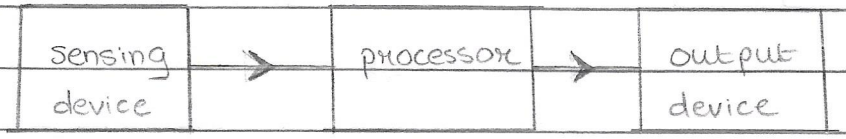
25 - Electronics

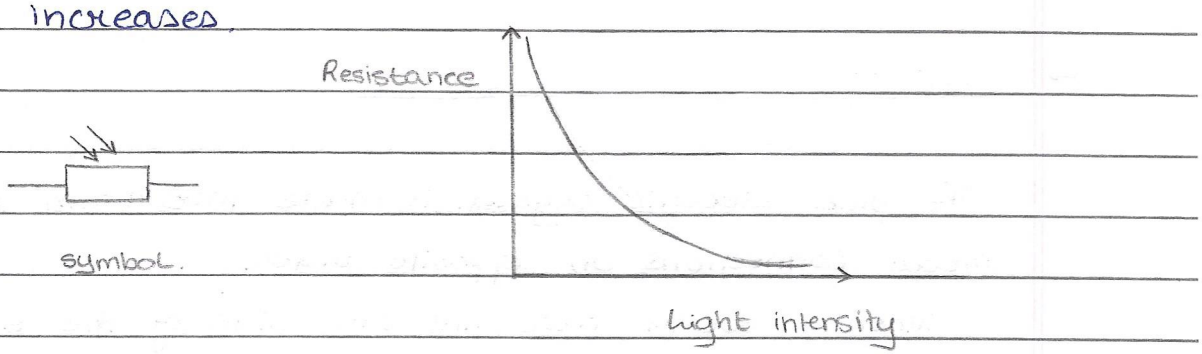
Q-1) What are electronic sensors?

> An electronic sensor consists of a sensing device, a processor that provides an output voltage, and an output device.



Q-2) Principle of an LDR (sensing device)

> When light is incident on a semi conductor material, the photons are absorbed producing more free e^-. Higher the intensity, more the number of free e^-. Hence, resistance of an LDR decreases as light intensity ~~incr~~ increases.

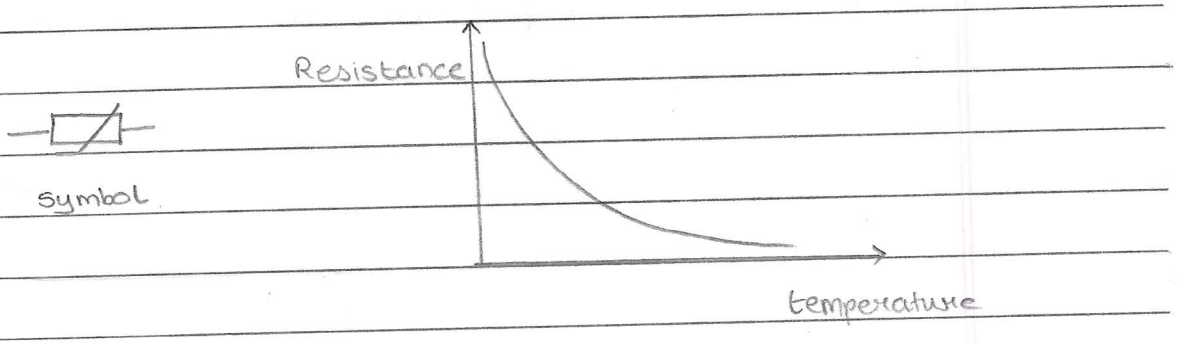


Q-3) Principle of a thermistor. (sensing device)

> When temperature of a semi-conductor material increases, the electrons have higher energy and become free e^- ∴ the number of free e^- increases.
Hence, the resistance of the thermistor decreases as temperature increases.

* Thermistor is more useful than a metal for sensing because

there is a much larger change in resistance compared to a metal.
However, the variation of resistance with temperature is non-linear ∴ calibration is required.



Q-4) Piezo electric effect. (sensing device)

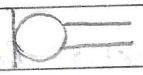
> When stress is applied to some crystal (eg: quartz), an emf is generated accross its opposite faces.
This is known as the piezo-electric effect and the crystal acts as a transducer.

→ Application in a microphone:

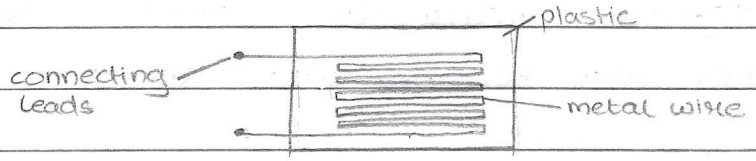
The piezo electric crystal is made into a thin sheet with metal connections on opposite sides.

When a sound wave hits one side of the sheet, the compressions and rarefactions cause the pressure to increase and decrease.

