LA-CoNGA physics
Introduction to Measurements Systems
Basic Concepts

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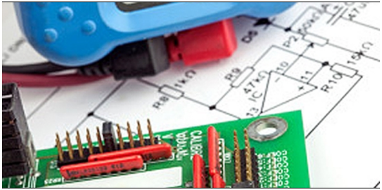


- Basics Electric Vocabulary
- Voltage and current
- Kirchoff's Laws
- Circuit elements
- Exercises

Current & Voltage

- We start our study of electronics with definitions and the basic laws that apply to all circuits
- In electronics, we are interested in keeping track of two basic quantities: the currents and voltages in a circuit.
- If you can make these quantities behave like you want, you have succeeded.
- **Current** measures the flow of charge past a point in the circuit. The units of current are thus coulombs per second or amperes, abbreviated as A. In this text we will use the symbol I or i for current.
- The work per unit charge required to move some charge between two points is called the **voltage** between those points. The units of voltage are thus joules per coulomb or volts, abbreviated V. In this text we will use the symbol V or v for voltage.

Kirchoff's Laws

- The sum of the currents into a node (i.e. any point on the circuit) equals the sum of the currents flowing out of the node. This is **Kirchoff's Current Law** (**KCL**) and expresses conservation of charge.

$$\sum_{k}^{n} I_k = 0 \tag{1}$$

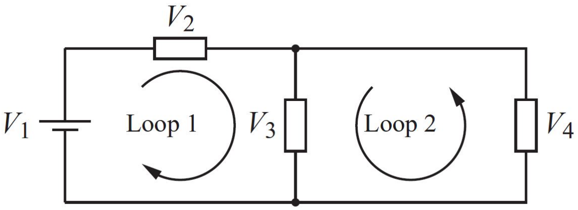
where the sum is over all currents into or out of the node.

- The sum of the voltages around any closed circuit is zero. This is **Kirchoff's Voltage Law** (**KVL**) and expresses conservation of energy. In equation form,

$$\sum_{k}^{n} V_k = 0 \tag{2}$$

Kirchoff's Laws

- We must use a convention to define the signs of the currents and voltages



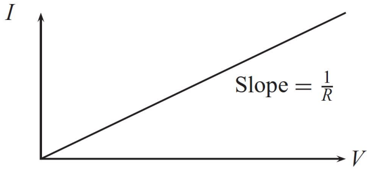
- The power P provided or consumed by a circuit device is given by

$$P = IV \quad (3)$$

The units of power are thus joules per second or watts, abbreviated W

- A common way to represent the behavior of a circuit device is the I–V characteristic. This is a plot of the current I through the device as a function of applied voltage V across the device.
- The resistor has a simple linear I–V characteristic (Ohm's Law)

$$V = IR \tag{4}$$



The constant of proportionality, R, is called the resistance of the device

Resistance

- The resistance of the device depends only on its physical properties – its size and composition. More specifically:

$$R = \rho \ \frac{L}{A} \tag{5}$$

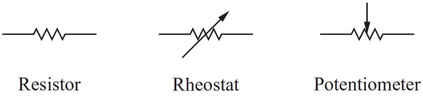
where ρ is the resistivity, L is the length, and A is the cross-sectional area of the material.

Material	$\rho (10^{-8} \Omega m)$
Silver	1.6
Copper	1.7
Nichrome	100
Carbon	3500

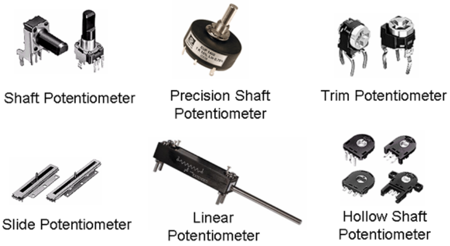
Table: The resistivity of some common electronic materials

Types of Resistors

- Resistors can be of a fixed or variable value



Schematic symbols for a fixed resistor and two types of variable resistors.



Equivalent circuit laws for resistors

Series and parallel

- When forming equivalent circuits, any number of resistors in series may be replaced by a single equivalent resistor given by:

$$R_{eq} = \sum_{i}^{n} R_i \tag{6}$$

The current I in any series element is the same.

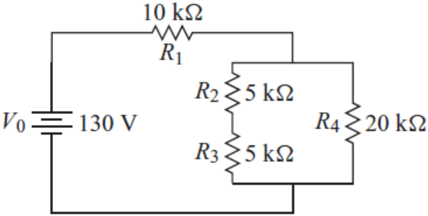
- When forming equivalent circuits, any number of resistors in parallel may be replaced by a single equivalent resistor given by:

$$\frac{1}{R_{eq}} = \sum_{i}^{n} \frac{1}{R_i} \tag{7}$$

All elements connected in parallel are at the same voltage V.

