Electronics II.

4. measurement

Symmetric difference amplifier

Aims:

Analysis and parameter measurement of symmetric difference amplifier made of bipolar transistors.

External sources:
Tietze-Schenk: Analogue and digital circuits

The *italic text* in this guide represents hints and voluntary measurements.

Component list

- 1pc MD2369 transistor pair (in common package, on a PCB)
- 1 pc BC337 transistor
- 1 pc ZPD3.3 Zener diode
- 1 pc symmetrising (balun) transformer
- 2 pcs 100kΩ
- 3 pcs 10kΩ
- 2 pcs 2kΩ
- 1 pc 1kΩ trimmer potentiometer

Exercises

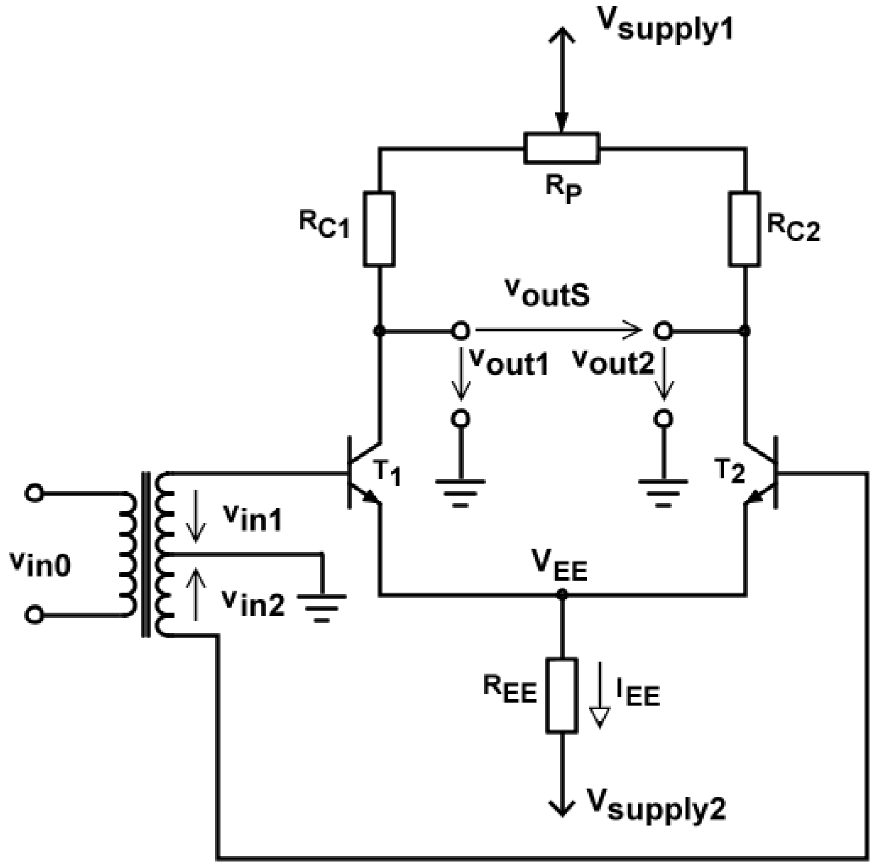

Figure 1.: symmetric input

Parameters:
$R_{C1}=R_{C2}=10k\Omega$; $R_{EE}=10k\Omega$; $R_P=1k\Omega$ trimmer ; $U_{supply1} = +12V$; $U_{supply2} = -12V$
Before starting the measurement, set up 20mA current limit on both power supply outputs!

I. Calculations (homework, before coming to laboratory!)

1) Calculate the operating point (DC) voltages and currents of the circuit on figure 1 in ideal case. (R_P setup 50-50%, $R_{C1}=R_{C2}$, transistor parameters equal).

2) Calculate the output offset voltage ($V_{C1}-V_{C2}$), if R_{C1} is 5% greater than the nominal value and $I_{C1}=1.1 \cdot I_{C2}$.

3) Calculate the symmetrical (differential) voltage gain in ideal case. [1]

$$A_{VSS} = \frac{v_{outS}}{v_{inS}} = \frac{v_{out1} - v_{out2}}{v_{in1} - v_{in2}},$$

if $v_{in1} = -v_{in2} = \frac{v_{inS}}{2}$

[1] In the symbols in this guide, the first index refers to the output, the second to the input. Eg. A_{VSC} is about how much a common mode input signal changes the symmetric (differential) output.

4) Calculate the common mode voltage gain in ideal case (see figure 2.)