The crystal changes shape in response to these pressure changes and a small voltage is created across the connections. The voltage is then amplified.
∴ the crystal and amplifier can be used to convert sound to electrical signal.


symbol for a microphone.

Q-5) The metal-wire strain gauge. (sensing device)



> The strain gauge consists of a thin metal wire encased in a plastic sheet.
When stretched, the wire becomes longer and narrower, which increases its resistance.

① $R = \frac{\rho L}{A}$ → assume area (A) is constant.

② $R + \Delta R = \frac{\rho (L + \Delta L)}{A}$

② − ① = $\Delta R = \frac{\rho \Delta L}{A}$ → ③

③ ÷ ① = $\frac{\Delta R}{R} = \frac{\Delta L}{L}$ ∴ $\Delta R \propto \Delta L$

* if change in area is considered then:

$\Delta R = \frac{2\rho \Delta L}{A}$ ∴ $\frac{\Delta R}{R} = \frac{2\Delta L}{L}$ ∴ $\Delta R \propto \Delta L$

Q-6) What is an operational amplifier? (op-amp) [processing device]

> An op-amp is an integrated circuit that contains about 20 transistors together with resistors and capacitors.

It has 2 inputs:

- inverting input (-ve)
- non-inverting input (+ve)

* An op-amp provides more voltage and current in the output than that present in the input.
To do this it has 2 power supplies (+Vs and -Vs)
* The largest voltage an op-amp can produce is a value close to the supply voltage
↳ in this case, the op-amp is saturated.

Functions of an op-amp:

① Comparator: compare 2 voltages and given an output depending on the result of comparison.
* if $V^+ > V^-$ → output is +ve
* if $V^+ < V^-$ → output is -ve

② Amplify a.c. and d.c. voltages.

③ Acts as a switch when voltage reaches a certain level.

Open loop gain:

$$G_o = \frac{V_o}{(V^+ - V^-)}$$

$$\therefore V_o = G_o (V^+ - V^-)$$

→ if by calculation, $V_o > V_s$ then output (V_o) is equal to V_s.
i.e. V_o can't exceed V_s.

Q-7) Properties of an ideal op-amp.

1 > Infinite open-loop gain
2 > Infinite input resistance
3 > Zero output resistance
4 > Infinite slew rate ie no time delay
5 > Infinite band width
6 > Zero noise contribution

Q-8) What is negative feedback?

> Negative feedback is when a part of the output of the op-amp is fed back to the inverting terminal of the op-amp, so as to reduce the gain of the amplifier.

$$V_o = G_o(V^+ - V^-)$$

$$V_o = G_o(V_{in} - V_{out}) \quad \text{--o } V_{out} \equiv V_o$$

$$G_o V_{in} = V_o + G_o V_o$$

$$G_o V_{in} = V_o(1 + G_o)$$

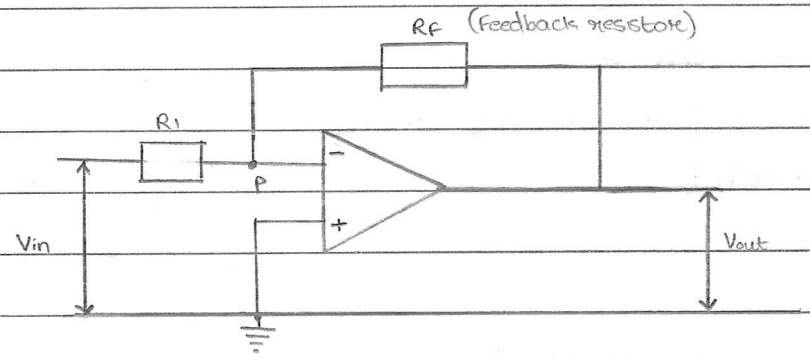
$$\therefore \text{Gain} = \frac{V_{out}}{V_{in}} \equiv \frac{G_o}{(1 + G_o)}$$

Advantages of negative feedback:

- less distortion
- increased bandwidth (range of frequencies with which gain is constant)
- gain is more stable & not affected by change in temperature etc...
- output resistance can be low and input high.

Q-9) Inverting and non-inverting amplifiers.

> Inverting amplifier:



- Input is supplied to the inverting terminal (-ve)
- Negative Feedback ; Gain is reduced
- Out-put voltage is NOT in phase with input.
  ie. when input is +ve, output is -ve...

