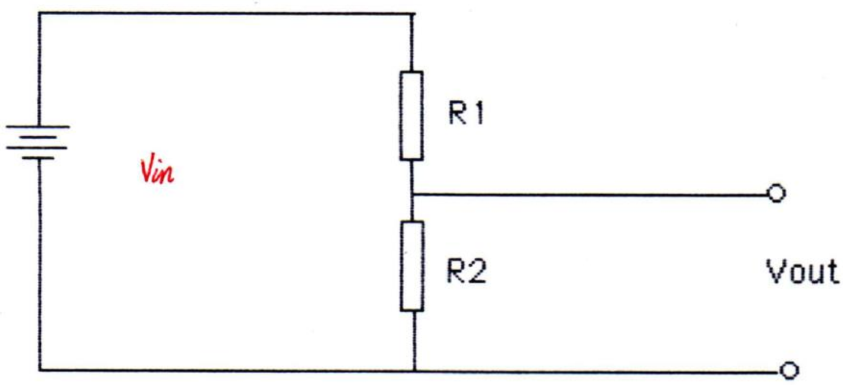
E.10 Transducers

A transducer is simply a device which receives a signal in the form of one type of energy and converts it into another. For example a microphone converts sound energy into electrical energy.
In the context of electricity, an input transducer would receive a signal and convert it to electrical energy. E.g. a microphone.
In the context of electricity, and output transducer would convert an electrical signal into another form of energy. E.g. a light globe.

E.10.1 Voltage Dividers

Sometimes the voltage supplied is greater than that needed by the circuit. A voltage divider is used to reduce the voltage.
A voltage divider consists of a series of resistors.



Since the resistance of the circuit is $R_1 + R_2$,

we can write $V_{in} = I\,(R_1 + R_2)$

The output voltage will be equal to the voltage across the second resistor

i.e. $V_{out} = I\,R_2$

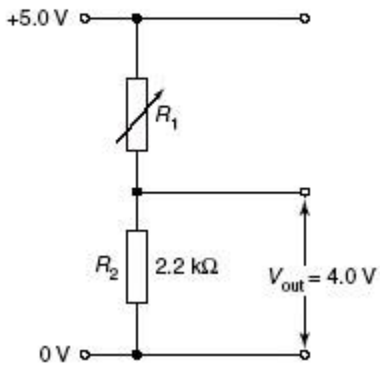
thus we have

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

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

Example

What would the resistance of the variable resistor have to be to give an output voltage of 4.0 V in the circuit shown?



Solution

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

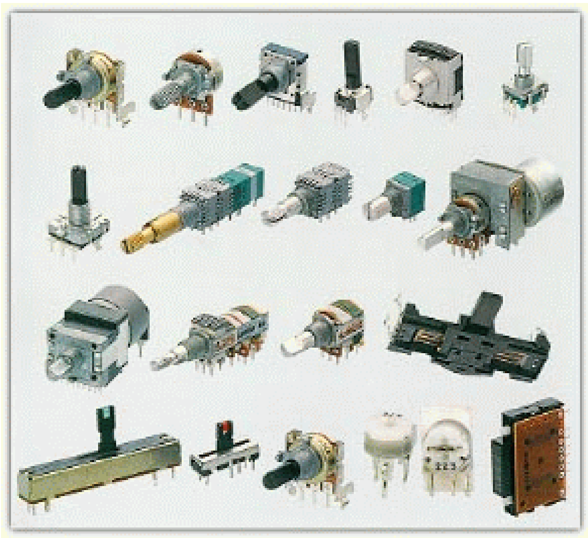
$$\frac{4.0}{5.0} = \frac{2200}{R_1 + 2200}$$

