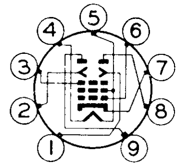
USING THE G-E 6AR8 SHEET BEAM TUBE

In Balanced Modulator, Synchronous Detector and Burst Gate Applications

DESCRIPTION AND RATING

The G-E 6AR8 sheet beam tube has attracted much attention for balanced modulator applications. It has the ability to perform mixing action of two input signals and cancel them in the output to provide an output signal equal to their sum or difference frequencies. Complete technical information is repeated on these pages, along with typical circuits in which radio amateurs have expressed an interest.

BASING DIAGRAM



RETMA 9DP

BOTTOM VIEW

GENERAL

Cathode—Coated Unipotential

Heater Voltage, AC or DC	6.3 Volts
Heater Current	0.3 Amperes

Envelope—T-6½, Glass
Base—E9-1, Small Button 9-Pin
Mounting Position—Any

Direct Interelectrode Capacitances, approximate*

Deflector-Number 1 to All	4.8 μμf
Deflector-Number 2 to All	4.8 μμf
Grid-Number 1 to All Except Plates	7.5 μμf
Plate-Number 1 to All	5.0 μμf
Plate-Number 2 to All	5.0 μμf
Grid-Number 1 to Deflector-Number 1, maximum	0.040 μμf
Grid-Number 1 to Deflector-Number 2, maximum	0.060 μμf
Plate-Number 1 to Plate-Number 2	0.4 μμf
Deflector-Number 1 to Deflector-Number 2	0.38 μμf

TERMINAL CONNECTIONS

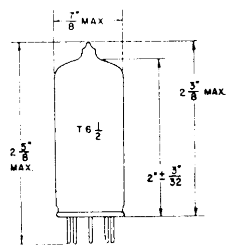
Pin 1—Deflector Number 2
Pin 2—Deflector Number 1
Pin 3—Accelerator
Pin 4—Heater
Pin 5—Heater, Internal Shield, and Focus Electrodes†
Pin 6—Grid Number 1 (Control Grid)
Pin 7—Cathode
Pin 8—Plate Number 2
Pin 9—Plate Number 1

MAXIMUM RATINGS

DESIGN-CENTER VALUES

Plate-Number 1 Voltage	300 Volts
Plate-Number 2 Voltage	300 Volts
Accelerator Voltage	300 Volts
Peak Positive Deflector-Number 1 Voltage	150 Volts
Peak Negative Deflector-Number 1 Voltage	150 Volts
Peak Positive Deflector-Number 2 Voltage	150 Volts
Peak Negative Deflector-Number 2 Voltage	150 Volts
Positive DC Grid-Number 1 Voltage	0 Volts
Plate-Number 1 Dissipation	2.0 Watts
Plate-Number 2 Dissipation	2.0 Watts
DC Cathode Current	30 Milliamperes
Grid-Number 1 Circuit Resistance	
With Fixed Bias	0.1 Megohms
With Cathode Bias	0.25 Megohms

PHYSICAL DIMENSIONS



RETMA 6-3

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS WITH DEFLECTORS GROUNDED

Plate-Number 1 Voltage	250	Volts
Plate-Number 2, Connected to Plate-Number 1		
Accelerator Voltage	250	Volts
Deflector-Number 1 Voltage	0	Volts
Deflector-Number 2 Voltage	0	Volts
Cathode-Bias Resistor	300	Ohms
Total Plate Current	10	Milliamperes
Accelerator Current	0.4	Milliamperes
Grid-Number 1 Transconductance	4000	Micromhos
Grid-Number 1 Voltage, approximate		
I_b (total) = 10 Microamperes	−14	Volts