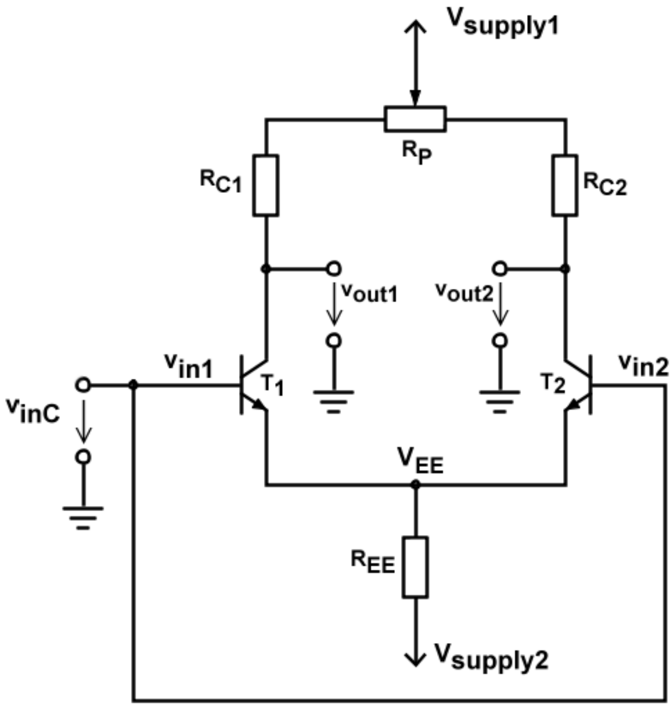

Figure 2.: common mode input

$$A_{VCC} = \frac{v_{outC}}{v_{inC}} = \frac{\frac{v_{out1} + v_{out2}}{2}}{\frac{v_{in1} + v_{in2}}{2}} = \frac{v_{out1} + v_{out2}}{v_{in1} + v_{in2}}, \text{ if } v_{inS}=0 \ (v_{in1} = v_{in2} = v_{inC})$$

Ideal case: $v_{out1} = v_{out2} = v_{outC}$

$$A_{VCC} = \frac{v_{outC}}{v_{inC}} = \frac{v_{out1}}{v_{in1}} = \frac{v_{out2}}{v_{in2}}$$

5) Calculate the differential voltage gain when using common mode input, in ideal case (that is, how much of the input CM signal transfers to a symmetric output).

$$A_{VSC} = \frac{v_{outS}}{v_{inC}} = \frac{v_{out1} - v_{out2}}{\frac{v_{in1} + v_{in2}}{2}}, \text{ if } v_{in1} = v_{in2} = v_{inC}$$

6) Calculate the previous two gains (A_{VCC} and A_{VSC}) if R_{C1}=10.1kΩ.

$$(v_{outC} = \frac{v_{out1} + v_{out2}}{2})$$

7) Calculate the Common Mode Rejection Ratio (CMRR) for ideal and non-ideal (ie. exercise 6.) for symmetric (differential) output.

$$CMRR = \frac{A_{VSS}}{A_{VSC}}$$

$$CMRR[dB] = 20\lg\frac{A_{VSS}}{A_{VSC}}[dB]$$

8) Calculate the CMRR if only one output (v_{out1}) is used (that is, we have an asymmetric output) (*In practice in such applications RC2 is replaced by a shortcircuit. Because we only have one output, only one index will be used for the gains, which will refer to the input.*)

$$CMRR_{asymmetric} = \frac{A_{VS}}{A_{VC}}$$

$$CMRR_{asymmetric}[dB] = 20\lg\frac{A_{VS}}{A_{VC}}[dB]$$

where

$$A_{VS} = \frac{v_{out1}}{v_{inS}} = \frac{A_{VSS}}{2},\ \text{if } v_{in1} = -v_{in2}$$

$$A_{VC} = \frac{v_{out1}}{v_{inC}} = \frac{v_{out1}}{v_{in1}},\ \text{if } v_{in1} = v_{in2} = v_{inC}$$

Calculate the DC emitter current for figure 3. Parameters: R_{E3}=2kΩ ; R_{B3}=2kΩ ; Z_1: ZPD3.3, $U_{supply1}$ = +12V ; $U_{supply2}$ = −12V

II. Measurements

1. Symmetric signal

Use the function generator to apply such a sinusoidal signal to the primary winding of the transformer so that the signal and the secondary windings has parameters f=5kHz, V_p=100mV. Examine the two secondary signals on the oscilloscope, make notes of the signals with correct phases and amplitudes. (The secondary coils should have equal number of windings. The symmetry of the two signals can be proven by using the ADD function of the scope (find it in Math menu for the digital scopes), the sum of the two should be zero).

2. Output offset

Build the circuit from figure 1. Don't connect the function generator to the transformer yet. The DC voltage between V_{out1} and V_{out2} is the output offset voltage. Change the value of R_P potentiometer until the offset voltage is minimal. Keep R_P in this position for the rest of the measurement. Write down the minimal value for the offset.

