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Mixer-Oscillator Circuit for FM and AM Using RCA-6J6 or RCA-19J6

RCA-6J6 and RCA-19J6 are twin-triode tubes designed to operate efficiently as oscillators and mixers at high frequencies, including the FM and television bands. These types are identical except for heater voltage and current ratings. This Note describes the application of the 6J6 or the 19J6 in an AM-FM circuit in which one section of the tube is used as a mixer and the other section as the local oscillator. In addition, the operating characteristics of one section of type 6J6 or 19J6 in mixer service are discussed in detail.

Triode Mixer Considerations

The principal advantage of a triode mixer is its low level of tube noise. The advantage is especially important at the higher frequencies at which most of the loading of the resonant circuits comes from the tubes. In the case of a pentode or a pentagrid converter, the major part of the output noise results from division of current between the plate and the screen circuits. In the AM broadcast band it is practical to use circuits of high enough impedance so that the noise from a pentagrid converter is less than the thermal-agitation noise from the input circuit. In the FM band, however, the advantage of lower noise from a triode can be fully utilized.

The local-oscillator voltage for a triode mixer may be applied at the control grid by inductive or capacitive coupling between the local-oscillator circuit and the control-grid circuit, or it may be introduced between cathode and ground. The control-grid bias must be sufficient to limit the grid current to a small value in order to prevent excessive loading of the input circuit. This bias may be obtained by use of a cathode resistor, or by use of a grid resistor of several megohms. In the latter case, the bias is obtained from the grid current caused by the oscillator voltage.

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The output resistance of a triode mixer is substantially lower than that of a pentode mixer or a pentagrid converter. Consequently, the gain realized from the triode is generally lower. The lower output impedance of the triode must also be taken into account in the design of the if transformer.

Characteristics

The curves of Fig.1 show the conversion transconductance, plate current, and plate resistance obtained from one section of type 6J6 or 19J6 as functions of the control-grid bias, when this bias is obtained by varying the local-oscillator voltage supplied to the control grid. These curves apply for a plate supply voltage of 100 volts. The maximum value of conversion transconductance, 1700 micromhos, is obtained with a bias

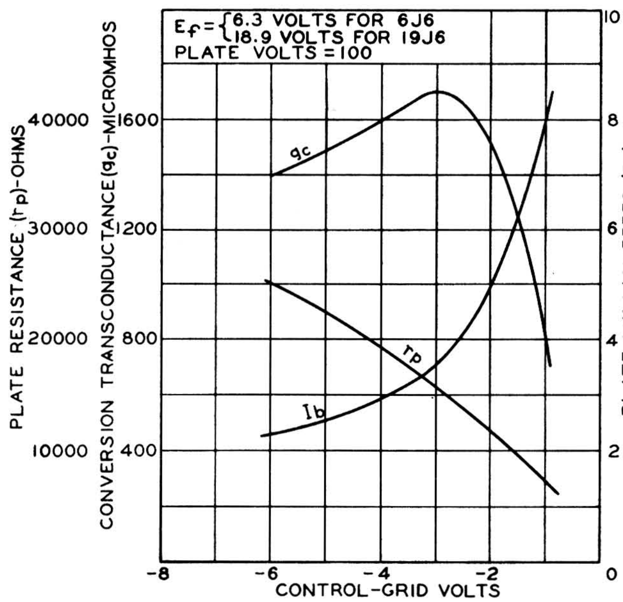


Fig. 1 - Operation Characteristics in Mixer Service.

of 3 volts developed from a peak oscillator voltage of approximately 2.5 volts. The plate resistance per section of either tube for this condition is about 16000 ohms and the plate current is 3.6 milliamperes. It is evident from the curves that lower values of oscillator voltage will reduce the plate resistance as well as lower the conversion transconductance. Higher values of oscillator voltage can be tolerated, but are objectionable because of increased radiation, particularly in receivers not using an rf stage.