AVERAGE DEFLECTOR CHARACTERISTICS

Plate-Number 1 Voltage	250	Volts
Plate-Number 2 Voltage	250	Volts
Accelerator Voltage	250	Volts
Cathode-Bias Resistor	300	Ohms
Deflector Switching Voltage, maximum‡	20	Volts
Deflector-Bias Voltage for Minimum Deflector Switching Voltage‡	−8	Volts
Voltage Difference between Deflectors for $I_{b1} = I_{b2}$, approximate	0	Volts
Plate-Number 1 Current, maximum		
$E_{d1} = -15$ Volts, $E_{d2} = +15$ Volts	1.0	Milliamperes
Plate-Number 2 Current, maximum		
$E_{d1} = +15$ Volts, $E_{d2} = -15$ Volts	1.0	Milliamperes
Deflector-Number 1 Current, maximum		
$E_{d1} = +25$ Volts, $E_{d2} = -25$ Volts	0.5	Milliamperes
Deflector-Number 2 Current, maximum		
$E_{d1} = -25$ Volts, $E_{d2} = +25$ Volts	0.5	Milliamperes

* Without external shield.
† Pin 5 should be connected directly to ground.
‡ Deflector switching voltage is defined as the total voltage change on either deflector with an equal and opposite change on the other deflector required to switch the plate current from one plate to the other.
Note: The 6AR8 should be so located in the receiver that it is not subjected to stray magnetic fields.

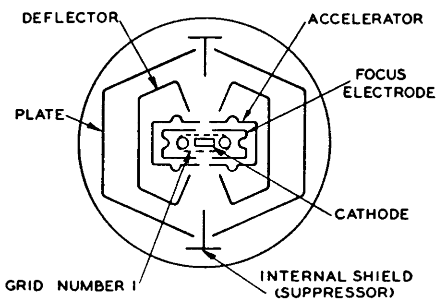


Fig. 1 CROSS-SECTION SCHEMATIC DIAGRAM OF THE 6AR8

OPERATING CONSIDERATIONS FOR THE 6AR8

A cross-section schematic diagram of the construction of the 6AR8 is shown. In this tube, the electrons pass from the cathode to either of the two plates in the form of a planar beam or "sheet." Before the electron stream emerges from the openings in the accelerator structure, it is acted on by the focus electrodes and the control grid. The focus electrode tends to converge the electrons into the required sheet beam, while the conventional grid-number 1 structure which surrounds the cathode serves to control the intensity of the beam.

Between the accelerator and the plates the electron beam passes between the deflector electrodes. Depending on the voltages applied to the deflectors, the beam will be directed entirely to either one or the other of the two plates or proportioned between them. The internal shield, located between the two plates, acts to suppress the interchange of secondary-emission electrons between the plates. The suppressor and the focus electrodes are internally connected to one side of the heater.

In normal operation, positive d-c voltages are applied to the accelerator and plates, and signal voltages are applied to the deflectors and control grid. The frequency of the signal applied to the deflectors determines the rate at which the plate current is switched between the two plates; the grid-number 1 voltage varies the magnitude of the plate current. The interesting tube characteristics which result from the unique construction of the 6AR8 are indicated by the average tube characteristic curves which follow. The tube may be considered as equivalent to a voltage-controlled single-pole double-throw switch through which a current, the magnitude of which is also voltage-controlled, flows.

If both plates and the accelerator are operated at +250 volts and a cathode-bias resistor of 300 ohms is employed, the deflectors require a peak switching voltage of 20 volts (or a peak voltage difference between deflectors of 40 volts) maximum to switch the plate current from one plate to the other. In a practical circuit, however, in which the deflectors are driven in push-pull with the center-tap of the source grounded, a somewhat higher value of deflector drive voltage must be used. The increased drive voltage is required to allow for those tubes in which the switching characteristics are somewhat offset with respect to zero voltage difference between deflectors.

For an accelerator voltage of +250 volts, the minimum deflector switching voltage occurs at a d-c deflector bias of approximately −8 volts; however, the d-c deflector bias is not particularly critical for focus as the deflection sensitivity characteristic exhibits a broad maximum. Care should be exercised, nevertheless, to assure that defocusing effects are not present whenever the tube is operated at conditions other than those recommended.

