Basic Electronics

CM0506 – Small Embedded Systems

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Lecture 2

Energy

Energy is work done (force $\times$ distance)

- 1 Joule (J) = 1 Newton (N) $\times$ 1 metre (m)

Power is rate of work, energy transfer

- Power = Energy/time
- 1 Watt (W) = 1 Joule / 1 second
- 1 Joule = 1 Watt $\times$ 1 second

Electrical Energy

- Electrical power = Voltage $\times$ Current
  - 1 Watt = 1 Volt $\times$ 1 Ampere (1 W=1 V$\times$1 A)
  - $P = VI$
- 1 Joule = 1 Watt $\times$ 1 second
- 1 Joule = 1 Volt $\times$ 1 Ampere $\times$ 1 second
- House meter measures units of electrical energy
  - 1 kW h = 1000 W$\times$1 h = 3 600 000 J

Charge

- Charge is a state of matter (like temperature, colour, density . . .)
- Electron is the smallest negatively charged particle
- Proton is the smallest positively charged particle
- An uncharged object/body has equal number of electrons and protons in all its constituent atoms

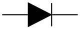
Charge

- Only electrons can leave the owning nucleus of the atom
- Absence of electrons results in positive charge
- Materials in which electrons can easily leave nuclei are called electrical conductors
  - copper
  - aluminium
  - silver
  - gold
- Materials in which electrons are tightly bound to their nuclei are called electrical insulators
  - rubber
  - mica
  - bakelite

Charge

- Electrical charge is measured in Coulombs C
- 1 Coulomb $= 6.3 \times 10^{18}$ electrons
- So 1 e $= 1.602 \times 10^{-19}$ Coulomb

Current

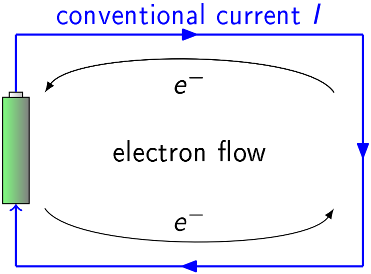
- An electrical current is flow of charge past across a point over a period of time
- 1 Ampere = 1 Coulomb/second
- (300 mA through your body can be fatal)
- Electron current – the actual movement of electrons
- Conventional current I – (opposite to electron flow)
  - flows from positive to negative
  - shows by arrows in symbols for diodes 

Voltage or Potential Difference

- It is the electrical force that can
  - push/pull charge
  - cause charge to move/flow
- 1 Volt = 1 Joule / Coulomb
- Constant voltage
  - Battery cell 1.5 V
  - 'square' battery 9 V
- time-varying voltage
  - UK houses are supplied with time-varying voltage of nominal value 230 V to 240 V (US 110 V)

Voltage

- Voltage comes before current
- Voltage across two ends of a conductor can cause a current



$$V = IR$$

so

$$I = \frac{V}{R}$$

Low resistance $\rightarrow$ high current

don't! Short-circuit

Resistance

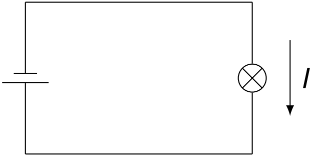
- Electrical appliances transform electrical energy into other forms
  - lightbulb
  - fan
  - radio
  - cooker
- Electrical appliances (and all materials) have electrical resistance:

"resistance to (flow of) electrical current"

- Unit is Ohm symbol Ω
- 1 ohm = 1Volt/1Ampere

Resistance

- $50\,\Omega$ is less resistance than $500\,\Omega$
- A resistance is better than a bare wire (short circuit)
- Still think! Check the expected current!



$$I = \frac{V}{R}$$

For a 1.5 V battery

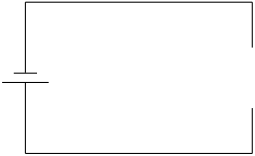
resistance	current
$50\,\Omega$	50 mA
$500\,\Omega$	5 mA

normal circuit

Resistance

Open circuit

- Break in connection
- $R = \infty$

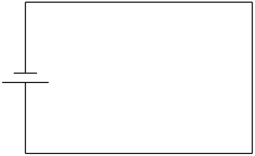


$$
\begin{aligned}
I &= \frac{V}{R} \\
\therefore I &= 0
\end{aligned}
$$

Resistance

Short circuit

- conducting connection
- $R = 0$



$$\begin{aligned} I &= \frac{V}{R} \\ \therefore I &= \infty \end{aligned}$$

Ohm's Law

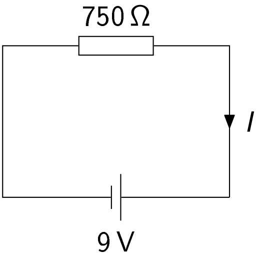
Ohm's law

states that the current through a conductor between two points is directly proportional to the potential difference across the two points.

