Lodz University of Technology
Institute of Physics

Laboratory of electronics

Exercise E04IFE

The common-emitter and common-collector amplifiers with Bipolar Junction Transistor

Version 1.1 (11 April 2018)

Table of contents:

Before you start to perform an experiment you are obliged to have mastered the following theoretical subjects:

1. Bipolar junction transistor (BJT) in common-emitter circuit – how it works – [1] and [4].
2. Common-emitter BJT amplifier with voltage-divider bias – how it works – [2] and [3].
3. Properties and characteristics of common-emitter and common-collector amplifiers [2] and [3].

1. Purpose of the exercise

To understand and analyze the principle of configuration and operation of the common-emitter and common-collector BJT amplifiers.

2. Hazards

Type	Absence	Low	Medium	High
electrical radiation hazards		+		
optical radiation hazards	+			
mechanical hazards (including acoustic hazards, noise)	+			
electromagnetic radiation hazards (invisible)	+			
biological hazards	+			
ionizing radiation hazards	+			
chemical hazards	+			
thermal hazards (including explosion and fire)	+			

The cables with banana plugs are designed exclusively to used in low-voltage circuits – DO NOT CONNECT THEM TO THE MAINS SUPPLY 230 V.

3. Introduction

Description of the measurement method for BJT amplifiers

The n-p-n bipolar junction transistor (BJT) is tested both in common-emitter and in common-collector circuits. The Power Supply SPD3303D together with Adjustable Voltage Regulator enable biasing of the transistor and allow to establish the quiescent point (Q-point) around which the current and voltage variations can occur as the response to an AC input signal.

The sinusoidal input signal from Function Generator (DF1641B) causes the base-emitter voltage to vary sinusoidally above and below its DC offset level. The resulting variation in base current produces a larger variation in collector current because of the current gain of transistor and variation of collector-emitter voltage.

To enable the estimation of the input signal amplification the oscilloscope has to work in the dual channel operation mode to display both the input and output signals at the same time.

4. Available equipment

4.1. Experimental module

The experimental module is presented detailed in the chapter 5.

The measurement station is equipped with a set of measuring equipment, which consists of the following devices:

- the laboratory power supply SPD3303D,
- the function generator DF1641B,
- the two-channel analogue oscilloscope GOS-620 or GOS-630,
- the multimeters: KT890, M 3800, M 4650, UT-804 or Protek 506.

The manuals of the above instruments are available on the Website [5].

4.2. Multimeters

DC or AC voltages can be measured using the following multimeters: KT890, M 3800, M 4650, UT-804 or Protek 506.

4.3. Power supply

The experimental module is powered by the laboratory power supply SPD3303D.

4.4. Function generator

As a source of sine signal the function generator FD1641B is used.

4.5. Oscilloscope

The waveforms of the input and output of amplifiers can be observed on the two-channel analogue oscilloscope GOS-620 or GOS-630. At the request of the students the analogue oscilloscope can be replaced with the digital two-channel oscilloscope type SDS1052DL.

5. Experimental procedure

5.1. The common-emitter amplifier with the dc base current - basic version

(The schematic setup is presented in Fig. 1a and the experimental module is presented in Fig. 1b).

Explanations: FG – functional generator, OSC – oscilloscope, CH1 and CH2 – channel inputs of oscilloscope.

1. Connect the circuit according to the diagrams presented in Figs. 1a and 1b. Set the switch R_1 to the "11" position, switch R_2 to the "∞" position, switch R_C to the "3", switch R_L to the "∞" position, and switch R_E to the "0" position.
2. Adjust the sine waveform of generator to 1 kHz frequency.
3. Connect the Power Supply with $+U_{CC}$ and $-U_{CC}$ terminals and set the voltage to 10 ÷ 12 V. After checking the circuit by the supervisor turn on the output of the power supply.
4. Watch the shape and peak-to-peak voltage of the output signal following the change of R_1 resistance (turn left or right the resistance R_1 knob). Observations should be performed both for small (50 mVp-p) and great (1 Vp-p) voltage of input signal. Before setting the required voltage generator, select the appropriate adjustment range 20 mVp-p ÷ 0.2 Vp-p or 0.2 Vp-p ÷ 2 Vp-p. In order to estimate the Q-point position record the obtained results on the data sheet in the Table 1a on the page Appendix A2. Describe the output signal as "sinusoidal ……" or "non-sinusoidal ……..".
5. Determine the value of R_1 resistance for the best choice of the Q-point on the basis of the lower deformation of the output signal and the best amplification of the input signal at the same time.
6. Estimate the input impedance of the amplifier for optimal Q-point. For this purpose apply the input signal to U_{IG} terminal and follow the instructions presented in 12-th point of experimental procedure in "E01=Metrology" considering the amplifier as four terminal network. Record the obtained results on the data sheet in the Table 1b on the page Appendix A2.
7. Estimate the output impedance of the amplifier. For this purpose set the lower value of R_L resistance. Record the obtained results on the data sheet in the Table 1c on the page Appendix A2 .

