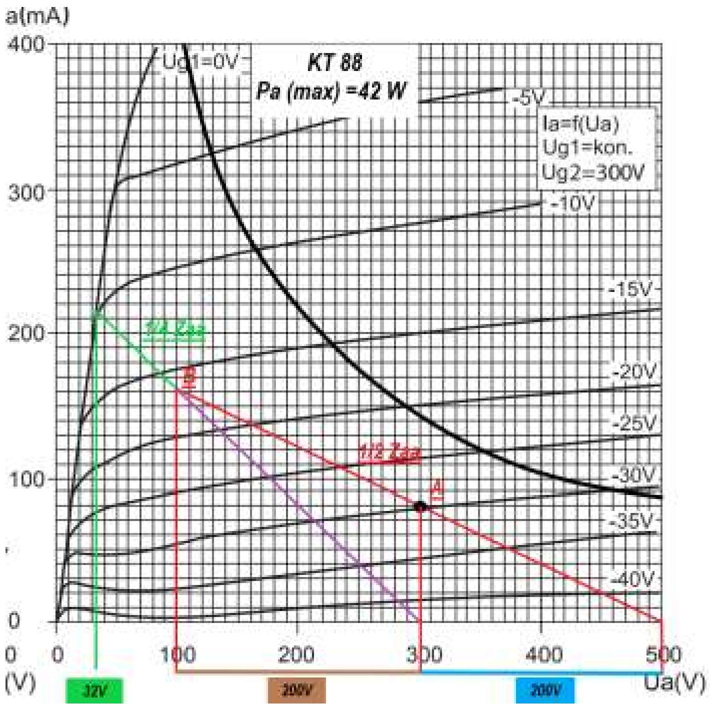
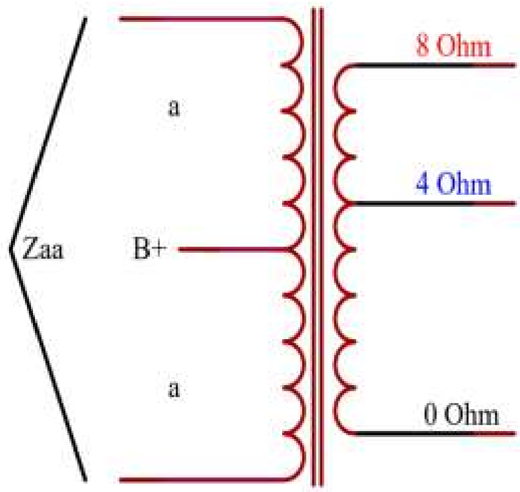
Calculating the push-pull output stage





<u>Suppose we have a:</u>

Supply voltage B+ = 300 V.
Ia per tube = 80mA.
Anode dissipation per tube is therefore:

P_a = U * I =300 V * 80 mA = 24 Watt (well within the norm), $P_{a(max)}$ is 42 Watt)

Point A = selected Bias current.
Point B = transition Class A to Class B

Z_{aa} = Primary impedance output transformer = 5 KΩ

½ Z_{aa} = 2,5 KΩ	In class A, **1** tube sees **1/2 Z_{aa}** and both tubes are in conduction.
¼ Z_{aa} = 1,25 KΩ	In class B **1** tube sees **1/4 Z_{aa}** and 1 tube is in conduction.

A characteristic of a transformer is that it can supply more voltage than the connected supply voltage **(B+).** (Temporary energy storage)

Calculating the Load Line for Class A:

U = I_a * ½ Z_{aa} = 80 mA x 2,5 KΩ = 200 V

Draw a line through **point A**, with intersections at **B+ = 500 V** and **B+ = 100 V**, starting from the zero line (500V). These points determine the slope angle. At 500V, the tube stops operating because this lies on the zero line.

