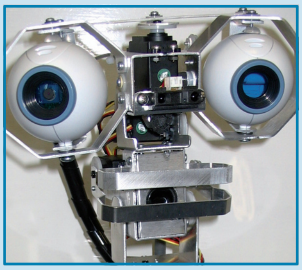
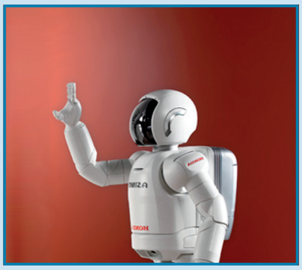
ROBOTIC SYSTEMS

Robotic systems and robots all have these basic components:

sensors --- control systems --- actuators





Sensors are systems which allow the robotic system to detect and measure the environment where it's operating. Sensors can be very simple, for example, a touch sensor built in the gripper on a robot could be a simple switch. Sensors can be much more complicated too: the London Congestion Charge Zone is 'patrolled' by an automated system that allows it to 'see' car number plates using CCTV cameras.

Control systems can also be very simple, performing a task like opening a window if a room gets too hot. More complicated systems include computers and the most complicated systems try to produce Artificial Intelligence (AI) so that robotic systems can make decisions and 'learn' from their mistakes.

Actuators are the devices that enable the robotic system to do things like move or walk or pick up things. Actuators usually involve motors of some sort.

To build a simple robotic system we need to know a little about sensors, control systems and actuators.

WHAT YOU HAVE TO DO

We have five main senses: sight, touch, hearing, smell and taste.

For an electronic system to sense its environment it must have sensors that convert these senses into electrical signals. Devices that convert signals (information) from non-electrical to electrical form are called input transducers. It is possible to make transducers that can respond to smell and taste but these are complex. Sensing sound is easier. Here, you are going to investigate simple transducers that detect light, temperature, moisture and pressure.

EQUIPMENT

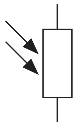
Your teacher will provide you with the relevant equipment for each investigation.

SAFETY NOTES

Take great care when using the sharp knife and the drill. Place a box of crumpled paper underneath the apparatus to catch any falling masses – and keep your toes out of the way!

METHOD: SENSING LIGHT

A light dependent resistor, LDR, is a light-sensing device.



1. Connect the LDR to the multimeter.
2. Set the multimeter to resistance range.
3. Vary the lighting level by, for example, covering the LDR with black card (for total darkness), having the room lights switched on and off or using a desk lamp.
4. Measure the resistance of the LDR at the various light levels.
5. For each lighting condition, measure the intensity of the light with a light meter.
6. Record your readings and plot a graph of *resistance* (ohms) against *light intensity*.

R /Ω	light intensity

7. Repeat with several different types of LDR. Make sure that each is tested in the same place in the room with the light receiving surface angled in the same way.

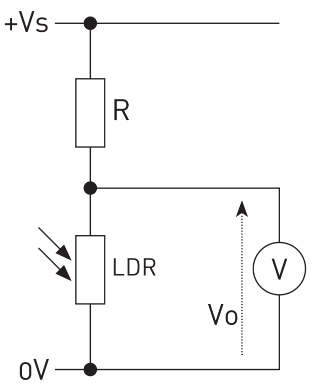
QUESTION

What does your graph tell you about the way the sensor works?

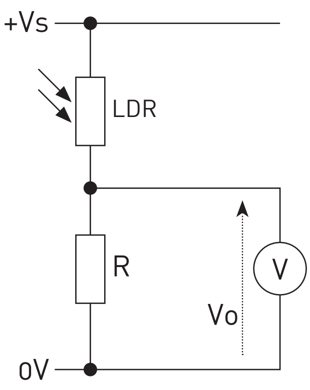
METHOD: TESTING THE LIGHT SENSOR CIRCUIT

1. Set the multimeter to read voltage.
2. Connect up the circuits as shown below.

circuit 1



circuit 2



Each circuit will produce a voltage signal, Vo, that depends on the condition of the sensing device. In circuit 1, Vo will increase as the resistance of the sensing device increases; in circuit 2, Vo will decrease as the resistance of the sensing device increases.

