BRIMAR

RECEIVING VALVE

6AU6

APPLICATION REPORT VAD/508.1

Standard Telephones and Cables Limited

FOOTSCRAY, KENT, ENGLAND

INTRODUCTION: The Brimar valve type 6AU6 is an indirectly heated RF pentode. The heater is intended for operation in parallel with other valves in AC operated equipment. The valve is designed for use as an RF or IF amplifier, suitable shielding and short leads provide a good performance in high frequency circuits. This report contains characteristics of the valve and details of its performance.

DESCRIPTION: The valve consists of a miniature RF pentode having a mutual conductance of the order of 5 mA/V and is mounted in a standard TS1* bulb and fitted with a B7G standard base.

CHARACTERISTICS:

Cathode: Indirectly heated
Voltage 6-3 volts
Current (nominal) 0-3 ampere
Max. DC Heater-Cathode potential 250 volts

Dimensions:
Max. Overall Length 2-1/8 ins.
Max. Diameter 3/4 in.
Max. Seated Height (excluding tip) 1-19/32 ins.

Base: Type B7G

Basing Connections:
Pin 1 Control Grid g1
Pin 2 Suppressor Grid gS and Internal Shield
Pin 3 Heater
Pin 4 Heater
Pin 5 Anode
Pin 6 Screen Grid gS
Pin 7 Cathode

Ratings:

PENTODE CONNECTIONS:
Max. Anode Voltage 300 volts
Max. Screen Voltage 150 volts
Max. Screen Supply Voltage 300 volts
Max. Anode Dissipation 3-0 watts
Max. Screen Dissipation 0-65 watt

TRIODE CONNECTION (Pins 2, 5 and 6 strapped)
Max. Anode Voltage 250 volts
Max. Anode Dissipation 3-2 watts

Capacities (approx.):*

PENTODE CONNECTED:
c Input 5-5 pF
c Output 5-0 pF
c g1, a 0-0035 pF max.

TRIODE CONNECTED:
c Input 3-1 pF
c Output 1-7 pF
c g1, a 2-5 pF

* Measured with no external shield.
GROUNDED GRID OPERATION:
Anode, Cathode: 0.013 pF
Input: 6.1 pF
Output: 5.4 pF

CHARACTERISTIC CURVES: Curves are attached to this report which show:

- Anode current plotted against control grid voltage for various screen voltage (I_a/V_g1) (Curve No. 308-32).
- Mutual conductance and anode impedance against control grid voltage (g_m/V_g1) (R_a/V_g1) (Curve No. 308-33).
- Anode current plotted against anode voltage (I_a/V_a) for a screen voltage of 150 volts (Curve No. 308-34) and for a screen voltage of 100 volts (Curve No. 308-35).
- Anode current plotted against anode voltage (I_a/V_a) connected as a triode (Curve No. 308-36).

TYPICAL OPERATION

CLASS “A” AMPLIFIER:

Pentode connected (g_a connected to cathode):

<table>
<thead>
<tr>
<th></th>
<th>6.3</th>
<th>6.3</th>
<th>6.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater Voltage</td>
<td>100</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Anode Voltage</td>
<td>100</td>
<td>125</td>
<td>150</td>
</tr>
<tr>
<td>Screen Voltage</td>
<td>140</td>
<td>100</td>
<td>68</td>
</tr>
<tr>
<td>Grid Voltage</td>
<td>5.2</td>
<td>7.6</td>
<td>10.8</td>
</tr>
<tr>
<td>Cathode Bias Resistor</td>
<td>2.0</td>
<td>3.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Anode Current</td>
<td>0.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Screen Current</td>
<td>3.9</td>
<td>4.45</td>
<td>5.2</td>
</tr>
<tr>
<td>Anode Impedance (r_a)</td>
<td>39</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>Mutual Conductance (g_m)</td>
<td>-4.5</td>
<td>-5.5</td>
<td>-6.35</td>
</tr>
<tr>
<td>Inner Amplification Factor (u_g1,g2)</td>
<td>-38</td>
<td>-81</td>
<td>-90</td>
</tr>
<tr>
<td>Grid Voltage for 1/100 g_m at V_g = -1</td>
<td>2350</td>
<td>2350</td>
<td>2600</td>
</tr>
<tr>
<td>Suppressor Grid Voltage for 1/100 g_m at V_g3 = 0</td>
<td>4200</td>
<td>3700</td>
<td>3400</td>
</tr>
<tr>
<td>Equivalent Noise Resistance (R_e)</td>
<td>950</td>
<td>920</td>
<td>900</td>
</tr>
</tbody>
</table>

