Phase Inverter Drive Voltage …by Earles L. McCaul

• Drive Voltage from Power Out

A phase inverter provides the in-phase and inverted drive voltages that are applied to the grids of the output tubes of a push-pull power amplifier. Each phase inverter output is a mirror image of the other—as the in-phase output voltage goes positive, the inverted output goes negative. To determine the required amplitude of these outputs we need to determine how far the output tube grid voltages need to be driven to achieve the desired output power.

The output transformer impedance is usually specified as plate-to-plate primary impedance $\mathbf{R_{PP}}$. In a class AB amplifier, while one tube is conducting and the other is in cutoff, the conducting tube is in parallel with only half the turns in the primary. Because impedance varies with the square of the turns ratio, this means that the equivalent primary impedance at that moment is $\mathbf{R_P = R_{PP}/4}$. The average value of $\mathbf{R_P}$ will be somewhat less because the opposite tube is not completely in cutoff.

The RMS plate current is equal to the transconductance of the tube $\mathbf{g_m}$ times the RMS grid voltage $\mathbf{V_g}$ supplied by one of the phase inverter outputs. The power out is then the equivalent primary impedance times the square of the RMS plate current:

$$\mathbf{P_o = R_P(g_m V_g)^2}$$

If we know the power out and want to solve for the RMS grid voltage we simply invert this formula:

$$\mathbf{V_g = (1/g_m)SQRT[P_o/R_P]}$$

To see how this works let's take a look at the example push-pull 6L6GC amplifier in the RCA Receiving Tube Manual [1]. The beam power tetrode in this application has a transconductance of $\mathbf{g_m = 0.0060A/V}$. The plate-to-plate primary impedance is $\mathbf{R_{PP} = 5.6k}$ **ohms,** which means that the equivalent primary impedance for only one tube is close [2] to $\mathbf{R_P = R_{PP}/4 = 1.4k}$ **ohms.** The actual value turns out to be $\mathbf{R_P = 1.25k}$ **ohms.** The output power is $\mathbf{P_o = 55}$ **watts,** so the RMS grid voltage at full power is

$$\mathbf{V_g = (1/g_m)SQRT\{P_o/R_P\} = (1/0.006A/V)SQRT[55W/1.25k\Omega] = 35\ volts}$$

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[1] RCA Receiving Tube Manual, RC-26, 5/68, pp.360-361.

[2] Class-A and Class-B push-pull equivalent single-tube impedances are respectively Rpp/2 and Rpp/4. Class-AB is between those values, but always slightly lower than Rpp/4.

Because this is a Class-AB$_1$ amplifier, meaning that the grid voltage never goes positive, the DC bias voltage must be more negative than -35 volts. For the RCA example it is -37 volts, providing a 2-volt margin. Figure 1 below highlights these values from the RCA data sheet.

PUSH-PULL CLASS AB$_1$ AMPLIFIER, VALUES FOR TWO TUBES				
Plate Voltage	360	360	450	Volts
Screen Voltage	270	270	400	Volts
Grid-Number 1 Voltage	−22.5	−22.5	−37	Volts
Peak AF Grid-to-Grid Voltage	45	45	70	Volts
Zero-Signal Plate Current	88	88	116	Milliamperes
Maximum-Signal Plate Current	132	140	210	Milliamperes
Zero-Signal Screen Current	5.0	5.0	5.6	Milliamperes
Maximum-Signal Screen Current	15	11	22	Milliamperes
Effective Load Resistance, Plate-to-Plate	6600	3800	5600	Ohms
Total Harmonic Distortion	2	2	1.8	Percent
Maximum-Signal Power Output	26.5	18	55	Watts

Figure 1 - RCA 6L6-GC 55W Class-AB$_1$ amplifier example data.

• Transformer Impedance

The equivalent primary impedance for one tube was calculated as $\mathbf{R_P = R_{PP}/4 = 1.4k}$ **ohms,** but the working value that we used was $\mathbf{R_P = 1.25k}$ **ohms.** The reason can be seen by taking a closer look at the 6L6GC datasheet. For the push-pull amplifier example, it specifies the maximum-signal RMS plate current as $\mathbf{I_P = 0.210A}$**,** so the maximum-signal RMS plate voltage is

$$\mathbf{V_P = P_o/I_P = 55W/0.210A_{(RMS)} = 262Vp_{(RMS)}}$$

From Ohm's Law the effective primary impedance for one tube is then simply

$$\mathbf{R_P = V_P/I_P = 262Vp_{(RMS)}/0.210A_{(RMS)} = 1.25k\Omega}$$

The difference between the calculated equivalent primary impedance of $\mathbf{R_P = R_{PP}/4 = 1.4k}$ **ohms** and the actual working value of $\mathbf{R_P = 1.25k}$ **ohms** is explained in the article “Output Transformer Load Factor.”

• Summary

Class-AB$_1$ designates operation such that the grid voltage never goes positive during normal operation, meaning the maximum AC-signal drive voltage from the phase inverter circuit cannot exceed the DC-bias voltage applied. This tells us that the “highest” drive signal voltage the inverter circuit should provide is $\mathbf{Vg_{(ac)} \leq Vg_{(dc)}}$. This also enables us to quickly determine maximum output power for different tubes and different values of output transformer plate-to-plate impedance using the simple equation $\mathbf{P_o = R_P(g_mV_g)^2}$.