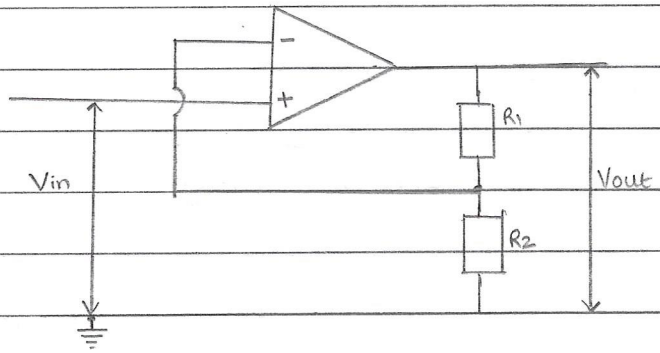
GAIN:

$$I_f = -I_{in}$$

$$\frac{V_{out}}{R_f} = -\frac{V_{in}}{R_{in}}$$

$$\therefore \quad G = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}.$$

> Non-inverting amplifier



- Input is supplied to the non-inverting terminal (+ve)
- Negative feedback ; Gain is reduced.
- Output voltage is always in phase with input
  i.e. when input is +ve, output is +ve...

GAIN:

$$V^+ = V^- = V_{in}$$

$$I = \frac{V_{out}}{R_1 + R_2} = \frac{V_{in}}{R_2}$$

$$\therefore G = \frac{V_{out}}{V_{in}} = \frac{R_1 + R_2}{R_2} \equiv 1 + \frac{R_1}{R_2}$$

Q-10) What is the virtual earth approximation?

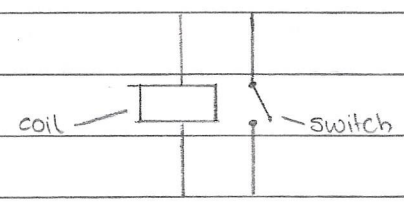
> It occurs in an inverting amplifier.

* Gain of op-amp is very large. Non-inverting (+) terminal is earthed. For the amplifier not to saturate, the inverting terminal must also be at earth potential. ∴ the point P is at the earth potential (0V) and is referred to as virtual earth.

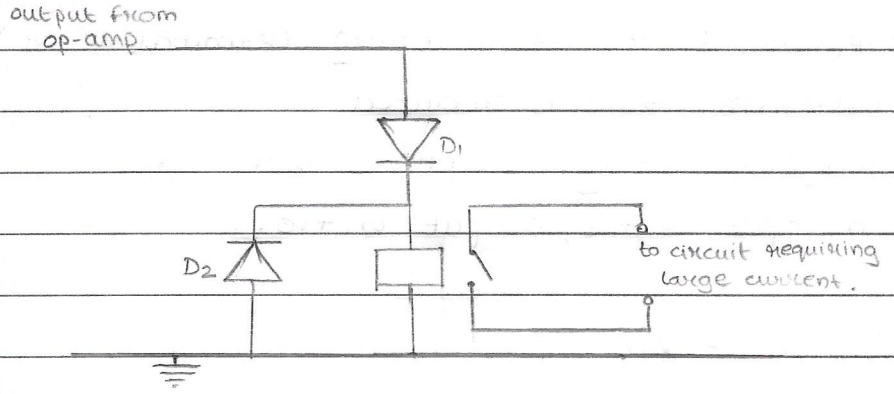
Q-11) Function of a relay. (output device)

> A relay is an electromagnetic switch operated by a small current in the coil.

When a small current passes through the coil of the relay, the iron core attracts a movable arm, causing a pair of contacts to close. This completes the second circuit, switching on a larger current in the second circuit.



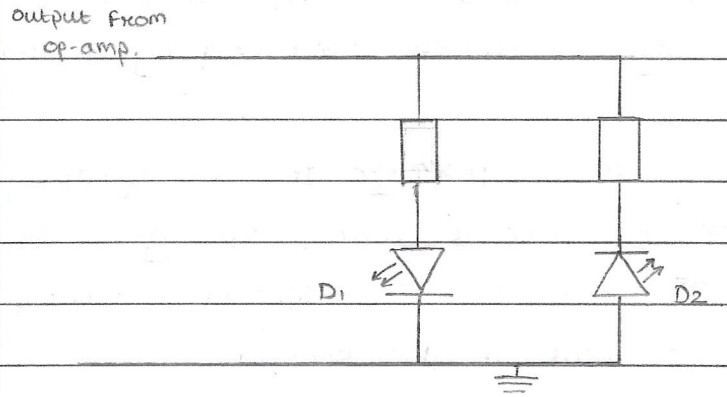
→ symbol for a relay.



- The diode D_1 ensures that the relay functions only when the output of the op-amp is positive.
- When current in the relay is turned off, there is a rapid fall in the magnetic flux within the coil, and a large e.m.f is induced, which can damage the op-amp
D_2 is able to pass the current round the coil, without any damage to the op-amp.

Q-12) Use of LED's (output device)

> LED shows the state of the output coming from an op-amp. A resistor is connected with the LED so that when the LED is forward biased, the current is not too large to damage it.



Q-13) Digital and analogue meters used as output devices.

> A digital or analogue voltmeter, connected between the op-amp output and earth will indicate the output voltage.

The output voltage will be proportional to the input to the processing unit.

It will also depend on the magnitude of whatever is being sensed but is unlikely to vary linearly with the change in this quantity.

∴ The voltmeter needs to be calibrated.

↳ using a calibration curve