CLASS B AMPLIFIER

I. OBJECTIVES

a) Determination of the voltage transfer characteristic for a class B amplifier.
b) To observe and determine the causes of the crossover distortions.
c) Learning some methods to reduce the crossover distortions:
  - biasing in class AB.
  - using an additional voltage amplifier and global negative feedback.

II. COMPONENTS AND INSTRUMENTATION

Use the experimental assembly composed by two voltage regulators (7809, 7909), two complementary BJTs BD441 (npn) and BD438 (pnp), two diodes, an operational amplifier 741, a simple switch, a double switch and a speaker of impedance 4Ω. To supply the assembly use a double power supply, and to apply the input voltage use a sine wave signal generator. We visualize the ac voltages with a dual channel oscilloscope.

III. PREPARATION

P.1. Class B amplifier

P1.1. Waveforms

- For the circuit in Fig. 1, what transistor is on for: (1) a positive v_i; (2) a negative v_i? Assume $V_{BE,on} = 0.6V$ for the npn transistor and $V_{BE,on} = -0.6V$ for the pnp transistor.
- Plot $v_o(t)$ assuming $v_i(t)$ is a sine wave with the amplitude of: (1) 0.3V; (2) 4V; (3) 9V.

P.1.2. The voltage transfer characteristic (VTC)

- For the circuit in Fig. 1, derive and plot the VTC $v_o(v_i)$ for the input voltage v_i in the range [-9V;9V].

P.1.3. Power gain

- Compute the voltage gain, the current gain and the power gain of the class B amplifier.

P.2. Class AB amplifier

P.2.1. Waveforms

One way to reduce the crossover distortions is to use the class AB amplifier, where the transistors T1 and T2 are pre-biased by a small dc current, through the R1, D1, D2, R2 network (Fig. 2).

- Find the values of the dc voltages in the bases of the two transistors from Fig. 2, in their bias points (v_i=0).
- Plot $v_o(t)$ for $v_i(t) = 0.3\sin 2\pi 1000t$ [V],[Hz].
- Plot $v_o(t)$ for $v_i(t)=4\sin 2\pi 1000t$ [V],[Hz].
- Now assume we connect the 4Ω impedance speaker as load resistor. Plot again $v_o(t)$ for $v_i(t)=4\sin 2\pi 1000t$ [V],[Hz] and compare it with $v_o(t)$ obtained before for the same $v_i(t)$, but with R_L=22Ω. Are the two waveforms different?

Suggestion: *For example, in the positive half-wave of $v_i(t)$ and $v_o(t)$, we must check if the current through R1 is large enough to ensure a sufficiently large base current for T1, to keep T1 in a_F. In a_F consider $\beta \approx 25$ (for both transistors).*

P.2.2 The VTC

- Derive and plot the VTC of the circuit in Fig. 2, for an input voltage range of [-9V; 9V].

P.3. Class B amplifier with additional voltage amplifier and global negative feedback

Another method to reduce the crossover distortions is to introduce an additional voltage amplifier before the output stage. This amplifier must have a very large voltage gain for small input voltages (around 0V), while for larger values of the input voltage, the voltage gain must become 1. Such a circuit with an OpAmp voltage amplifier and NF is presented in Fig. 3. For small v_i (around 0V) the transistors enter in off state, so no signal is transmitted through the feedback path and the amplifier's gain is the open loop gain of the O.A., which is very high. Therefore, for very small values of v_i around 0V, the voltage in the base terminals of the transistors (which is v_i multiplied by the very high open loop gain of the O.A.) exceeds the threshold voltages of the BJTs (±0.65V), causing either the npn transistor (for v_i>0) or the pnp transistor (for $v_i<0$) to enter a_F region, thus closing the feedback loop. In this case, $v_o=v_i$.

P.3.1. Waveforms

- Find the range of the input voltage v_i for which $v_o=0$.
- Plot $v_o(t)$ for $v_i(t)$ – sine wave of 4V amplitude.

P.3.2. The voltage transfer characteristic

- Derive and plot the VTC $v_o(v_i)$ for v_i in the range [-9V;9V].
- Connect as load resistor the 4Ω impedance speaker. How does this influence the VTC? Re-plot the VTC $v_o(v_i)$ according to this case.

Suggestion: *The output voltage limitation will take place at a smaller value. Take into account the fact that the IC 741 has a short-circuit protection that limits the output current to approx. 25mA.*

IV. EXPLORATIONS AND RESULTS

1. Class B amplifier

1.1.Waveforms

Explorations

Build the circuit from Fig. 1: K2 on 1(**ATTENTION**: on the experimental assembly there are two switches denoted K2. For the first one, position 1 means second and third terminals connected together; for the second one, position 1 means first and second terminals connected together).

- supply the circuit with $\pm V_{PS}=\pm 12V$.
- $v_i(t)$ is a sine wave of 1 KHz frequency, from a signal generator and it is applied at terminal A.
- Visualize simultaneously $v_i(t)$ and $v_o(t)$ with the dual channel oscilloscope, for the following amplitudes of $v_i(t)$: 0.3V, 4V and 9V.

