The transistor as an amplifier

Experiment Objectives

- Learning about the common emitter as an important basic circuit of the transistor for voltage amplification
- Setting an amplifier circuit's operating point
- Measuring input and output voltages using an oscilloscope and determining the amplification

Basic Information

The common emitter is used in most transistor amplifiers. The input signal is thereby applied to the base, and the output signal goes to the collector.

The experiment determines the voltage amplification as:

$$B_U = \frac{\Delta U_A}{\Delta U_E}$$

It corresponds to the ratio of the collector's resistance to the emitter's $\frac{R_C}{R_E}$, if $R_{CE} << B_I \cdot R_E$ (B_I: current gain).

First of all, the operating point is set by the direct current voltage applied and the voltage divider at the transistor's base. Correct settings produce an undistorted amplified input signal.

In this experiment, the operating point is set with a sinusoidal input signal that overrides the amplifier. The direct voltage is set with the voltage divider applied to the base, such that the output signal is cut symmetrically. If the operating point's setting is optimal, then the output voltage corresponds to half of the operating voltage.

The total amplitude $\Delta U = U_{SS}$ is then measured for each of the input and output voltages. The amplification is calculated from these and compared to the ratio of the emitter's resistance to the collector's.

Apparatus

1 Plug-in board DIN A4	576 74
1 STE Transistor BD 137, NPN, emitter bottom	578 67
1 STE Resistor 1 kΩ, 1.4 W, 5 %	577 44
1 STE Resistor 10 kΩ, 0.5 W	577 56
1 STE Resistor 47 kΩ, 0.5 W	577 64
1 STE Regulation resistor 10 kΩ, 1 W	577 80
1 STE Regulation resistor 47 kΩ, 1 W	577 82
1 STE Capacitor 47 µF, 40 V, 20 %	578 38
1 STE Capacitor 100 µF, 35 V, 20 %	578 39
1 STE Capacitor 470 µF, 16 V, 20 %	578 40
1 Set of 10 bridging plugs	501 48
1 Function generator S 12	522 621
1 AC/DC Power supply 0...12 V / 3 A	521 485
1 Two-channel oscilloscope 303	575 211
2 Screened cables BNC/4 mm	575 24
1 Pair of cables, 50 cm, red and blue	501 45
1 Pair of cables, 50 cm, black	501 451

Setup

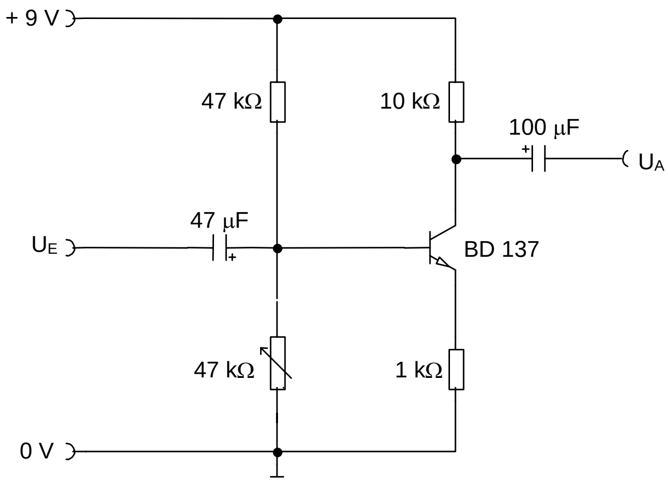

Illustration 1: Circuit to set the operating point

KEM/JN 0407

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– Experiment setup according to Illustration 1.

– Measure the input voltage U_E with Channel 1 on the oscilloscope and the output voltage U_A with Channel 2:
Settings: Time: 0.2 msec / DIV
Y I: 0.5 V / DIV AC
Y II: 5 V / DIV AC
Pay attention to any common ground connection.

– Set a sinusoidal signal with a frequency f = 1 kHz and a voltage U_S = 1 V on the function generator.

Procedure

a) Setting the operating point

– Turn on the power supply and set the operating voltage to 9 V.

– Set the 47 kΩ regulation resistor so that the output signal is bound symmetrically.

– If necessary, increase the input signal's amplitude a little so that the bound is clearly visible.

– The operating point is set correctly if the bound is symmetrical.

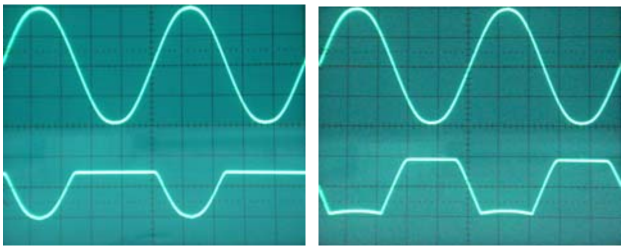

Illustration 2: Oscilloscope images while setting the operating point
top: input signal, bottom: output signal
left: operating point set incorrectly
right: operating point set correctly

b) Determination of the output voltage at the operating point

– Remove the function generator's connections.