The circuit diagram for two 6AR8 tubes employed as synchronous detectorsπ in a color television receiver is shown. In this arrangement, positive voltages are applied directly to the accelerator grids and through load resistors R1, R2, R4 and R5 to each of the plates. The chrominance signal is applied to the control grid of each tube. The 3.58-megacycle reference signal is applied in push-pull between the deflectors of each tube. The small coupling capacitor, Cc, between the tuned driving circuits provides the necessary 90-degree phase shift for the I and Q detectors. Also each tube is biased with a cathode resistor, R3 and R6; resistor R6 is variable so that the relative gains of the two demodulators can be adjusted.

In principle, the 6AR8 circuit is a product-demodulator type of synchronous detector; however, because the circuit uses a double-plate sheet-beam tube rather than a dual-control pentode or heptode, certain significant operating features result. First the 6AR8 circuit is capable of delivering relatively large and balanced output voltages which exhibit good linearity. Because output voltages are available of both positive and negative polarities, the need for the incorporation of phase-inverter circuits in the matrix section of the color receiver is completely eliminated. Also, providing the oscillator reference voltage is adequate to switch the plate currents between the two plates, the circuit is insensitive to variations in the amplitude of the oscillator voltage over a wide range. Furthermore, unlike the pentode or heptode synchronous detector circuits in which the third grid is driven positive by the oscillator reference voltage, the deflectors of the 6AR8 require very little excitation power. Consequently, less power is required from the 3.85-megacycle reference oscillator in the sheet-beam tube circuit.

Another feature is that space-charge coupling effects, which are inherently present in dual-control pentodes and heptodes, are unnoticeable in the 6AR8. Also, unlike most dual-control pentodes and heptodes in which the screen current is an appreciable percent of the plate current, the accelerator current of the 6AR8 is less than one-twentieth of its plate current.

π R. Adler and C. Heuer, "Color Decoder Simplifications Based on a Beam-Deflection Tube," Trans. IRE, PGBTR-5, Jan. 1954.

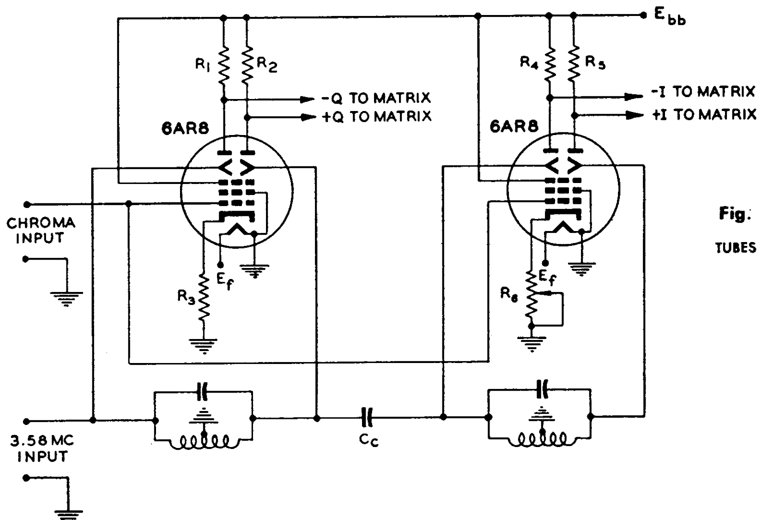


Fig. 2 CIRCUIT DIAGRAM OF TWO 6AR8 TUBES USED AS SYNCHRONOUS DETECTORS

TYPICAL CIRCUITS USING THE G-E 6AR8

The G-E 6AR8 sheet beam tube is, by its very nature, suited for a number of circuit applications in amateur radio single sideband transmitting and receiving equipment. The following circuits illustrate these applications.

Component values as shown will provide normal performance of these circuits in most cases. However, in certain instances, the values of cathode resistances may require lowering to obtain optimum circuit performance. Also, shielding and other r. f. constructional practices, have not been shown.