$$V = IR \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

Ohm's Law

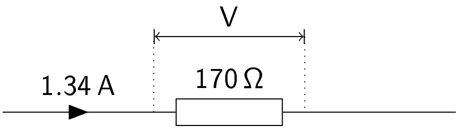
$I = V/R$



$$I = \frac{9}{750} = 0.012\,\mathrm{A} = 12\,\mathrm{mA}$$

Ohm's Law

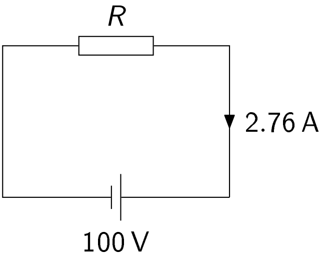
$V = IR$



$$V = 1.34 \times 170 = 227.8\,\mathrm{V}$$

Ohm's Law

$R = V/I$



$$R = \frac{100}{2.76} = 36.2\,\Omega$$

Resistor Colour Coding

- Carbon resistors – small size – hence coded
- Surface mount – even smaller – same scheme using small printing
-

Bk	Br	R	O	Y	Gn	Bu	V	Gy	W
0	1	2	3	4	5	6	7	8	9

- Tolerance

Gold	5%
Silver	10%

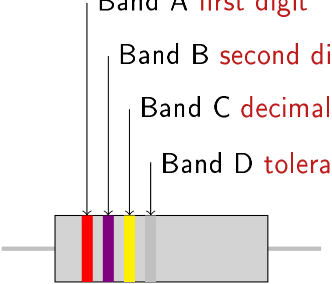
Hold with bands at left

Band A first digit

Band B second digit

Band C decimal multiplier

Band D tolerance



Red	Violet	Yellow	Silver
2	7	4	10%
2	7	$\times 10^4$	$\pm 10\%$

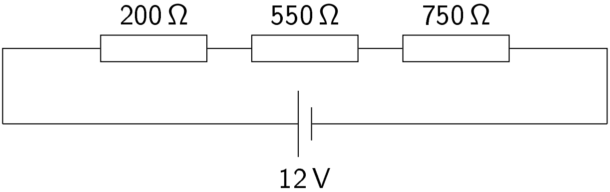
Resistance is $270\,000\,\Omega$ or $270\,\text{k}\Omega$

Value may be between

$243\,\text{k}\Omega$ and $297\,\text{k}\Omega$

Series Circuits

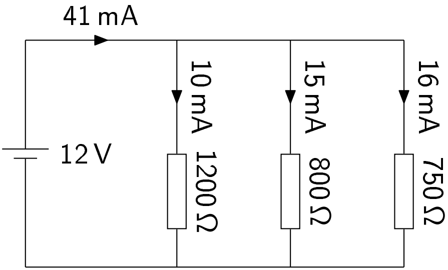
- Same current in all parts
- Total resistance is sum of all resistances
- Series IR drops the sum of voltage drops



$$I = \frac{V}{R} = \frac{V}{\sum R} = \frac{12}{200 + 550 + 750} = \frac{12}{1500} = 8\,\text{mA}$$

Parallel Circuits

- Applied voltage is the same across all branches
- Each branch current is V_A/R
- Current draw I_T is sum of branch currents



$$
\begin{aligned}
I_1 &= \frac{12}{1200} = 10\,\text{mA} \\
I_2 &= \frac{12}{800} = 15\,\text{mA} \\
I_3 &= \frac{12}{750} = 16\,\text{mA} \\
I_T &= 10 + 15 + 16 = 41
\end{aligned}
$$

Kirchoff's Laws

Continuity laws

- Similar to conservation of mass and energy laws
- Charge is conserved (mass)
- Voltage is conserved (energy)