Fig.2 shows the variation of conversion transconductance with control-grid bias when additional bias is supplied from an avc system, the oscillator voltage being held constant. This operation characteristic is obtained with type 19J6 in an ac/dc receiver. In a receiver in which higher voltages are available, the cutoff voltage of the triode can be extended to larger negative values by obtaining the plate voltage through a series resistor.

Design of Intermediate-Frequency Transformer

The intermediate-frequency transformer between the mixer plate and the grid of the first if stage must be designed to give satisfactory gain and selectivity when it is loaded on the primary side with an impedance of 16000 ohms from the plate of the mixer tube. For the AM broadcast band, because it is desirable that the first if circuit shall not be loaded too much by the plate resistance of the tube, a low-impedance connection to the transformer primary is suggested. This connection may be conveniently obtained by using a winding similar to one used with a high-impedance tube (pentode or pentagrid converter) but with a tap located so as to present the desired impedance to the triode plate. If it is desired to obtain the same selectivity as would be obtained from a high-impedance tube, the voltage ratio between this tap and the high-potential side of the winding must be equal to the square root of the ratio of the plate resistance of the high-impedance tube to that of the triode. Thus, if the plate-resistance values compared are one megohm and 16000 ohms, the voltage ratio should be approximately 8 to 1.

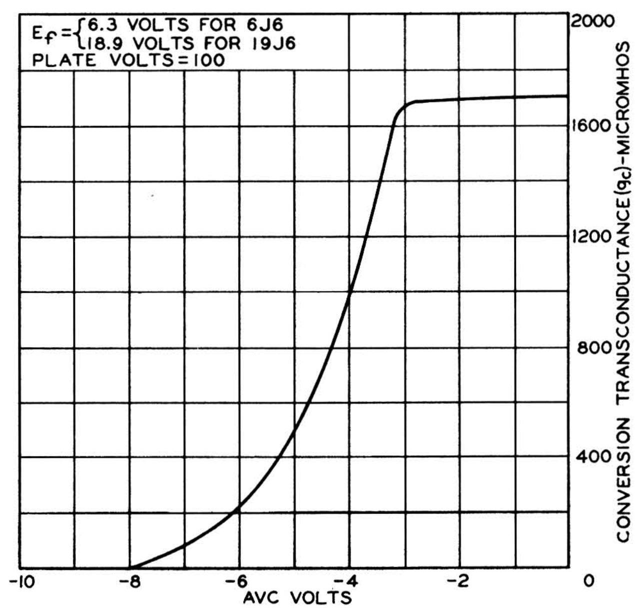


Fig. 2 - Operation Characteristics Obtained When Additional Bias is Supplied from AVC System.

A similar result can be obtained by using a low L/C ratio in the if transformer primary. If the Q of the low-inductance winding is the same as that of the high-inductance winding for which it is substituted, the ratio of capacitances required for tubes with high and low values of plate resistance is the reciprocal of the ratio of output resistances. Thus, if the tube with a 1-megohm plate resistance requires a capacitance of 120 μμf, a tube with a 16000-ohm plate resistance would require a capacitance of 7500 μμf for the same selectivity. Such a capacitor, however, is likely to be rather bulky.

Selectivity may be sacrificed for amplification by the use of a higher tap position or of a higher L/C ratio than the values suggested above. In the FM band, it is common practice to use a primary circuit impedance several times higher than the tube plate resistance, so that the amplification obtained approaches the maximum possible value for the mixer tube.

Input Conductance and Feedback Considerations

In the AM band, the short-circuit input conductance of the 6J6 mixer is determined by the signal-grid current. For a bias of 3 volts and a resistance of 6 megohms this current is 0.5 microampere. The corresponding conductance in micromhos is of the order of ten times this current value; that is, 5 micromhos, or a resistance of 200,000 ohms. A resistance of this value would load the input circuit considerably. When a tapped if transformer is used, however, the leakage inductance at the tap in conjunction with the plate-to-grid capacitance of the tube results in some negative conductance. At 1600 kilocycles, an inductance of 12.5 microhenries in the plate circuit would produce a negative conductance of 5 micromhos. The value of conductance will be highest at the high-frequency end of the broadcast band which is desirable because the effect of the circuit loading is also greater at higher frequencies.