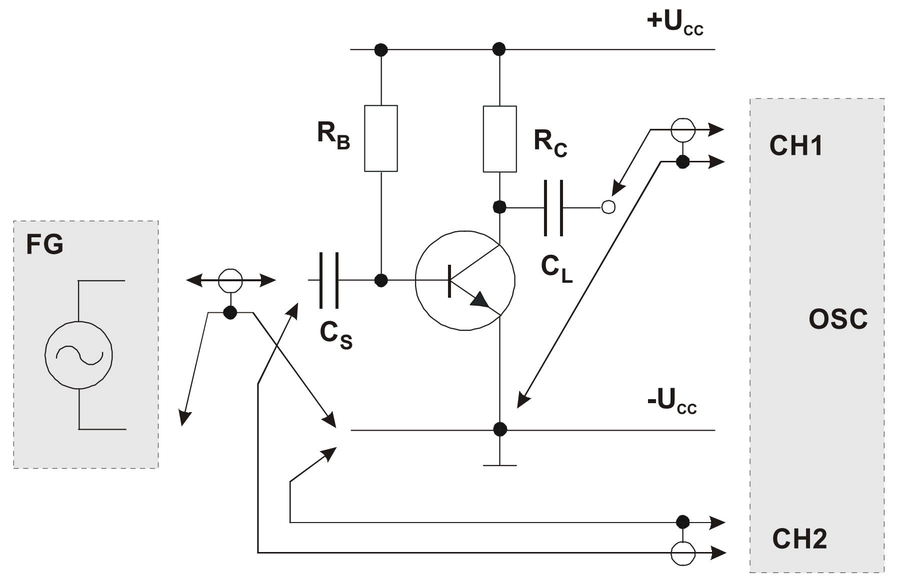
+Ucc
RB
RC
CH1
FG
CL
CS
OSC
-Ucc
CH2

Fig. 1a.

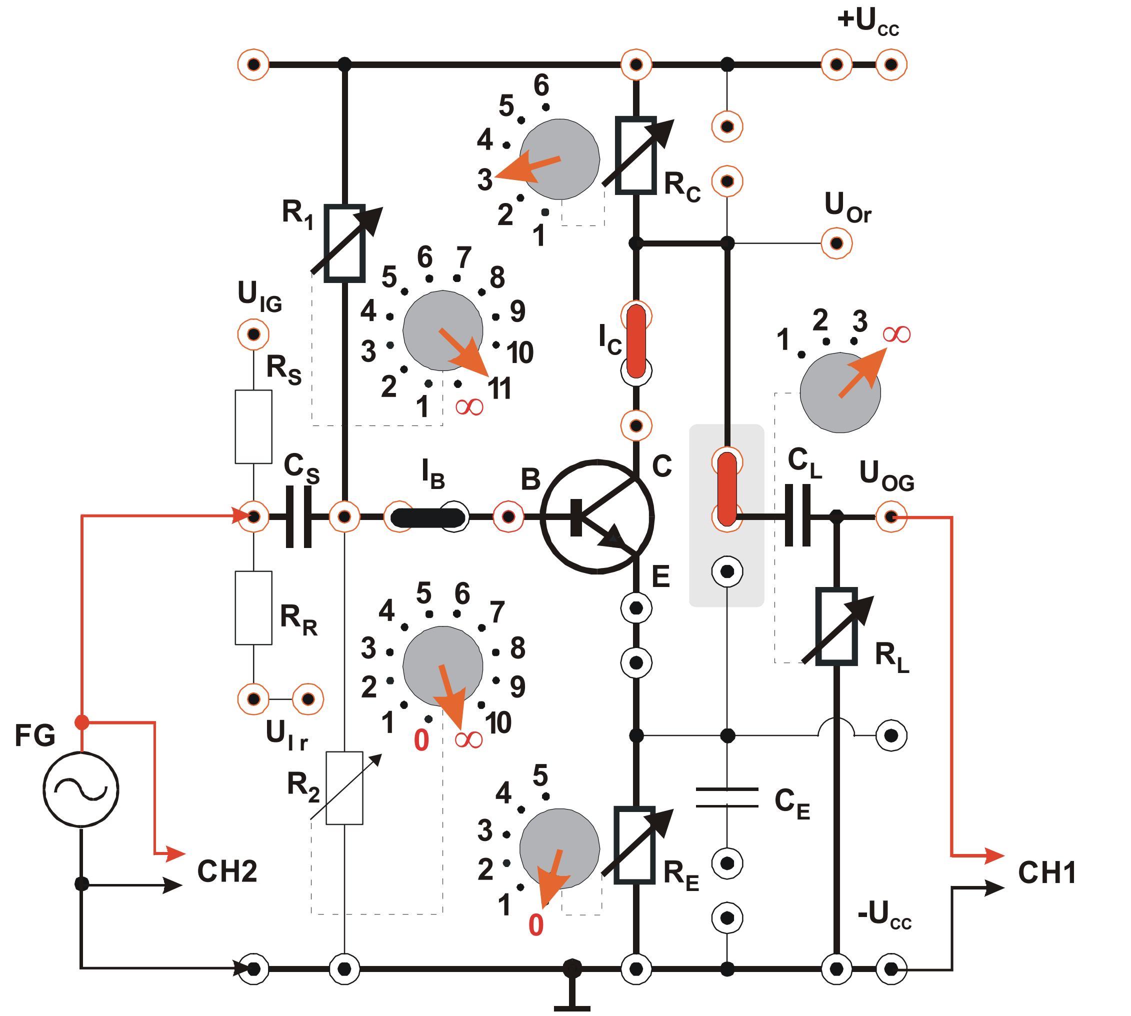
+Ucc
RC
UOr
R1
UIG
RS
IC
CS
IB
B
C
CL
UOG
E
RR
RL
UIr
FG
R2
CE
RE
CH2
CH1
-Ucc

Fig. 1b.