Triode Connected:

<table>
<thead>
<tr>
<th></th>
<th>6.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater Voltage</td>
<td>250</td>
</tr>
<tr>
<td>Anode Voltage</td>
<td>4</td>
</tr>
<tr>
<td>Grid Voltage</td>
<td>36</td>
</tr>
<tr>
<td>Amplification Factor</td>
<td>7500</td>
</tr>
<tr>
<td>Anode Impedance</td>
<td>4.8</td>
</tr>
<tr>
<td>Mutual Conductance</td>
<td>12.2</td>
</tr>
</tbody>
</table>

OPERATION AS AN RF OR IF AMPLIFIER:
The valve is very suitable for service in the above application. It is recommended that cathode bias be always used rather than fixed bias and that normally the suppressor grid (g3) and the internal shield be connected to the cathode at the socket.
The valve socket should be so mounted that the grid and anode leads to the remainder of the circuit run in opposite directions to each other and are as short as is practicable in order to ensure high gain with stability. The decoupling components should also be chosen and located with care for similar reasons.

When used in VHF receivers the valve may be employed with normal pentode connections or as a grounded grid amplifier at frequencies of the order of 100 Mc/s. It is also very efficient as an IF amplifier using intermediate frequencies around 10 Mc/s. When so employed a stage gain of 47 times can be expected with a total bandwidth of 200 Kc/s for 3 dB down with IF coils of Q 70 and tuning capacity 50 pF.

For those applications where very high frequencies are employed and changes in input capacity, and input impedance are undesirable, it is advised that grid bias is applied to the control grid and suppressor grid simultaneously, the control grid being biased to a value of approximately 2% of that applied to the suppressor grid.

Curves are attached to this report as follows:

Input capacity and input impedance plotted against control grid voltage for the sliding screen conditions at 50 Mc/s (Curve No. 308-38) similarly but for autobias (Curve No. 308-39) input capacity and input impedance against suppressor grid voltage (Vg3) at 50 Mc/s with control grid voltage 2% of Vg3 (Curve No. 308-40). Curves Nos. 308-41, -42 and -43 are similar to the above but taken at a frequency of 90 Mc/s.

**OPERATION AS A RESISTANCE-CAPACITY COUPLED AMPLIFIER:**

**Pentode Connected:** The valve is very suitable for use as an RC coupled amplifier and below is a table giving a summary of useful values at two different supply voltages for a distortion of approximately 5% harmonic:

**a. Anode Supply Voltage Va(b) — 100 volts:**

<table>
<thead>
<tr>
<th>Anode Load (R_a megohms)</th>
<th>0.1</th>
<th>0.22</th>
<th>0.47</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Screen Resistor (R_g2 megohms)</td>
<td>0.09</td>
<td>0.25</td>
<td>0.75</td>
</tr>
<tr>
<td>Grid Leak (succeeding valve) (megohms)</td>
<td>0.22 0.47 0.22 0.47 0.47 1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cathode Resistor (ohms)</td>
<td>2100 2100 3300 3300 6400 6400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage (peak)</td>
<td>32 37 25 32 27 32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>72 88 72 100 100 125</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**b. Anode Supply Voltage Va(b) — 300 volts:**

