Voltage, Current, Resistance, Capacitance and Inductance

Really basic electrical engineering.

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Electricity and conductors

- Electricity is the movement of electrons.
- Electrons move easily through a conductor
  - silver, copper, aluminium, molybdenum
- Electrons do not move easily through an insulator
  - air, glass, silicon dioxide (SiO_2)
- Electrons move with reasonable ease through a semiconductor
  - silicon, germanium, gallium arsenide

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Electrons and protons

- Normally, materials have the same number of electrons
  - which carry a negative charge
- …and protons
  - which carry a positive charge
- and such materials carry no (net) charge

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Potential difference: volts:

- When there is an imbalance of electrons and protons in a material, the material carries an electric charge
- If there are too many electrons
  - the material is negatively charged (-ve)
- If there are too few electrons
  - the material is positively charged (+ve)
- If two pieces of material have differing charges, there is a **potential difference** between them
  - Measured in Volts.

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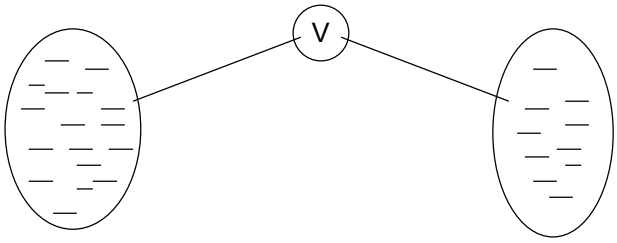
Potential difference ct'd

- If two pieces of material have differing charges, there is said to be a potential difference between them
- The potential difference is measured in volts
- The potential of the place with fewer electrons is higher than that of the place with more electrons



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Flow of electrons: Current

- If materials with a potential difference are connected by a conductor, electrons will tend to move so that their charges equalise.
- Electrons flow from the more negatively charged to the less negatively charged place
- Electron flow is from the less positively charged to the more positively charged place
- When electrons move, a **current** is said to flow
  - so a current is the flow of electrons through something
  - current is measured in amperes (or amps)

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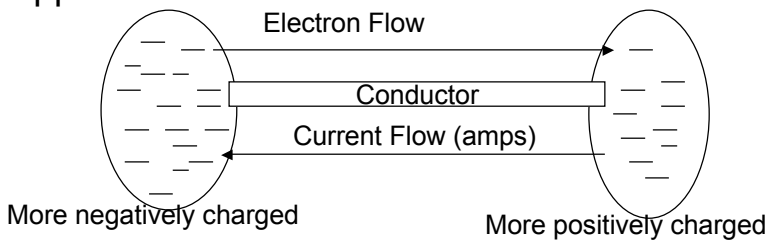
Current flow

- Unfortunately, the conventional notation is the other way round from electron flow
  - a positive current flow occurs in the direction opposite to the actual flow of electrons



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Resistance

- A property of all materials, relating to how well they can carry electricity.
- Conductor: low resistance
- Insulator: high resistance.
- Measured in Ohms Ω. Symbol R.
- Often kilohm, megohm, or gigohm.

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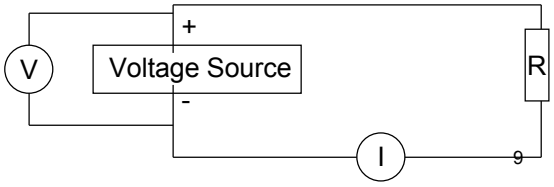
Ohms Law

There is a relationship between potential difference, current flow, and resistance, called Ohms Law: V=IR

- V is potential difference in volts
- I is current flow in amps
- R is resistance in ohms.

- Thus, if V= 1 volt, R=10 ohms, a current of 0.1 amps would flow



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Capacitance

- A property of electrical systems.
- Relates to building up an electric field.
- And to how much electricity they store
- Measured in Farads, F (huge). Symbol C.

- (usually microfarads μF, or nanofarad nF or picofarad (pf) or even femtofarads)

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Inductance

- A property of wires.
- Relates to them building up a magnetic field
- Measured in Henrys. Symbol L.

- Often millihenries, or microhenries…)

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Why does this matter?

- Electronic digital computers often need to move digital signals from place to place
  - From CPU to memory
  - From CPU register to register, etc.
- Moving electrical signals along wires always involves R, C, L.

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Digital signals

- Digital electronic signals usually use one voltage to represent 0, and another to represent 1.
- Voltage (potential difference) measured with respect to ground
- 0 volts Logic 0
- 5 volts Logic 1
  - Often not 5 volts, but 3, or 2.7 or 1.5…
  - Actual signal is analogue
    - Interpretation (0 or 1) changes at some in-between voltage

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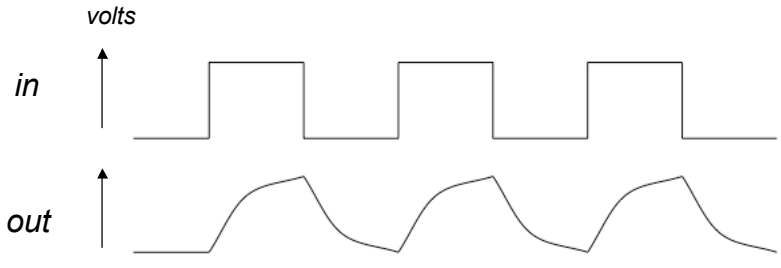
Why is this of interest?

- Real digital signals change rapidly
- Problem: sudden changes get made less sudden!



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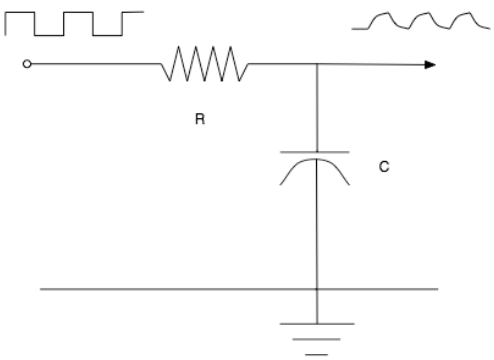
Example: simple RC circuit

- R is resistance of a wire, C is capacitance of wire
- Input is square wave
- Output rises and falls more slowly



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What can go wrong?

- If the frequency of the input is high,
- And R and C are (relatively) large,
- Output signal may not reach the 1 state, before the signal starts to fall,
- Then errors will occur.

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