APPLICATION NOTE No. 80
October 20, 1937

APPLICATION NOTE
ON
OPERATION OF THE 6V6-G

The 6V6-G is a beam power output tube that is capable of furnishing more than 4 watts at approximately 6 per cent distortion when 250 volts are applied to plate and screen. The principle of operation of the 6V6-G is similar to that of the 6L6: directed electron beams and aligned grids are used to obtain high plate-circuit efficiency, low screen current, and high power sensitivity. The 6V6-G is usually used single-ended or push-pull in the output stages of resistance-coupled amplifiers. In a radio receiver, a single-ended amplifier is usually fed by a single-tube voltage amplifier; a push-pull output stage is usually fed by a phase inverter. The accompanying diagrams and tables furnish design information for these arrangements.

A grid-resistor value of 0.25 megohm for the output stage is listed in the tables. This value of resistor is less than the recommended maximum value for self-bias operation (0.5 megohm) and greater than the recommended maximum value for 100 per cent fixed-bias operation (0.05 megohm). Thus, 0.25 megohm is suitable for either self-bias or partial-fixed-bias operation of the 6V6-G. When the output tubes are self-biased, an additional resistor of 0.25 megohm may be used for the grid-circuit filter. The use of a higher value of grid resistor (no grid-circuit filter) does not affect performance materially, because gain and output voltage are nearly maximum for the constants shown.

The data in Table I apply to the cascade amplifier of Fig.1A and to the phase-inverter circuit of Fig.1B. The output voltage from any of the voltage amplifiers listed in Table I is more than that required by either the single-ended or push-pull output stage. The values of $R_L$ and $R_g$ were selected on the basis of reasonable gain and good high-frequency response at less than 5 per cent distortion.

In the phase-inverter circuit of Fig.1B, a tube $T_2$ having a gain $G_2$ obtains its signal voltage from a portion of $R_g$; the output of $T_2$ feeds one of the push-pull output tubes. The proper point P on $R_g$ for the grid connection of $T_2$ is obtained from the relation

$$R_{g1} = \frac{R_g}{G_2}$$

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where the values of $R_2$ and $G_2$ are given in the tables. The values of $R_{g1}$ are given in Table II for twin-triode tube types. The circuit for these types is shown in Fig.2.

Table III furnishes design data for the pentode-type voltage amplifier of Fig.3. A low value of plate load is desirable, because microphonic and hum outputs are reduced to acceptable levels. The use of a series screen resistor and self-bias for the voltage amplifier reduces the effects of varying line voltage and possible differences between tubes.

The circuit of Fig.4 is another type of phase inverter. The output of $T_1$ feeds $T_2$, which is connected in an inverse-feedback circuit. The output of $T_2$ is split into two phases, each of which furnishes voltage for an output tube. $T_2$ is usually a 6F5 or a 6C5; the values of components used in this circuit for these tube types are tabulated in Table IV.

The gain of $T_2$ is nearly independent of the tube type, because a large amount of inverse feedback is used; for this circuit, one-half the output of $T_2$ is fed back to the input of $T_2$. The stage gain with feedback is

$$G_r = \frac{G_0}{1 + nG_0},$$

where $G_0$ is the gain of the stage without feedback and $n$ is the fraction of the output voltage fed back to the input. Thus, when $T_2$ is a 6F5, $G_0 = 63$ and $G_r = 1.94$. When $T_2$ is a 6C5, $G_0 = 14$ and $G_r = 1.75$. For example, when the bias on the output tubes is -15 volts, the output of $T_1$ should be somewhat more than 15 volts peak for maximum power output. $T_2$ does not draw grid current until the peak value of the input signal is approximately 25 volts for the 6F5 and approximately 40 volts for the 6C5.

The phase-inverter circuit of Fig.4 has practical advantages over the circuits of Figs.1B and 2 in that the effects of possible variations between tubes are small. In the circuit of Fig.4, normal variations between tubes in position $T_1$ affect the input to each 6V6-G tube by the same amount; the effects of normal variations between tubes in position $T_2$ are negligible because of the inverse-feedback arrangement. In the circuits of Figs.1B and 2, normal variations between tubes in position $T_2$ and variations in the value of $R_2$ affect the input to only one 6V6-G tube; normal variations between tubes in position $T_1$ affect the input to both 6V6-G tubes by the same amount.