5.2. The common-emitter amplifier with dc base current and stabilization of the emitter current - basic version

(The schematic setup is presented in Fig. 2a and the experimental module is presented in Fig. 2b).

Explanations: FG – functional generator, OSC – oscilloscope, CH1 and CH2 – channel inputs of oscilloscope.

1. Connect the circuit according to the diagrams presented in Figs. 2a and 2b. Set the switch R_1 to the "11" position, switch R_2 to the "∞" position, switch R_C to the "3", switch R_L to the "∞" position, and switch R_E to the "4" position.
2. Adjust the sine waveform of generator to 1 kHz frequency.
3. Connect the Power Supply with $+U_{CC}$ and $-U_{CC}$ terminals and set the voltage to 10 ÷ 12 V. After checking the circuit by the supervisor turn on the output of the power supply.
4. Watch the shape and peak-to-peak voltage of the output signal following the change of R_1 resistance (turn left or right the resistance R_1 knob). Observations should be performed both for small (50 mVp-p) and great (1 Vp-p) voltage of input signal. Before setting the required voltage generator, select the appropriate adjustment range 20 mVp-p ÷ 0.2 Vp-p or 0.2 Vp-p ÷ 2 Vp-p. In order to estimate the Q-point position record the obtained results on the data sheet in the Table 2a on the page Appendix A3. Describe the output signal as "sinusoidal ……" or "non-sinusoidal ……."
5. Find the optimal position of the Q-point on the basis of the lower deformation of the output signal and the best amplification of the input signal at the same time. Estimate the input and the output impedance. Record the obtained results on the data sheet in the Table 2b and Table 2c on the page Appendix A3.
6. For the optimal position of the Q-point estimate the gain of the amplifier following the change of the R_E resistance (set the R_E switch on the relevant positions from "1" to "5"). Record the obtained results on the data sheet in the Table 2d on the page Appendix A3.

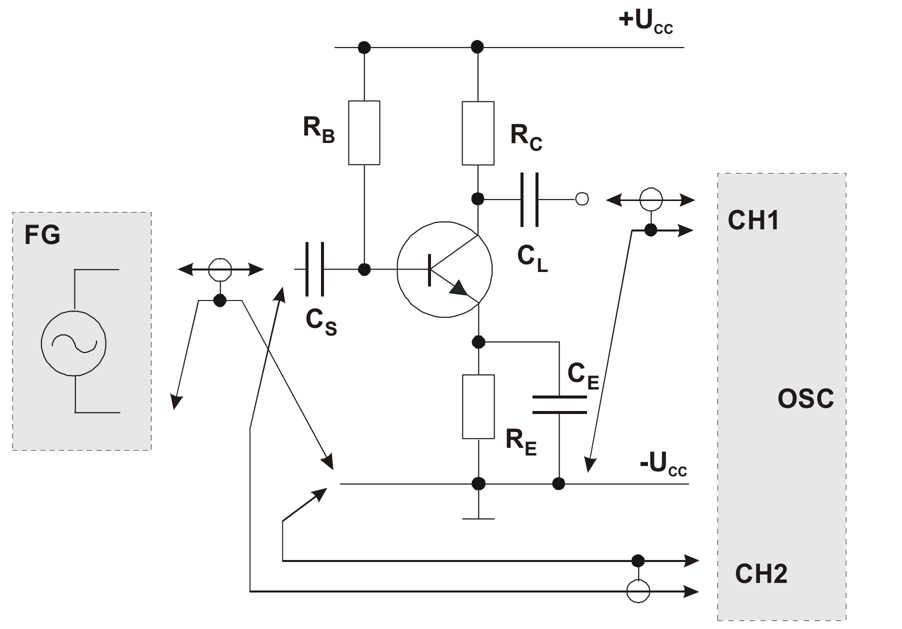
+Ucc
RB
RC
FG
CH1
CL
CS
CE
OSC
RE
-Ucc
CH2

Fig. 2a.

