Plate Conduction Angle…by Earles L. McCaul

• Relationship to Plate Dissipation

In a push-pull, Class-AB power amplifier operating at maximum power, each tube conducts slightly more than half the time. For a pure sine wave input, for example, a tube conducts slightly more than 180 degrees out of the 360 degrees of the sine wave. The rest of the time it is in cutoff while the other tube takes over. The angle over which a tube conducts is called, not surprisingly, the "conduction angle." For a Class-A amplifier, in which both tubes conduct all the time, the conduction angle is **CA = 360.** For a Class-B amplifier, in which only one tube conducts at a time, **CA = 180** degrees. A Class AB amplifier falls somewhere in between.

Each tube has a quiescent (idle) plate dissipation equal to its plate voltage times its plate current:

$\mathbf{P_{PQ} = V_{PQ} \times I_{PQ}}$ …in average watts.

Most people assume that higher quiescent plate dissipation means a higher conduction angle. This holds true in the extremes: a Class B amplifier has zero idle plate dissipation and a conduction angle of 180 degrees, whereas a Class-A amplifier has a high idle plate dissipation and the conduction angle is 360 degrees. In the realm of Class-AB amplifiers, however, the relationship is not quite so simple.

• The DC-to-PK Plate Current Ratio

For Class AB audio power amplifiers, RCA literature [1] gives an optimal plate idle current to plate peak current ratio of between 1-to-5 and 1-to-10. Consider, for example, the high power (55 watt) low-distortion (less than 1.8 percent THD) Class AB amplifier listed in the RCA 6L6GC data sheet[2]. The plate idle current for two tubes is **116mA**, so $\mathbf{Ip_Q = 58mA}$ for one tube, and the plate maximum power peak current is $\mathbf{Ip_{(pk)} = 297mA}$**.** The plate conduction angle is related to the plate DC-to-PK current ratio by the formula:

$\mathbf{CA = 2 \times ACOS[-I_{PQ} / I_{P(pk)}] = 202.5\ degrees}$

When we subtract 180-degrees from the plate conduction angle, we find there are 22.5-degrees of overlap where both power tubes are conducting, a value that coincides well with the 10-percent to 15-percent overlap rule-of-thumb commonly used to ensure the elimination of crossover distortion. Most low-distortion (less than 2-percent THD) Class AB audio amplifiers have conduction angles between 195 and 205 degrees, or typically about 200 degrees, indicating there are about 15-25 degrees of conduction overlap. RCA design guidelines recommend an $\mathbf{I_{PQ}}$ to $\mathbf{I_{P(pk)}}$ ratio of between 1/5 and 1/10. This corresponds to conduction angles between 192 and

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1 **RCA Transmitting Tubes,** Technical Manual TT-5, 10/62, page 52.

2 **RCA Receiving Tube Manual,** Technical Series RC-26, 5/68, page 360-361.

203 degrees (53 percent and 56 percent of 360) when we plug these into the formula for **CA,** so the RCA amps are closer to Class-B operation.

An interesting benchmark is illustrated on the graph in Figure 1 below, which shows the current ratio versus conduction angle. When the ratio reaches 50 percent, the conduction angle only reaches 240 degrees, which is exactly one-third of the way from Class-B toward Class-A.

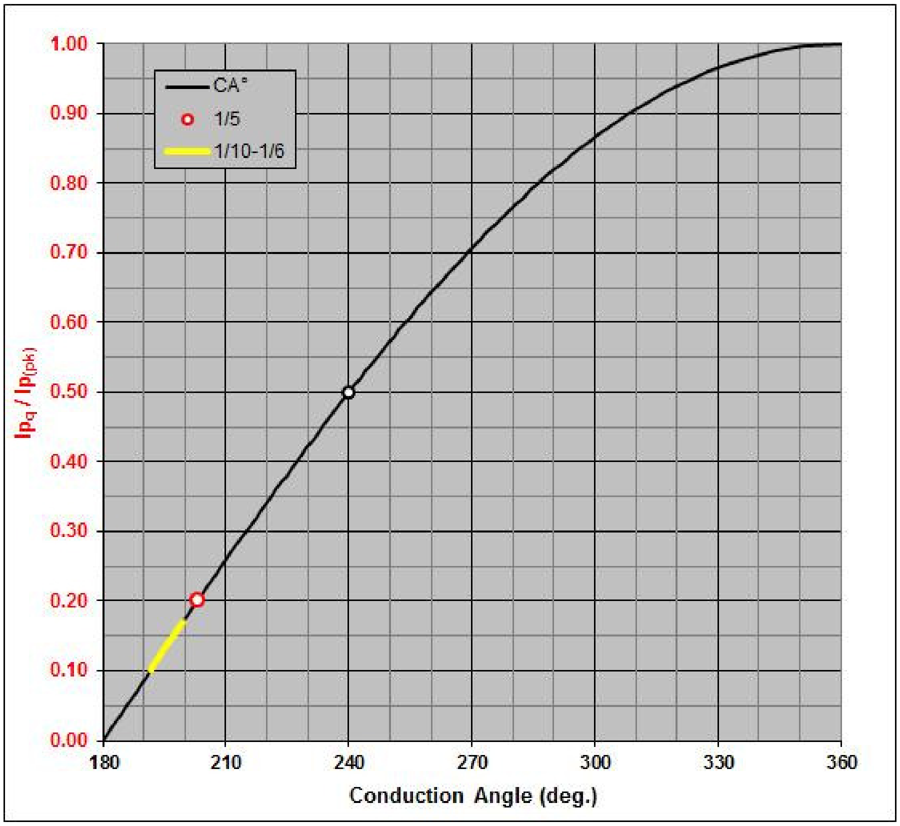

Figure 1 - Plate Conduction Angle vs. DC-to-PK Current Ratio

To see how well these conduction angles compare to their corresponding idle plate power dissipation values the RCA 6L6GC amplifier is compared with a typical Fender 6L6GC amp in Table 1 below. Note their greatly different idle plate dissipation ($\mathbf{Pp_Q}$) values!

Table 1 – Example RCA 55W amplifier vs. typical Fender 45W amplifier.

Class-AB_1 Amplifier	Zpp	Vp_Q	Pd_Q	%Pd	Ip_Q	$Ip_{(pk)}$	ratio	CA
RCA **55W** 6L6GC	5,600Ω	450V	26.0W	87%	58mA	297mA	1/5	203 deg.
typical Fender **45W** 6L6GC	4,000Ω	460V	16.6W	55%	36mA	315mA	1/9	193 deg.

• Summary

A higher quiescent idle plate dissipation does not necessarily mean a higher conduction angle—conduction angle is solely determined by the plate DC-to-PK current ratio.