Results

- The waveforms of $v_i(t)$ and $v_o(t)$ for the amplitude of v_i of 0.3V, 4V and 9V.
- Explain why $v_o(t)=0$ for $v_i(t)$ having an amplitude of 0.3V.
- Explain why $v_o(t)$ is not a clean sine wave for the amplitude of v_i of 4V.

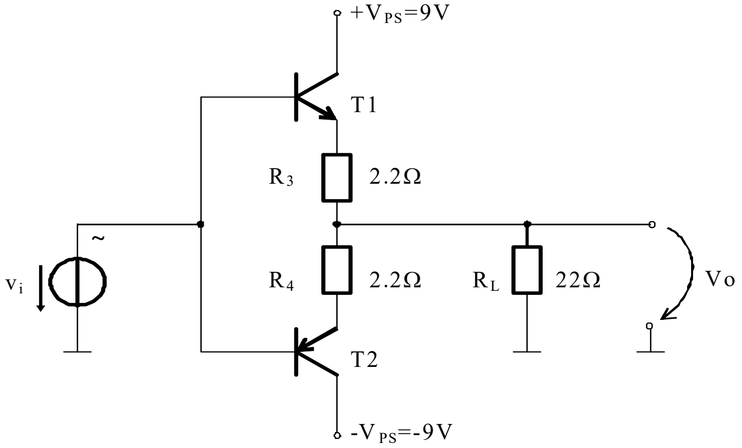

Fig. 1. Class B amplifier

- Why is $v_o(t)$ upper and lower limited when v_i amplitude is 9V? Who gives the upper and lower limits of v_o? Comment on the magnitude of the crossover distortions in this case.
- Why are the $v_o(t)$ distortions around 0V called "crossover distortions"?
- Give the range of values of v_i for which v_o=0.

1.2. The voltage transfer characteristic (VTC)

Explorations

Use the circuit from Fig. 1.

- $v_i(t) = 9\sin 2\pi \cdot 1000t$ [V],[Hz].
- Visualize the VTC with the oscilloscope set in Y-X mode.

Results

- The VTC for v_i in the range [-9V; 9V].
- Give the range of values of v_i for which v_o=0.
- On which line segment of the VTC is: (1) the npn transistor on; (2) the pnp transistor on?
- Is the variation of v_o obtained in 1.1. in accordance with the VTC obtained here?

1.3. The power gain

Explorations

Use the circuit from Fig. 1.

- $v_i(t) = 4\sin 2\pi \cdot 1000t$ [V],[Hz].
- Connect the 4Ω impedance speaker to the signal source (between A-DIF and GND), and then as load resistor at the amplifier's output (between OUT-DIF and GND).
- In which case is the acoustic signal stronger? Why?

2. Class AB amplifier

2.1. Waveforms

Explorations

Build the circuit from Fig. 2.: K2 on 2(**ATTENTION**: on the experimental assembly there are two switches denoted K2. For the first one, position 2 means first and second terminals connected together; for the second one, position 2 means second and third terminals connected together).

- Apply v_i at terminal AB.
- Visualize $v_i(t)$ and $v_o(t)$ for $v_i(t)$ sine wave of 1KHz frequency and 0.3V amplitude.
- Repeat the visualization when v_i is a sine wave of 1KHz frequency and 4V amplitude.
- Consider v_i sine wave of 1KHz frequency and 4V amplitude. Connect the 4Ω impedance speaker as load resistor. Visualize again $v_i(t)$ and $v_o(t)$.

Results

- $v_i(t)$ and $v_o(t)$ for the amplitude of $v_i(t)$ of 0.3V and 4V.
- Are there crossover distortions? Why?
- $v_o(t)$ when the speaker is used as load (lowered load impedance).
- Explain the limitation of v_o.

2.2. The VTC

Explorations

Use the circuit from Fig. 2.

- Visualize the VTC when v_i is a sine wave of 1KHz frequency and 9V amplitude.

Results

- The VTC.
- Find the upper and the lower limits of the voltage v_o .
- Compare the VTC obtained here with the one from 1.2.

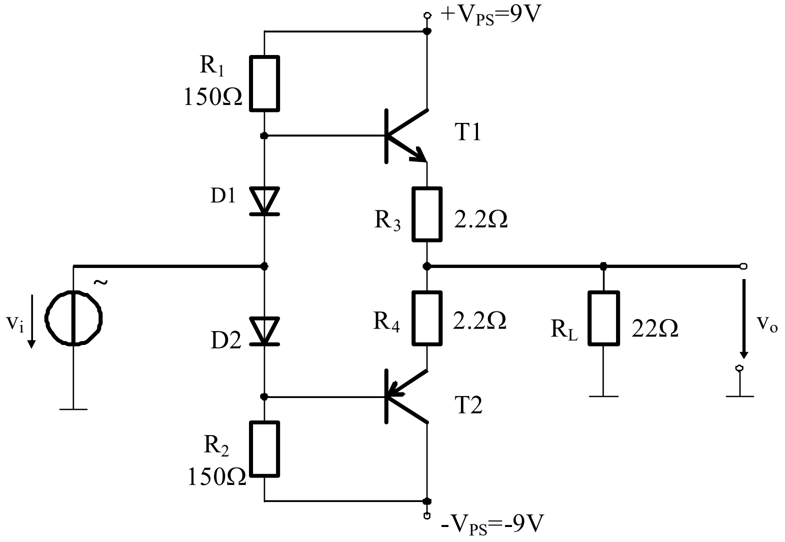

Fig. 2. Class AB amplifier

3. Class B amplifier with additional voltage amplifier and global NF

3.1. Waveforms

Explorations

Build the circuit from Fig. 3: K1 closed (one jumper connected to K1), K2 on 1; apply v_i at the RN terminal.