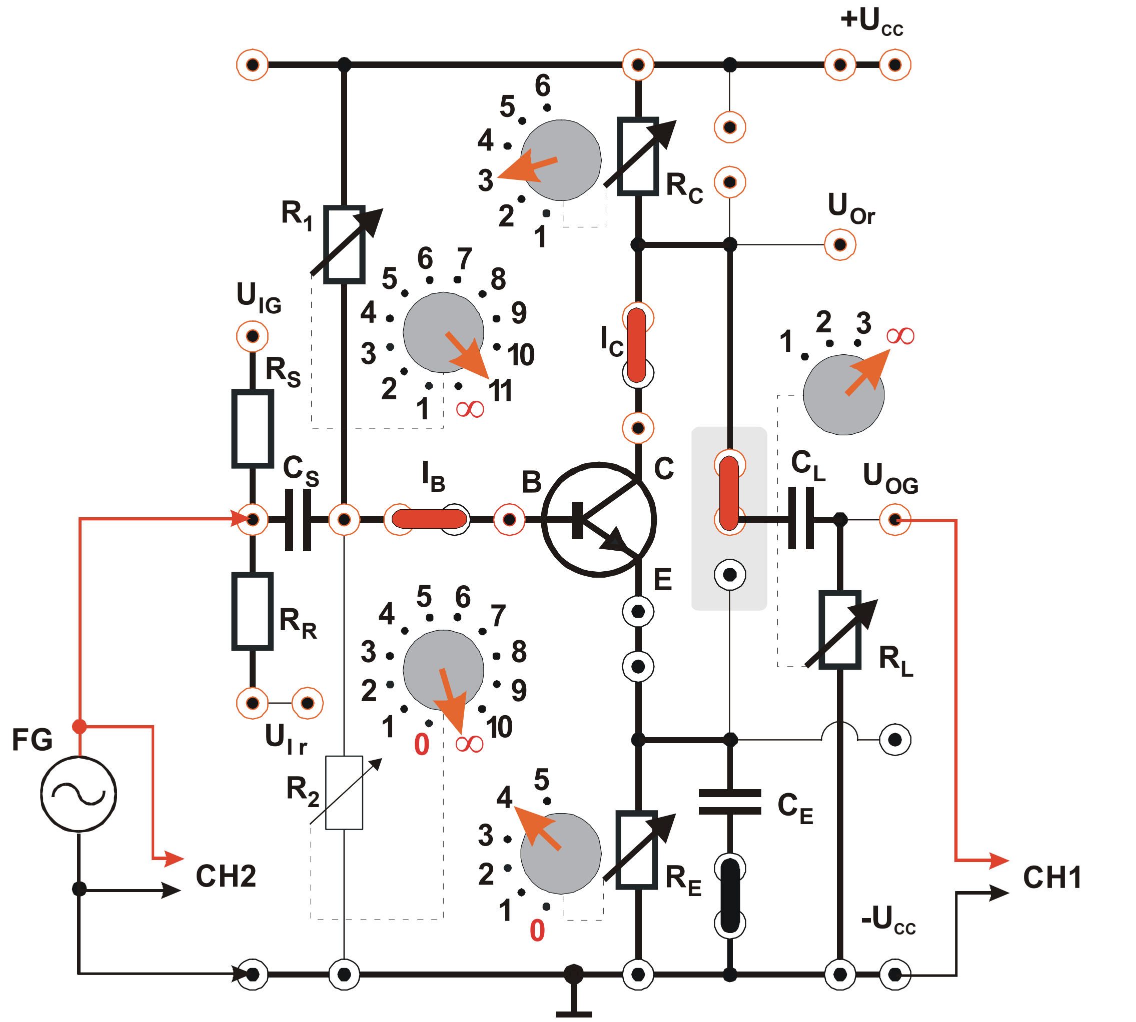
+Ucc
R1
RC
UOr
UIG
RS
IC
CS
IB
B
C
CL
UOG
E
RR
RL
FG
UIr
R2
CE
RE
CH2
CH1
-Ucc

Fig. 2b.

5.3. The common-emitter amplifier with voltage-divider bias and stabilisation of he emitter current - basic version

(The schematic setup is presented in Fig. 3a and the experimental module is presented in Fig. 3b).

Explanations: FG – functional generator, OSC – oscilloscope, CH1 and CH2 – channel inputs of oscilloscope.

1. Connect the circuit according to the diagrams presented in Figs. 3a and 3b. Set the switch R_1 to the "11" position, switch R_2 to the "10" position, switch R_C to the "3", switch R_L to the "∞" position, and switch R_E to the "4" position.
2. Adjust the sine waveform of generator to 1 kHz frequency.
3. Connect the Power Supply with $+U_{CC}$ and $-U_{CC}$ terminals and set the voltage to 10 ÷ 12 V. After checking the circuit by the supervisor turn on the output of the power supply.
4. Watch the shape and peak-to-peak voltage of the output signal following the change of R_1 resistance (turn left or right the resistance R_1 knob). Observations should be performed both for small (50 mVp-p) and great (1 Vp-p) voltage of input signal. Before setting the required voltage generator, select the appropriate adjustment range 20 mVp-p ÷ 0.2 Vp-p or 0.2 Vp-p ÷ 2 Vp-p. In order to estimate the Q-point position record the obtained results on the data sheet in the Table 3a on the page Appendix A4. Describe the output signal as "sinusoidal ……" or "non-sinusoidal ……..".
5. Find the optimal position of the Q-point on the basis of the lower deformation of output signal and the best amplification of the input signal at the same time. Estimate the input and output impedances. Record the obtained results on the data sheet in the Table 3b and Table 3c on the page Appendix A4.
6. For the optimal position of the Q-point estimate the gain of the amplifier following the change of the R_E resistance (set the R_E switch on the relevant positions from "1" to "5"). Record the obtained results on the data sheet in the Table 3d on the page Appendix A4.