Kirchoff's Current Law

The algebraic sum of all currents entering and leaving any point in a circuit must equal zero

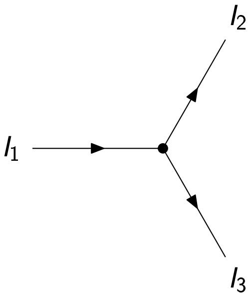
Kirchoff's Voltage Law

For any loop or closed path in a circuit, the algebraic sum of voltages must equal zero

Kirchoff's Current Law

- The algebraic sum of all currents entering and leaving any point in a circuit must equal zero
- Currents entering and leaving a node are equal

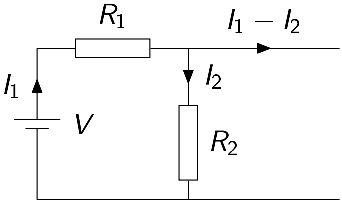
$$I_1 = I_2 + I_3$$



Kirchoff's Voltage Law

- For any loop or closed path in a circuit, the algebraic sum of voltages must equal zero
- The sum of voltage sources must equal the sum of voltage drops around the loop

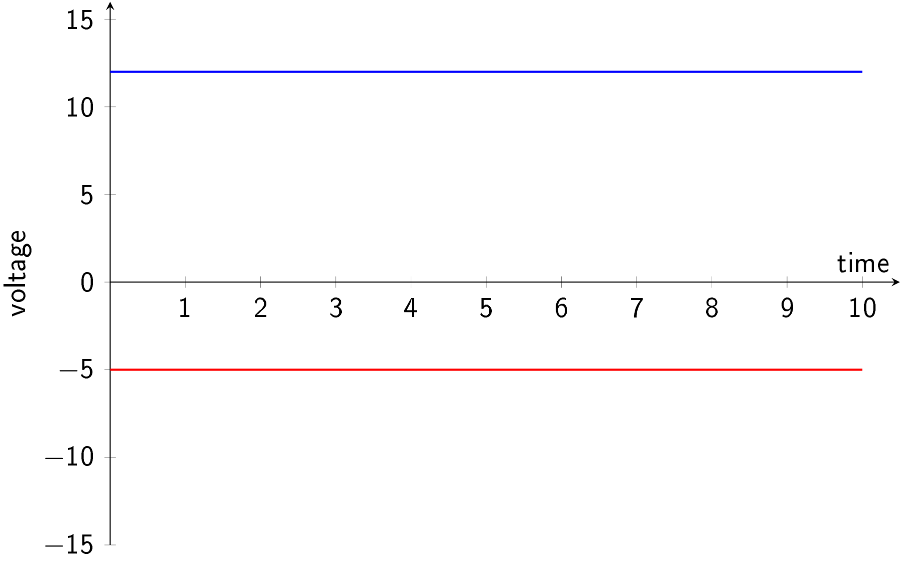
$$V = I_1 R_1 + I_2 R_2$$



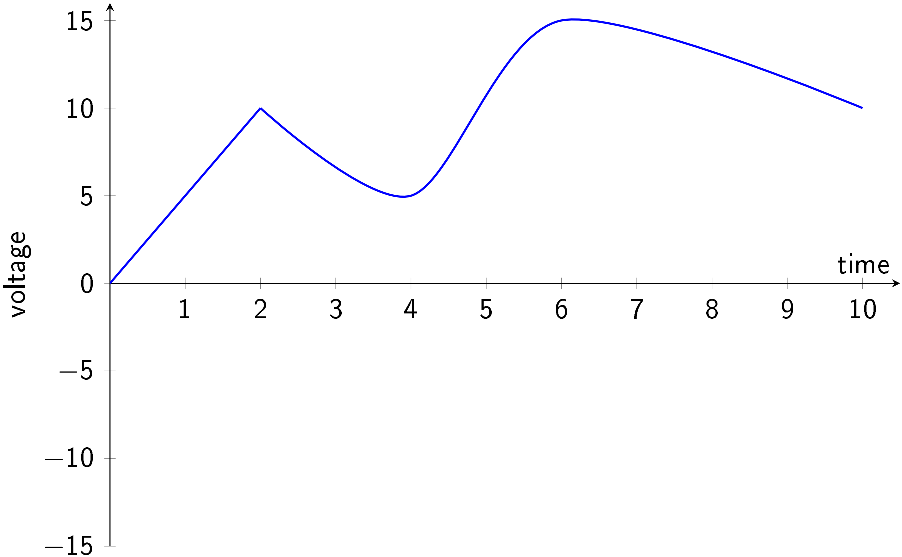
AC/DC or AV/DV ?

