Lab-Report
Analogue Electronics

Push-Pull Amplifiers

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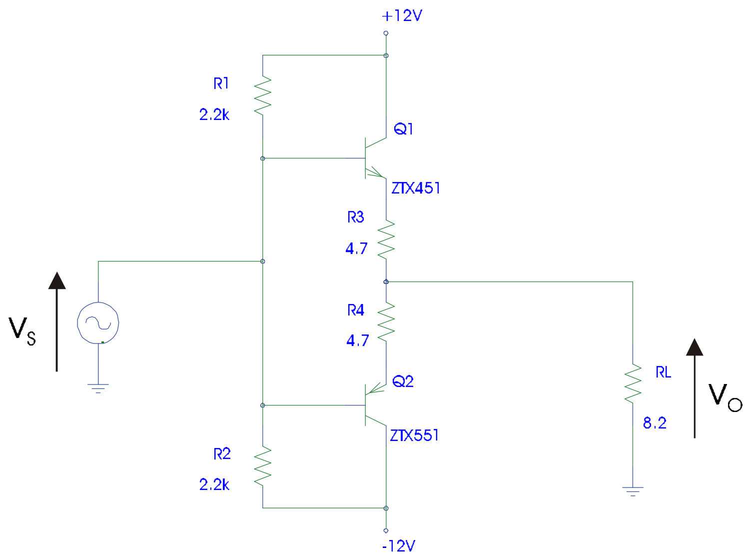
1. Contents

2. Class-B power amplifier

a) DC-Bias

The DC-Bias of the push-pull class-B amplifier below was to determine.

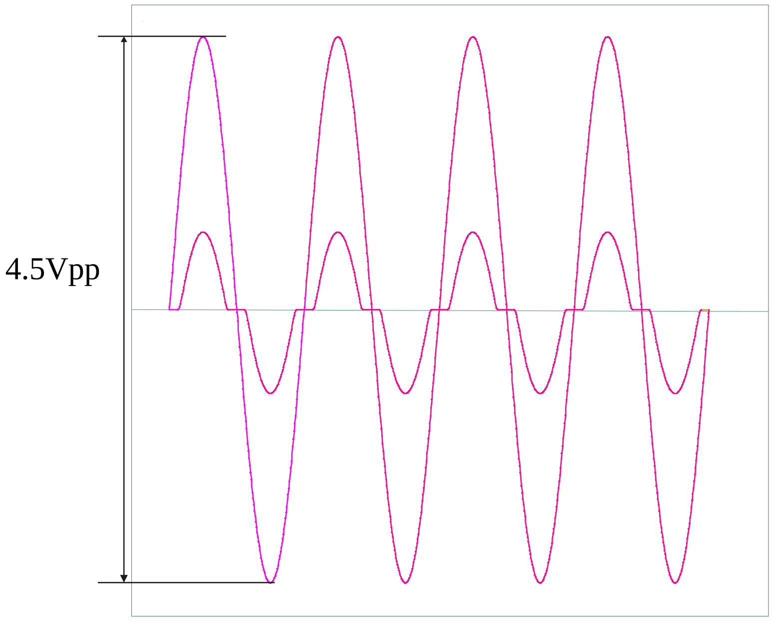


V_{R1}= 12.02V
V_{BEQ1}=23.3mV
V_{CEQ1}=12V
V_{R3}= 0V
V_{R4}= 0V
V_{RL}= 0V
V_{BEQ2}=17.2mV
V_{CEQ2}=12V
V_{R2}= 12V
I_{DC+-}= 5.5mA
I_+= 37.8mA
I_-= 37.9mA

The DC-Bias shows, that there is no current through the transistors without a signal voltage v_s because the base inputs are short circuited. The current of about 5.5mA is caused only through the base resistors R_1 and R_2. $\underline{I}=(V_{CC1}+V_{CC2})/(R_1+R_2)=\underline{5.45mA}$.
A class-B amplifier works by opening either the NPN or the PNP transistor through the signal voltage v_s. So the class-B amplifier only works, if the signal input voltage is above the break voltage (~0.7V) of the transistors.

b) AC Power Characteristiccs

Next step was to determine the AC-Power Characteristics. Therefor the input signal v_i was raised, until the output voltage v_o became $1V_{pp}$.
An approximate printout of the oscilloscope's display can bee seen in the figure below.



v_s=4.5Vpp (1.573VAC)
v_o=2Vpp (0.602VAC)

The distortions at the 0V regions are determined the transistor's break through voltage.