The range of Vo depends on:

- how widely the quantity being sensed varies (e.g. changing the light level from total darkness to bright sunshine has a greater effect than turning the classroom lights on/off)

- the type of sensor being used

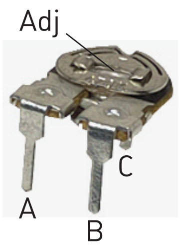
- the value of the resistance, R - using a variable resistor instead of a fixed resistor will allow you to adjust the sensing circuit.

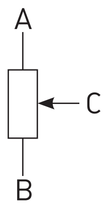
3. Change the brightness of the light falling on the LDRs by covering them with your hand.
4. Note how the voltage measured by the voltmeter varies as the light level falls.
5. Try different values of R (for example: 1 kΩ, BROWN BLACK RED GOLD, 10 kΩ, BROWN BLACK ORANGE GOLD and 100 kΩ BROWN BLACK YELLOW GOLD) noting the change in voltage.

QUESTIONS

1. The range of the voltage Vo is the difference between the biggest and smallest values. What range of voltages can you get by covering the LDR with your hand?

Changing the value of R changes the size of the voltage, Vo, that the sensor produces at a given level of brightness. Replace the fixed resistor, R, with a variable resistor (pot).





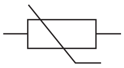
Connect wires to leg **C** and *either* leg **A** or leg **B**. (Only *two* leads are needed.)

Vary the resistance using a small screw driver in the **Adj** slot.

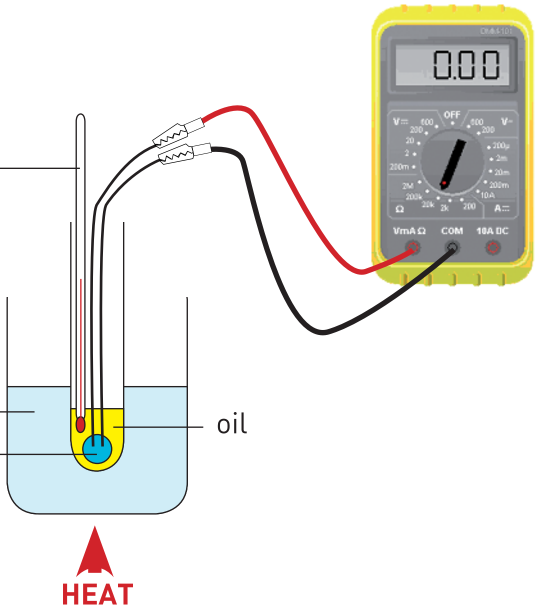
2. What is the optimum value of R for the LDR you are using? Explain why this is the best value.

METHOD: SENSING TEMPERATURE

A thermistor is a temperature-sensing device.

 thermistor symbol

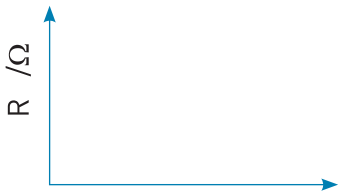
1. Set up the apparatus as shown in the diagram.



Note: Cooking oil helps the heat transfer to the thermistor and doesn't conduct electricity.

2. Use a hotplate or tripod, gauze and Bunsen burner as the heat source.
3. Set the multimeter to resistance range.
4. Measure the resistance of the thermistor over a range of temperatures – use iced water to lower the starting temperature to 0 °C.
5. Record your results. Plot a graph of *resistance*, R (ohms), against *temperature*, t (°C).