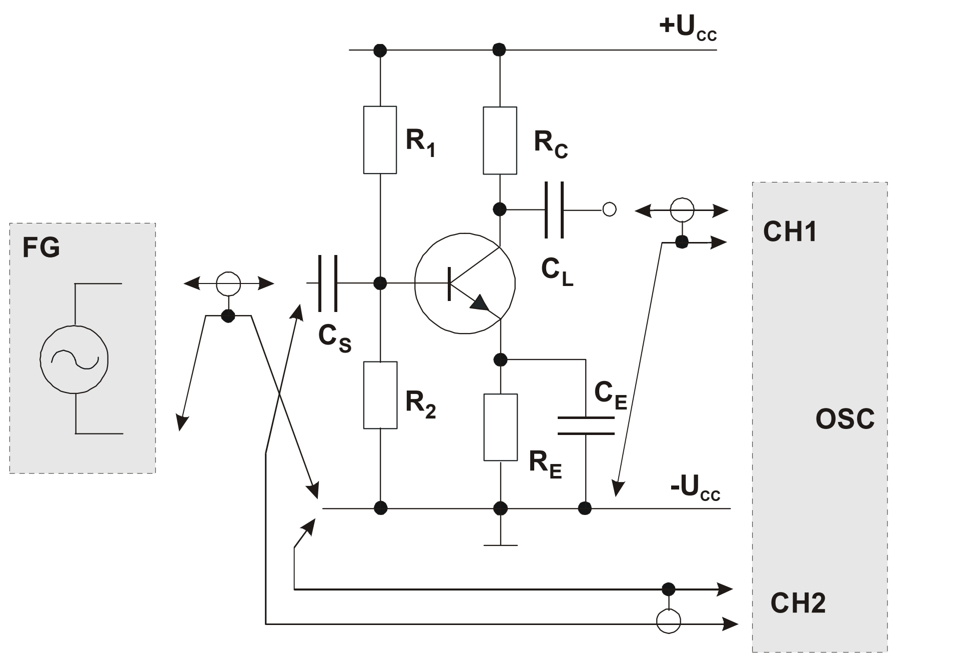
+Ucc
R1
RC
CL
CH1
FG
CS
CE
OSC
R2
RE
-Ucc
CH2

Fig. 3a.

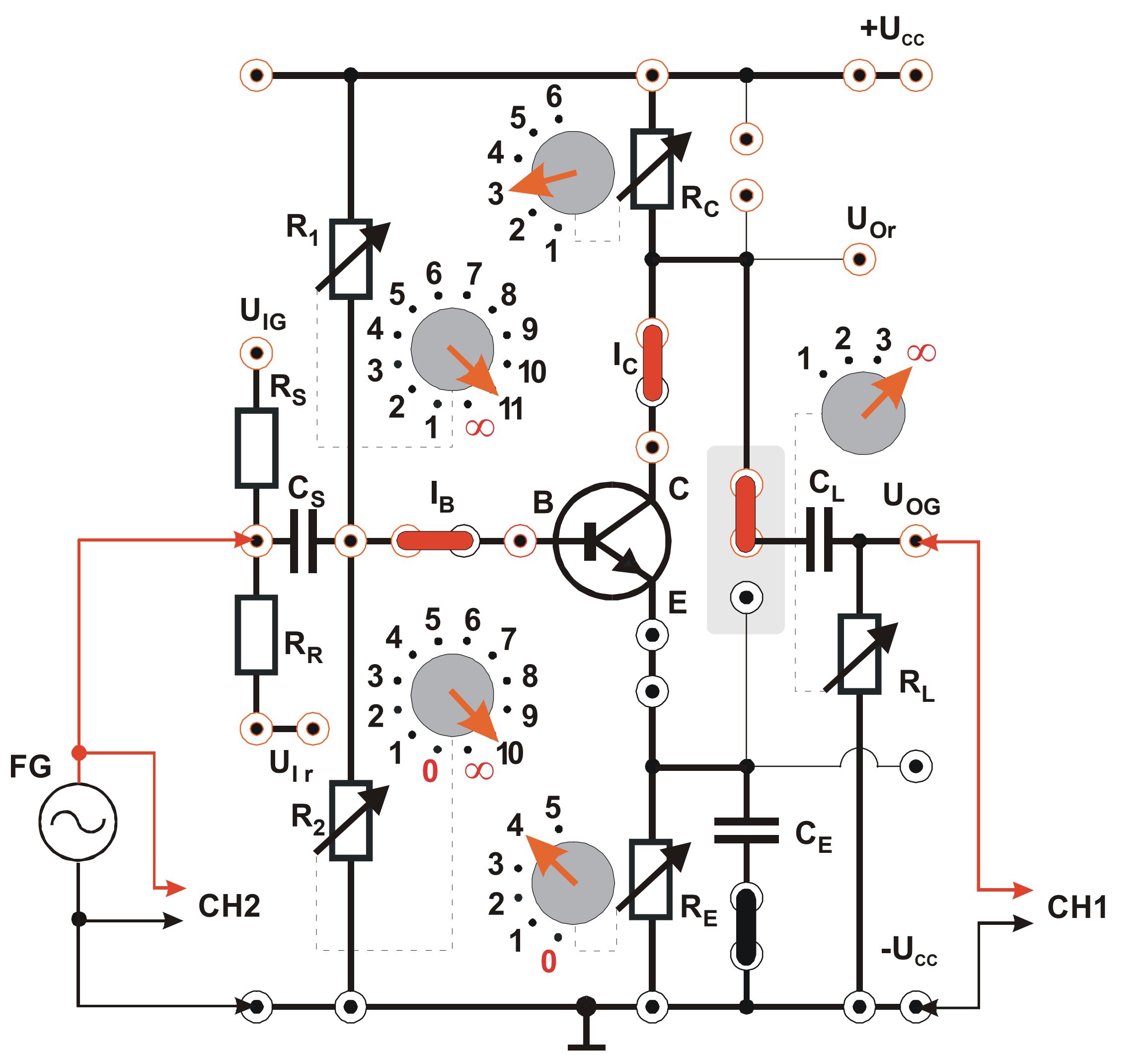
+Ucc
RC
UOr
R1
UIG
RS
IC
CS
IB
B
C
CL
UOG
E
RR
RL
UIr
FG
R2
CE
RE
CH2
CH1
-Ucc

Fig. 3b.

