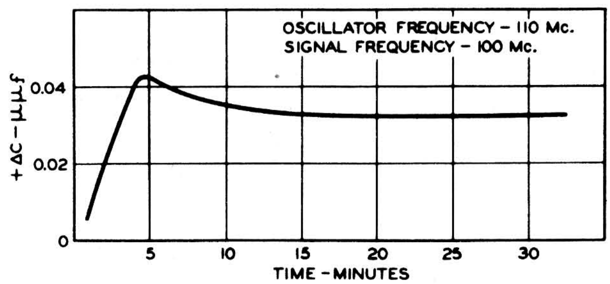


Fig.4 – 6BE6 Warm-up Capacitance Shift in FM Band.

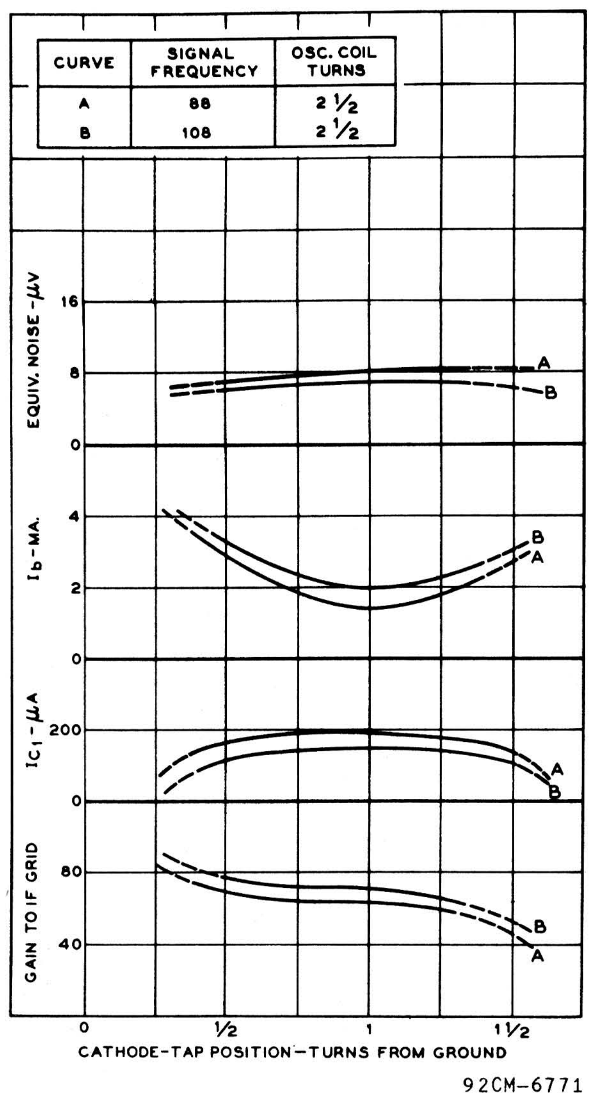


Fig.5 – Operation Characteristics of 6BE6 With Change of Cathode-Tap Position in Circuit of Fig.3.