R /Ω	t /°C



6. Repeat with different types of thermistor.

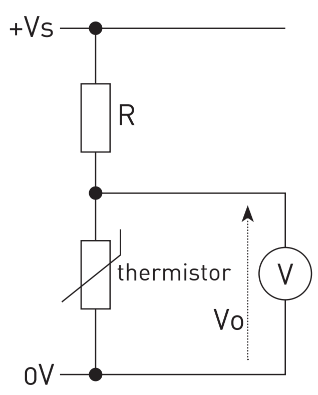
QUESTION

What does your graph tell you about the way the sensor works?

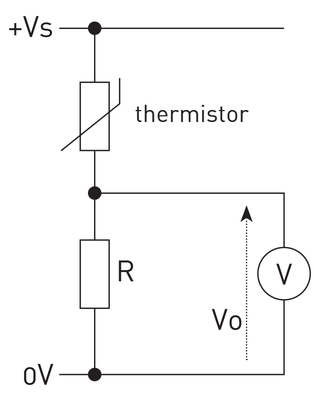
METHOD: TESTING THE TEMPERATURE SENSOR CIRCUIT

1. Set the multimeter to read voltage.
2. Connect up the circuits as shown below, inserting thermistors as the sensors.

circuit 1



circuit 2



Each circuit will produce a voltage signal, Vo, that depends on the condition of the sensing device. In circuit 1, Vo will increase as the resistance of the sensing device increases; in circuit 2, Vo will decrease as the resistance of the sensing device increases.

The range of Vo depends on:

- how widely the quantity being sensed varies (e.g. if the temperature changes are just a few degrees or if they are a larger range)

- the type of sensor being used

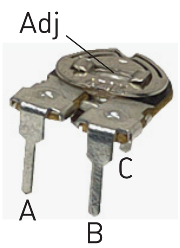
- the value of the resistance, R - using a variable resistor instead of a fixed resistor will allow you to adjust the sensing circuit.

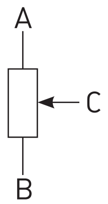
3. Place the thermistor in the oil as before.
4. Change the temperature of the water bath.
5. Note how the voltage measured by the voltmeter varies as the temperature increases.
6. Try different values of R (for example: 1 kΩ, BROWN BLACK RED GOLD, 10 kΩ, BROWN BLACK ORANGE GOLD and 100 kΩ BROWN BLACK YELLOW GOLD) noting the change in voltage.

QUESTIONS

1. What is the range of voltage change when you heat the water from 0 °C (need to start with lots of ice) to 70 °C?

Changing the value of R changes the size of the voltage, Vo, that the sensor produces at a given temperature. Replace the fixed resistor, R, with a variable resistor (pot).





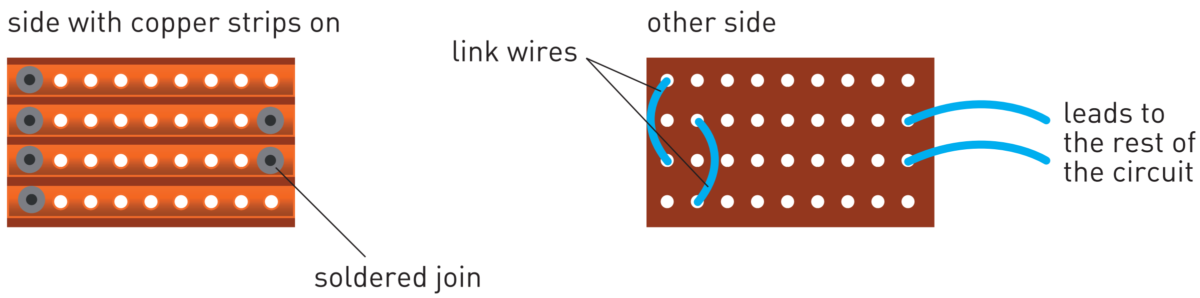
Connect wires to leg **C** and *either* leg **A** or leg **B**. (Only *two* leads are needed.)

Vary the resistance using a small screw driver in the **Adj** slot.

