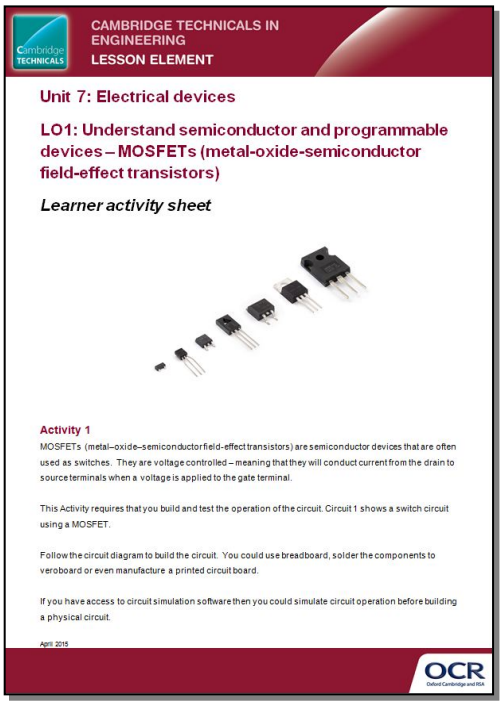
Unit 7: Electrical devices

LO1: Understand semiconductor and programmable devices
MOSFETs (metal-oxide-semiconductor field-effect transistors)

Instructions and answers for teachers

These instructions should accompany the OCR resource 'LO1: Understand semiconductor and programmable devices – MOSFETs (metal-oxide-semiconductor field-effect transistors)' *activity which supports Cambridge Technicals in Engineering Level 3.*


CAMBRIDGE TECHNICALS IN ENGINEERING
LESSON ELEMENT

Unit 7: Electrical devices

LO1: Understand semiconductor and programmable devices – MOSFETs (metal-oxide-semiconductor field-effect transistors)

Learner activity sheet

Activity 1

MOSFETs (metal–oxide–semiconductor field-effect transistors) are semiconductor devices that are often used as switches. They are voltage controlled – meaning that they will conduct current from the drain to source terminals when a voltage is applied to the gate terminal.

This Activity requires that you build and test the operation of the circuit. Circuit 1 shows a switch circuit using a MOSFET.

Follow the circuit diagram to build the circuit. You could use breadboard, solder the components to veroboard or even manufacture a printed circuit board.

If you have access to circuit simulation software then you could simulate circuit operation before building a physical circuit.

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The Activity:

In this task the students are tasked with familiarising themselves with MOSFETs.

This activity offers an opportunity for English skills development.

This activity offers an opportunity for maths skills development.

Suggested timings:

2 hours

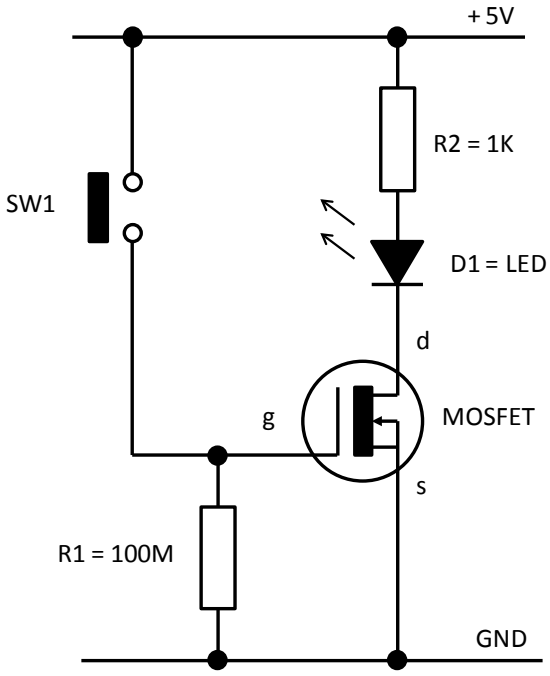
Activity 1

For Activity 1 learners have been tasked to investigate the operation of a MOSFET switching circuit, show in Circuit 1.

Learners could build the circuit using breadboard, veroboard (and soldered construction) or using a printed circuit board.

Alternatively or additionally, the circuit could be simulated using circuit simulation software.

A suitable MOSFET is the BS107 N-channel MOSFET (although an alternative device could be used). The datasheet for the BS107 can be found at the following website:
http://www.rapidonline.com/design-technology/bs170-n-channel-mosfet-fch-47-0142#techSpecshttp://www.rapidonline.com/design-technology/bs170-n-channel-mosfet-fch-47-0142#techSpecs



Circuit 1

The circuit operates as a switch, with current flowing from drain to source when a voltage is applied to the gate terminal via SW1.