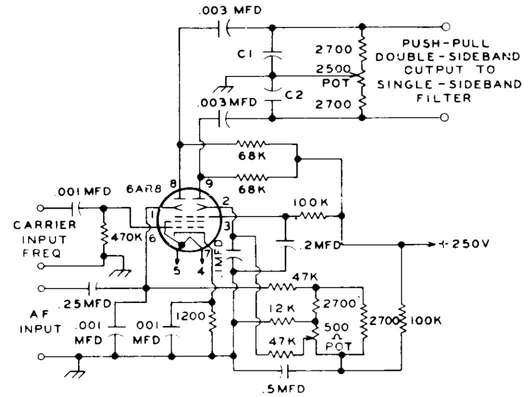


Fig. 3 Suggested circuit for a balanced modulator using the 6AR8 sheet beam tube with the audio signal applied to one beam deflecting plate, and the r.f. signal to be modulated applied to the control grid. All resistances are in ohms, 1/2 watt unless otherwise specified. "K" equals 1,000. Capacitance values are in microfarads (mfd), except where specified. Capacitors C_1 and C_2 should be equal in value, with a total series capacitance of the proper value to resonate the input side of the sideband filter at the operating frequency.

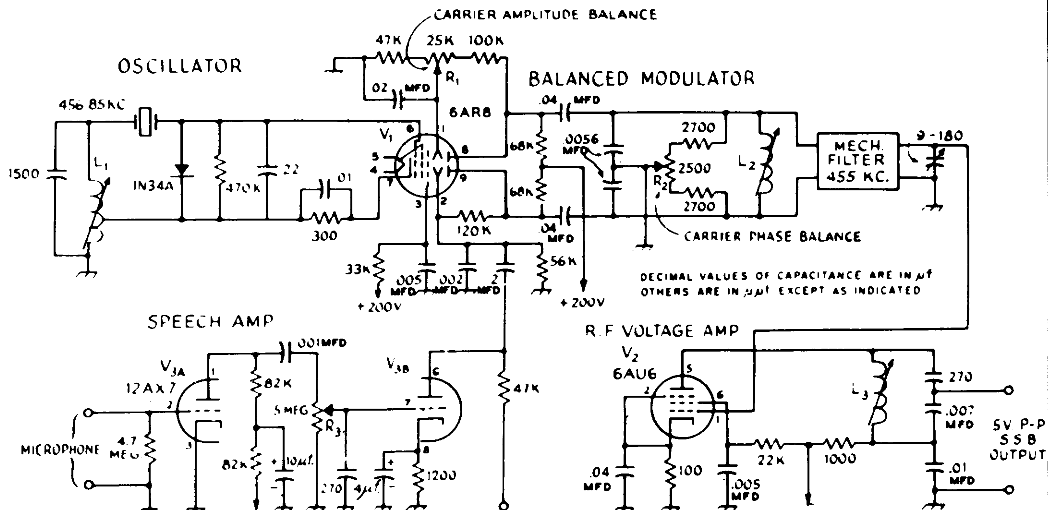


Fig. 4 Suggested schematic diagram of a simplified filter-type single sideband generator operating at 455 kilocycles. The G-E 6AR8 sheet beam tube combines the functions of carrier oscillator, and balanced modulator. The output from the 6AR8 plates is a double sideband, suppressed carrier signal. One sideband is removed after passage through the bandpass filter at the right. All resistances are in ohms, 1/2 watt rating unless specified. Potentiometers R_1, R_2 and R_3 have composition elements. Capacitances are in micro-microfarads, unless value is specified in microfarads (mfd). Capacitors with polarized markings are electrolytic types.

