Part 0 - Prerequisites

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Required software

- Windows
  - Microchip Studio (Optionally: MPLAB X)
- Mac OS/Linux
  - MPLAB X
- All OS
  - TeraTerm (Optionally: PuTTY, other serial COM interface)
  - Only AVR is required, other devices can be ignored (unchecked) during installment
    - SAM
    - PIC
    - UC3
    - dsPIC
    - etc

Basic Electronics

- A refresher for those who have been out of the game for a while
- An introduction to the uninitiated
- Not a comprehensive guide!
  - If nothing makes sense, go online and learn more!
  - Keywords
    - Kirchoff's laws
    - Ohm's law
    - Introduction to electronics
  - Try GPT UiO?
    - GPT is a good tool to be introduced to a topic
    - But some things are still best learnt the "hard way"

Electrical Circuits

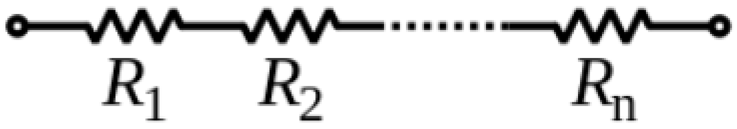
- Flow of current and electric potentials can be used to do useful things
  - Analogy: Liquids in pipes and plumbing
    - Electric potential – Pressure
    - Current – Flow
- Maxwell’s laws
  - A time varying magnetic field gives rise to electric fields, and vice versa
  - Electric fields – Potential difference
    - Monopoles exist – Free charges
  - Magnetic fields – Current flow
    - Monopoles do not exist
- Fields beyond scope of introduction
  - Potential is measured in Volts [V] between two points
  - Current is measured in Ampere [A] in cross-section

Passive Components

- Resistor
  - Restricts current flow
  - Real component – induces losses
- Capacitor
  - Stores energy in the form of electric fields
  - Lossless (in theory)
- Inductor
  - Stores energy in the form of magnetic fields
  - Lossless (in theory)

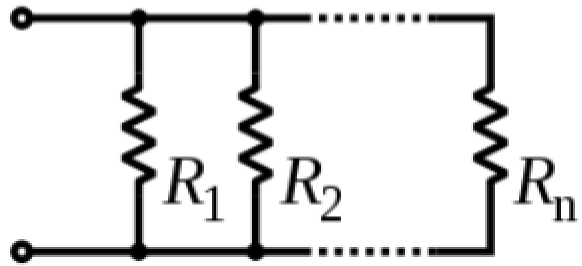
Resistor

- Value of a resistor is measured in Ohms [Ω]
- Energy dissipated as heat
    - P = V * I
    - Power = Voltage * Current
- Ohms law
    - V = I * R
    - Voltage = Current * Resistance
- Equivalent series resistance
    - Sum of resistor values
- Equivalent parallel resistance
    - Inverse sum of inverse resistances



$$R_{eq} = R_1 + R_2 + \cdots + R_n.$$

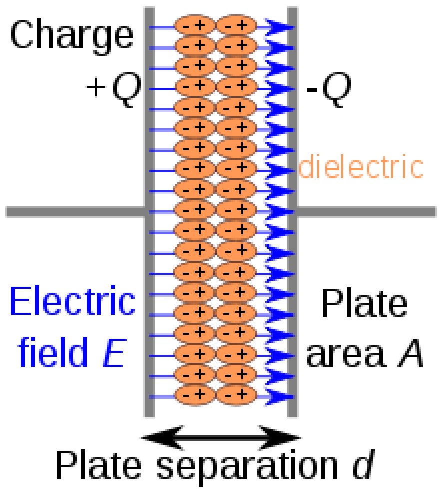
Stolen from Wikipedia



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}.$$

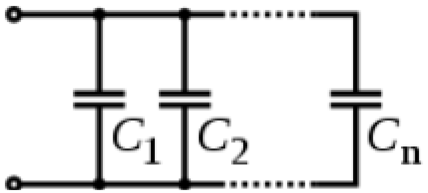
Capacitor

- Stores charges
  - Analogy: Miniature battery
- Value of capacitor measured in Farads [F]
- Reactive
  - Acts as a lossless resistor for alternating currents
    - Measured in Ohms
  - X = 1/(2πf C) [Ω]
  - Reactance [Ω] = 1/(2π * frequency * Capacitance)