A disadvantage of the phase-inverter circuit of Fig.4 is the possibility of obtaining high hum output when the gain following $T_2$ is high. Heater-cathode leakage, if present, may cause hum voltage to be developed across $R_1$ (the resistor connected in the cathode circuit), which is impressed on the grid of $T_2$ through $R_o$. For this reason, $T_2$ should feed the 6V6-G tubes directly, as shown in Fig.4.
Figs. 5, 6, 7, 8, and 9 show operating characteristics of the 6V6-G. Figs. 5 and 6 are plate families for 250 and 300 volts on the screen, respectively. Fig. 7 is a plate family for zero bias with screen voltage as the parameter. This family is useful for determining the operation of the tube at other than listed screen voltages. The method of using this type of family has been described in Application Note No. 61.

Fig. 8 shows the relations between power output, distortion, plate dissipation, and screen dissipation vs load resistance. This set of data is important because it indicates the necessity for using the proper value of load resistance. Operation with an abnormally high load resistance in order to obtain high power output is not desirable from the standpoint of tube life.

The data in Fig. 9 show the relation between distortion and input signal vs power output for single-ended operation of a 6V6-G. These data obtain for a 5000-ohm load and for a grid bias equal to -12.5 volts.

The bias for 250-volt, push-pull operation is -15 volts. This bias may be obtained from a self-bias resistor or from a partially fixed-bias source. The rise in d-c plate and screen currents with power output is small, approximately 16 ma. for fixed-bias operation; hence, a power supply with relatively poor regulation may be used without much loss in power output. The following conditions obtain for the output stage.

<table>
<thead>
<tr>
<th></th>
<th>Single-Tube Output</th>
<th>Push-Pull Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volts</td>
<td>Volts</td>
</tr>
<tr>
<td>Heater Voltage</td>
<td>6.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Plate Voltage</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Screen Voltage</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>Grid Bias</td>
<td>-12.5</td>
<td>-15</td>
</tr>
<tr>
<td>Peak Signal Voltage</td>
<td>12.5</td>
<td>30*</td>
</tr>
<tr>
<td>Zero-Signal Plate Current</td>
<td>45</td>
<td>70</td>
</tr>
<tr>
<td>Max.-Signal Plate Current</td>
<td>47</td>
<td>79</td>
</tr>
<tr>
<td>Zero-Signal Screen Current</td>
<td>4.5</td>
<td>5</td>
</tr>
<tr>
<td>Max.-Signal Screen Current</td>
<td>6.5</td>
<td>12</td>
</tr>
<tr>
<td>Load</td>
<td>5000</td>
<td>10000**</td>
</tr>
<tr>
<td>Power Output</td>
<td>4.25</td>
<td>8.5</td>
</tr>
<tr>
<td>Total Harmonic Distortion</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Second Harmonic</td>
<td>4.5</td>
<td>---</td>
</tr>
<tr>
<td>Third Harmonic</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*Grid-to-grid
**Plate-to-plate

AN-80
CASCADE AMPLIFIER CIRCUIT
USING 6V6-G IN ONE STAGE
AND A TRIODE IN THE OTHER

VOLTAGE AMPLIFIER

TYPE 6V6-G

250 OHMS

FIG. 1A

PHASE-INVERTER CIRCUIT
USING TWO 6V6-G'S IN THE
PUSH-PULL OUTPUT STAGE
AND TRIODE PREAMPLIFIERS

TYPE 6V6-G

10 µf MIN.

FIG. 1B

R = GRID-BIAS RESISTOR FOR PUSH-PULL 6V6-G's
≥ 165 OHMS WHEN B+ IS 250 VOLTS
≥ 195 OHMS WHEN B+ IS 300 VOLTS

<table>
<thead>
<tr>
<th>TRIODE VOLTAGE AMPLIFIER (T₁ or T₂)</th>
<th>R_L (M)</th>
<th>R_q (M)</th>
<th>R_C (Q)</th>
<th>C (µf)</th>
<th>GAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A6, 75</td>
<td>0.1</td>
<td>0.25</td>
<td>2200</td>
<td>0.015</td>
<td>39</td>
</tr>
<tr>
<td>6C5; also 6C6, 6J7, 57 as triodes</td>
<td>0.1</td>
<td>0.25</td>
<td>5300</td>
<td>0.015</td>
<td>13</td>
</tr>
<tr>
<td>6F5</td>
<td>0.1</td>
<td>0.25</td>
<td>1600</td>
<td>0.010</td>
<td>49</td>
</tr>
<tr>
<td>6Q7</td>
<td>0.1</td>
<td>0.25</td>
<td>1500</td>
<td>0.015</td>
<td>39</td>
</tr>
<tr>
<td>6R7</td>
<td>0.1</td>
<td>0.25</td>
<td>3800</td>
<td>0.015</td>
<td>10</td>
</tr>
<tr>
<td>55, 85</td>
<td>0.1</td>
<td>0.25</td>
<td>8300</td>
<td>0.015</td>
<td>5.7</td>
</tr>
<tr>
<td>56, 76</td>
<td>0.1</td>
<td>0.25</td>
<td>6400</td>
<td>0.020</td>
<td>10</td>
</tr>
</tbody>
</table>

* Voltage amplifier only.