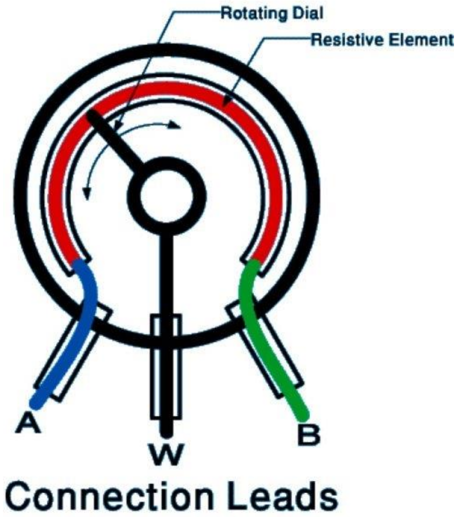
$$4.0\,R_1 + 8800 = 11000$$

$$R_1 = 550\ \Omega$$

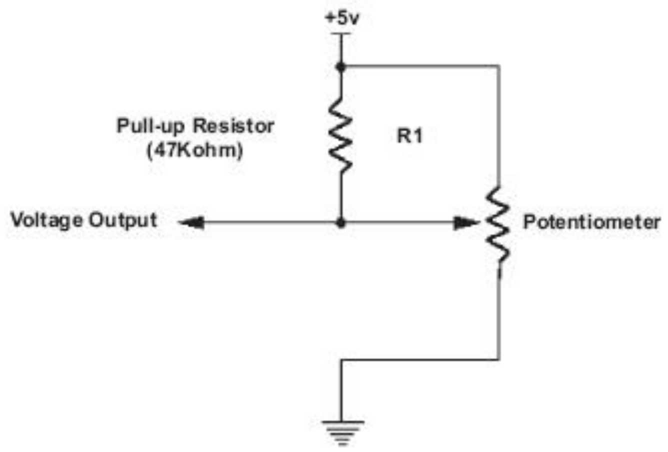
E.10.2 Potentiometer

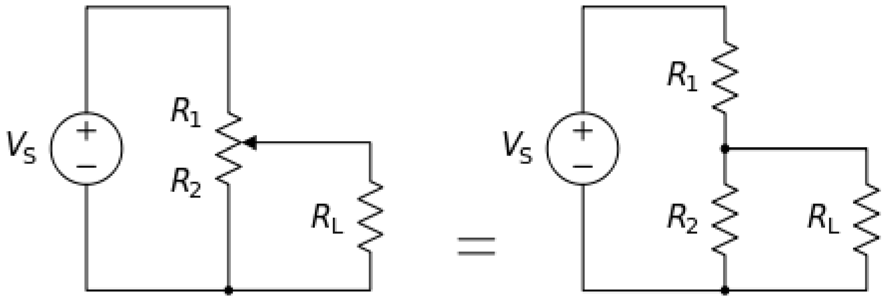
A potentiometer is simply a resistor where the resistance can easily be changed. Potentiometers come in different forms, but all have the same basic design.





Potentiometers are considered a signal processing component as they can be connected in a voltage divider circuit.





Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment.

E.11 Input Transducers

E.11.1 Thermistors

A thermistor is an input transducer made from a mixture of semiconductors. The resistance of a thermistor varies with the temperature. A characteristic curve is used to determine the resistance at a particular temperature, an example is shown in the figure below.

Thermistors are considered to be input transducers because they convert thermal energy into a voltage when they are used in potential dividers. Thermistors are used in fire alarms, temperature circuits in car engines, electronic thermometers for measuring temperature and thermostats for controlling the temperature in household and industrial equipment.