5.4. The common-collector amplifier with voltage-divider bias – extended version

(The schematic setup is presented in Fig. 4a and the experimental module is presented in Fig. 4b)

Explanations: FG – functional generator, OSC – oscilloscope, CH1 and CH2 – channel inputs of oscilloscope.

1. Connect the circuit according to the diagrams presented in Figs. 4a and 4b. Set the rotary function switch of the DMM ammeter to the 200 mA or 400 mA range (depending on the type of multimeter) for measurement of I_C and rotary function switch of the DMM ammeter to the 2 mA or 4 mA range (depending on the type of multimeter) for measurement of I_B. Set the switch R_1 to the “11” position, switch R_2 to the “10” position, switch R_L to the “∞” position, and switch R_E to the “5” position.
2. Adjust the sine waveform of generator to 1 kHz frequency.
3. Connect the Power Supply with $+U_{CC}$ and $-U_{CC}$ terminals and set the voltage to 10 ÷ 12 V. After checking the circuit by the supervisor turn on the output of the power supply.
4. Watch the shape and peak-to-peak voltage of the output signal following the change of R_1 resistance (turn left or right the resistance R_1 knob). Observations should be performed both for small (50 mVp-p) and great (1 Vp-p) voltage of input signal. Before setting the required voltage generator, select the appropriate adjustment range 20 mVp-p ÷ 0.2 Vp-p or 0.2 Vp-p ÷ 2 Vp-p. In order to estimate the Q-point position record the obtained results on the data sheet in the Table 4a on the page Appendix A5. Describe the output signal as “sinusoidal ……” or “non-sinusoidal ……..”.
5. Find the optimal position of the Q-point on the basis of the lower deformation of output signal and the best amplification of the input signal at the same time. Estimate the input and output impedances. For this purpose apply the input signal to U_{Ir} terminal. Record the obtained results on the data sheet in the Table 4b on the page Appendix A5.
6. For the optimal position of the Q-point estimate the gain of the amplifier following the change of the R_E resistance (set the R_E switch on the relevant positions from “2” to “5”). **Warning!!!. Do not select the position “1” nor “0”.** Record the obtained results on the data sheet in the Table 4b on the page Appendix A5.

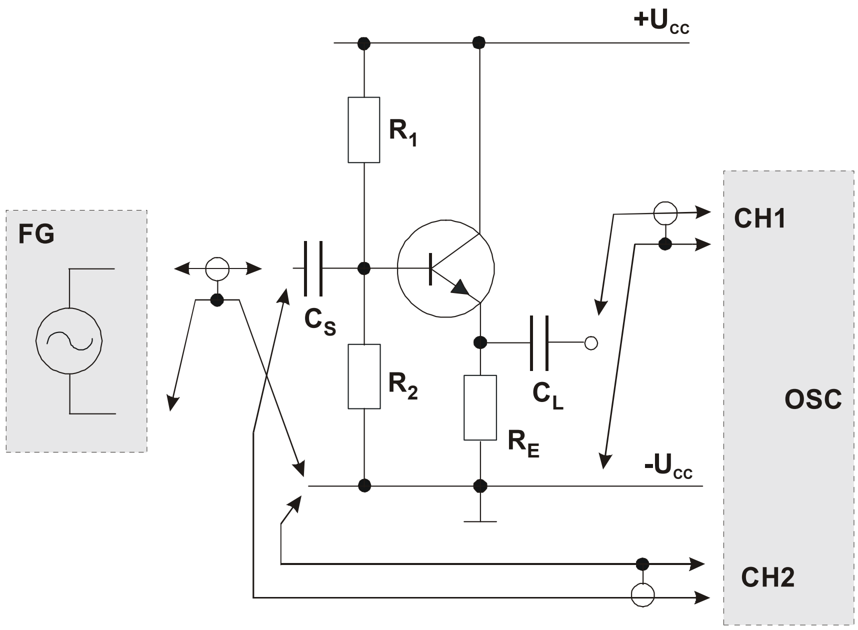

Fig. 4a.