2. What is the optimum value of R for the thermistor you are using? Why is this the best value?

SENSING MOISTURE

A simple moisture sensor can be made using copper stripboard:



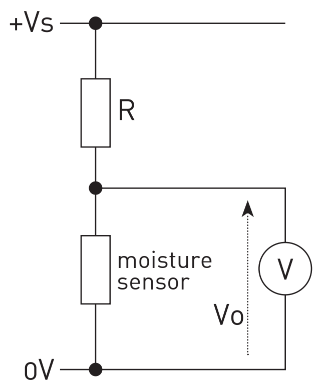
Alternate tracks are joined together with link wires, as shown. Each pair of linked tracks is separated from the other by an insulator, so the resistance between the leads will be very large (more than a million ohms) when the sensor is dry. Moisture will lower the resistance.

1. Make the moisture sensor as on the diagram above.
2. Connect the moisture sensor to the multimeter.
3. Set the multimeter to resistance range.
4. Vary the moisture level by, for example,
   - fully immersing in water (you can try distilled water and tap water to see if there is a difference – try adding a few drops of vinegar)
   - dipping it into water so that it is only partly under the water
   - in soil, in a plant pot, and adding water to the soil
   - trying different types of soil (such as sand and potting compost).
5. Measure the resistance of the moisture sensor in the various conditions.
6. Record your readings and display them in a bar chart.

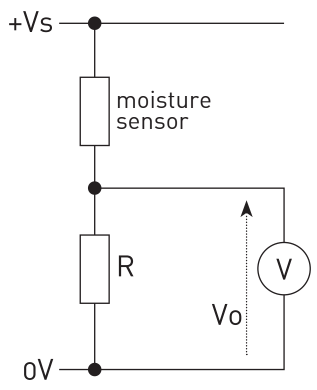
METHOD: TESTING THE MOISTURE SENSOR CIRCUIT

1. Set the multimeter to read voltage.
2. Connect up the circuits as shown below, inserting your moisture meter as the sensor.

circuit 1



circuit 2



Each circuit will produce a voltage signal, Vo, that depends on the condition of the sensing device. In circuit 1, Vo will increase as the resistance of the sensing device increases; in circuit 2, Vo will decrease as the resistance of the sensing device increases.

The range of Vo depends on:

- how widely the quantity being sensed varies

- the type of sensor being used

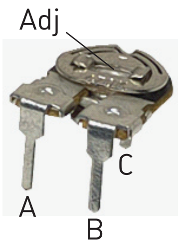
- the value of the resistance, R - using a variable resistor instead of a fixed resistor will allow you to adjust the sensing circuit.

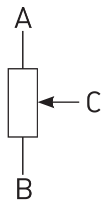
3. Place the meter in a plant pot of dry soil.
4. Note how the voltage measured by the voltmeter varies as the moisture increases.
5. Try different values of R (for example: 1 kΩ, BROWN BLACK RED GOLD, 10 kΩ, BROWN BLACK ORANGE GOLD and 100 kΩ BROWN BLACK YELLOW GOLD) noting the change in voltage.

QUESTIONS

1. How is the range of the voltage change affected when you increase the moisture to fully saturated?

Changing the value of R changes the size of the voltage, Vo, that the sensor produces at a given moisture level. Replace the fixed resistor, R, with a variable resistor (pot).





Connect wires to leg **C** and *either* leg **A** or leg **B**. (Only *two* leads are needed.)

Vary the resistance using a small screw driver in the **Adj** slot.