All AC values were measured with a FLUKE 4510 digital multimeter

The output power is determined by:

$$P_O = \frac{(v_{OAC})^2}{R_L} = \frac{(0.602V_{AC})^2}{8.2\Omega} = 44.2\text{mW}$$

The Power efficiency η is defined by the ratio of output power to input power. So the maximum value for η can be 1 (but not here).

$$\eta_{max} = \frac{P_{out}}{P_{in}}$$

$$\eta_{max} = \frac{V_C I_C}{2V_{CC} I_C}$$

$$\eta_{max} = \frac{\frac{V_{max}}{\sqrt{2}} \frac{I_{max}}{\sqrt{2}}}{2V_{max} \frac{I_{max}}{\pi}}$$

$$\underline{\underline{\eta_{max} = 78.5\%}}$$

η with the measured values:

$$\eta = \frac{P_{out}}{P_{in}}$$

$$\eta = \frac{v_o^{\ 2} / R_L}{V_{CC}(I_+ + I_-)}$$

$$\eta = \frac{0.602^2 V^2 / 8.2\Omega}{12V(37.9mA + 37.9mA)}$$

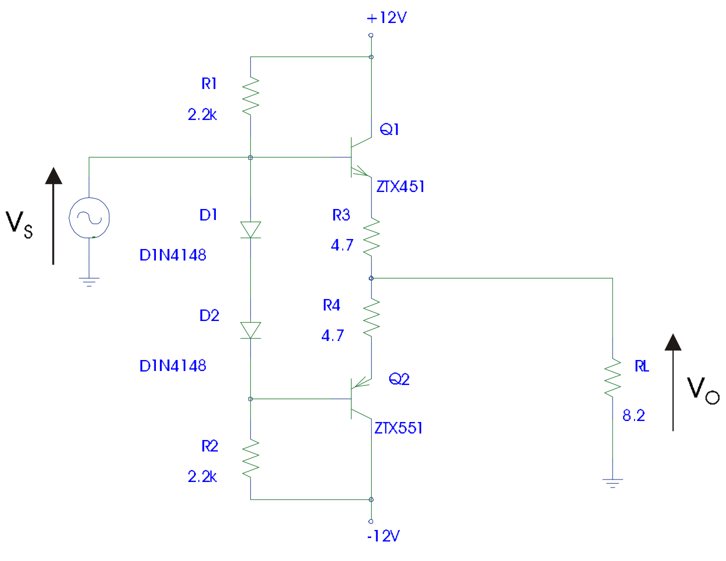
$$\underline{\underline{\eta = 4.9\%}}$$

The Power efficiency is very low, because the maximum power efficiency can only be reached at maximum output signal voltage.

3. Class-AB power amplifier with duo supplies

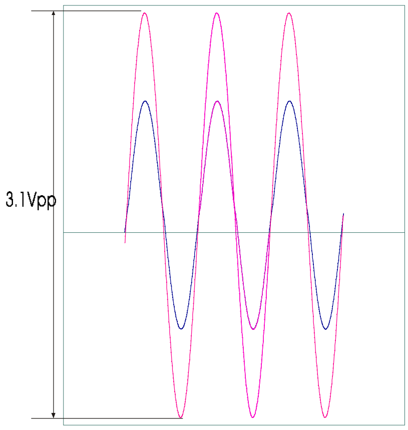
a) DC-Bias

At first the DC-bias of the class-AB power amplifier was to determine.