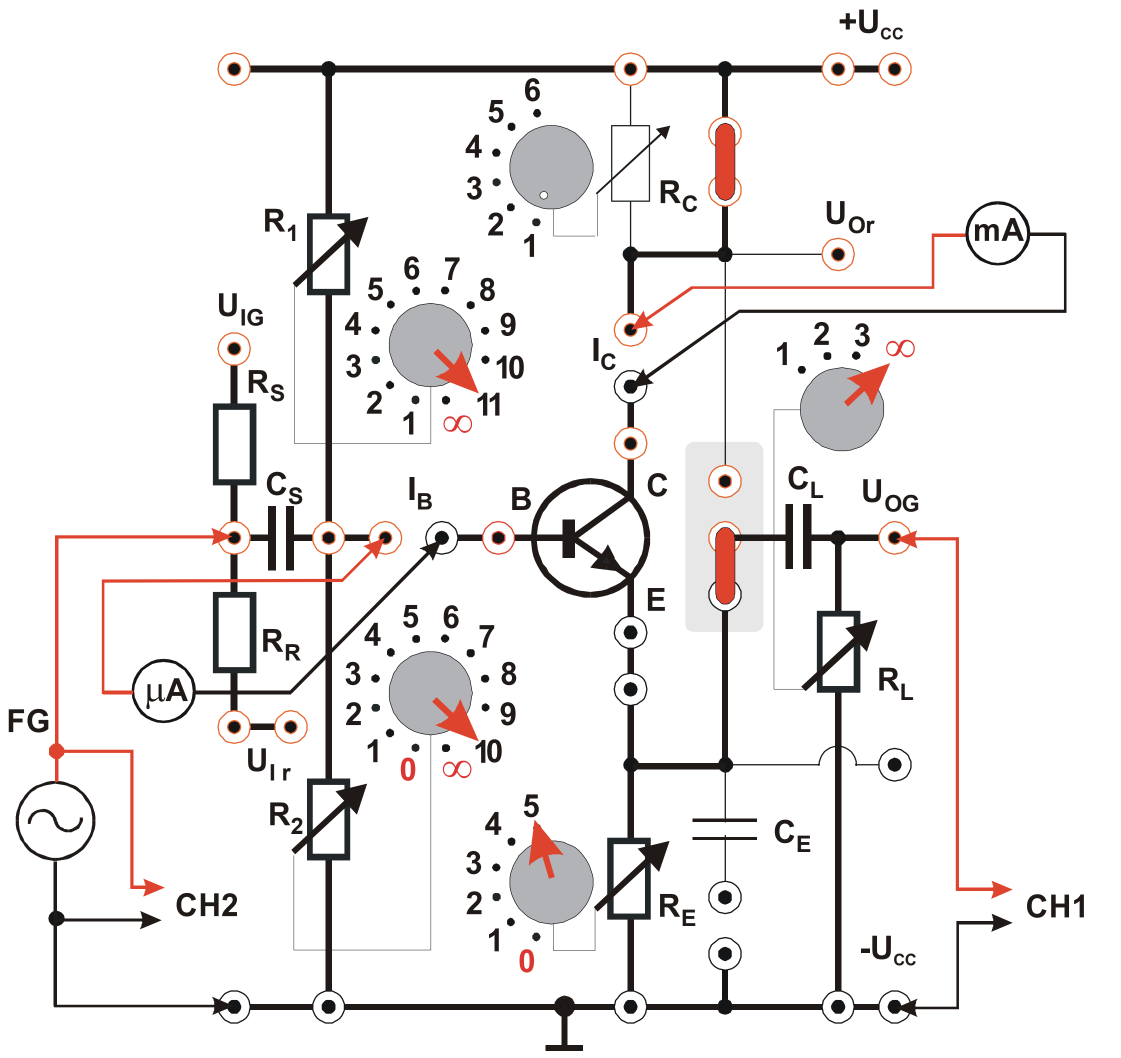

Fig. M4b.

6. Report elaboration

Report has to be composed of:

1. Front page (by using a pattern),
2. Description of experiment purposes,
3. Schematic diagrams of tested circuits,
4. List of the used instruments and devices (id number, type, settings and rang values),
5. Results of measurements (including oscillograms and tables),
6. Calculations and analysis of obtained results,
7. Final remarks and conclusions.

On the basis of the obtained results one should:

1. Assess the influence of R_1 or R_2 on the shape of amplified signal and on the choice of the optimal Q-point.
2. Estimate the input and the output impedance of each amplifier (without error calculations) treating amplifier as a four-terminal network in exercise E01 “Metrology”.
3. Compare the properties of common-emitter and common-collector amplifiers.
4. Evaluate the influence of input signal voltage on the gain level for the optimal Q-point of amplifiers under investigation.
5. Estimate the influence of R_E on shape and amount of gain of amplified signal.

7. References

7.1. Basic reference materials

[1] M. Rusek, J. Pasierbiński, *Elementy i układy elektroniczne w pytaniach i odpowiedziach*, WNT, Warszawa, 1999.
[2] Z. Nosal, J.Baranowski, *Układy elektroniczne. Cz. I. Układy analogowe liniowe*, Seria Podręczniki Akademickie, (Elektronika, Informatyka, Telekomunikacja), WNT, Warszawa, 2003.
[3] A. Filipowski, *Układy elektroniczne analogowe i cyfrowe*, Seria Podręczniki Akademickie, (Elektronika, Informatyka, Telekomunikacja), WNT, Warszawa, 2005.
[4] P. Horowitz, W. Hill, *Sztuka elektroniki. Cz. 1.*, (tłum. ang.), WKiŁ, Warszawa, 2003.