- Remember voltage comes first
- Direct Voltage $\rightarrow$ Direct Current
- Alternating Voltage $\rightarrow$ Alternating Current
- DC implies DV
- AC implies AV
- DV should be called Constant Voltage: does not vary with time say $12\,\mathrm{V}$ or $-5\,\mathrm{V}$
- Measured with respect to 'ground' i.e. $0.0\,\mathrm{V}$

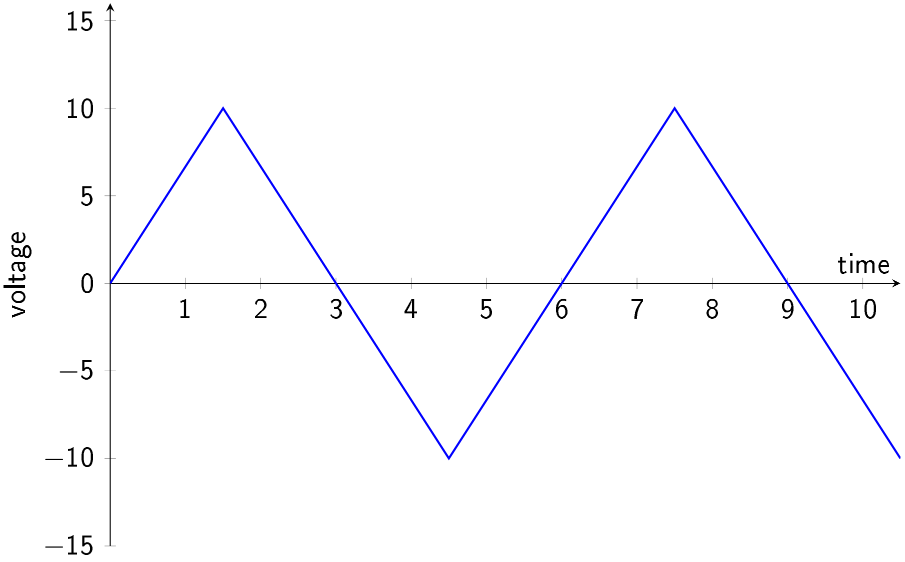
DC (DV)