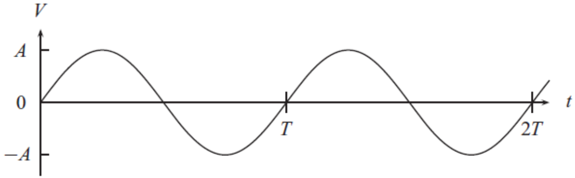
Finding an equivalent circuit

- For the circuit shown, how much current flows through the $20K$ resistor? What must its power rating be?



AC signals

- So far our examples have used constant voltage sources such as batteries. Constant voltages and currents are described as *DC* quantities in electronics.
- On the other hand, voltages and currents that vary in time are called AC quantities. For future reference, we list here some of the most common *AC* signals.
- Sinusoidal signals. This is probably the most fundamental signal in electronics since, as we will see later, any signal can be constructed from sinusoidal signals



$$V = Asin(2\pi ft + \phi) = Asin(\omega t + \phi) \quad (8)$$

There are several ways to specify the amplitude of a sinusoidal signal that are in common use. These include the following:

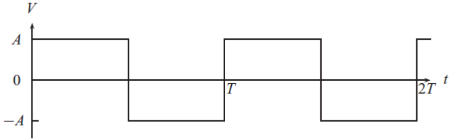
- The peak amplitude A or A_p.
- The peak-to-peak amplitude $A_{pp} = 2A$.
- The rems amplitude $A_{rms} = A/\sqrt{2}$. This is useful for power calculations involving sinusoidal waves.

$$P = \frac{1}{T}\int_0^T \frac{V^2}{R}dt = \frac{1}{TR}\int_0^T A^2 sin^2(\omega t + \phi)dt = \frac{A_{rms}^2}{R} \tag{9}$$

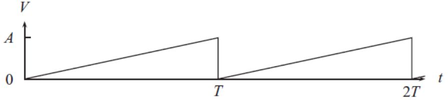
- Decibels (abbreviated dB) are used to compare the amplitude of two signals, say A_1 and A_2:

$$dB = 20 log_{10}\frac{A_2}{A_1} = 10 log_{10}\left(\frac{A_2}{A_1}\right)^2 = 10 log_{10}\frac{P_2}{P_1} \tag{10}$$

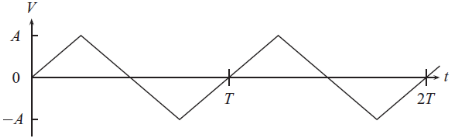
- Square wave. Specified by an amplitude and a frequency (or period).



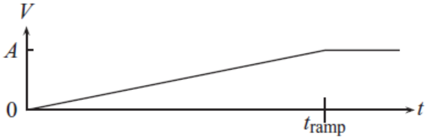
- Sawtooth wave. Specified by an amplitude and a frequency (or period).



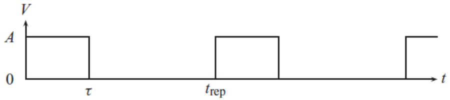
- Triangle wave. Specified by an amplitude and a frequency (or period).



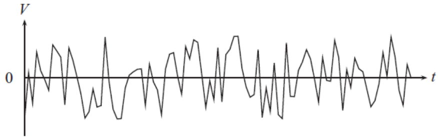
- Ramp. Specified by an amplitude and a ramp time.



- Pulse train. Specified by an amplitude, a pulse width τ , and a repetition time t_{rep}. The duty cycle of a pulse train is defined as τ / t_{rep} .

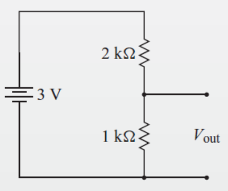


- Noise. These are random signals of thermal origin or simply unwanted signals coupled into the circuit. Noise is usually described by its frequency content, but that is a more advanced topic.

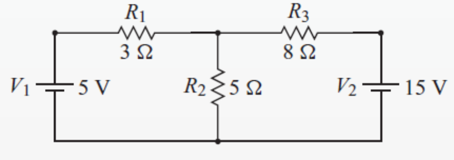


Exercises

- The output of the voltage divider of Fig. 1.32 is to be measured with voltmeters with input resistances of 100Ω , $1K\Omega$, $50K\Omega$, and $1M\Omega$. What voltage will each indicate?



- Compute the current through R2 and R3



Hint: use the superposition principle

References

- Basic Electronics for Scientists and Engineers, D. Eggleston, 2nh Ed Chap 1
- Kirchhoff's Law, Junction & Loop Rule, Ohm's Law - KCL & KVL Circuit Analysis