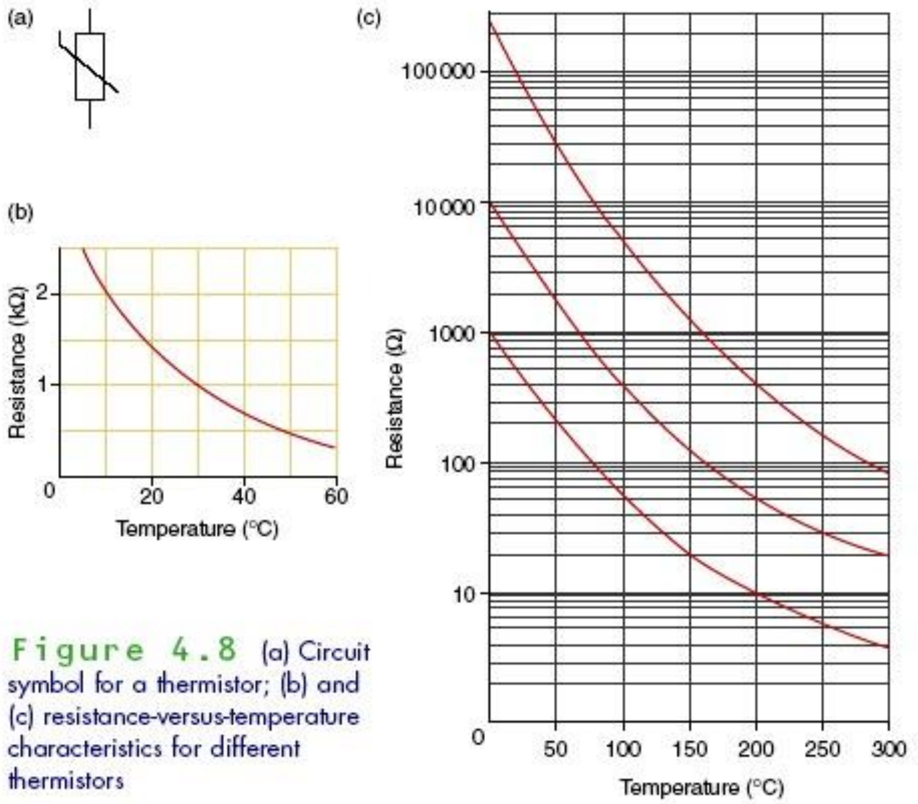
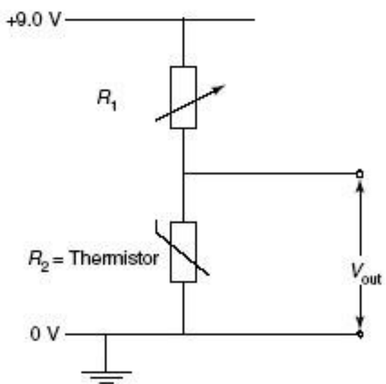


Figure 4.8 (a) Circuit symbol for a thermistor; (b) and (c) resistance-versus-temperature characteristics for different thermistors

Example

A thermistor has the temperature-resistance characteristic shown by the bottom curve in figure 4.8(c) above. It is placed in the voltage divider shown.



(a) What is the resistance of the thermistor when the temperature is 150°C?

(b) What is the value of the variable resistor if the temperature is 200°C and Vout is 6.0 V?

Solution

(a) From the graph, when the temperature is 150°C, the resistance is 20 Ω.

(b) From the graph, when the temperature is 200°C, the resistance is 10 Ω.

$V_{in} = 9.0$ V, $V_{out} = 6.0$ V, $R_2 = 10\ \Omega$, $R_1 = ?$

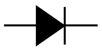
$$\frac{V_{out}}{V_{in}} = \frac{R_2}{R_1 + R_2}$$

$$\frac{6.0}{9.0} = \frac{10}{R_1 + 10}$$

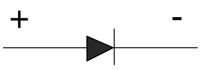
$$6.0R_1 + 60 = 90$$

$$R_1 = 5\Omega$$

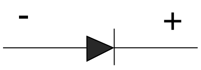
E.11.2 Diodes

A diode is a circuit component which allows current to flow in only one direction. The symbol is  Conventional current flows in the direction indicated by the arrow. Diodes are constructed from two different types of material, *p-type* and *n-type*. *p-type* has an excess of positive charge and *n-type* has an excess of negative charge. More detailed information in text page 131 – Physics in action. Typically the major component of a diode is silicon or germanium.