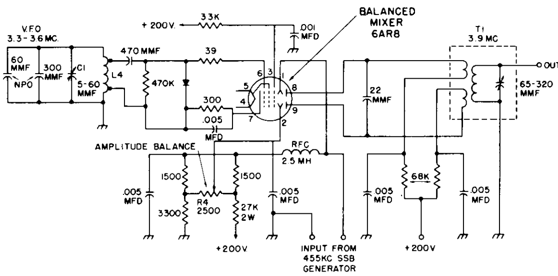


Fig. 5. Suggested schematic diagram of a G-E 6AR8 sheet beam tube operating as a combined tunable oscillator (VFO) and mixer. Circuit values are shown for a tunable oscillator operating at 3.3 to 3.6 megacycles, with a 455-kilocycle SSB signal applied to one beam deflection plate. The sum of the two input frequencies appears in the output circuit, T_1, tuned to the 3.8 to 4.0-megacycle range. The oscillator coil, L_4, has an inductance of 4.7 microhenries. It was wound on a 3/4-inch diameter ceramic coil form, with 21 turns of No. 20 enameled wire spacewound 1 inch long. The cathode tap is 3 turns, and the grid tap 10 turns, from the grounded end.

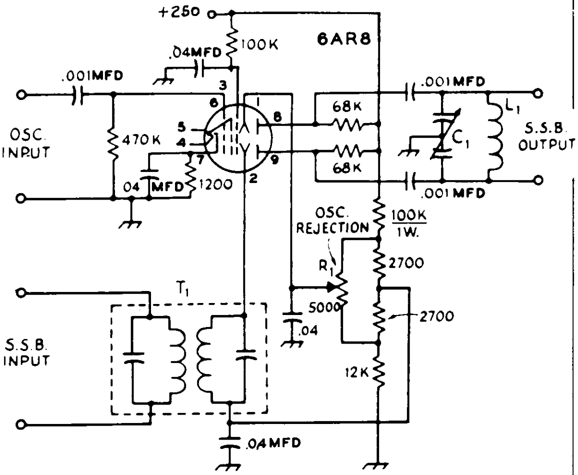


Fig. 6 Suggested schematic diagram for a 6AR8 tube in a balanced mixer circuit. This circuit is suitable for combining two input signals from a SSB generator and tunable oscillator (VFO), and obtaining either the sum or difference signal in the tuned output circuit, C_1--L_1. Conventional tuned circuits may be used here, and in T_1. All resistances are in ohms, 1/2 watt, unless specified. Capacitances are in microfarads (mfd). A linear taper composition potentiometer should be used for R_1.

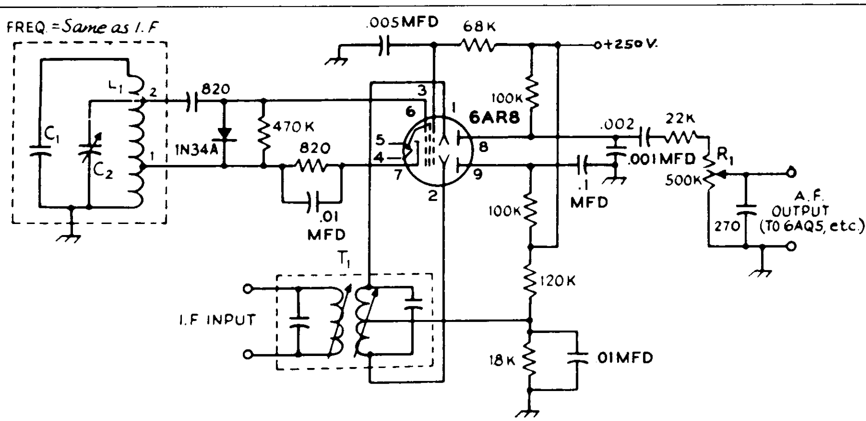


Fig. 7. Suggested circuit for a 1-tube product detector using the G-E 6AR8 sheet beam tube. The circuit contains its own carrier oscillator utilizing the cathode, control grid and number three grid elements. The beam deflecting plates are in the detection circuit, and the audio output signal is taken from the plates. The oscillator tuned circuit should have high capacitance for best stability. Taps 1 and 2 on L_1 should be about 5 and 25 percent, respectively, from the grounded end. Resistances are in ohms, 1/2-watt rating. Capacitances in decimals are in microfarads (mfd); those in whole numbers are in micro-microfarads (mmf).

