The field-effect transistor as a switch

Experiment Objectives

- Determination of the switch-on resistance.
- Measurement of the switch-off damping in the application as low-frequency circuit.

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.

So the field-effect transistor functions as a semiconductor resistor, for which the voltage applied to the gate G changes the conductivity or the resistance.

This experiment will first of all determine the source-drain path's forward resistance R_{SD} in the static case, where the gate and the drain are on the potential, i.e. the gate has a voltage U_G = 0 V. In this situation the field-effect transistor connects through. For this reason, this resistance is designated as a switch-on resistance.

In the second part of the experiment, a low-frequency alternating voltage is applied as the input signal, and the output signal's dependence on the gate voltage U_{GS} is investigated. This signal is not completely disconnected, but only greatly damped. For the shut-off damping, we have:

$$d = 10 \cdot log\,(\frac{U_E}{U_A})^2 \qquad (1)$$

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 47 kΩ, 0.5 W	577 64
1 STE Potentiometer 1 kΩ, 1 W	577 92
1 Function generator S 12	522 621
1 DC power supply 0...+/- 15 V	521 45
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 Pair of cables, 50 cm, black	501 451

Setup

Procedure

a) Determination of the switch-on resistance

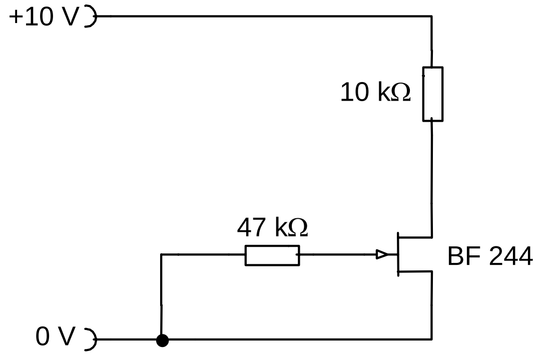


Illustration 1

– Experiment setup according to Illustration 1.

– Turn on the operating voltage and set it to 10 V.

– Measure the voltages at the resistor R_V (= 10kΩ), U_{DS} and U_{GS}.

KEM/JN 0407

b) Investigation of the gate voltage's influence

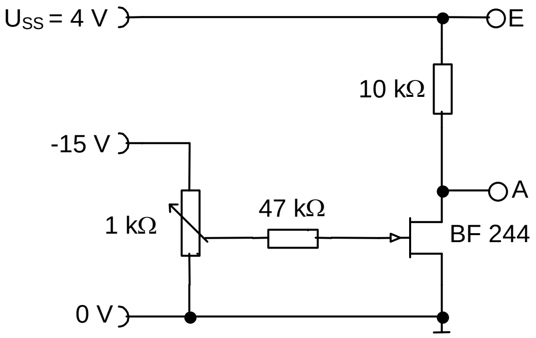


Illustration 2

- Circuit according to Illustration 2.
- Connect the oscilloscope to measure the input signal at E and the output signal at A.
- Connect the multimeter to measure the gate voltage U_{GS}.
- Turn on the operating voltage and set it to 15 V. Pay attention to the polarity in doing so.
- Supply a sinusoidal signal where U_S = 2 V and f = 1 kHz.
- Set the gate voltage U_{GS} = -10 V with the potentiometer. Observe the curves of the input voltage and output voltage with the oscilloscope.
- Reduce the gate voltage U_{GS} until the output curve begins to warp in the negative. Measure U_{GS}.
- Reduce the gate voltage U_{GS} more until the output curve begins to diminish in the positive. Measure U_{GS}.
- Reduce the gate voltage U_{GS} to 0 V. Measure $U_{E,SS}$ and $U_{A,SS}$ and calculate the switch-off damping according to (1).

Measurement Examples

a) Determination of the switch-on resistance

U_{GS} = 0 V

U_{Rv}	U_{DS}
9.8 V	0.24 V

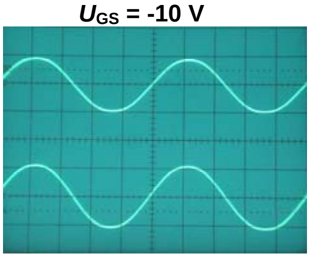
From $I = \frac{U_{Rv}}{R} = \frac{9.8\ \text{V}}{10\ \text{k}\Omega} = 0.98\ \text{mA}$ we get

$$R_{SD} = R_{On} = \frac{U}{I} = \frac{0.24\ \text{V}}{0.98\ \text{mA}} = 245\ \Omega$$

b) Investigation of the gate voltage's influence

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

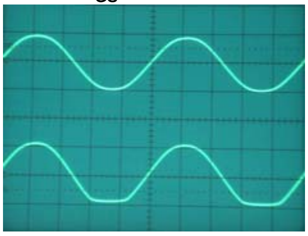
U_{GS} = -10 V

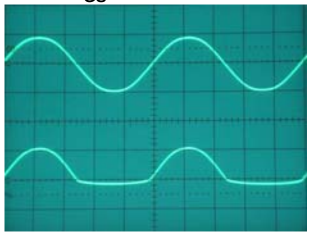


Y I:	2 V/div	DC
Y II:	2 V/div	DC
Sweep:	0.2 msec/div	

- For a gate voltage U_{GS} = -10 V (R_{SD} >> R_V), an alternating voltage goes through undistorted:

U_{GS} = -2.8 V **U_{GS} = -1.5 V**

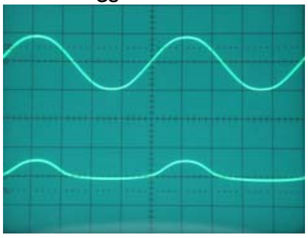




Y I:	2 V/div	DC
Y II:	2 V/div	DC
Sweep:	0.2 msec/div	

- If the gate voltage is in the range -3 V < U_{GS} < -1.4 V, then the negative half-wave is damped. The positive half-wave goes through undistorted.

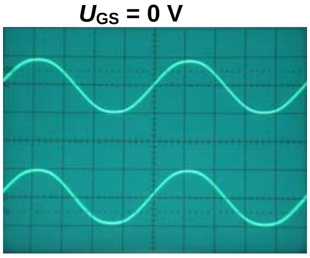
U_{GS} = -0.8 V



Y I:	2 V/div	DC
Y II:	2 V/div	DC
Sweep:	0.2 msec/div	

- From a gate voltage of U_{GS} < -1.4 V a positive signal is also damped.

U_{GS} = 0 V



Y I:	2 V/div	DC
Y II:	50 mV/div	DC
Sweep:	0.2 msec/div	

- For a gate voltage U_{GS} = 0 V (R_{SD} << R_V), the alternating voltage goes through undistorted again, but it is severely damped or shifted. (*The bottom curve's scale changes!*):

Attenuation calculation

- The input signal $U_{E,SS}$ = 4 V has declined to $U_{A,SS}$ = 88 mV, so:

$$\frac{U_A}{U_E} = \frac{0.088\ \text{V}}{4\ \text{V}} = 0.022\,,$$

i.e. the input signal is attenuated by 97.8 % to 2.2%. That in turn corresponds to the ratio of the switch-on resistance R_{On} to the multiplier R_V:

$$\frac{R_{On}}{R_V} = \frac{245\ \Omega}{10\ \text{k}\Omega} = 0.0245\,.$$

- From (1), we have for the shut-off damping:

$$d = 10 \cdot \log\left(\frac{4\ \text{V}}{0.088\ \text{V}}\right)^2 \approx 33\ \text{dB}$$