With the device in the ON state, D1 LED will illuminate.

The function of R1 is to discharge the capacitance of the gate terminal once SW1 is opened, thus causing the MOSFET to turn off.

Answers to questions:

1. **What happens when SW1 is pressed and held?**

When SW1 is pressed and held, a voltage is applied to the gate terminal. This causes the MOSFET to allow a current to flow from drain to source, and D1 LED illuminates.

2. **What happens when SW1 is released?**

When SW1 is released, any charge caused by the capacitance of the gate terminal is discharged via R1. The MOSFET turns off, and D1 LED extinguishes.

3. **Remove R1 from the circuit – what happens when SW1 is pressed and held?**

With R1 removed, the LED will illuminate as in part (1) when SW1 is closed.

4. **With R1 removed, what happens when SW1 is released – and why does this happen?**

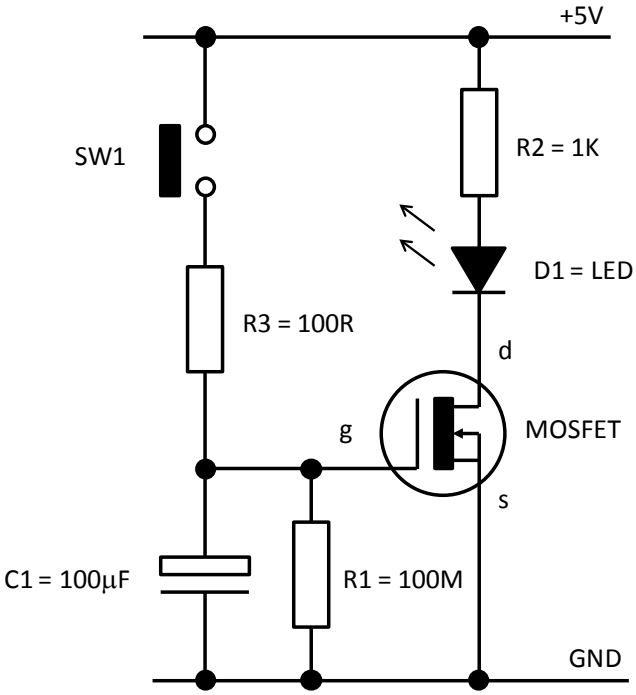
With R1 removed, the MOSFET will remain in the ON state (D1 LED illuminated) once SW1 is opened. This is because there is a small amount of capacitance at the gate terminal which will maintain the gate voltage for a while (up to several hours).

This experiment proves that that the MOSFET requires only an extremely low current at its gate terminal in order to operate.

Activity 2

In Activity 2 learners investigate operation of the MOSFET switching circuit with a capacitor connected between the gate terminal and ground (0V). The capacitor charges through R3 and is an RC circuit. Learners may recall RC circuits and time constant CR.

The circuit is shown in Circuit 2.



With SW1 closed, a voltage is applied to the gate terminal of the MOSFET and C1 also charges.

With SW1 opened, C1 will slowly discharge through R1 and the gate terminal, and D1 LED will remain at full brightness for a while before dimming until it is off.

Answers to questions:

1. **What happens when SW1 is pressed and held?**

A voltage is applied to the gate terminal causing the MOSFET to turn on, and D1 LED to illuminate. C1 also charges through R3.

2. **What happens when SW1 is released?**

C1 discharges through R1 and the gate terminal of the MOSFET. D1 LED remains at full brightness for a while before slowly dimming until it is off. The MOSFET turns off.

3. **Remove R1 from the circuit – what happens when SW1 is pressed and held?**

With R1 removed, the same happens as in part (1) above.

4. **With R1 still removed, what happens when SW1 is released, and why?**

With R1 removed, the MOSFET will continue to conduct for a very long time, with D1 LED illuminated. C1 will discharge very slowly through the gate terminal. Discharge may take hours or days.

The experiment again proves that the MOSFET requires only an extremely low current at its gate terminal in order to operate as a switch.

Activity 3

The MOSFET differs from a bipolar transistor in that:

- It is a voltage-controlled device, not current controlled as in the case of a bipolar transistor.
- The MOSFET only requires an extremely low gate drive current in order to operate. The base drive current for a bipolar transistor is larger.
- The MOSFET is most commonly used as a switch (although it can operate as an amplifier). The bipolar transistor can be used as a switch and as an amplifier.
- The MOSFET can switch large voltages and currents – with typical applications including switch-mode power supplies and motor speed controllers.

Learners may find other similarities and differences between the MOSFET and bipolar transistor, and could tabulate their findings.

Further devices such as the thyristor and IGBT (insulated gate bipolar transistor) could also be included in the comparison.

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