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PHASE-INVERTER CIRCUIT USING TWO 6V6-G'S IN THE PUSH-PULL OUTPUT STAGE AND A TWIN TRIODE AS THE PREAMPLIFIER

![Circuit Diagram]

**FIG. 2**

$R = $ GRID-BIAS RESISTOR FOR PUSH-PULL 6V6-G'S

- 165 OHMS WHEN B+ IS 250 VOLTS
- 195 OHMS WHEN B+ IS 300 VOLTS

<table>
<thead>
<tr>
<th>TWIN TRIODE</th>
<th>$R_L$</th>
<th>$R_g$</th>
<th>$R_{g1}$</th>
<th>$R_c$</th>
<th>$C$</th>
<th>GAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>6A6, 6N7, 55</td>
<td>0.1</td>
<td>0.25</td>
<td>11350</td>
<td>1500</td>
<td>0.015</td>
<td>22</td>
</tr>
<tr>
<td>79</td>
<td>0.1</td>
<td>0.25</td>
<td>7350</td>
<td>1000</td>
<td>0.010</td>
<td>34</td>
</tr>
</tbody>
</table>

* One unit only of twin triode.

CASCADE AMPLIFIER CIRCUIT USING 6V6-G IN ONE STAGE AND A PENTODE IN THE OTHER

![Circuit Diagram]

**FIG. 3**

**TABLE III**

<table>
<thead>
<tr>
<th>PENTODE VOLTAGE AMPLIFIER</th>
<th>$R_L$</th>
<th>$R_g$</th>
<th>$R_d$</th>
<th>$R_c$</th>
<th>$C_d$</th>
<th>$C$</th>
<th>GAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>287, 6B7, 6B8</td>
<td>0.1</td>
<td>0.25</td>
<td>0.55</td>
<td>1100</td>
<td>0.09</td>
<td>0.015</td>
<td>47</td>
</tr>
<tr>
<td>6C6, 6J7, 57</td>
<td>0.1</td>
<td>0.25</td>
<td>0.50</td>
<td>450</td>
<td>0.07</td>
<td>0.010</td>
<td>82</td>
</tr>
</tbody>
</table>

* Voltage amplifier only.

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PHASE-INVERTER CIRCUIT USING TWO 6V6-G'S IN THE PUSH-PULL OUTPUT STAGE AND INVERSE-FEEDBACK IN THE PRECEDING VOLTAGE AMPLIFIER STAGE

FIG. 4

R = GRID-BIAS RESISTOR FOR PUSH-PULL 6V6-G'S
\[ \begin{align*}
165 \text{ OHMS WHEN B+ IS 250 VOLTS} \\
195 \text{ OHMS WHEN B+ IS 300 VOLTS}
\end{align*} \]

<table>
<thead>
<tr>
<th>TABLE</th>
<th>TRIODE VOLTAGE AMPLIFIER ( T_2 )</th>
<th>( R_L ) Megohms</th>
<th>( R_g ) Megohms</th>
<th>( R_c ) Ohms</th>
<th>( C ) ( \mu )F</th>
<th>GAIN (*) ( E_0/E_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>6F5</td>
<td>0.125</td>
<td>0.25</td>
<td>3200</td>
<td>0.015</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>6C5</td>
<td>0.125</td>
<td>0.25</td>
<td>12300</td>
<td>0.016</td>
<td>25</td>
</tr>
</tbody>
</table>

* Approximate.
AVERAGE PLATE CHARACTERISTICS
WITH $E_{C1}$ AS VARIABLE

$E_f = 6.3$ VOLTS
SCREEN VOLTS = 300

FIG. 6
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AVERAGE PLATE CHARACTERISTICS
WITH \( E_{C2} \) AS VARIABLE

\( E_f = 6.3 \) VOLTS  CONTROL-GRID VOLTS = 0

SCREEN VOLTS  \( E_{C2} \)  PLATE MILLIAMPERES

150  250  500  1000  2000  3000  4000  5000

FIG. 7

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