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 $U_G = 0 \text{ V}$. 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:

$$d = 10 \cdot \log \left( \frac{U_E}{U_A} \right)^2$$  \hspace{1cm} (1)

### Apparatus

<table>
<thead>
<tr>
<th>Description</th>
<th>Code</th>
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</thead>
<tbody>
<tr>
<td>1 Plug-in board DIN A4</td>
<td>576 74</td>
</tr>
<tr>
<td>1 Set of 10 bridging plugs</td>
<td>501 48</td>
</tr>
<tr>
<td>1 STE Transistor BF 244 (FET)</td>
<td>578 77</td>
</tr>
<tr>
<td>1 STE Resistor 10 kΩ, 0.5 W</td>
<td>577 56</td>
</tr>
<tr>
<td>1 STE Resistor 47 kΩ, 0.5 W</td>
<td>577 64</td>
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<tr>
<td>1 STE Potentiometer 1 kΩ, 1 W</td>
<td>577 92</td>
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<tr>
<td>1 Function generator S 12</td>
<td>522 621</td>
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<tr>
<td>1 DC power supply 0...+/- 15 V</td>
<td>521 45</td>
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<tr>
<td>1 Multimeter LDanalog 20</td>
<td>531 120</td>
</tr>
<tr>
<td>1 Two-channel oscilloscope 303</td>
<td>575 211</td>
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<tr>
<td>2 Screened cables BNC/4 mm</td>
<td>575 24</td>
</tr>
<tr>
<td>2 Pairs of cables, 50 cm, red and blue</td>
<td>501 45</td>
</tr>
<tr>
<td>1 Pair of cables, 50 cm, black</td>
<td>501 451</td>
</tr>
</tbody>
</table>

### Setup Procedure

#### a) Determination of the switch-on resistance

1. Turn on the operating voltage and set it to 10 V.
2. Measure the voltages at the resistor $R_V$ ($= 10k\Omega$), $U_{DS}$ and $U_{GS}$.

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 $R_V$ ($= 10k\Omega$), $U_{DS}$ and $U_{GS}$. 
b) Investigation of the gate voltage's influence

\[ U_{SS} = 4 \text{ V} \]

\[ -15 \text{ V} \]

\[ 1 \text{ k}\Omega \]

\[ 47 \text{ k}\Omega \]

\[ 0 \text{ V} \]

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 \( U_{S} = 2 \text{ V} \) and \( f = 1 \text{ kHz} \).
– Set the gate voltage \( U_{GS} = -10 \text{ V} \) 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

\[ U_{GS} = 0 \text{ V} \]

\[ U_{Rv} \quad U_{GS} \]

9.8 V \quad 0.24 V

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

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

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.

\[ U_{GS} = -10 \text{ V} \]

\[ U_{GS} = -2.8 \text{ V} \]

\[ U_{GS} = -1.5 \text{ V} \]

\[ U_{GS} = -0.8 \text{ V} \]

\[ U_{GS} = 0 \text{ V} \]

– For a gate voltage \( U_{GS} = -10 \text{ V} \) (\( R_{SD} \ll R_{V} \)), an alternating voltage goes through undistorted:

\[ \left( \frac{4 \text{ V}}{0.088 \text{ V}} \right)^2 \approx 33 \text{ dB} \]