The field-effect transistor as an amplifier

Experiment Objectives

- Learning about the setup of the field-effect transistor's basic circuits.
- Determining amplification factors.

Basic Information

As a field-effect, an electric field's action is denoted on electric load carriers. This effect is used with so-called field-effect transistors (FET). Unlike bipolar transistors, these use only one type of load carrier, which is why they are also designated as unipolar transistors. The field-effect transistors' advantage is in their ability to operate or to control current with no load.

Unlike bipolar NPN or PNP transistors, the field-effect transistor needs no control current, only a control voltage. The control electrode G (gate) works like a capacitor with an electric field that cancels the load carrier from the line channel between the source S and the drain D or enhances it. The gate input (gate-source path) is therefore very highly resistive.

This study investigates the three basic circuits of the field-effect transistor as an amplifier. These field-effect transistor circuits correspond to bipolar transistors as follows:

Common source	–	Common emitter
Common drain	–	Common collector
Common gate	–	Common base

The voltage's, the amperage's and the power's amplification factors are calculated as follows:

$$V_U = \frac{U_\mathrm{A}}{U_\mathrm{E}} \qquad V_I = \frac{I_\mathrm{A}}{I_\mathrm{E}} \qquad V_P = \frac{P_\mathrm{A}}{P_\mathrm{E}} \qquad (1)$$

Apparatus

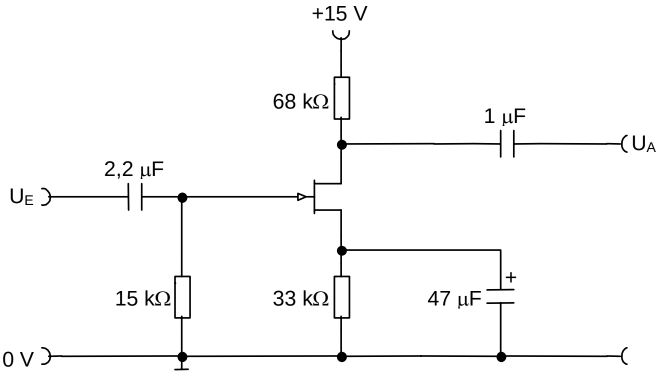
1 Plug-in board DIN A4 .... 576 74
1 Set of 10 bridging plugs 501 48
1 STE Transistor BF 244 (FET)............................. 578 77
1 STE Resistor 10 kΩ, 0.5 W 577 56
1 STE Resistor 15 kΩ, 0.5 W 577 58
1 STE Resistor 33 kΩ, 0.5 W 577 61
1 STE Resistor 68 kΩ, 0.5 W, 1 % 577 657
1 STE Resistor 100 kΩ, 0.5 W, 1 % 577 68
1 STE Resistor 1 MΩ, 0.5 W 577 76
2 STE Capacitors 1 µF, 100 V, 20 % 578 35
1 STE Capacitor 2.2 µF, 63 V, 20 % 578 36
1 STE Capacitor 47 µF, 40 V, 20 % 578 38
1 DC power supply 0...+/- 15 V 521 45
1 Function generator S 12..................................... 522 621
1 Multimeter LDanalog 20 .... 531 120
1 Two-channel oscilloscope 303 .... 575 211
2 Screened cables BNC/4 mm 575 24
2 Pairs of cables, 50 cm, red and blue 501 45
1 Connecting lead, Ø 2,5 mm², 50 cm, black 501 28

KEM/JN 0407

Setup

Procedure

a) Field-effect transistor in common source



– Experiment setup according to the illustration.

– Turn on the operating voltage and set it to 15 V.

– Set the function generator to a sinusoidal signal with f = 50 Hz and bring it to the input.

– Observe the input voltage (U_E) and output voltage (U_A) with the oscilloscope.

– Magnify the input signal's amplitude at the function generator as long as the output signal is still sinusoidal.

– Determine the effective voltages $U_{\mathrm{eff}} = \frac{1}{\sqrt{2}} \frac{U_{\mathrm{SS}}}{2}$ at the input and output (open-circuit voltage) using the oscilloscope.

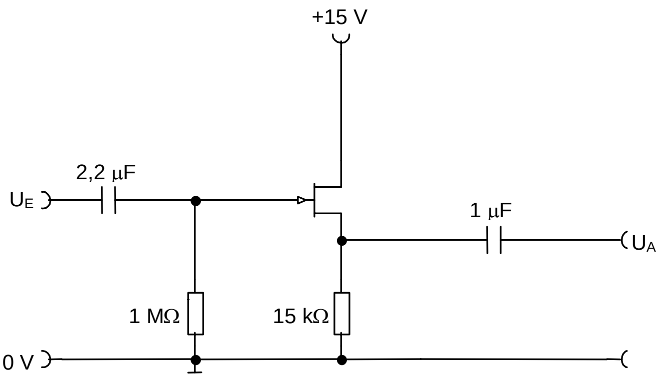
– Measure the input amperage with the multimeter.

– Short-circuit the output and measure its amperage (short circuit current).