2. What is the optimum value of R for your moisture sensor? Why is this the best value?

METHOD: SENSING PRESSURE

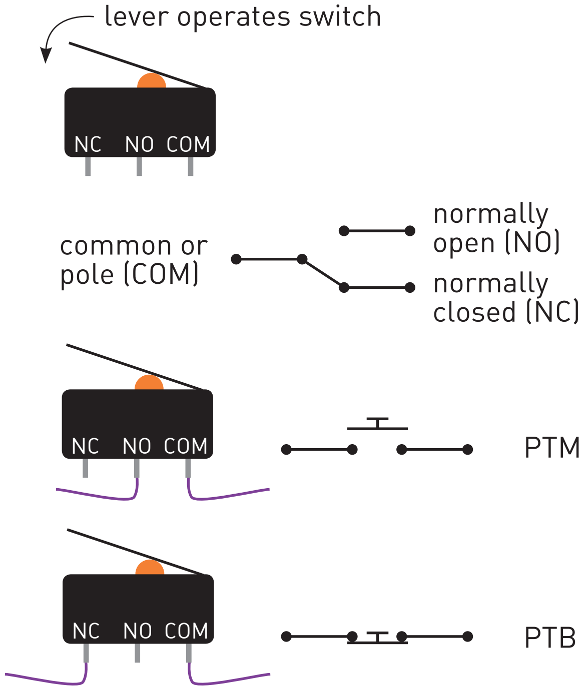
Switches are pressure-sensing devices.

- They are available in lots of forms.
- Switches either have very large resistance when open or very small resistance, close to zero, when closed. You can check this with a multimeter set to a resistance range.

Microswitches

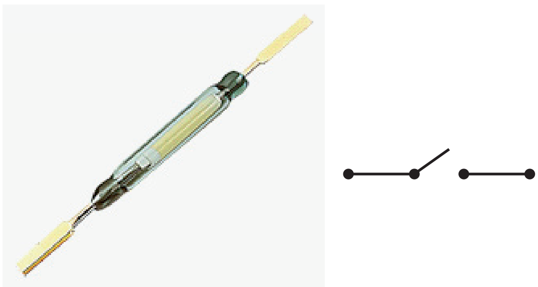
Microswitches (which are operated by a very small force/movement) are often used to sense the limits of movement of a robotic system. Typically microswitches have changeover contacts.

Microswitches have a 'momentary action', that is, they spring back to the original condition when you stop pressing them. You can wire them up to make either a push-to-make (PTM) switch or push-to-break (PTB) switch:



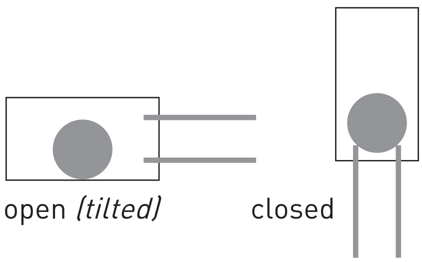
Reed switches

A single pole single throw (SPST) switch is enclosed in a glass tube (be careful, these are easily broken). The switch is normally open, but closes when a magnet is brought close to the reed switch. When the magnet is removed the switch springs open once more. Reed switches can be used as limit switches.



Tilt switches

Tilt switches can be used to tell which way up something is or what angle it is to the vertical or horizontal. A simple form of tilt switch has a metal ball and two metal contacts inside a metal can. When the sensor is in a certain position (shown right), then the metal ball completes the circuit. When the switch is tilted, the ball does not complete the circuit.



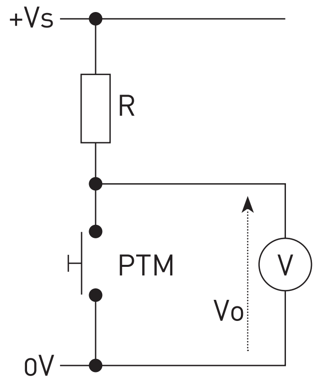
QUESTIONS

1. (a) How close does the magnet need to be to operate the reed switch?
   (b) Does it matter what type of magnet you use, or which way round the magnet is?
2. Use a protractor and a multimeter (set to resistance range) to find out the angle that the tilt switch opens/closes.

