Circuits Reference Card

Physical Quantities

Quantity	Symbol	Units	Equivalents
Charge	q	coulomb	C
Current	$i = \frac{dq}{dt}$	ampere	$\mathrm{A} = \frac{\mathrm{C}}{\mathrm{s}}$
Voltage	$v = \frac{dw}{dq}$	volt	$\mathrm{V} = \frac{\mathrm{J}}{\mathrm{C}}$
Power	$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = v \cdot i$	watt	$\mathrm{W} = \frac{\mathrm{J}}{\mathrm{s}} = \mathrm{V} \cdot \mathrm{A}$
Resistance	$R = \frac{v}{i}$	ohm	$\Omega = \frac{\mathrm{V}}{\mathrm{A}} = \frac{\mathrm{W}}{\mathrm{A}^2} = \frac{\mathrm{V}^2}{\mathrm{W}}$

Conservation Laws

KVL (loop) $\sum_k V_k = 0$

KCL (node) $\sum_k I_k = 0$

Material Properties

Resistance $R = \frac{\rho \cdot l}{A}$

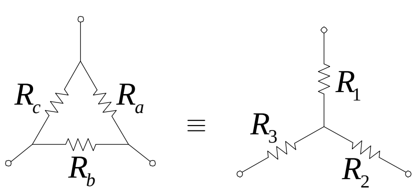
Useful Shortcuts

Series resistance $R_{\text{series}} = \sum_k R_k$

Parallel resistance $R_{\text{parallel}} = \frac{1}{\sum_k \frac{1}{R_k}}$

Voltage divider (series) $v_{R_k} = \left(\frac{R_k}{R_{\text{series}}}\right) V_s$

Current divider (node) $I_{R_k} = \left(\frac{R_{\text{parallel}}}{R_k}\right) I_s$



$$R_1 = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_a = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_3}$$

Nodal Voltage Analysis

1. Choose a ground node (0 V) and label all other nodes.
2. Write current equations at labeled nodes using KCL.
3. Replace resistor currents using Ohm's law.
4. Replace resistor voltages using nodal voltages.
5. Solve the system of linear equations.

Supernodes: voltage sources & elements in parallel with them.

Mesh Analysis

1. Assign mesh currents i_k to each mesh loop.
2. Write voltage equations for each mesh using KVL.
3. Replace resistor voltages using Ohm's law.
4. Replace resistor currents with mesh currents
5. Solve the system of linear equations.

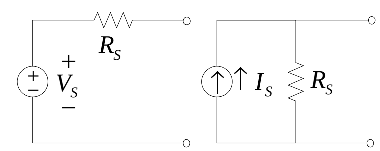
Supermesh: exclude any current source & elements in series with it if they are shared by two meshes.

Superposition

1. Consider one *independent* source at a time. Kill all the others:
   - replace voltage sources with a short.
   - replace current sources with an open.
2. Analyze the circuit with the single source and repeat.
3. Sum the results.

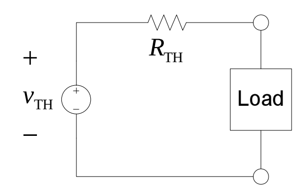
Source Transformation

These two circuits behave identically if we choose $V_S = I_S R_S$.



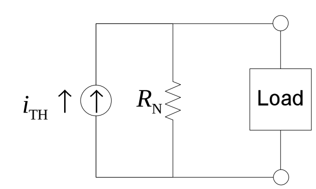
Thévenin's Theorem

1. Replace the load with an open.
2. Find $v_{\text{TH}} = v_{\text{open circuit}}$.
3. Kill the independent sources.
4. Find $R_{\text{TH}} = \frac{v_{\text{TEST}}}{i_{\text{TEST}}}$.
5. Restore the load.



Norton's Theorem

1. Replace the load with a short.
2. Find $v_{\text{N}} = v_{\text{short circuit}}$.
3. Kill the independent sources.
4. Open circuit and find $R_{\text{N}} = R_{\text{TH}}$.
5. Restore the load.



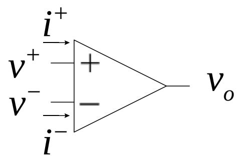
Maximum Power Transfer

Choose $R_{\mathrm{L}} = R_{\mathrm{TH}}$.