<table>
<thead>
<tr>
<th>Anode Load (R_a megohms)</th>
<th>0.1</th>
<th>0.22</th>
<th>0.47</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Screen Resistor (R_g2 megohms)</td>
<td>0.25</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Grid Leak (succeeding valve) (megohms)</td>
<td>0.22 0.47 0.22 0.47 0.47 1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cathode Resistor (ohms)</td>
<td>600 700 1000 1000 1800 1800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage (peak)</td>
<td>103 130 892 108 94 105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>145 170 164 230 250 320</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Curves are attached to this report showing the characteristics when used under RC coupled amplifier conditions at an HT line voltage of 250 volts. Curve No. 308-29 is plotted with an anode load resistor of 470,000 ohms and shows the relation between anode, current, screen current and control grid voltage for various screen voltages. Curves Nos. 308-30 and -31 are similar to the above but plotted with anode load resistors of 220,000 and 100,000 ohms respectively. The method of using these curves to design an RC coupled amplifier is described below.

If for example it is desired to use the valve at a supply voltage (\(V_{a(b)}\)) of 250 volts with an anode load resistor of 220,000 ohms and a succeeding valve grid leak of 470,000 ohms, then an examination of the Curve No. 308-30 shows that grid current (\(I_{g1}\)) commences at about \(-1\) volts, hence a grid bias should be chosen such that the signal never swings the grid to a value of less than \(-1\) volt. If a value of 1·5 volts is taken, then fairly straight portions of the \(I_a/V_{g1}\) curves are available for \(V_{g2}\) 50 volts. Taking the operating point as \(V_{g2}\) 50 volts and \(V_{g1}\) \(-1\cdot5\) volts, the anode current will be 0·54 mA and the screen current \(I_{2}\) 0·27 mA, hence the cathode resistor will be \(\frac{1·5 \times 1000}{0·54 + 0·27} = \frac{250}{0·27} = 925\) or 1850 ohms. The screen drooping resistor would be \(\frac{250}{50} = 5\) or 0·75 megohms. If the grid has a peak AF input of \(\pm 0·3\) volts as a maximum, the anode current will vary from 0·24 mA at a grid voltage of 1·8 volts to 0·94 mA at 1·2 volts, hence a change of 0·70 mA in 220,000 ohms is 154 volts peak-peak. This is an output of 77 volts peak and a voltage gain of \(\frac{470,000}{220,000 + 470,000} = \frac{470,000}{220,000} = 0·68\), hence the actual operating gain will be 175 and the output voltage 17·5 volts peak for an input of 0·1 volts peak. An estimate of the distortion can be obtained by calculating in a similar manner the voltage gain for the positive swing 1·5 to 1·2 volts and the negative swing 1·5 to 1·8 volts separately the resultant figures indicating the amount by which one peak is amplified more than the other.

**Triode Connected:** The valve may be used as a triode R-C coupled amplifier, and a graph is attached to this report showing the relation between the various valve parameters under conditions of resistance coupling. This graph (No. 308-37) is taken at an anode supply voltage (\(V_{a(b)}\)) of 250 volts with three values of anode load resistor, viz., 47,000, 100,000 and 220,000 ohms and plots the anode current, amplification factor, mutual conductance and anode impedance against grid voltage. From this graph the correct grid bias (cathode resistor) can be obtained, also the stage gain can be calculated and an estimate made of the distortion. The graph is not drawn beyond the limits of start of grid current or around the grid cut-off region.

Below follows a description of the method of using this graph.