3. Symmetrical voltage gain

Use the function generator to apply such a sinusoidal signal to the primary winding of the transformer so that the signal and the secondary windings has parameters f=5kHz, V_{eff}=20mV. (Measure effective value (RMS) using the AC mode of the multimeter.)

Using an oscilloscope check if the input signals (v_{in1} and v_{in2}) are distorted. If they are, decrease the input voltage amplitude.

Examine and draw the time functions of $v_{in1} - v_{out1}$; $v_{in2} - v_{out2}$ signal pairs, the $v_{outS} - v_{inS}$ signal pair and the v_{EE} signal.

Find out A_{VSS} from the measured v_{outS} and v_{inS} peak-to-peak or rms values. Compare it to the previously calculated value.

4. Common mode voltage gain

Here we don't need the transformer. Instead, connect the two inputs together to the function generator (figure 2.). Use f=5kHz, V_p=2V sine).

Check whether the input signals are not distorted. Use an AC multimeter to measure the output signals v_{out1} and v_{out2}. (*Compare the oscilloscope and the multimeter on the applicability of measuring these small signals.*)

Find out A_{VSC}. $A_{VSC} = \frac{v_{outS}}{v_{inC}} = \frac{v_{out1} - v_{out2}}{\frac{v_{in1} + v_{in2}}{2}}$, if $v_{in1} = v_{in2} = v_{inC}$

Find out the CMRR. Use the A_{VSS} from the previous exercise and A_{VSC} from this exercise. *(Find out CMRR for the asymmetric (one sided) output as well. Use the v_{out1} values from this and the last exercise.)*

5. Symmetric amplifier with current generator

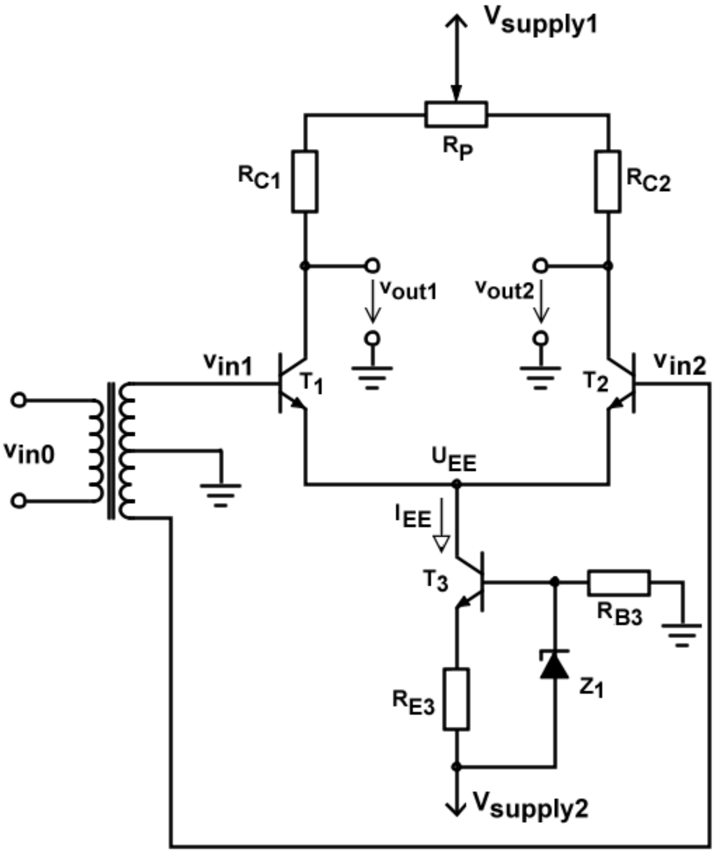

Figure3.: symmetric amplifier with current generator

Build the circuit from figure 3! Parameters: same as previously, plus R_{E3}=2kΩ ; R_{B3}=2kΩ ; Z_1: ZPD3.3 ; $U_{supply1} = +12V$; $U_{supply2} = -12V$

Do exercises 3 and 4 for this circuit, too! Compare the results with the previous results (ie. without the current generator) and analyse the difference.

(Find out the r_{EE} dynamic resistance of the current generator. This practically replaces R_{EE} in the AC calculations. Use the information from Electronics I. laboratory measurement 2, current generator output resistance. Use a common mode DC input signal and measure V_{EE} and I_{EE} in at least two points. The dynamic resistance will be $r_{EE} = \frac{\Delta V_{EE}}{\Delta I_{EE}}$ *)*

Test questions

1) Draw a symmetric difference amplifier circuit with transistors! Note the inputs and outputs.
2) Explain the operation of the diff.amp. with symmetric input!
3) Explain the operation of the diff.amp. with common mode input!
4) What is the CMRR for differential output?
5) What is the CMRR for asymmetric output?
6) What are the criteria for a large CMRR?
7) What are the advantages of using a current generator instead of R_{EE} resistor?