Topic 6 recap

- Operational Amplifiers (Op Amps) are **active** elements.
  - They can be modelled as a **voltage-controlled voltage source**.
  - Op Amp circuits are designed to perform **mathematical operations** on input signals. They are manufactured in the form of Integrated circuits (ICs).
- From the 8 pins of the Op Amp IC, we are only interested in 5 of them.
  - Inverting input v_1 (pin 2).
  - Non-inverting input v_2 (pin 3).
  - Output v_o (pin 6).
  - Positive power supply V^+ (pin 7).
  - Negative power supply V^- (pin 4).
- The output of the Op Amp in open-loop is proportional to the differential input voltage.

  $v_o = Av_d = (v_2 - v_1)$, where A is the open-loop gain (in the range of 10^5 to 10^8).
- Op Amp circuits should be operated in the **linear region** to avoid **saturation** of the output (output should not exceed the voltage of power supply $|V_{cc}|$).

$$-V_{cc} \leq v_o \leq V_{cc}$$

Topic 6 recap

- An **Ideal Op Amp** has the following properties:
  - **Open-loop gain** close to **infinity**, $A \simeq \infty$.
  - **Input** resistance close to, **infinity** $R_i \simeq \infty\ \Omega$ (open circuit).
  - **Output** resistance close to **zero**, $R_o \simeq 0\ \Omega$ (short circuit).
  - The **currents** into both terminals are **zero**.

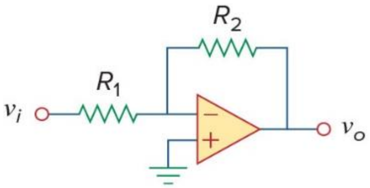
$$i_1 = i_2 = 0$$

  - The **voltage** across the input terminals is **zero** (if there is negative feedback).

$$v_d = v_2 - v_1 = 0 \quad \text{or} \quad v_1 = v_2$$

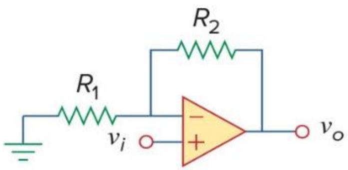
- Use **Nodal analysis** to solve and analyse Op Amp circuits.
  - KCL at input nodes to calculate v_0.
  - Once output voltage v_0 is found, use KCL at output node to find output current i_0(if needed).
  - Gain of the circuit = ratio of output to the input (v_0 / v_i).
- Op Amp circuits are mostly used in **negative feedback** configuration.
  - The output is fed back to the inverting input via feedback resistor R_f.
  - The inverting input and non-inverting input are connected to either ground or a source via input resistor R_1.

Topic 6 recap



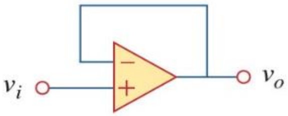
Inverting amplifier

$$v_o = -\frac{R_2}{R_1} v_i$$



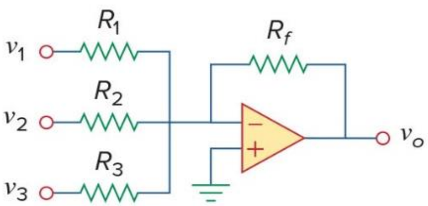
Noninverting amplifier

$$v_0 = \left(1 + \frac{R_2}{R_1}\right) v_i$$



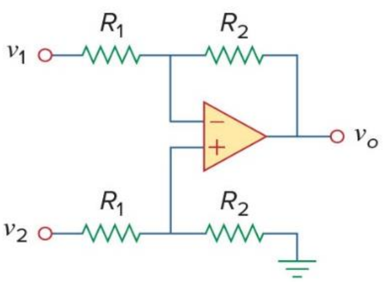
Voltage follower

$$v_o = v_i$$



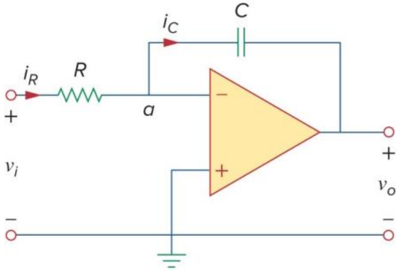
Summer

$$v_o = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3} v_3\right)$$



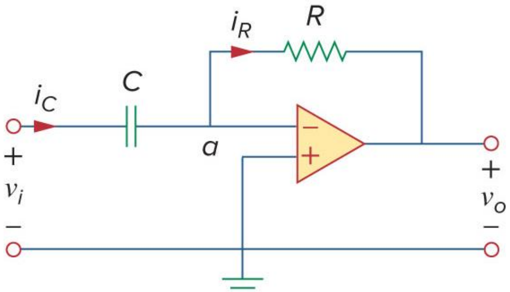
Difference amplifier

$$v_o = \frac{R_2}{R_1}(v_2 - v_1)$$



Integrator

$$v_o(t) = -\frac{1}{RC}\int_0^t v_i(\tau)d\tau$$



Differentiator

$$v_o(t) = -RC\frac{dv_i}{dt}$$