If for example it is desired to use a valve at a supply voltage of 250 volts, and anode load of 220,000 ohms and a succeeding valve grid leak of 470,000 ohms, then to determine the grid bias an inspection of the graph indicates a relatively linear portion of the curve of anode current/grid volts over the range of \(-1\) to \(-6\) volts, the mid point being \(-3\cdot5\) volts. At this point the anode current is 0·67 mA hence the cathode resistance should be 520 ohms. The peak input voltage is 2·5 volts and the R.M.S. input 1·75 volts. Following the grid bias voltage upward on the curve it is evident that with an anode load of 220,000 ohms, the amplification factor (\(\mu\)) is 29, and the anode impedance is 26,000 ohms. The anode load is effectively in parallel with the succeeding valve grid leak as regards the signal but not as regards the anode current, hence the
effective signal value of the anode load is 220,000 ohms in parallel with 470,000 ohms or is 150,000 ohms. The stage gain is:

\[
\frac{\mu R_a}{R_a + r_a}
\]

or in the above case:

\[
\frac{29 \times 150,000}{150,000 + 26,000} = 25
\]

The peak input voltage above was 2.5 volts hence the peak output voltage will be this figure multiplied by the stage gain or 62 volts or 44 volts R.M.S.

An estimate of the distortion may be made by calculating from the graph as above the stage gain at the extremes of grid bias; in the example the stage gain at —1 volts is 30 and at —6 volts is 20, hence the positive peaks of the signal output will be less than the negative.

OPERATION AS AN FM LIMITER:

The high slope and short grid base make the valve very suitable for use as a limiter for FM receivers. A curve (No. 308.46) attached to this report, shows the operation as a limiter for two different conditions, Curve No. 1 threshold at 1 volt, and Curve No. 2 for 0.5 volts, the output being approximately 10 volts and 6 volts respectively.
BRIMAR 6AU6
Anode supply voltage $V_{dd} = 250$ volts
Anode load resistor $R_a = 100 \, k\Omega$

- - - Anode current
-- -- Screen current
BRIMAR 6AU6
ANODE & SCREEN CURRENT
versus GRID 1 VOLTAGE $V_{g1}$
Anode voltage $V_a = 250$ volts
Grid 3 voltage $V_{g3} = 0$ volts
Anode current $I_a$
Screen current $I_{sh}$
BRIMAR 6AU6
ANODE IMPEDANCE & MUTUAL CONDUCTANCE
versus GRID 1 VOLTAGE $V_{g1}$
Anode voltage $V_a = 250$ volts
Grid 3 voltage $V_{g3} = 0$ volts

Screen voltage $V_{g2} = 150$ volts
BRIMAR 6AU6
CONNECTED AS TRIODE
Grids 2eJ connected to anode
Anode supply voltage 250 volts
Anode load resistors kΩ
1  100
2  220
3  470

ANODE IMPEDANCE rA kΩ
0  0
20  20
40  40
60  60
80  80
100  100

GRID 1 VOLTAGE VOLTS
0  0
-1  -1
-2  -2
-3  -3
-4  -4
-5  -5
-6  -6

ANODE CURRENT Ia mA & MUTUAL CONDUCTANCE gm ma/V
0  0
20  20
40  40
60  60
80  80
100  100

AMPLIFICATION FACTOR µ
0  0
25  25
50  50
75  75
100  100

VAD/308.37
BRIMAR 6AU6

INPUT RESISTANCE versus CATHODE BIAS VOLTAGE
at 50 Mc/s
Anode voltage $V_a = 250$ volts
Screen supply voltage $V_{g2}$
= 250 volts
Screen series resistor = 22 kΩ
Grid 3 voltage $V_{g3} = 0$ volts
BRIMAR 6AU6

INPUT RESISTANCE versus
GRID 3 VOLTAGE $V_{g3}$ at 50Mc/s

Anode voltage $V_a = 250$ volts
Screen supply voltage $V_{g2}(\omega)$
= 250 volts via 22kΩ

Grid 1 voltage $V_{g1} = 2\%$ of
Grid 3 voltage $V_{g3}$ as circuit.

All condensers 0.01μF
BRIMAR 6AU6

INPUT RESISTANCE versus
CATHODE BIAS VOLTAGE
at 90 Mc/s.
Anode voltage $V_a = 250$ volts
Screen supply voltage $V_g = 250$ volts
Screen series resistor $= 22k\Omega$
Grid 3 voltage $V_g = 0$ volts