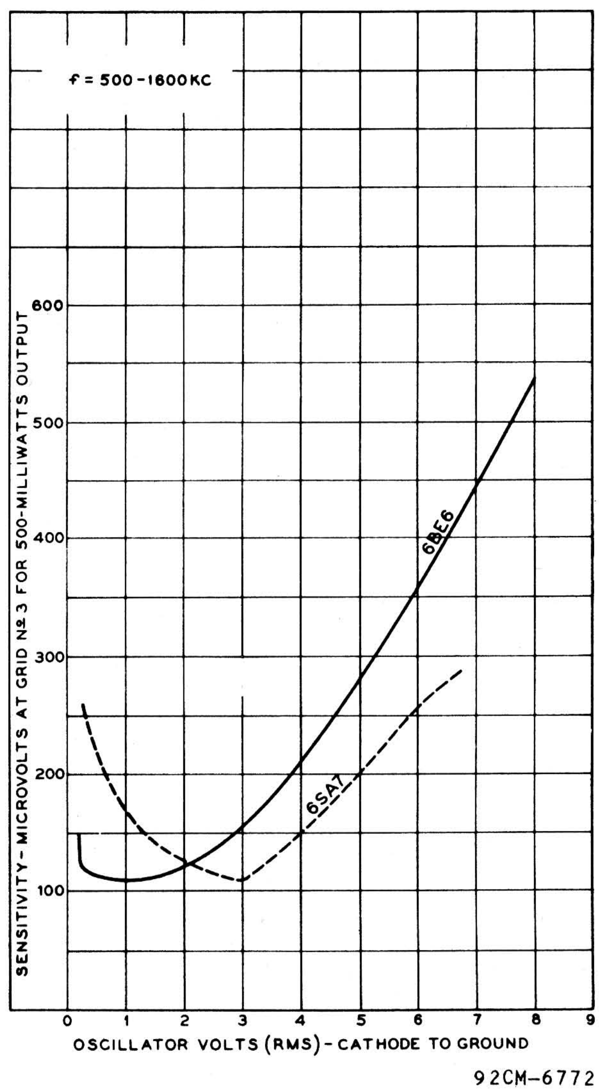


Fig.6 – Sensitivity of 6BE6 Compared With That of 6SA7.

oscillator thereby causing a change in oscillator-grid current and converter-plate current. This condition, while complicating the initial circuit adjustment, does not impair the receiver performance because the signal-grid circuit must be considerably detuned before the oscillator is appreciably affected. When the input circuit is properly tuned, the cathode tap may be re-adjusted to provide an oscillator-grid current of approximately 300 microamperes. This adjustment results in a converter-plate current of approximately 3 milliamperes and a screen current of approximately 7 milliamperes. Fig.5 shows oscillator-grid current, converter-plate current, conversion gain, and equivalent noise as a function of the position of the cathode tap.

5. After the converter has been properly adjusted, apply the signal to the grid of the rf amplifier and connect the amplifier plate to the top of the signal-grid coil of the converter through the coupling capacitor. A slight additional adjustment of the coil and the trimmer capacitor can now be made in order to obtain proper tracking.
6. Insert the antenna coil and change the values of inductance and fixed capacitance so as to obtain proper tracking. Connect the signal grid of the rf amplifier to the top of the coil. The signal generator is connected through 300 ohms to the tap.

It must be recognized that the efficiency of the oscillator circuit will affect the oscillator-grid current. This current should not be permitted to drop below 160 microamperes at the nominal supply voltage if operation is to be maintained satisfactorily at low line voltage. Since the inductance of the lead from the cathode tap on the coil to the tube socket accounts for considerable degeneration of the signal, it should be as short as possible. In order to reduce the effects upon the oscillator frequency of the variations in the heater-to-cathode capacitance, it is advisable to operate the heater at rf cathode potential in the manner indicated in the circuit diagram (Fig.3). This method of operation considerably reduces microphonic effects, caused by mechanical vibration or acoustic feedback.

Because considerable oscillator voltage is developed at the signal grid when the tube operates at high frequencies, it is necessary to return the signal grid to ground directly and not through the avc system. If appreciable resistance is placed in the signal-grid circuit, the grid current, due to the rectification of oscillator voltage at the signal grid, will develop a voltage across the grid resistance. This voltage will bias the tube and, consequently, reduce the conversion transconductance. No avc voltage, therefore, should be applied to the converter when it is operated in the FM band.

A 3-ohm resistor in series with the signal grid of the converter and connected as closely as possible to the grid terminal may remove parasitic oscillations. The gain, however, may be somewhat reduced. In the circuit used in these investigations, this expedient was not necessary.

Application of the 6BE6 in the Standard Broadcast Band

When the 6BE6 is used in the standard broadcast band, its sensitivity, as a function of the voltage across the oscillator-coil section between ground and cathode (with self-excitation) is given in the curves of Fig.6. For comparison, a curve for the 6SA7, the metal tube equivalent, is also given. The noise-equivalent resistance calculated for the 6BE6 is of the same order as the circuit impedance obtained in typical broadcast circuits (approximately 100,000 ohms). Since the increase in circuit noise is only 2 to 3 db, the use of an rf stage, from the standpoint of noise reduction, is unimportant. In the frequency range of 500 to 1600 kilocycles, the measured equivalent noise side-band input in a typical receiver with an antenna gain of 5 is 3.5 microvolts.

The maintenance of best signal-to-noise ratios with strong signals requires that the gain of the first tube be maintained as high as possible until the signal has become strong enough to override the noise. When the if tube is a 6BA6, it is desirable for best signal-to-noise ratios to apply full avc voltage to the if amplifier and approximately 25 per cent less avc voltage to the converter.

Application of the 6BE6 in the Short-Wave Bands

The cathode voltage at the low-frequency end of each band should be adjusted to approximately 0.8 volts (RMS). It is likely, however, to rise at the higher frequencies and cause some loss in sensitivity. The use of a 5- or 10-ohm resistor in the oscillator-grid lead may be needed to prevent parasitic oscillations.