Stolen from Wikipedia

$$\frac{1}{C_{eq}} = \sum_i \frac{1}{C_i} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$$

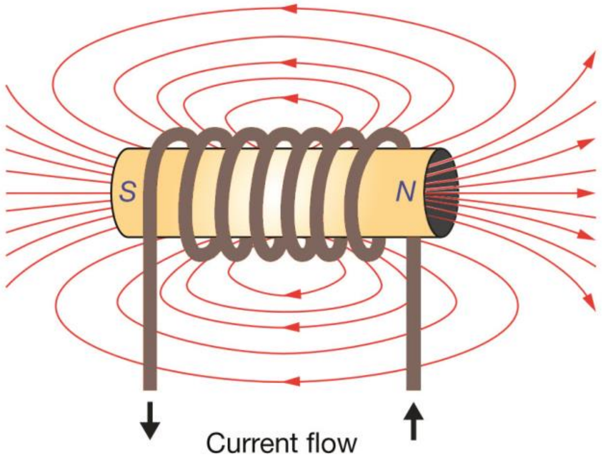


$$C_{eq} = \sum_i C_i = C_1 + C_2 + \cdots + C_n$$

Khoa Tran

Inductor

- Stores energy in a magnetic field
  - Inverse of a capacitor
- Value of inductor measured in Henry [H]
- Reactive
  - X = 2πf L [Ω]
  - Reactance = 2π * frequency * Inductance



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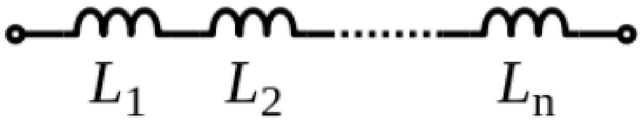
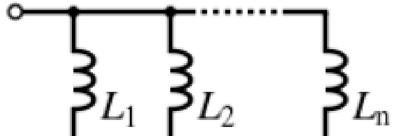


$$L_{eq} = L_1 + L_2 + \cdots + L_n$$



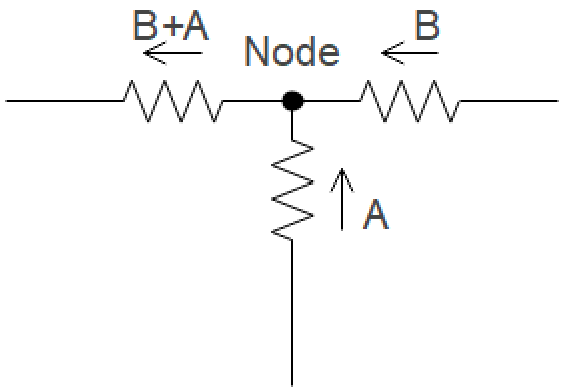
$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}$$

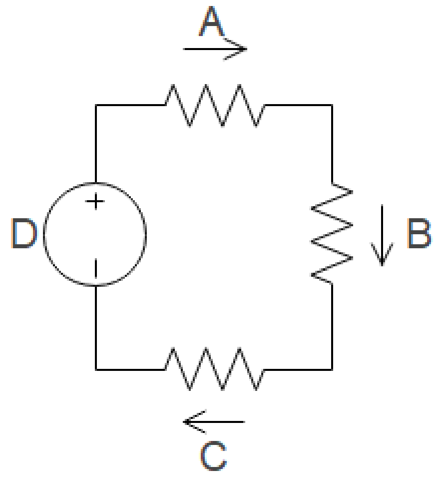
Impedance

- Complex number
  - Resistance [real]
  - Reactance [imaginary]
  - Z = R + jX [Polar form]
- Frequency dependent
  - Reactance can become dominant for high frequencies
- Ohms law can still be used