– Settings on the oscilloscope:
Y I: 0.1 V / DIV DC
Y II: 1 V / DIV DC

– Measure the base voltage U_{BE} and the collector voltage U_{CE} directly at the transistor. Pay attention to any common ground connection.

– If necessary, slightly correct the operating point using the 47 kΩ regulation resistor.

c) Determination of the voltage amplification

– Reconnect and set the function generator and oscilloscope as in a) (Illustration 1).

– Reduce the function generator's voltage until the output signal is undistorted, i.e. it is no longer bound.

– Observe and measure the input ($U_{E,SS}$) and output voltages ($U_{A,SS}$), and calculate the amplification. Do so by changing the oscilloscope's settings (Y I and Y II).

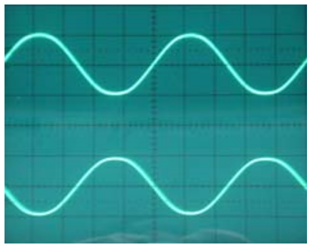

Illustration 3: Oscilloscope image while determining the voltage amplification
top: input signal, bottom: output signal

d) Modification of the voltage amplification

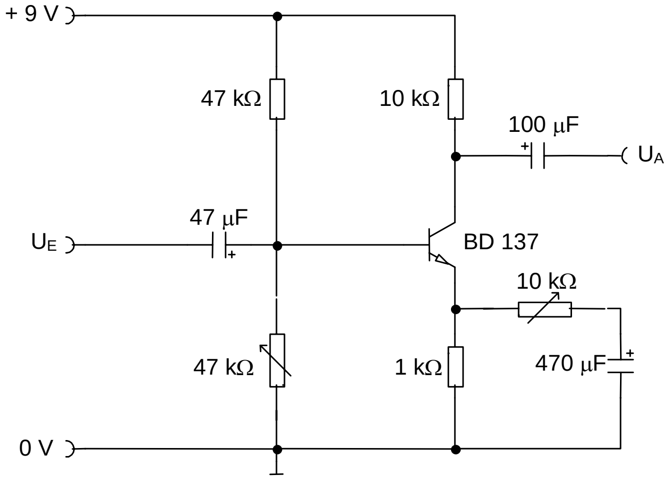

Illustration 4: A single-stage amplifier's circuit with an adjustable amplifier

– Extend the circuit according to Illustration 2.

– Reduce the input voltage as much as possible (until $U_{E,SS}$ is approx. 0.1 V). If necessary, magnify the amplification on the oscilloscope.

– Reduce the 10 kΩ regulation resistor's resistance so that the output signal just becomes undistorted.

– Measure the input ($U_{E,SS}$) and output voltages ($U_{A,SS}$) and calculate the amplification. Do so by changing the oscilloscope's settings (Y I and Y II).

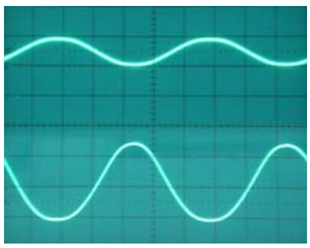

Illustration 5: Oscilloscope image when changing the voltage amplification
top: input signal, bottom: output signal

Measurement Examples and Analysis

b) U_{BE} = 0.57 V

U_{CE} = 4.5 V

It is possible to set the operating point using the alternating voltage transmission. The operating point could also be set by setting the voltage U_{CE} with the DC voltage component.

c) The output signal is greater than the input signal and shifted by 180°.

Input voltage: $U_{E,SS}$ = 0.44 V

Output voltage: $U_{A,SS}$ = 4.6 V

For the amplification:

$$B_U = \frac{4{,}6\ \text{V}}{0{,}44\ \text{V}} = 10{,}5\text{, compared to } \frac{R_C}{R_E} = \frac{10\ \text{k}\Omega}{1\ \text{k}\Omega} = 10$$

d) Input voltage: $U_{E,SS}$ = 43 mV

Output voltage: $U_{A,SS}$ = 6.2 V

For the amplification:

$$B_U = \frac{6{,}2\ \text{V}}{0{,}043\ \text{V}} \approx 144$$

Changing the value of the emitter's resistance (here, 10 kΩ regulation resistor) can vary the single-stage amplifier's voltage amplification. The capacitor prevents a shift in the DC voltage component's set operating point so that the amplification's variation only works for the AC voltage component (input signal).