7.2. Other reference materials

[5] User guides for multimeters, power supply, function generator, and oscilloscope available on the website:
https://fizyka.p.lodz.pl/pl/dla-studentow/fundamentals-of-electronics/

8. Appendixes

A1. The tables of resistor's values:

Position	Resistance of $\mathbf{R_1}$
1	22 kΩ
2	30 kΩ
3	39 kΩ
4	47 kΩ
5	56 kΩ
6	68 kΩ
7	82 kΩ
8	100 kΩ
9	220 kΩ
10	430 kΩ
11	1000 kΩ
∞	∞

Position	Resistance of $\mathbf{R_2}$
0	0
1	5.6 kΩ
2	6.8 kΩ
3	7.5 kΩ
4	8.2 kΩ
5	9.1 kΩ
6	10 kΩ
7	15 kΩ
8	22 kΩ
9	30 kΩ

Position	Resistance of $\mathbf{R_E}$
0	0
1	0.10 kΩ
2	0.22 kΩ
3	0.43 kΩ
4	0.82 kΩ
5	1.20 kΩ

Position	Resistance of $\mathbf{R_C}$
1	0.56 kΩ
2	1.20 kΩ
3	2.40 kΩ
4	4.70 kΩ
5	6.80 kΩ
6	9.10 kΩ

$\mathbf{R_S}$	2.4 kΩ
$\mathbf{R_R}$	24 kΩ

Position	Resistance of $\mathbf{R_L}$
1	0.51 kΩ
2	2 kΩ
3	10 kΩ
∞	∞

A2. The tables 1a, 1b and 1c

Table 1a.

<table>
<tr><th rowspan="3">#</th><th colspan="4">Input signal</th><th colspan="4">Output signal</th><th rowspan="3">Gain</th><th rowspan="3">collector -ground voltage</th></tr>
<tr><th rowspan="2">Vp-p [V]</th><th colspan="2">Resistance R_1</th><th rowspan="2">Description</th><th rowspan="2">Vp-p [V]</th><th colspan="2">Resistance R_C</th><th rowspan="2">Description</th></tr>
<tr><th>[Ω]</th><th>Pos.</th><th>[Ω]</th><th>Pos.</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 1b.

#	Resistance [Ω]		U_{OUT} (Vp-p) [mV] [V]
1	R_S =	0	
2	R_S =		

Table 1c.

#	Resistance [Ω]		U_{OUT} (Vp-p) [mV] [V]
1	R_L =	∞	
2	R_L =		

A3. The tables 2a, 2b and 2c

Table 2a.

<table>
<tr><th rowspan="3">#</th><th colspan="4">Input signal ; R_E = ... [Ω]</th><th colspan="4">Output signal</th><th rowspan="3">Gain</th></tr>
<tr><th rowspan="2">Vp-p [V]</th><th colspan="2">Resistance R_1</th><th rowspan="2">Description</th><th rowspan="2">Vp-p [V]</th><th colspan="2">Resistance R_C</th><th rowspan="2">Description</th></tr>
<tr><th>[Ω]</th><th>Pos.</th><th>[Ω]</th><th>Pos.</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 2b.

#	Resistance [Ω]		U_{OUT} (Vp-p) [mV] [V]
1	R_S =	0	
2	R_S =		

Table 2c.

#	Resistance [Ω]		U_{OUT} (Vp-p) [mV] [V]
1	R_L =	∞	
2	R_L =		

Table 2d.

<table>
<tr><th rowspan="3">#</th><th colspan="4">Input signal ; R_C = ... [Ω]</th><th colspan="4">Output signal</th><th rowspan="3">Gain</th></tr>
<tr><th rowspan="2">Vp-p [V]</th><th colspan="2">Resistance R_1</th><th rowspan="2">Description</th><th rowspan="2">Vp-p [V]</th><th colspan="2">Resistance R_E</th><th rowspan="2">Description</th></tr>
<tr><th>[Ω]</th><th>Pos.</th><th>[Ω]</th><th>Pos.</th></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

A4. The tables 3a, 3b and 3c

Table 3a.

#	Input signal ; R_E = ... [Ω]						Output signal				Gain
	Vp-p [V]	R_1		R_2		Description	Vp-p [V]	R_C		Description	
		[Ω]	Pos.	[Ω]	Pos.			[Ω]	Pos.		
1											
2											
3											

Table 3b.

#	Resistance [Ω]		U_{OUT} (Vp-p) [mV] [V]
1	R_S =	0	
2	R_S =		

Table 3c.

#	Resistance [Ω]		U_{OUT} (Vp-p) [mV] [V]
1	R_L =	∞	
2	R_L =		

Table 3d.

#	Input signal ; R_C = ... [Ω]				Output signal				Gain
	Vp-p [V]	Resistance R_1		Description	Vp-p [V]	Resistance R_E		Description	
		[Ω]	Pos.			[Ω]	Pos.		
1									
2									
3									

A5. The tables 4a and 4b

Table 4a.

#	Input signal						Output signal				Gain
	Vp-p [V]	R_1		R_2		Description	Vp-p [V]	R_E		Description	
		[Ω]	Pos.	[Ω]	Pos.			[Ω]	Pos.		
1											
2											
3											

Table 4b.

#	Resistance [Ω]		U_{OUT} (Vp-p) [mV] [V]
1	R_R =	0	
2	R_R =		
3	R_L =	∞	
4	R_L =		