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

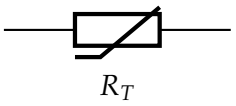
Electronic systems have three parts: a change in a physical property (temperature, pressure…) is picked up by a ___sensor___; the electrical signal goes to a ___processing unit___; the processor gives an output voltage to drive an ___output device___.

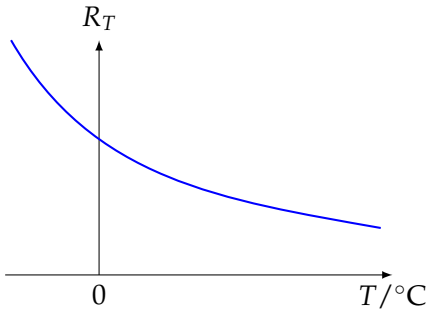
Sensors

Thermistor

A ___thermistor___ is a component whose ___resistance varies with temperature___.

- ___NTC___ (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)



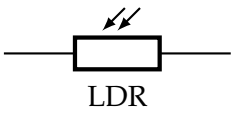


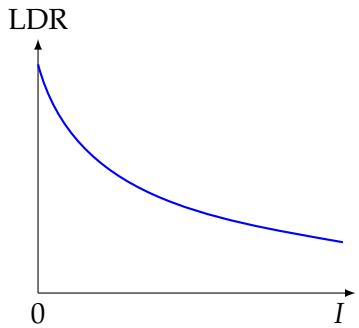
NTC thermistor.

Light-dependent resistor (LDR)

A ___light-dependent resistor___ has a resistance that ___decreases___ as the light intensity ___increases___.

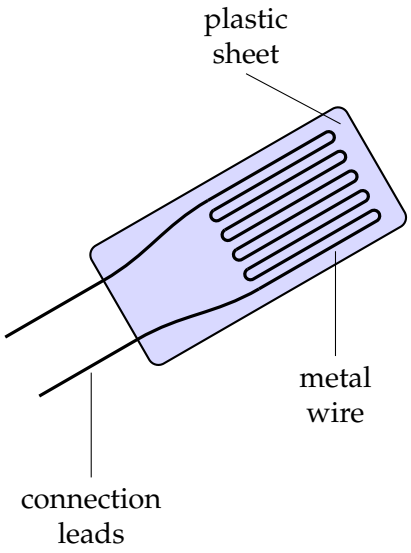
- the variation is ___non-linear___
- light gives bound electrons enough energy to become ___conducting___: brighter light means more ___free electrons___
- in the dark: $R \approx$ ___10^5 to 10^7___ Ω in bright light: $R \approx$ ___10^2 to 10^3___ Ω





LDR resistance falls as light intensity rises.

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.

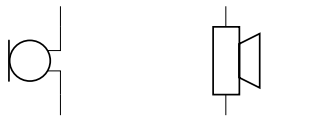
$\frac{\Delta R}{R} = \frac{2\Delta l}{l} = 2 \times 0.0010 = 0.0020$
$\Delta R = 0.0020 \times 120 = 0.24\ \Omega$, so $R = 120.24\ \Omega$ ($\approx 120.2\ \Omega$)

Piezo-electric transducer

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

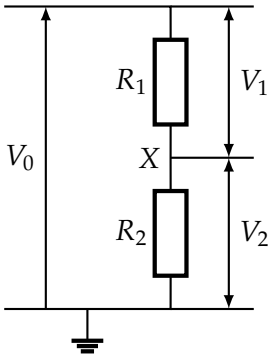
- when the material is compressed, a p.d. is produced across it. A p.d. applied across it makes it change shape.
- **generating sound**: an a.c. voltage makes the material vibrate at the same frequency, giving compressions and rarefactions of air: loudspeakers and buzzers
- **detecting sound**: pressure 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.

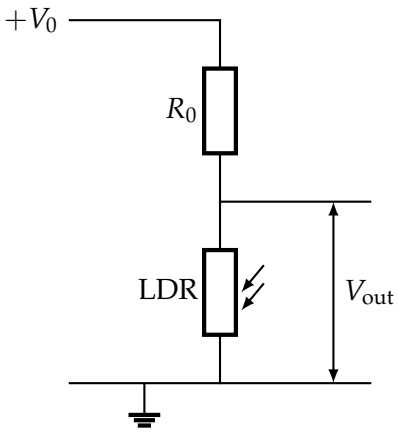
- $V_0 =$ $V_1 + V_2$, and the same current I flows through both, so $\frac{V_1}{V_2} = \frac{R_1}{R_2}$
- the voltage is shared in proportion to the resistance:

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

- 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.

$V_1 = \frac{2.0}{2.0+6.0} \times 12 = 3.0\ \text{V}$ $\quad V_2 = \frac{6.0}{2.0+6.0} \times 12 = 9.0\ \text{V}$
(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 kΩ and $V_0 = +15$ 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.