$P_{R_{\mathrm{L}}} = \dfrac{V_{\mathrm{TH}}^2}{4R_{\mathrm{TH}}}$

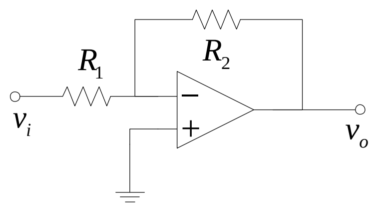
Ideal Op Amp

- $v_{\mathrm{o}} = A\,(v^+ - v^-)$
- $i^+ = i^- = 0$
- $R_{\mathrm{in}} = \infty$
- $R_{\mathrm{out}} = 0$
- $A = \infty$
- With negative feedback, $v^+ \approx v^-$



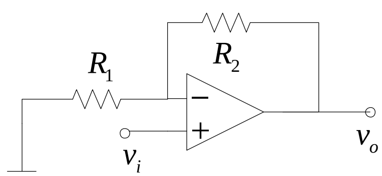
Inverting Op Amp

- $v_{\mathrm{o}} = -\frac{R_2}{R_1} v_{\mathrm{i}}$



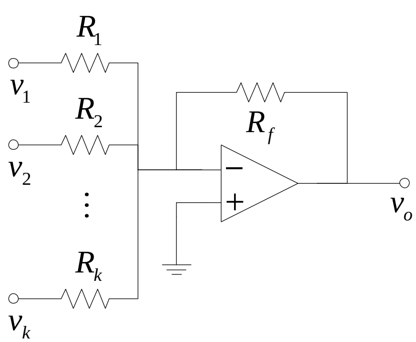
Non-Inverting Op Amp

- $v_{\mathrm{o}} = \left(1 + \frac{R_2}{R_1}\right) v_{\mathrm{i}}$



Summing Op Amp

- $v_{\mathrm{o}} = -R_f \displaystyle\sum_{i=0}^{k} \frac{v_{\mathrm{i}}}{R_i}$



Capacitors and Inductors

Quantity	**Symbol**	**Units**	**Equivalents**
Capacitance	$C = \epsilon \dfrac{A}{d}$	farad	$\mathrm{F} = \dfrac{\mathrm{C}}{\mathrm{V}} = \mathrm{S} \cdot \mathrm{s} = \dfrac{\mathrm{s}}{\Omega} = \dfrac{\mathrm{J}}{\mathrm{V}^2}$
Inductance	$L = \dfrac{N^2 \mu A}{l}$	henry	$\mathrm{H} = \Omega \cdot \mathrm{s} = \dfrac{\mathrm{J}}{\mathrm{A}^2}$

$$q = Cv \qquad i = C\frac{dv}{dt} \qquad w_C = \frac{1}{2}Cv^2 \qquad C_{\text{series}} = \frac{1}{\displaystyle\sum_i \frac{1}{C_i}} \qquad C_{\text{parallel}} = \sum_i C_i$$

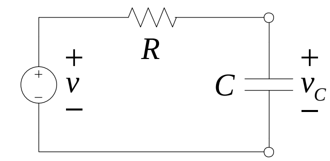
$$v = L\frac{di}{dt} \qquad w_L = \frac{1}{2}Li^2 \qquad L_{\text{series}} = \sum_i L_i \qquad L_{\text{parallel}} = \frac{1}{\displaystyle\sum_i \frac{1}{L_i}}$$

Voltage Divider $\quad v_{C_k} = \frac{C_{\text{series}}}{C_k} v_S \qquad$ Current Divider $\quad i_{C_k} = \frac{C_k}{C_{\text{parallel}}} i_S$

$v_{L_k} = \frac{L_k}{L_{\text{series}}} v_S \qquad i_{L_k} = \frac{L_{\text{parallel}}}{L_k} i_S$

First-Order Circuits

$$v_C(t) = V_{C_{\mathrm{F}}} + (V_{C_{\mathrm{I}}} - V_{C_{\mathrm{F}}})\, e^{-(t-t_0)/\tau} \qquad \tau = RC \qquad V_{C_{\mathrm{F}}} = v$$



$$i_L(t) = I_{L_{\mathrm{F}}} + (I_{L_{\mathrm{I}}} - I_{L_{\mathrm{F}}})\, e^{-(t-t_0)/\tau} \qquad \tau = \frac{L}{R} \qquad I_{L_{\mathrm{F}}} = i$$