Kirchhoff's laws

- Current law
  - Sum of currents flowing into a node is equal to the sum of currents flowing out
  - Conservation of current – Current can't disappear
- Voltage law
  - Sum of voltages for any closed loop is zero
  - Conservation of potential – Voltages can't disappear

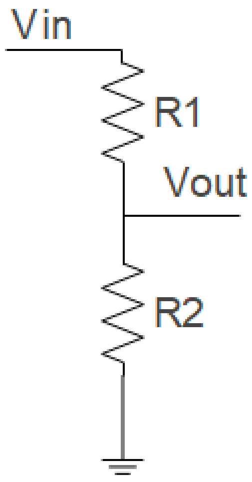




A+B+C+D = 0

Using Kirchhoff and Ohm's laws

- Voltage law
  - Voltage over R1 and R2 must be equal to Vin
- Current law
  - Assuming no current flows out of Vout
  - Current through R1 and R2 must be the same
- Ohm's law
  - V = I * R
  - I = Vin (R1 + R2)
  - Vout = V_R2 = I * R2
    Vout = Vin / (R1 + R2) * R2
    Vout = (R2 / (R1 + R2)) * Vin
- This circuit is called a voltage divider



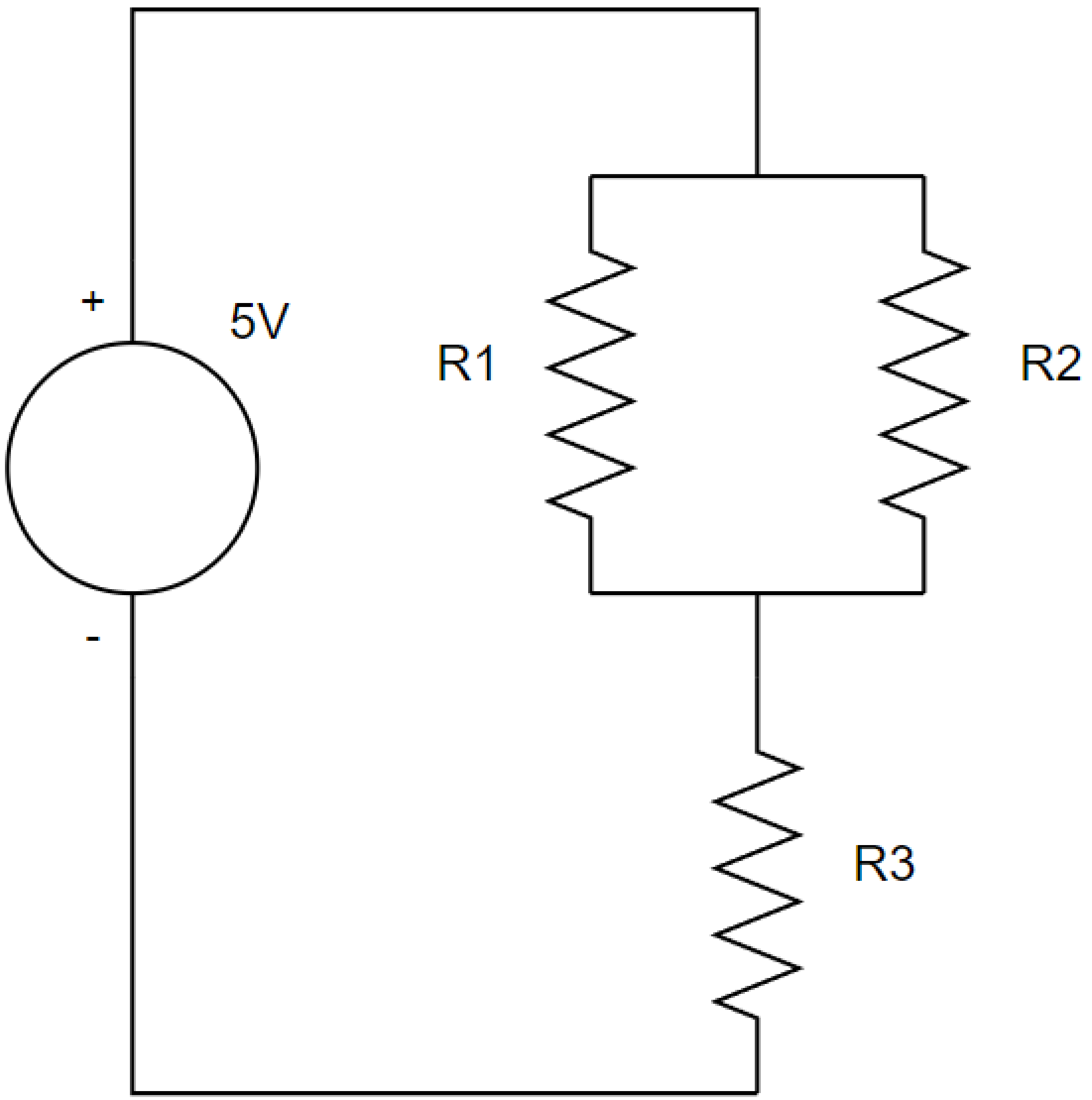
Vout = (R2 / (R1 + R2)) Vin

Sanity Check

- R1 = R2 = 220 Ohm
- R3 = 110 Ohm

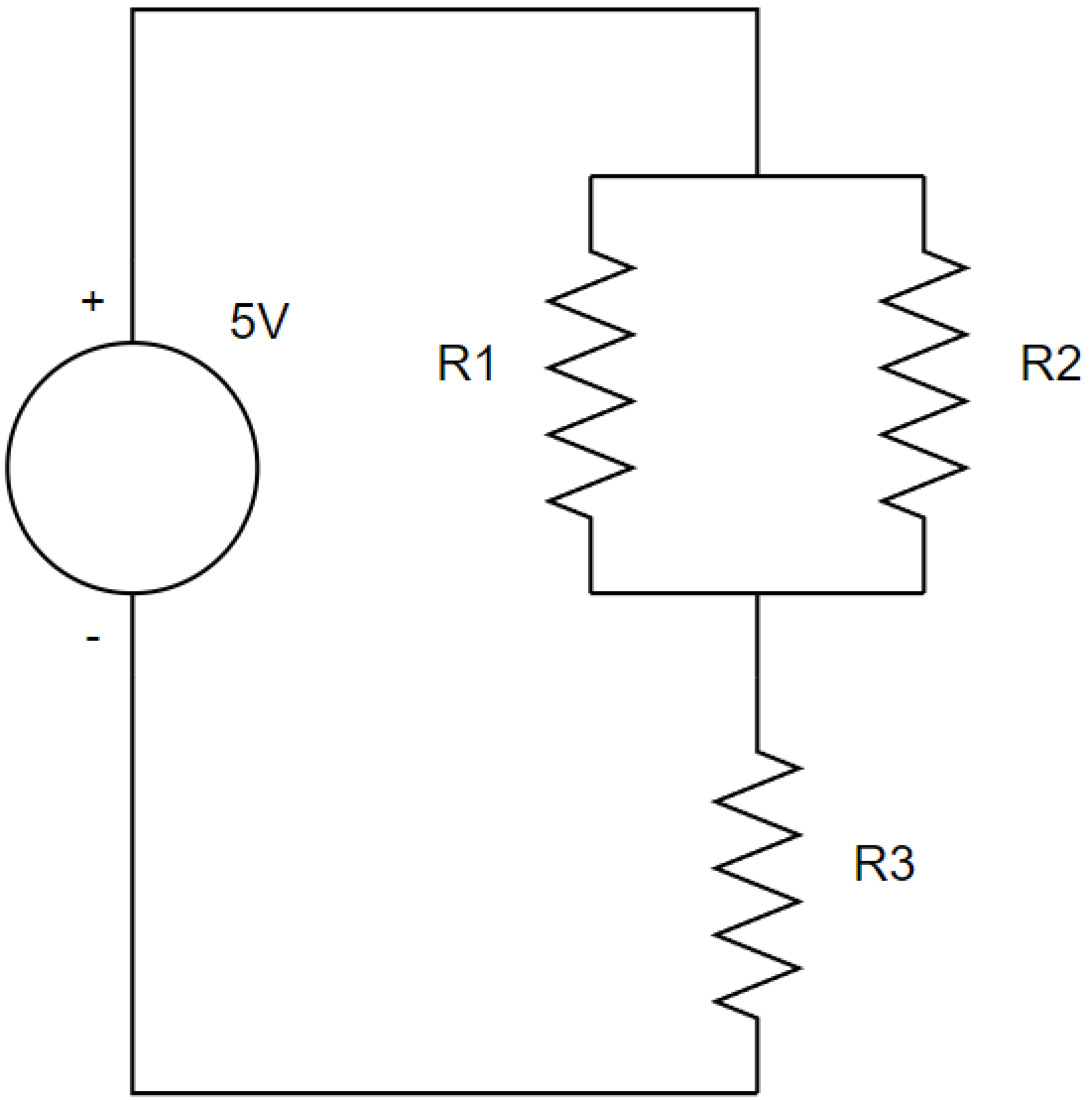
- What is the
  - Voltage over R3?
  - Current through R3?
  - Current through R1