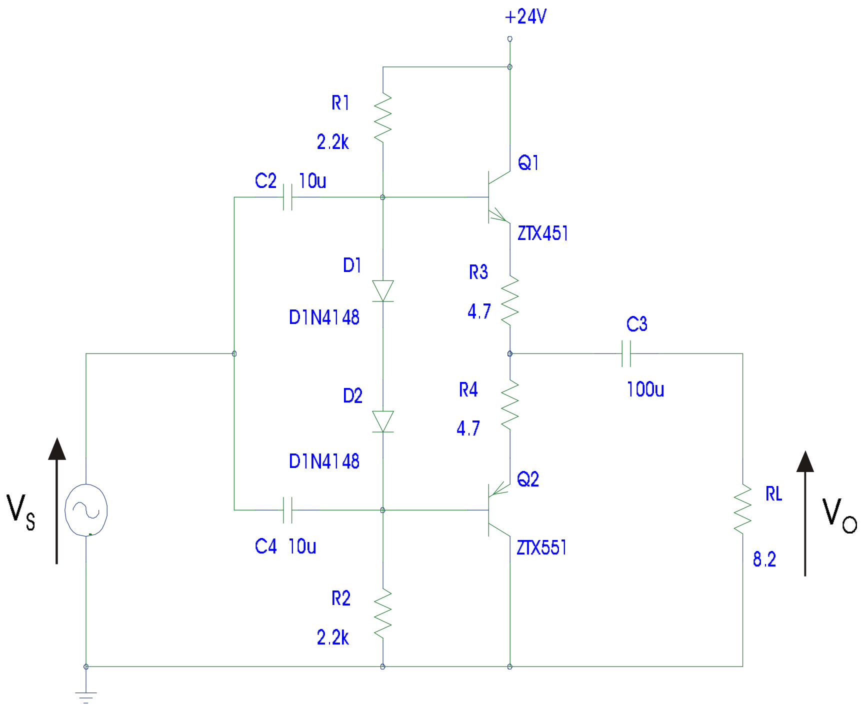
V_{R1}= 11.4V
V_{BEQ1}=0.610V
V_{CEQ1}=11.98V
V_{R3}= 62mV
V_{D1}= 705mV
V_{D2}= 680mV
V_{R4}= 65mV
V_{R2}= 11.26V
V_{BEQ2}=605mV
V_{CEQ2}=11.83V
V_{R2}= 11.12V
I_{DC+}= 23mA
I_{DC-}= 29.3mA
I_{+SIG}= 28.7mA
I_{-SIG}= 83.4mA

Now the current throug the different resistors can be determined:



b) AC Power Characteristiccs

The distortion of the class-AB amplifier is much lower than the of the class-B amplifier because the bases of the transistors are DC-biased through the diodes and so the quiescent point is shifted into the linear region of the transistor.
Class-AB means, that each of the transistors conducts for more than half a cycle (class-B each transistor conducts for only half a cycle, or a little bit less).
This can easily be seen in the following figure.



v_s=3.1Vpp
(1.066VAC)
v_o=2Vpp
(0.711VAC)

The value of v_{OAC} is now more exactly because of the less distortion (The measuring instrument is gauged to sinus signals).

With the measured signal voltages the power efficiency can be determined.

$$\eta = \frac{P_{out}}{P_{in}}$$

$$\eta = \frac{v_o^{\,2} / R_L}{V_{CC}(I_{+Sig} + I_{-Sig})}$$

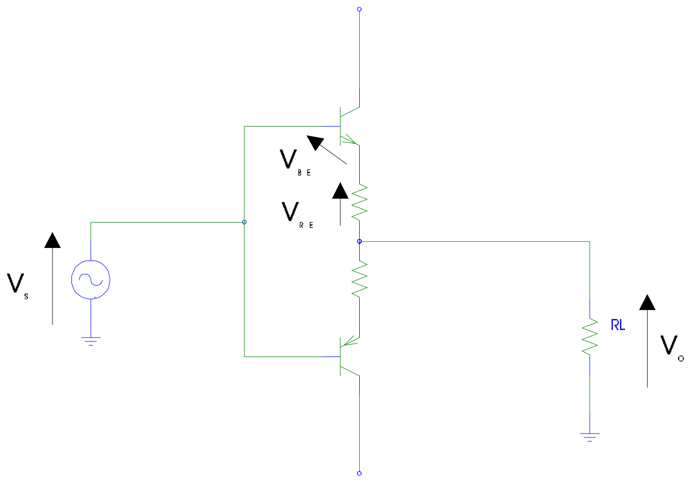
$$\eta = \frac{0.711^2\,V^2 / 8.2\Omega}{12V(28.7mA + 83.4mA)}$$

$$\underline{\underline{\eta = 4.6\%}}$$

The maximum theoretical value should be about the same than the power efficieny of the class-B amplifier, because the output stage has not been changed.

