Electronics

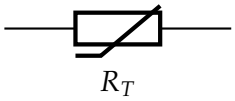
Name _____ Date _____

By the end of this topic I can…
- describe the thermistor, LDR, strain gauge and piezo-electric transducer
- use $\Delta R/R = 2\Delta l/l$ for a strain gauge
- analyse a potential divider and a sensing circuit

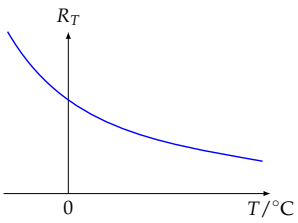
Electronic systems have three parts: a change in a physical property (temperature, pressure…) is picked up by a sensor; the electrical signal goes to a processing unit; the processor gives an output voltage to drive an output device.

Sensors

Thermistor



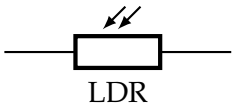
A thermistor is a component whose resistance varies with temperature.



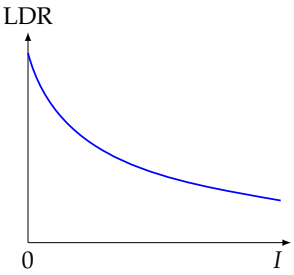
NTC thermistor.

- NTC (negative temperature coefficient): resistance decreases as temperature rises. (A-level uses NTC only.)
- the relation is non-linear: the curve looks like an exponential decay
- **explanation**: at low temperature electrons are bound to atoms; at high temperature they gain energy and break free, so there are more free electrons to conduct (band theory)

Light-dependent resistor (LDR)



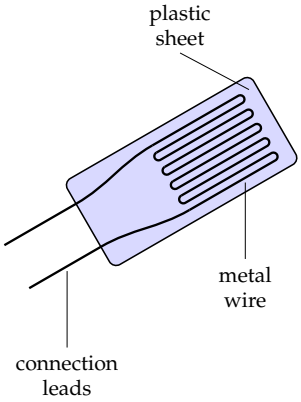
A light-dependent resistor has a resistance that decreases as the light intensity increases.



LDR resistance falls as light intensity rises.

- the variation is non-linear
- light gives bound electrons enough energy to become conducting: brighter light means more free electrons
- in the dark: $R \approx$ 10^5 to 10^7 Ω in bright light: $R \approx$ 10^2 to 10^3 Ω

Strain gauge



A strain gauge is used to measure the width of a narrow crack. A long folded metal wire is sealed on a plastic sheet. As the crack widens the gauge is stretched, the wire gets longer, and its resistance changes.

- resistance of a wire: $R = \frac{\rho l}{A}$
- if only the length changes (area constant): $\Delta R = \frac{\rho \Delta l}{A}$, so

$$\frac{\Delta R}{R} = \frac{\Delta l}{l}$$

- in fact the volume $V = Al$ stays constant, so as the wire gets longer it also gets thinner. Both effects increase the resistance, giving an extra factor of two (for small strains):

$$\frac{\Delta R}{R} = \frac{2\Delta l}{l}$$

Question 31.1 A strain gauge has resistance 120 Ω. As a crack widens the wire stretches by 0.10%. Find the new resistance.

$\frac{\Delta R}{R} = \frac{2\Delta l}{l} = 2 \times 0.0010 = 0.0020$
$\Delta R = 0.0020 \times 120 = 0.24\ \Omega$, so $R = 120.24\ \Omega$ ($\approx 120.2\ \Omega$)

Piezo-electric transducer

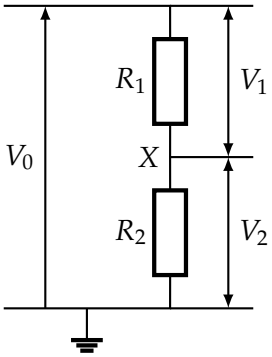
A piezo-electric transducer transforms mechanical energy into electrical energy, or vice versa.

- when the material is compressed, a p.d. is produced across it. A p.d. applied across it makes it change shape.
- **generating sound**: an a.c. voltage makes the material vibrate at the same frequency, giving compressions and rarefactions of air: loudspeakers and buzzers
- **detecting sound**: pressure variations produce an a.c. voltage across the device: microphones
- **mechanism**: the material contains polarised molecules (dipoles). When compressed they rearrange, so the charge density varies and a small p.d. appears.



microphone loudspeaker

Processors: the potential divider



Sensors such as the thermistor and LDR only change their resistance, but output devices are driven by voltages. A potential divider turns a change in resistance into a change in voltage.

A potential divider is two resistors in series connected across a fixed voltage supply.

- $V_0 =$ $V_1 + V_2$, and the same current I flows through both, so

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

- the voltage is shared in proportion to the resistance:

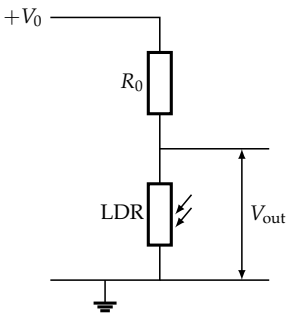
$$V_1 = \frac{R_1}{R_1 + R_2} V_0 \qquad V_2 = \frac{R_2}{R_1 + R_2} V_0$$

- if R_1 increases (R_2 fixed): V_1 increases and V_2 decreases. If R_1 decreases: V_1 decreases and V_2 increases.

- potential is measured relative to a reference point called earth (or ground), defined as zero. In the diagram the potential at X equals V_2.

Question 31.2 A potential divider has $R_1 = 2.0\ \text{k}\Omega$ and $R_2 = 6.0\ \text{k}\Omega$ across a 12 V supply. Find V_1 and V_2.

$V_1 = \dfrac{2.0}{2.0 + 6.0} \times 12 = 3.0\ \text{V}$ $\quad V_2 = \dfrac{6.0}{2.0 + 6.0} \times 12 = 9.0\ \text{V}$
(check: $3.0 + 9.0 = 12\ \text{V}$)



Example 31.1 For the sensing circuit shown, suggest how the output voltage changes as the light level increases.

Light intensity increases, so the resistance of the LDR ___decreases___.
The current in the circuit increases, so the p.d. across R_0 increases.
So the p.d. across the LDR becomes smaller: V_{out} **decreases**.
(Check with $V_{out} = \dfrac{R_{LDR}}{R_{LDR} + R_0} V_0$: lower R_{LDR} gives lower V_{out}.)

Question 31.3 In the example, $R_0 = 8.0\ \text{k}\Omega$, the LDR has $12\ \text{k}\Omega$ and $V_0 = +15\ \text{V}$. Find V_{out}.

$$V_{out} = \frac{12}{12 + 8.0} \times 15 = 9.0\ \text{V}$$

Question 31.4 Design a sensing circuit that produces a greater output voltage as the temperature of the sensor rises. Explain how it works.

Connect an NTC thermistor in series with a fixed resistor R across the supply, and take V_{out} across the **fixed resistor**.
As temperature rises the thermistor's resistance falls, so the current increases and the p.d. across R increases. (Equivalently the thermistor takes a smaller share of V_0.) So V_{out} rises.