- $v_i(t) = 4\sin 2\pi \cdot 1000t[V],[Hz]$.
- Visualize simultaneously $v_i(t)$ and $v_{o,OA}(t)$, and then $v_i(t)$ and $v_o(t)$.

Results

- $v_i(t)$, $v_{o,OA}(t)$, $v_o(t)$;
- Explain the distortions of $v_{o,OA}(t)$ around 0V.
- Is $v_o(t)$ distorted?

3.2. The voltage transfer characteristic

Explorations

Use the circuit from Fig. 3.

- Visualize the VTC for $v_i(t) = 4\sin 2\pi\cdot 1000t$ [V],[Hz].
- Repeat the visualization when the 4Ω impedance speaker is connected as load resistor.

Results

- Draw the VTCs for: (1) R_L=22Ω; (2) R_L=4Ω (the speaker connected to the output).
- Compare the VTC for R_L=22Ω with the VTCs obtained at 1.1 and 2.1.
- Explain the limitation of v_o at a smaller value when the speaker is connected at the output than in the case of R_L=22Ω (speaker not connected at the output).

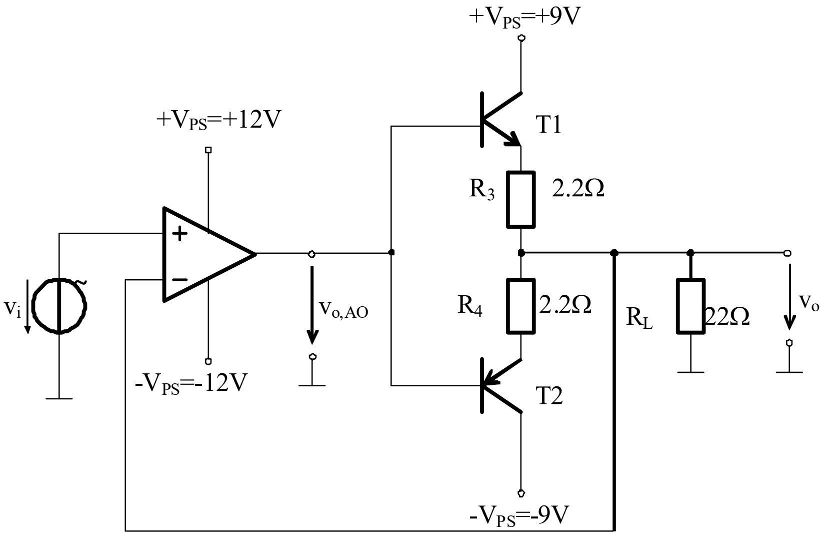

Fig. 3. Amplifier with global NF

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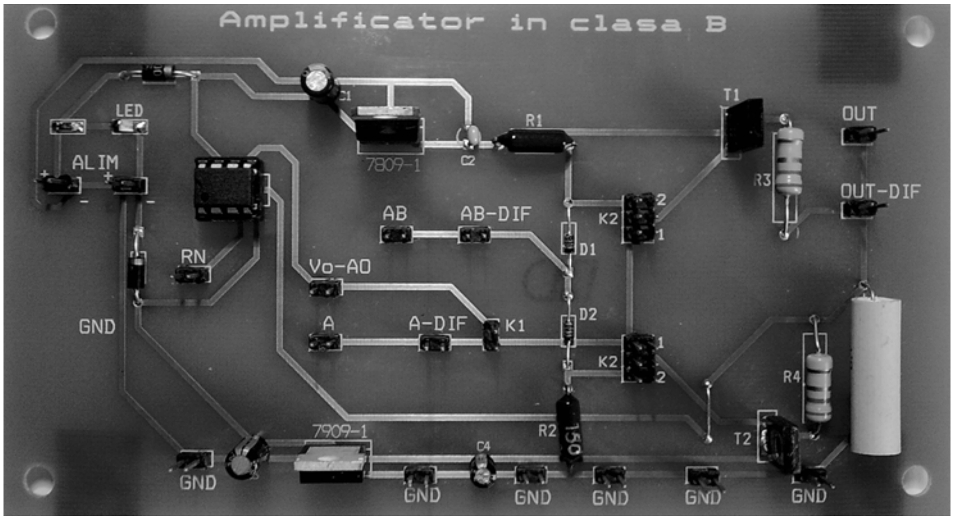

Fig. 4. Experimental assembly