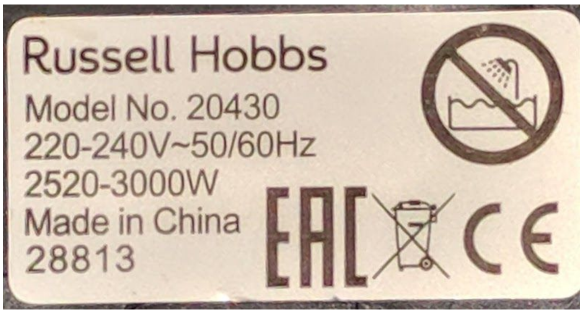
Power and Energy

Introduction



Power and Energy seem more related to Physics than Electronics and indeed they probably are. However, the power equation is necessary to calculate the correct choice of fuse, the current required by a certain output device and what rating of resistor to use in a given situation.

The power equation influences circuit design and construction and the energy concept is necessary to understand power.

The label on my kettle tells me the Voltage and Power but I need to work out the current.

Basic concepts

Definition: Power = Energy transferred / time taken and is measured in Watts.

1 Watt is 1 Joule of energy transferred every second.

However, this is not very useful in electronics as we don't have an easy way to measure energy transferred or the time taken. What we are comfortable measuring in an electronics lab are quantities such as voltage, current and resistance. The various definitions can be combined as follows to give a useful result:

Starting with the definitions of voltage and current we have: $V = E \div Q$ and $I = Q \div t$

Which can be rearranged to give $E = V \times Q$ and $t = Q \div I$

Using these in the definition of power we get $P = E \div t = (V \times Q) \div (Q \div I) = V \times I$

So, not a definition, but a useful working equation in electronics, we have:

$$P = I \times V$$

This can be rearranged to give:

$$V = P \div I$$

and

$$I = P \div V$$

Here V is the potential difference across the component in question and I is the current flowing through the component.

By combining $P = V \times I$ and $V = I \times R$ we can also use

$$P = I^2 \times R$$

By combining $P = V \times I$ and $I = V \div R$ we can also use

$$P = V^2 \div R$$

Examples

1. What is the power dissipated in a 6 V bulb that takes a current of 200 mA?

   200 mA = 0.2 A and therefore P = 6 x 0.2 = 1.2 W

2. What current does a 60 W mains light bulb take if the mains voltage is 230 V?

   $I = P \div V$ and so $I = 60 \div 230 = 0.24$ A

3. What voltage does a 120 W bulb operate at if it draws a current of 10 A?

   $V = P \div I$ and therefore $V = 120 \div 10 = 12$ V

4. How much power is dissipated by a 100 Ω resistor connected to a 12 V power supply?

   $P = V^2 \div R$ therefore $P = 144 \div 100 = 1.44$ W (the standard resistors used in electronics are rated at 1/4 W)

5. What is the power rating of a heater that has a resistance of 50 Ω and takes a current of 2 A?

   $P = I^2 \times R$ and so $P = 4 \times 50 = 200$ W

Using the power equation to calculate resistors power ratings

Resistors get hot and, if they get too hot, they stop working so it is important to know the power rating of a resistor for use in a circuit. Basic resistors used in circuit building are either 1/8 W or 1/4 W and slightly bigger 1/2 W ones are also common. For higher power applications power resistors are used and may be rated at 1 W, 5 W, 20 W 100 W etc depending on the manufacturer.

Consider a 470 Ω resistor used as a current limiting resistor with an LED. The current through the LED and resistor is 20 mA. What power rating is suitable for the resistor?

$P = I^2 \times R$ and $I = 0.02$ A therefore $P = 0.022 \times 470 = 0.19$ W.

A 1/8 W resistor would not be appropriate (1/8 W = 0.125 W) as this is the maximum power rating and is less than the 0.19 W being dissipated. However, a 1/4 W resistor would be suitable.

Using the power equation to calculate fuses ratings

It is important to fit a fuse with the correct rating to provide maximum protection. Consider a domestic appliance such as a hair dryer that runs off the 230 V mains supply and dissipates 650 W.

Given that 3 A, 5 A and 13 A fuses are available, which would be most suitable?

$I = P \div V$ and so $I = 650 \div 230 = 2.8$ A.

Therefore a 3 A fuse would probably be okay. However, in reality, a 5 A fuse would be more reliable as the 3 A fuse would be working at the upper end of its current carrying capability.

In cars, large currents are required by the lights and other accessories. Consider a pair of headlights, each rated at 42 W and running off the 12 V supply.

What fuse would be suitable to protect the headlamp circuit given values of 5 A, 10 A, 15 A, 20 A, 25 A and 30 A are available?

$I = P \div V$ and so $I = (2 \times 42) \div 12 = 7$ A.

Therefore a 10 A fuse would be adequate.

Using the power equation to calculate power ratings

A domestic HiFi has a maximum output voltage of 70 V and is connected to 8 Ω speakers. What power must the speakers be able to handle, as a minimum?

$P = V^2 \div R$ and so $P = 70^2 \div 8 = 612$ W ... quite a big HiFi.

Energy

Starting with the definition of power, Power = Energy transferred ÷ time taken, we have

$E = P \times t$

or, substituting P = V × I,

$E = V \times I \times t$

which is probably more useful in physics but does have applications in electronics too.

Domestic Energy

In physics and electronics, units of Watts and Joules are fine. However, in a domestic situation, these are not always appropriate. Power is measured in kilowatts and time is measured in hours. When we buy electricity we are paying for energy, not power, so what is the domestic unit of energy?

E = P x t and so, in domestic terms, energy paid for is measured in kWh (kilowatt hours).

1 kWh is 1 kW of power transferred for 1 hour - like boiling a 1kW kettle continuously for an hour.

Converting back to standard units, 1 kWh in Joules = Power in Watts × time in seconds = (1 × 1000) × (60 × 60) = 3.6 MJ. One unit of domestic electricity is 3.6 MJ of energy.

Website

http://www.pfnicholls.com/Electronics/power.html

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