BALANCED MODULATORS

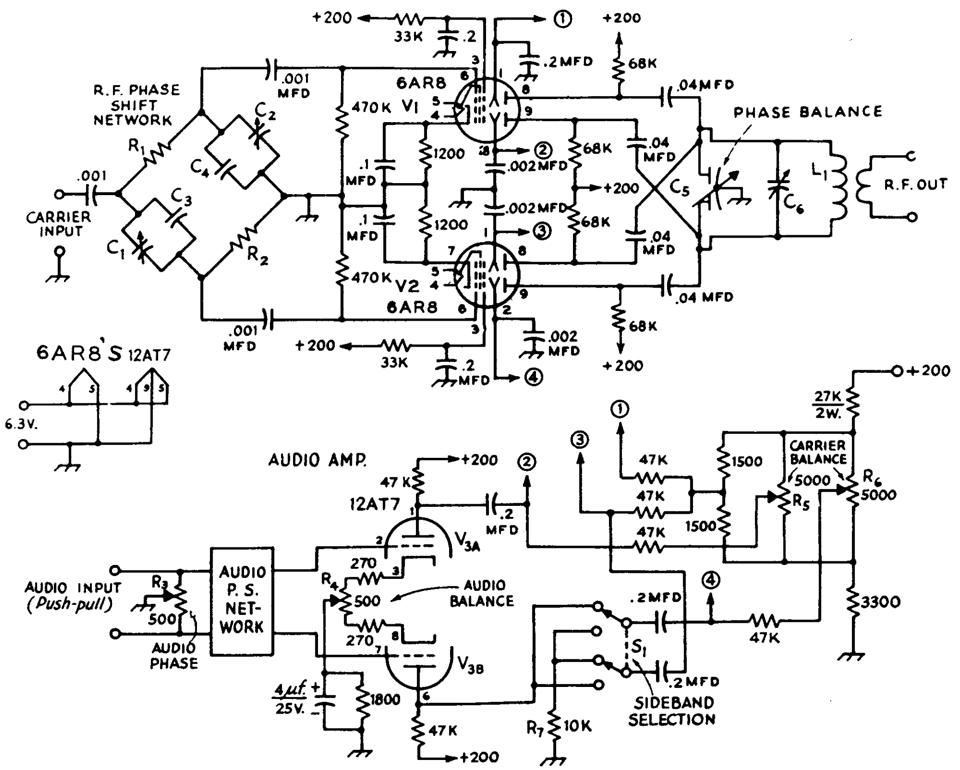


Fig. 8. Suggested schematic diagram for a phasing type SSB generator featuring a double balanced modulator with two 6AR8 sheet beam tubes. This circuit is suitable over the range from intermediate frequencies to approximately 30 megacycles. Capacitances are in micro-microfarads (mmf), except those marked "uf", which are in microfarads (mfd). Resistances are in ohms, 1/2 watt rating unless otherwise specified. Values for capacitors C_1, C_2, C_3, C_4, C_5, and C_6, and coil L_1 will depend on the operating frequency. Values for C_3 and C_4 should be chosen so that their reactance at the operating frequency is equal to the resistance of R_1 and R_2, which should be 100 ohms each, with exact values closely matched.

A SSB exciter construction article with the 6AR8 as a balanced modulator was described in the July, 1956 issue of CQ, on pages 24 to 31. This filter type exciter was designed and constructed by William I. Orr, W6SAI.

Additional material on applications of sheet beam receiving tubes has been published in the March, 1960 issue of QST magazine.

A new article showing the G-E 6AR8 as a balanced modulator in a simple double sideband transmitter, reconstructed from a surplus Command Set transmitter, appears in the May, 1961 issue of CQ magazine, on pages 48 through 51.

A new type of miniature sheet beam tube which has low output capacitances, and thus is capable of operating in balanced modulator circuits well into the VHF region, has just been announced by the General Electric Receiving Tube Department. It is known as the 7763 and will appear in G-E HAM NEWS articles during 1962.