c) Voltage Amplification

The Voltage amplification A_V of a push-pull amplifier is below 1, because it only consists of 2 emitter follower, which have no voltage amplification. It can be seen, that the output can be at maximum as large than the input voltage v_s minus the two break through voltages of the transistors and minus the voltage drop at the two emitter resistors.



$$0V = v_S - V_{BE} - v_{RE} - v_o$$

$$v_o = v_s - V_{BE} - v_{RE}$$

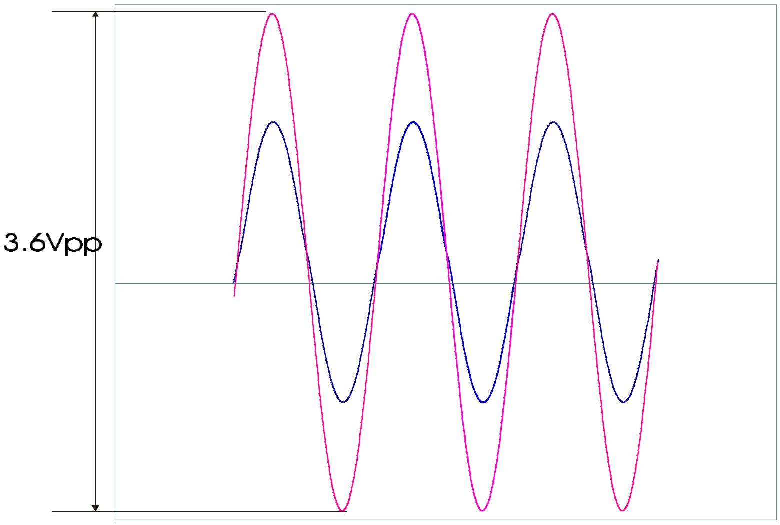
$$\underline{\underline{v_{o\,max} = v_s - V_{BE} - v_{RE}}}$$

So the signal voltage, which is put to th einput of the push-pull amplifier has to be properly amplified (~ to the region of V_{CC}) for getting the maximum power output.
This is valid for ALL “common collector” push-pull amplifiers and is only once shown here.

4. Class-AB power amplifier with a single supply

In very much electronic devices push-pull amplifiers are needed because of their low output impedance. But not in all these devices dual power supplies are available, since they are more expensive. But a push-pull amplifier can be realised without dual-supply, by using coupling capacitors or transformers for separation the DC-bias from inputs and outputs.

a) DC-Bias of the class-AB amplifier with a single supply



$V_{R1}=$ 11.37V
$V_{BEQ1}=$0.618V
$V_{CEQ1}=$12.77V
$V_{R3}=$ 91.5mV
$V_{D1}=$ 705mV
$V_{D2}=$ 689mV
$V_{R4}=$ 87.2mV
$V_{R2}=$ 11.26V
$V_{BEQ2}=$63mV
$V_{CEQ2}=$11.82V
$V_{R2}=$ 11.29V
$I_{+}=$ 27.0mA
$I_{+SIG}=$ 44.2mA

The circuit is equivalent to the class-AB power amplifier with single supply. The supply voltage is 24V. At the amplifier with duo supply the supply voltage was 24V too ($2xV_{CC}$). The difference is only that the lower potential is now ground and therefore the inputs and outputs have to pass coupling capacitors.

The currents through the resistors can now be determined:

$$\underline{\underline{I_{R1}}} = \frac{V_{R1}}{R_1} = \frac{11.37V}{2.2k\Omega} = \underline{\underline{5.2mA}}$$

$$\underline{\underline{I_{R2}}} = \frac{V_{R2}}{R_2} = \frac{11.29V}{2.2k\Omega} = \underline{\underline{5.1mA}}$$