Now calculate the power in Class A using the RMS voltage **(V_{rms}).** The previously calculated 200V is a peak voltage **(V_p)** and must be converted to RMS voltage **(V_{rms}).**

$$V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{200\ V}{1{,}414} = 141{,}4\ V_{rms}$$

$$P_{tube} = \frac{{V_{rms}}^2}{\frac{1}{2}Z_{aa}} = \frac{141{,}4\ V * 141{,}4\ V}{2500\Omega} = 7{,}9\ \text{Watt per tube}$$

The power in Class A is therefore 2 x 7.9 W = 15.8 Watts.

Calculating the Load Line for Class B:

Draw a line from the 0 line at **B+ = 300 V** to point **B** and extend the line until **Ug1 = 0V.** This determines the slope angle for Class B.

Note: The **purple line** is a guideline and should be ignored further.

Now you can also calculate the power in Class B.

$$V_p = 300\ V - 32\ V = 268\ V_p$$

$$V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{268\ V}{1{,}414} = 189{,}5\ V_{rms}$$

$$P_{tube} = \frac{{V_{rms}}^2}{\frac{1}{4}Z_{aa}} = \frac{189{,}5V * 189{,}5V}{1250\Omega} = 28{,}7\ \text{Watt}$$

Power Class B = 28,7 Watt

Note: This is not multiplied by 2, because in Class B, only one tube is conducting.

So:

Class A : 0 - 15,8 Watts
Class B: 15,8 - 28,7 Watts

It is essential to choose the **quiescent point A** in such a way that, at a grid voltage **Ug1 = -20V**, the anode voltage **Ua (V)** is equal to that at a grid voltage **Ug1 = -40V**, relative to the bias point. In this case, the bias point is **Ug1 = -30V**, as the amplifier typically operates in Class A.

So:

At **Ug1 = -20V**, you have a voltage of **160 V_a.**
At **Ug1 = -30V**, you have a voltage of **300 V_a.**
At **Ug1 = -40V**, you have a voltage of **450 V_a.**

450 V_a - 300 V_a = 150 V_a
300 V_a - 160 V_a = 140 V_a

There is a difference of **10 V**, resulting in second harmonic distortion. This can be calculated as a percentage.

$$THD_2 = \frac{150\,V - 140\,V}{150\,V + 140\,V} * 100 = 3{,}44\ \%$$

The primary impedance **(Z_{aa})** can be influenced by the speaker impedance **(Z_{ls})** to which it is connected. In other words, the speaker impedance **(Z_{ls})** plays a determining role in establishing the primary impedance **(Z_{aa})** of the output transformer.

If the manufacturer specifies a **Z_{aa}= 5KΩ**, and you connect a speaker with an impedance of **Zls = 8Ω** to the 8Ω tap of the output transformer, the **Z_{aa}** remains **5KΩ**. The same applies to a **Z_{ls} = 4Ω** speaker impedance connected to the **4Ω** tap of the output transformer.

If a **Z_{ls}** of **8Ω** is connected to the **4Ω** tap of the output transformer, the **Z_{aa}** will be **10KΩ**. This results in a more horizontal load line and generally less distortion. The downside is that the power output is halved, but this is not necessarily a problem if sufficient power is available.

If a **Zls = 4Ω** is connected to the **8Ω** tap of the output transformer, then **Z_{aa}** becomes **2.5KΩ**. This results in a more vertical load line and usually more distortion. However, this also increases power output, but caution is required, as exceeding the maximum power rating of the output tube can be risky. Therefore, this is not recommended.

Based on this information, the winding ratio of the output transformer can also be calculated.

For the **8Ω** tap:

$$\text{Winding ratio}\ \frac{N_p}{N_s} = \sqrt{\frac{Z_{aa}}{Z_{ls}}} = \sqrt{\frac{5000\Omega}{8\Omega}} = \sqrt{625} = 25$$

For the **4Ω** tap:

$$\text{Winding ratio}\ \frac{N_p}{N_s} = \sqrt{\frac{Z_{aa}}{Z_{ls}}} = \sqrt{\frac{5000\Omega}{4\Omega}} = \sqrt{1250} = 35{,}3$$