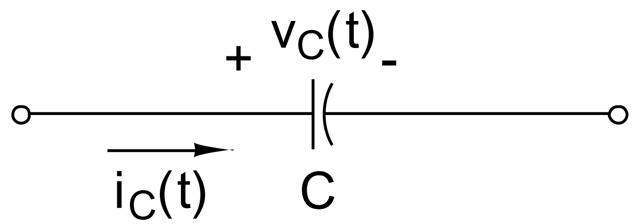
Capacitors and Inductors- this stuff's a charge

Capacitance, C- relates voltage and stored charge in a capacitor. The unit of capacitance is the farad (F).



$$q(t) = Cv_C(t)$$

Current and voltage relationships:

$$i_C(t) = \frac{dq(t)}{dt} = C\frac{dv_C(t)}{dt} \qquad (1)$$

$$v_C(t) = v_C(t_o) + \frac{1}{C}\int_{t_o}^{t} i_C(x)dx$$

Power:

$$p_C(t) = i_C(t)v_C(t) = C\frac{dv_C(t)}{dt}v_C(t) = \frac{d}{dt}\left[\frac{1}{2}Cv_C^2(t)\right] \qquad (2)$$

Energy:

$$w_C(t) = \int p_C(x)dx = \frac{1}{2}Cv_C^2(t) \qquad (3)$$

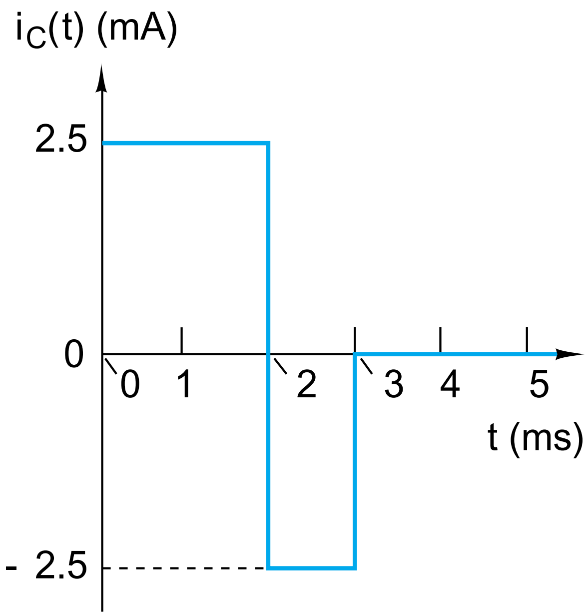
In summary:

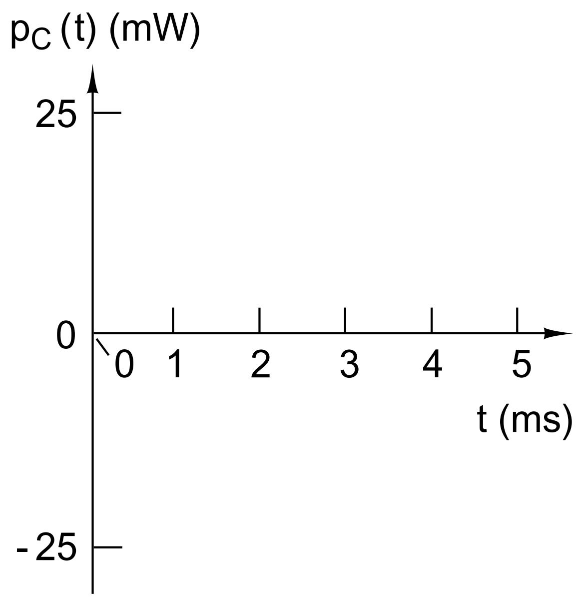
1) The current through the capacitor is zero unless voltage is changing (from (1)). Thus, current is zero for dc voltages (open circuit)