– Connect the load resistor 10 kΩ to the output; determine the output voltage and amperage.

– Calculate the powers and the amplification factors according to (1).

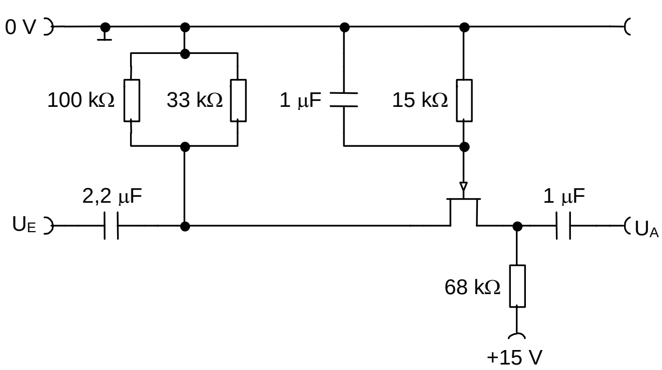
b) Field-effect transistor in common drain



– Repeat the experiment according to a).

– Calculate the amperage with $I_{\mathrm{E,eff}} = \frac{U_{\mathrm{E,eff}}}{1\ \mathrm{M\Omega}}$.

c) Field-effect transistor in common gate



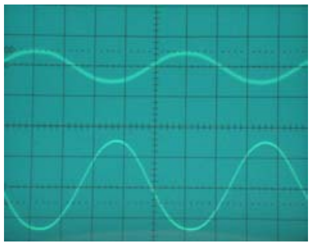
– Repeat the experiment according to a).

Note: The experiments should also be conducted with other frequencies.

Measurement Examples

a) Field-effect transistor in common source

Note: In each of the oscilloscope images, the input voltage is represented on top and the output voltage on the bottom.

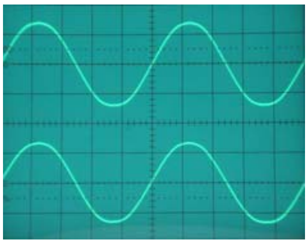


Y I: 50 mV/div AC
Y II: 0.5 V/div AC
Sweep: 5 msec/div

Input E		
Voltage	$U_{E,\mathrm{eff}}$	28 mV
Amperage	$I_{E,\mathrm{eff}}$	2 µA
Power	P_E	0.056 µW
Output A		
Idle	$U_{A,\mathrm{eff}}$	350 mV
	V_U	12.5
Short circuit	$I_{A,\mathrm{eff}}$	11 µA
	V_I	5.5
Charge with 10 kΩ	$U_{A,\mathrm{eff}}$	106 mV
	$I_{A,\mathrm{eff}}$	9 µA
	P_A	0.95 µW
	V_U	3.8
	V_I	4.5
	V_P	17
	$V_U \cdot V_I$	17

– The power amplification factor is produced by the product of the amperage's and the voltage's amplification factors: $V_P \approx V_U \cdot V_I$

b) Field-effect transistor in common drain



Y I: 0.2 V/div AC
Y II: 0.2 V/div AC
Sweep: 5 msec/div

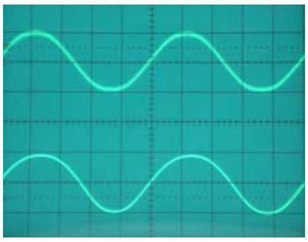
Input E		
Voltage	$U_{E,eff}$	180 mV
Amperage	$I_{E,eff}$	0.18 µA
Power	P_E	0.03 µW
Output A		
Idle	$U_{A,eff}$	180 mV
	V_U	1
Short circuit	$I_{A,eff}$	44 µA
	V_I	240
Charge with 10 kΩ	$U_{A,eff}$	155 mV
	$I_{A,eff}$	15 µA
	P_A	2.3µW
	V_U	0.9
	V_I	83
	V_P	77
	$V_U \cdot V_I$	75

– The voltage amplification factor is about 1 (no voltage amplification): $V_U \approx 1$

– Therefore the power amplification factor matches that of the amperage: $V_P \approx V_I$

– The amperage amplification is large.

c) Field-effect transistor in common gate



Y I: 50 mV/div AC
Y II: 1 V/div AC
Sweep: 5 msec/div

Input E		
Voltage	$U_{E,eff}$	35 mV
Amperage	$I_{E,eff}$	12.5 µA
Power	P_E	0.44 µW
Output A		
Idle	$U_{A,eff}$	670 mV
	V_U	19
Short circuit	$I_{A,eff}$	14 µA
	V_I	1.1
Charge with 10 kΩ	$U_{A,eff}$	120 mV
	$I_{A,eff}$	12 µA
	P_A	1.44 µW
	V_U	3.4
	V_I	0.96
	V_P	3.3
	$V_U \cdot V_I$	3.3

– The amperage amplification factor is about 1 (no amperage amplification): $V_I \approx 1$

– Therefore the power amplification factor matches that of the voltage: $V_P \approx V_U$

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