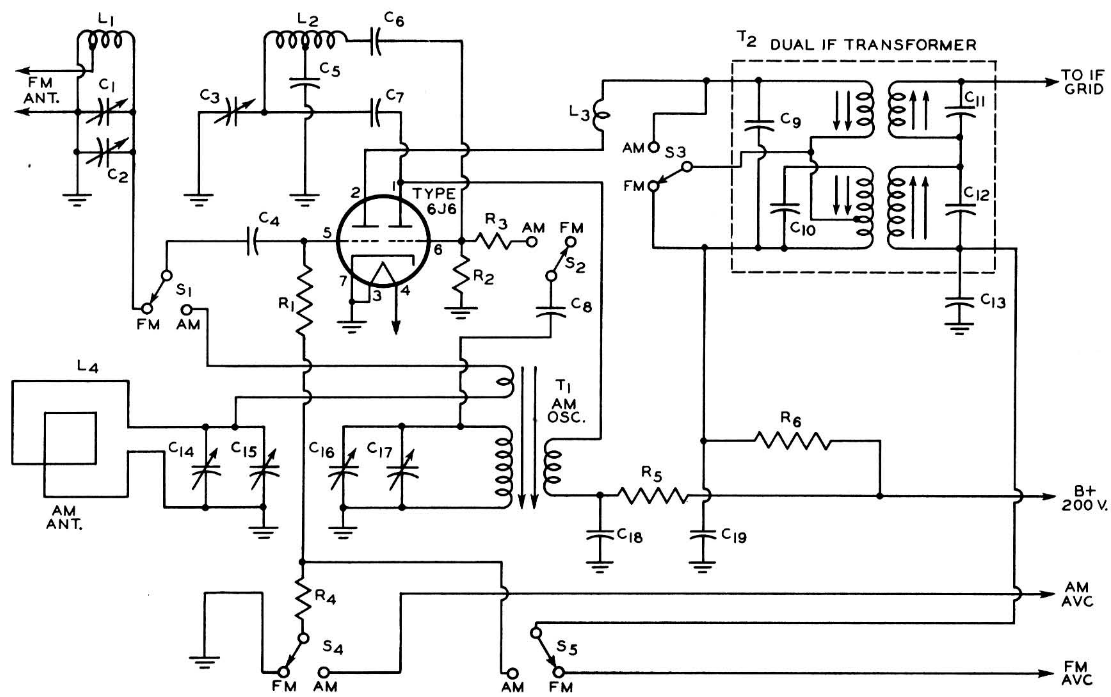
In the FM band, the transit-time effect and the feedback produced by the inductance of the cathode lead result in grid-circuit loading. In addition, because the if transformer presents capacitive reactance to the signal frequencies, additional loading results should the if transformer comprise the whole of the plate impedance. It is desirable, therefore, to include series inductance in the plate circuit of the tube to produce enough regeneration to partially counteract these input loading effects. The inductance may take the form of a long lead, or a small, single-turn coil. At 100 megacycles, an inductance of 0.03 microhenry produces a negative conductance of 50 micromhos. Because the short-circuit input conductance of type 6J6 used as a mixer at 100 megacycles is in the order of 50 micromhos, a higher value of plate inductance would cause oscillation at the signal frequency.

Circuit Considerations

The circuit diagram, Fig.3, shows a 6J6 tube employed as an oscillator and mixer with plate supply voltages derived from a 200-volt supply through series resistors. For type 19J6 with a 100-volt supply, as in an ac/dc receiver, the series resistors are omitted or reduced to lower values if it is desired to retain them as rf filters.

Triode section 2 (plate pin 1, grid pin 6) of the 6J6 or 19J6 should be used as the oscillator section. The other triode section has a getter support attached to its plate and, therefore, would be more susceptible to microphonic disturbances if used as an oscillator. The heater should be at the same rf potential as the cathode to avoid heater-cathode microphonics. This requirement presents no problem in the circuit of Fig.3 because the cathode and one side of the heater are grounded.