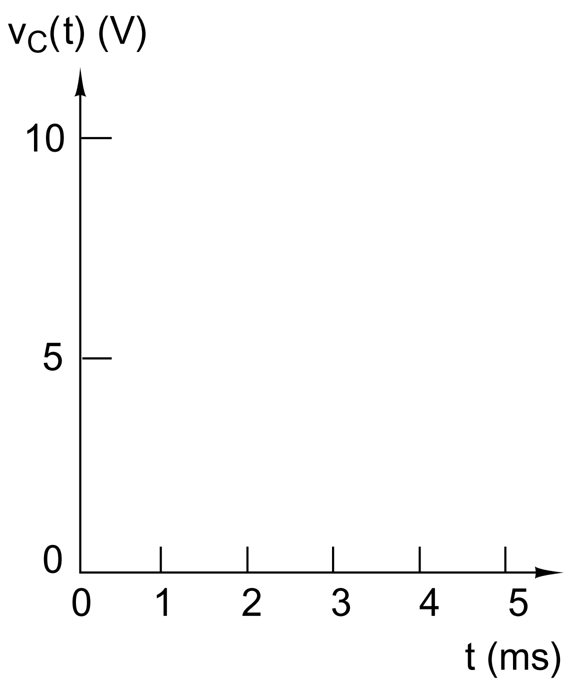
2) The voltage across the capacitor is continuous in time otherwise current and power would have to be infinite at the discontinuity (from (1 and 2))

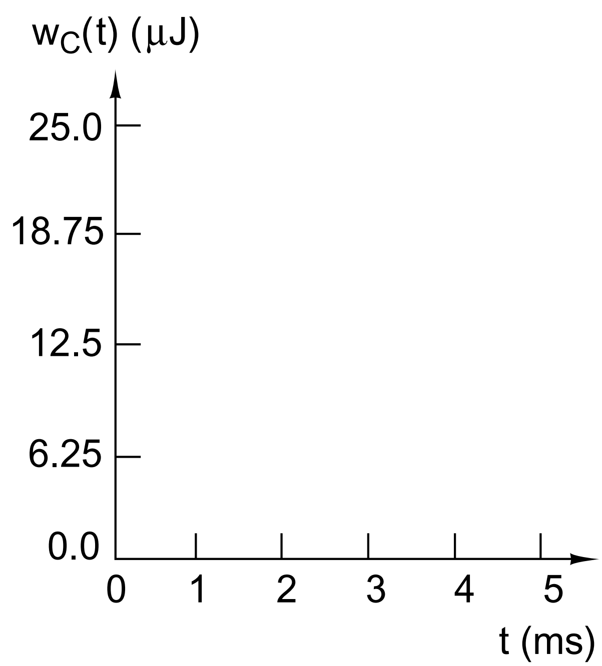
3) The capacitor absorbs power from the circuit when storing energy and returns previously stored energy when delivering power. The net energy transfer is non-negative (since (3) can never be negative), thus the capacitor is a passive element

Given $i_C(t)$, solve for $v_C(t)$, $p_C(t)$, and $w_C(t)$ for a 0.5 μF Capacitor

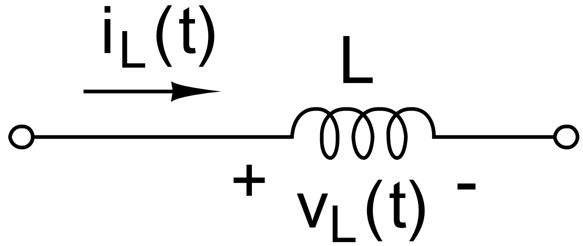








Inductance, L- relates voltage and stored energy in an inductor. The unit of inductance is the henry (H).



$$\lambda(t) = Li_L(t)$$

Current and voltage relationships:

$$v_L(t) = \frac{d\lambda(t)}{dt} = L\frac{di_L(t)}{dt} \tag{4}$$

$$i_L(t) = i_L(t_o) + \frac{1}{L}\int_{t_o}^{t} v_L(x)dx$$

Power:

$$p_L(t) = i_L(t)v_L(t) = L\frac{di_L(t)}{dt}i_L(t) = \frac{d}{dt}\left[\frac{1}{2}Li_L^2(t)\right] \tag{5}$$

Energy:

$$w_L(t) = \int p_L(x)dx = \frac{1}{2}Li_L^2(t) \tag{6}$$

In summary:

4) The ~~current through~~ voltage across the ~~capacitor~~ inductor is zero unless ~~voltage~~ current is changing (from (4)). Thus, ~~current~~ voltage is zero for dc current (short circuit)

5) The ~~voltage across~~ current through the ~~capacitor~~ inductor is continuous in time otherwise ~~current~~ voltage and power would have to be infinite at the discontinuity (from (4 and 5))

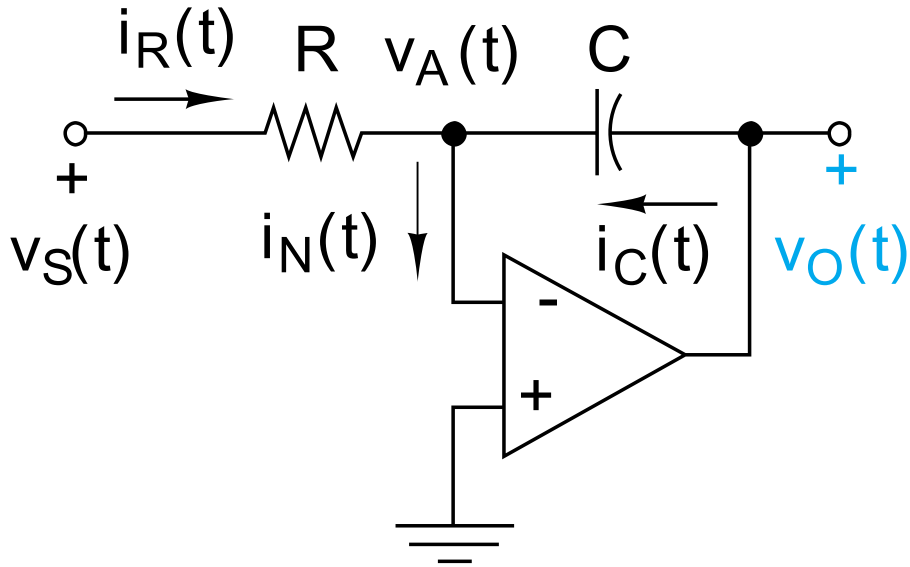
6) The ~~capacitor~~ inductor absorbs power from the circuit when storing energy and returns previously stored energy when delivering power. The net energy transfer is non-negative (since (6) can never be negative), thus the ~~capacitor~~ inductor is a passive element

Duality

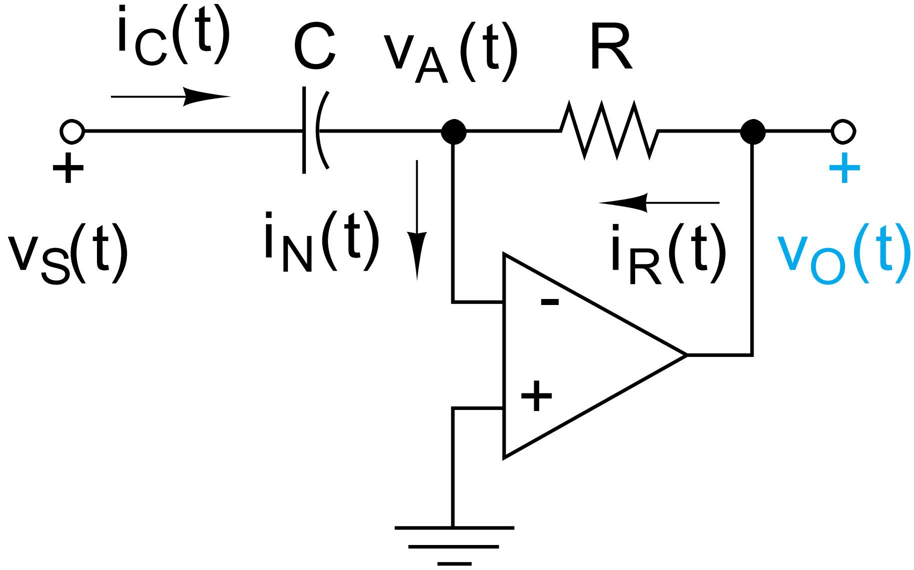
voltage	⇔	current
KVL	⇔	KCL
loop	⇔	node
resistance	⇔	conductance
voltage source	⇔	current source
Thevenin	⇔	Norton
short circuit	⇔	open circuit
series	⇔	parallel
capacitance	⇔	inductance
flux linkage	⇔	charge