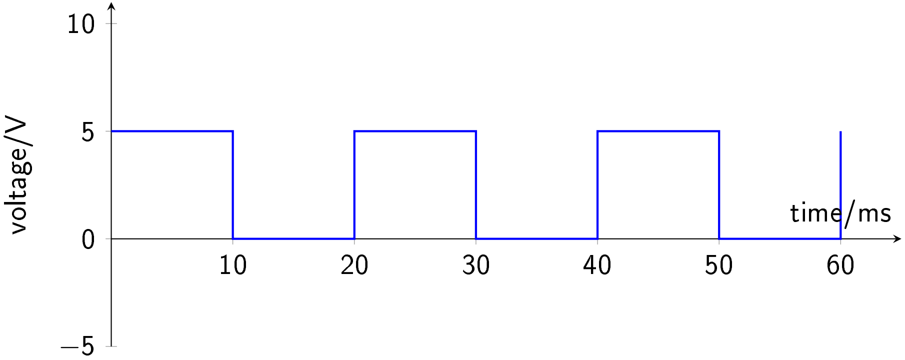
Time Varying Voltage



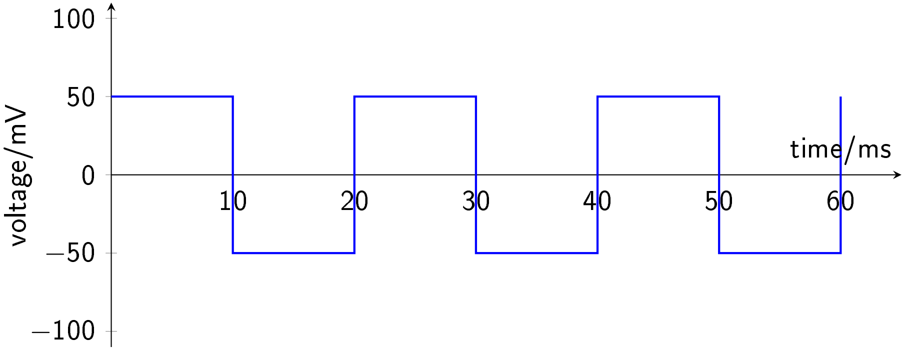
Alternating Periodic Voltage



Clock signal

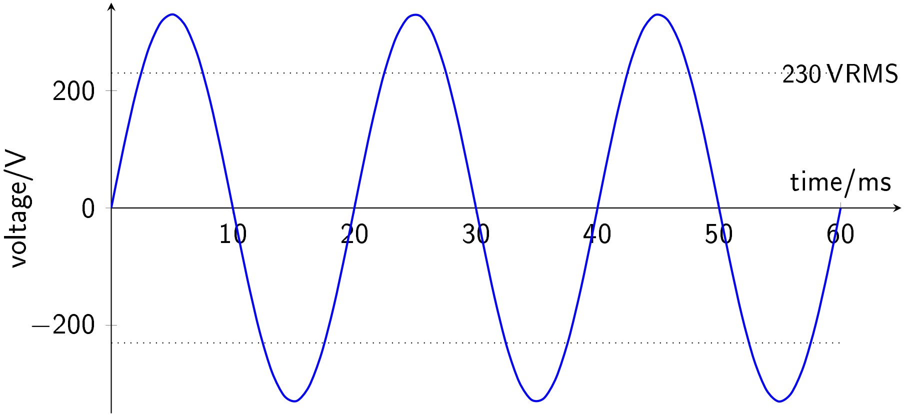


Square wave



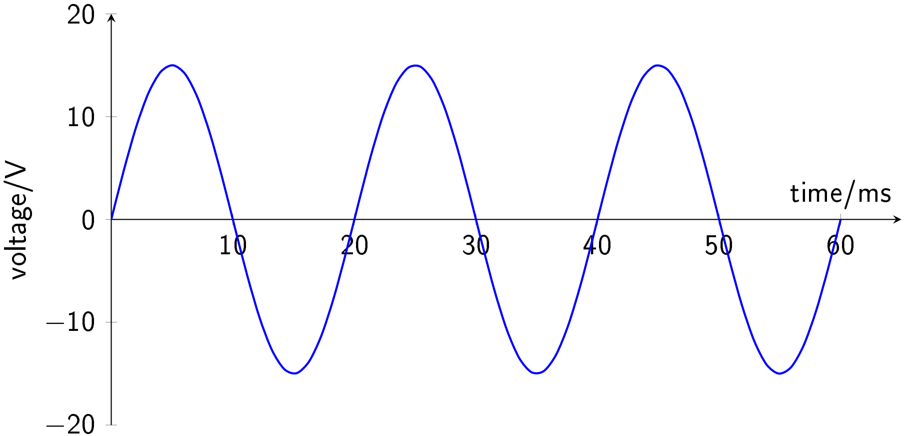
UK Mains Voltage

230 Vpp 50 Hz AC



Sine wave – safe

±15 V 50 Hz AC



Wavelength, Bandwidth

- Electromagnetic waves are sinusoids that travel with speed of light $c = 3 \times 10^8\,\mathrm{m\,s^{-1}}$
- for waves
    - velocity = frequency *times* wavelength

$$v = f\lambda$$

    - Say $f = 2\,\mathrm{MHz}$ (million cycles per sec)
    - then wavelength $\lambda = 300000000/2000000 = 150\,\mathrm{m}$
- Bandwidth refers to a range of frequencies
    - e.g FM radio: $88\,\mathrm{MHz} - 108\,\mathrm{MHz}$
    - so bandwidth $= 20\,\mathrm{MHz}$

Notable frequency ranges

Human speech	100 Hz to 7000 Hz
Intelligent part (voice band)	300 Hz to 3400 Hz
Telephone	250 Hz to 3500 Hz
Audible	20 Hz to 20 000 Hz
In music	:

low frequencies Bass
high frequencies Treble