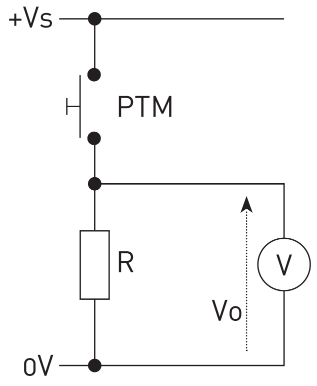
METHOD: TESTING THE PRESSURE SENSOR CIRCUIT

1. Set the multimeter to read voltage.
2. Connect up the circuits as shown below, inserting PTM switches as the sensors.

circuit 1



circuit 2



The range of Vo depends on:

- how widely the quantity being sensed varies

- the type of sensor being used

- the value of the resistance, R - using a variable resistor instead of a fixed resistor will allow you to adjust the sensing circuit.

3. Turn the switch on and off.
4. Note how the voltage measured by the voltmeter varies.
5. Try different values of R (for example: 1 kΩ, BROWN BLACK RED GOLD, 10 kΩ, BROWN BLACK ORANGE GOLD and 100 kΩ BROWN BLACK YELLOW GOLD) noting the change in voltage.

QUESTIONS

1. The way that the voltage output changes is different from the light, temperature and moisture sensing circuits. Describe how it is different.

HEALTH AND SAFETY

A risk assessment must be made before starting any practical work. Care will need to be taken if students use a Bunsen burner to heat the water. Students will require close supervision and must take care with the hot soldering iron, if they make their own moisture meter.

THE INVESTIGATION

This practical activity is the first of a series of three, taking students through the key elements of robotic systems.

The various investigations might be arranged:

- as a carousel, or
- different groups could work with different sensors and then share results in a plenary.

A variety of testing options are included within each part of the investigation. To control the time aspect, pre-select the extent of each test environment. Issue pages as appropriate or leave a copy at each carousel station.

Note: For the soil experiment (testing the moisture sensor circuit) it may be better to use large value resistors. Try 100 kΩ, 220 kΩ (RED RED YELLOW GOLD), 390 kΩ (ORANGE WHITE YELLOW GOLD) and, therefore, use a 500 kW pot. This should produce a better range.

Time required

Depending on how students are arranged and how much assembly they undertake, this activity will take at least one session to complete. Additional time would be needed for any plenary.

TECHNICIAN EQUIPMENT LIST

per pair or carousel station

All codes and prices (2007) are from Rapid Electronics.

general

building and testing circuits

- protobloc (34-0650 £2.40)
- digital multimeter (85-0662 £4.50)
- connecting wire
- stabilised DC supply 5–12 V (6 V or 9 V batteries could be used)

light

- digital light meter (85-2436 £39.99)
- black card
- desk lamp

temperature

- waterproof digital thermometer (85-2379 £9.10) or
- 0-100 °C thermometer (85-2653 £0.99)
- test tube (large enough to accommodate the thermometer and the thermistor)
- beaker
- cooking oil
- hotplate or tripod, gauze and Bunsen burner
- ice and water

moisture

- copper stripboard (34-0540 £4.80 per sheet)
- soldering iron and stand
- non-lead solder
- beaker or similar for waterbath
- tap water, distilled water, vinegar
- plant pot, soil, sand, potting compost

pressure

- magnet
- protractor

Sensors

light dependent resistors with different characteristics

- 58-0134 (£0.30)
- 58-0127 (£0.41)
- 58-0132 (£0.85)

thermistors with different characteristics (£0.21 each)

- 61-0400
- 61-0405
- 61-0410
- 61-0415
- 61-0420

switches

- lever microminiature microswitch (78-0735 £0.38)
- reed switch (78-1012 £0.41)
- tilt switch (78-0752 £0.50)

range of fixed value resistors and/or pots

- resistor kit (13-0200 £8.30)
- preset pot kit (13-0225 £7.25)

TECHNICIAN NOTES

Do not use solder with colophony (rosin) flux. Non-lead solders generally require high temperature; be aware that some older soldering irons may not get hot enough.