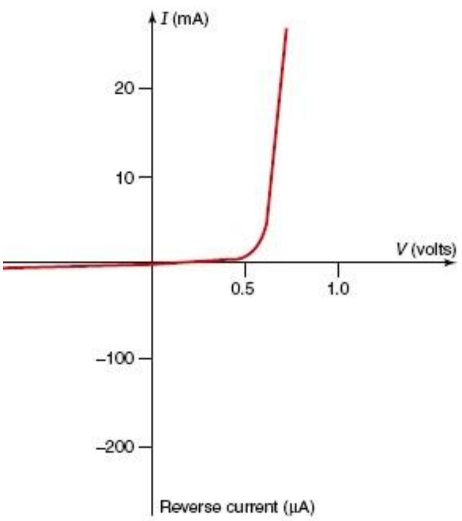
A *diode* is an electronic device that can be used to control voltage. It conducts when it is forward biased, and current drops to practically zero when it is reverse biased.



Forward bias, $R \rightarrow 0$.



Reverse bias, $R \rightarrow \infty$



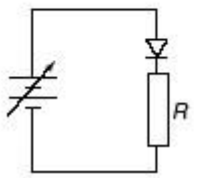
A typical characteristic curve for a diode is shown.

As indicated by the curve when the current flows the diode acts as a very low resistance using little electrical energy – in this case about 0.7V.

However when the current tries to flow in the reverse direction the diode acts as a very high resistance using all the available electrical energy.

Example.

If the emf of the supply in circuit to the right is 10 V, and the value of the resistor is 100 Ω, estimate the current flowing through the diode.



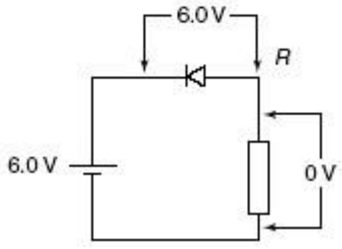
The diode can be assumed to have a voltage drop of about 0.7 V across it. Therefore, the voltage drop across the resistor is 9.3 V. The current through the resistor is found using Ohm's Law.

V = I R

9.3 = I × 100

I = 0.093 A, or 93 mA

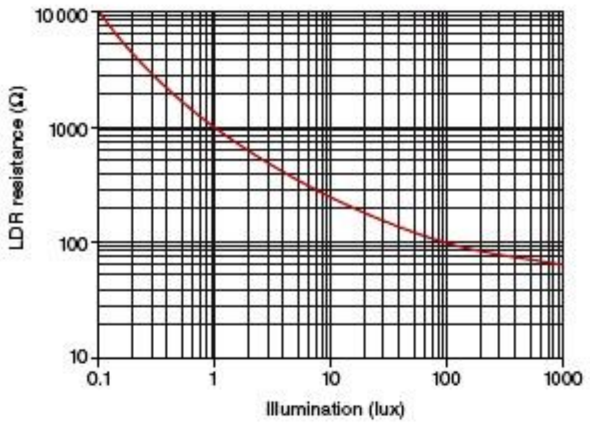
As the diode and resistor are in **series**, the current through the diode is also 93 mA.



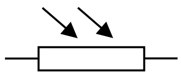
Note that when a diode is reverse biased, as shown to the left, very little current flows through the diode and the resistor. The voltage drop across the resistor will be negligible and all the voltage drop will be across the diode.

E.11.3 Light-Dependent Resistors

A light-dependent resistor (LDR) is a semiconductor device that has a resistance which decreases with the amount of light falling on it. The figure below gives an example of a graph that shows the relationship between resistance and light intensity for an LDR.