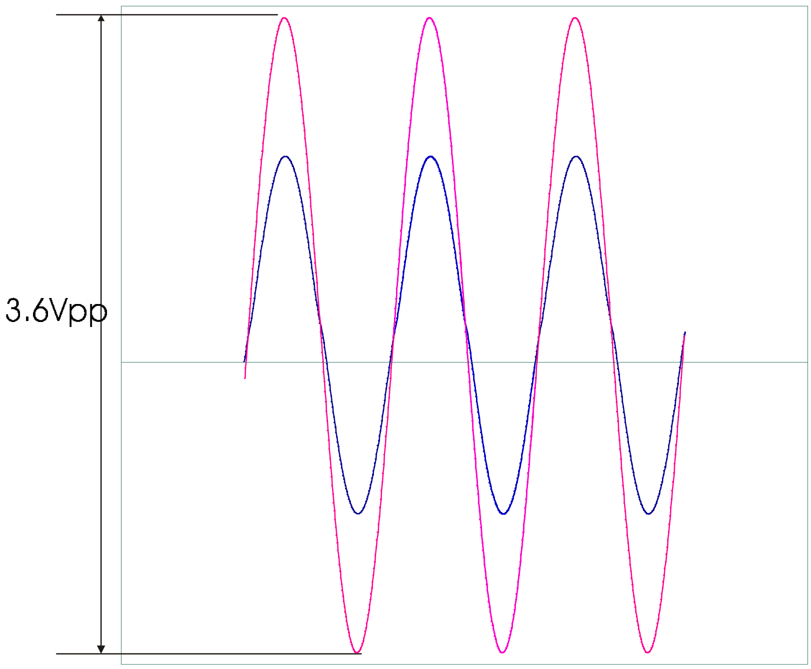
$$\underline{\underline{I_{R3}}} = \frac{V_{R3}}{R_3} = \frac{62mV}{4.7\Omega} = \underline{\underline{19.47mA}}$$

$$\underline{\underline{I_{R4}}} = \frac{V_{R4}}{R_4} = \frac{87.2mV}{4.7\Omega} = \underline{\underline{18.6mA}}$$

All values are very close to those of Part 2 of the lab → equivalent circuits.

b) AC Power Characteristiccs

Also the AC-characteristics are equivalent to the push-pull amplifier with duo supplies.



v_s=3.6Vpp (1.25VAC)
v_o=2Vpp (0.727VAC)

The measured values are nearly the same than in the 2nd part of the LAB.

Now with the measured signal voltages the power efficiency can be determined.

$$\eta = \frac{P_{out}}{P_{in}}$$

$$\eta = \frac{v_o^2 / R_L}{V_{CC}(I_{+Sig} + I_{-Sig})}$$

$$\eta = \frac{0.727^2 V^2 / 8.2\Omega}{24V \times 44.2mA}$$

$$\underline{\underline{\eta = 6.1\%}}$$

The different values for the power efficiency don't depend on the different power efficiencies of the different amplifiers.
The various values of the power efficiency are in the region of measurement uncertainty.
For a comparable measurement the amplifiers have to be tested with maximum input levels.

c) Lower cut-off frequency

The lower cut-off frequency of the single supply class-AB amplifier is above all determined by the value of the output coupling capacitor C_3.

$$f_{CL} = \frac{1}{2\pi\tau_{C3}}$$

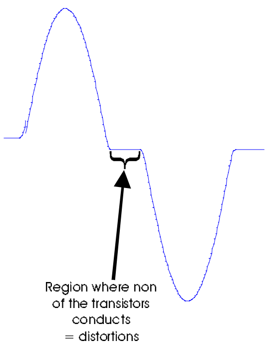
$$f_{CL} = \frac{1}{2\pi(R_3 + R_L)C_3}$$

$$f_{CL} = \frac{1}{2\pi \times 12.9\Omega \times 100\mu F}$$

$$\underline{\underline{f_{CL} = 124.4Hz}}$$

5. Conclusion

Push-pull amplifiers are used in electronics since the first days of amplifiers. They can be used for low, middle and high frequency power amplification, or wherever high powers, low distortion rates, or both are required.



Objectives of the lab were to measure major aspects of class-B and class-AB push-pull amplifiers, like the input and output power, the power efficiency, the AC-voltages and the DC-bias.

The major difference between class-AB and class-B push-pull amplifiers is the distortion rate. The distortion rate of the class-B amplifier is high, because the amplification especially of small signals is not performed at the linear regions of the transistors. The signal voltage has to be above the break through voltage to open each of the transistors.
Advantage of the class-B amplifier is, that it need only very small current, if there is no input voltage.

The class-AB amplifier reduces the problem of the small signal amplification by using a more linear region for small signal amplifications. The transistors are pre-biased for instance like in the lab by two diodes. So every transistor conducts for more than one cycle.
Usually a push-pull amplifier needs a dual voltage supply, but by means of input and output coupling capacitor a single voltage supply is sufficient, because there is non difference between two voltages, each the same (one positive, one negative) amount, or one voltage source with double amount.