- Solution on next slide



Solution

- Voltage over R3?
  - We know
    - R1 = R2 = 220 Ohm
    - R3 = 110 Ohm
  - Equivalent parallel resistance of R1 || R2 = 110 Ohm
  - We can now use the voltage divider formula to get 2.5 V over R3
- Current through R3?
  - Equivalent series resistance of (R1 || R2) + R3 = 220 Ohm
  - Current law: Current into node = current out of node
    - I_(R1||R2) = I_R3
  - Ohm's law
    - V = I * R => I = V/R = 5 / 220 = 22.7 mA
- Current through R1?
  - Same resistance for R1 and R2 means current is split equally between both resistors
  - Current law: I_(R1||R2) = I_R3
  - I_R1 = I_R3 / 2 = 11.35 mA

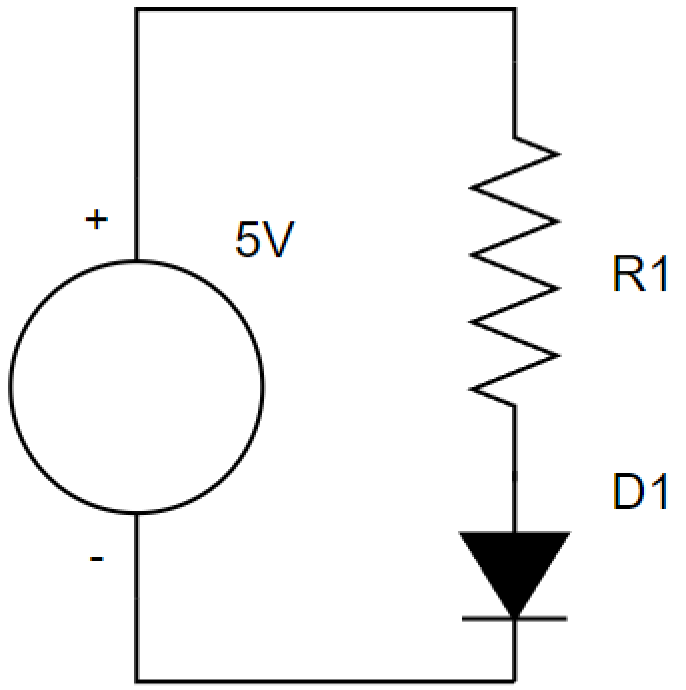


Sanity Check

- R1 = 1kΩ
- D1 has a voltage drop of 2 V

- What is the current through the diode D1?

- Solution next slide



Sanity Check

- What is the current through the diode D1?
  - Voltage drop over D1 = 2 V
  - Voltage law: 5 V = V_R1 + V_D1
    - Voltage over R1 must be 5 – 2 = 3 V
  - Current law: Current through R1 and D1 must be equal
    - I_R1 = I_D1
  - Ohm's law: V = I * R
    - V_R1 = I_R1 * R1
    - I_R1 = I_D1 = V_R1 / R1 = 3/1000 = 3 mA