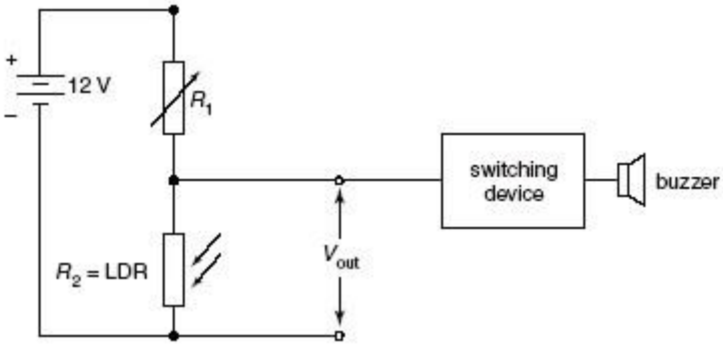


Note that in this example, the scales on both axes are logarithmic. Each line represents the next whole number multiple of the previously stated power of ten. For example, on the horizontal scale the lines to the right of that labelled 10 are 20, 30, 40 and so on. Similarly, the lines above that labelled 100 are 200, 300, 400 and so on.

The symbol for an LDR is  and they are made from cadmium sulfide.

Example.

A shop minder circuit consists of a beam of light that shines onto the voltage divider circuit, as shown below. The LDR has the same characteristic as that shown in figure above.



(a) What is the resistance of the LDR when the light intensity is 1.0 lux?

(b) If the variable resistor is set at 500 Ω, calculate the value of *V*out when the light intensity is 1.0 lux.

(c) What is the value of the variable resistor if the light intensity is 0.1 lux and *V*out is 6.0 V?

Solution

(a) Reading from the graph, when the intensity is 1.0 lux, *R*2 = 1 kΩ.

(c) *V*in = 12 V, *R*1 = 500 Ω, *R*2 = 1000 Ω, *V*out = ?

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

$$\frac{V_{out}}{12} = \frac{1000}{500 + 1000}$$

$$V_{out} = 12 \times \frac{1000}{1500}$$

V_{out} = 8.0 V

(d) From the graph, when the intensity is 0.1 lux, *R* 2 = 10 kΩ.

*V*in = 12 V, *V*out = 6 V, *R*2 = 10 000 Ω, *R*1 = ?

$$\frac{6}{12} = \frac{10\,000}{R_1 + 10\,000}$$

$$6R_1 + 60\,000 = 120\,000$$

R_1 = 10 000 Ω

E.12 Output Transducers

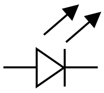
E.12.1 Light-Emitting Diodes (LED)

Light-emitting diodes are a small semiconductor diode which emits light when a current passes through it. They have many applications and are starting to replaced ordinary light bulbs.

The advantages of LED's are:

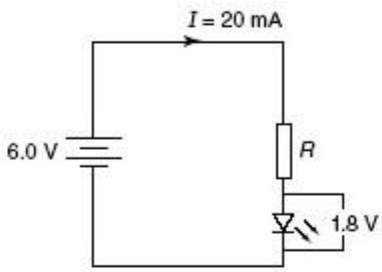
- More durable
- Operate at low voltages
- Last for a long time (500 000 hours or more)
- Faster to respond
- Use less power

The wavelength emitted depends on the amount of phosphorus and arsenic in the semiconductor material. Generally LED's operate between 1.6 and 2.8V.

The symbol for an LED is 

Example

The LED shown has a voltage drop across it of 1.8 V and carries a current of 20 mA.



(a) What is the voltage drop across the limiting resistor?

(b) What is the value, *R*, of the limiting resistor?

Solution

(a) The emf of the source equals the sum of the voltage drops around the circuit. So the voltage drop across the resistor is 4.2 V.

(b) The current through the resistor is the same as that through the LED: 20 mA or 0.020 A.

The value of *R* is calculated using the formula:

$$V = IR$$

$$4.2 = 0.020 \times R$$

So $R = 210\ \Omega$.

Problem Set #6: Text Section 4.3 Page 148 & 149 All Questions