Inductive coupling is used between the oscillator coil (L_2) and the rf coil (L_1) to obtain the desired oscillator voltage at the mixer grid. In the particular layout used, sufficient coupling is obtained



C1: Antenna Tuning Capacitor, 7 – 25 μμf (FM)
C2: Trimmer Capacitor, 2 – 17 μμf (FM)
C3: Oscillator Tuning Capacitor, 7.5 – 22.5 μμf (FM)
C4: 1500 μμf, mica
C5: 56 μμf, mica
C6: 15 μμf, mica
C7: 68 μμf, mica
C8: 150 μμf, mica
C9: 33 μμf, mica
C10: 160 μμf, mica
C11: 3 μμf, mica
C12: 160 μμf, mica
C13: 0.01 μf, paper, 50 volts
C14: Antenna Tuning Capacitor, 11 – 408 μμf (AM)
C15: Trimmer Capacitor, 2 – 17 μμf (AM)
C16: Oscillator Tuning Capacitor, 9 – 180 μμf (AM)
C17: Trimmer Capacitor, 2 – 17 μμf (AM)
C18: 0.01 μf, paper, 250 volts
C19: 0.01 μf, paper, 250 volts
L1: RF Coil (FM)
L2: Oscillator Coil (FM)
L3: See Text
L4: Loop Antenna, 550 – 1600 kc (AM)
R1: 3.9 megohms, 0.5 watt
R2: 22000 ohms, 0.5 watt
R3: 100 ohms, 0.5 watt
R4: 2.2 megohms, 0.5 watt
R5: 18000 ohms, 1 watt
R6: 27000 ohms, 0.5 watt
S1 S2 S3 S4 S5: Ganged Five-Section Switch
T1: Oscillator Transformer (AM)
T2: Dual IF Transformer (AM and FM)

Fig.3 - Mixer-Oscillator Circuit for AM-FM Receiver.

when the two coils are separated by about 2 inches. The oscillator coil (L_2) has a total of 4-3/4 turns: 2-1/2 turns between the plate end and the tap, and 1-1/4 turns between the tap and the grid end. The rf coil (L_1) has 1-3/4 turns, tapped at 1/2 turn from the grounded end for the antenna connection. The switching arrangement used requires only one connection between the oscillator circuit and the switch. The switch is open for the FM position. The 100-ohm resistor (R_3) is used to prevent oscillation at the FM frequency when the switch is in the AM position.

The transformer (T_1) for the AM oscillator includes an extra winding to supply oscillator voltage to the mixer section of the tube. Because this winding is connected between the mixer grid and the high-potential side of the AM circuit, the capacitance between this winding and the other windings should be small.

The bias developed at the mixer grid is approximately 2.8 volts in the AM band and 2.5 volts in the FM band. For the FM band, the total resistance between grid and ground is about 6 megohms. In the AM band, avc voltage is applied to the mixer triode through resistors R_1 and R_4.

A dual if transformer is used. The AM primary is tapped; the FM primary is designed to operate with a capacitance consisting of a 33-µµf capacitor plus the output capacitance of the tube. Both windings are tuned with movable iron cores. When one band is used, the unused primary winding of the other is short-circuited.

Performance

In the AM band, the conversion gain between mixer grid and first if grid is about 26. The if selectivity, the image rejection ratio, and the if rejection ratio are nearly the same as the values usually obtained with pentagrid converter tubes. Only four per cent of the noise output appears to come from the mixer tube, the balance being thermal-agitation noise from the input circuit.

In the FM band, the gain measured from the terminals of the signal generator to the grid of the first if stage is 18 to 26. A 300-ohm dummy antenna is connected between the signal generator and the antenna input circuit when this measurement is made. The signal input required to obtain a signal-to-noise ratio of 20 db (signal deviation: 22.5 kc at a 400-cycle modulation frequency is 5.5 to 10 microvolts.

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