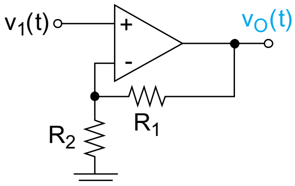
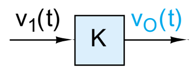
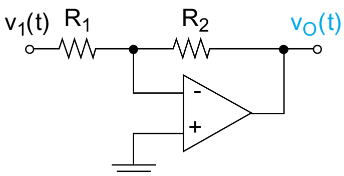
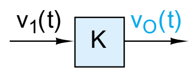
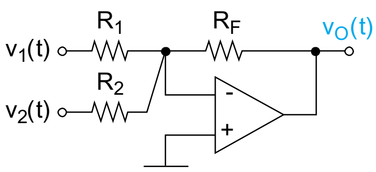
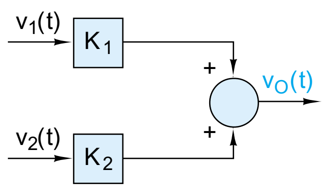
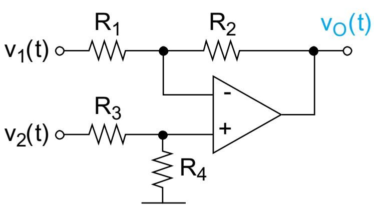
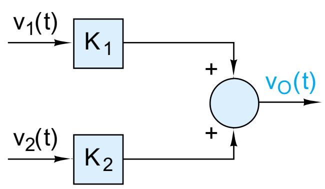
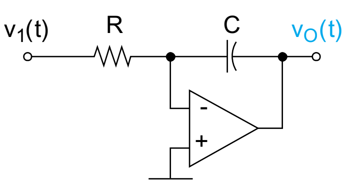
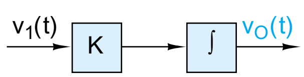
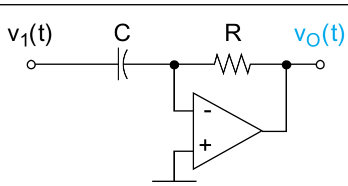
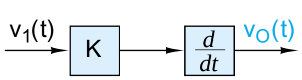
If every electrical term in a correct statement about circuit behavior is replaced by its dual, then the result is another correct statement.

Capacitor, meet Op Amp...

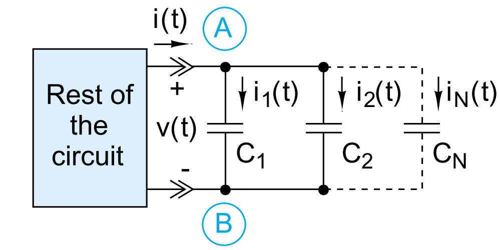


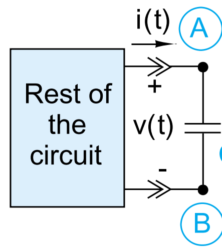
Op Amp, meet capacitor...



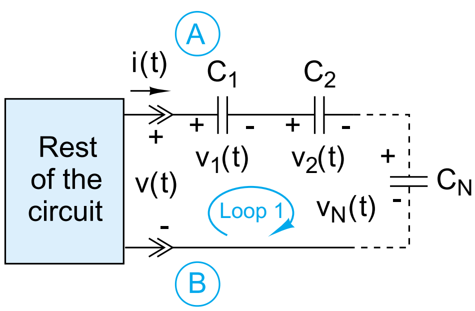
Circuit	Block diagram	Gains
		$K = \frac{R_1 + R_2}{R_2}$
		$K = -\frac{R_2}{R_1}$
		$K_1 = -\frac{R_F}{R_1}$ - $K_2 = \frac{R_F}{R_2}$
		$K_1 = -\frac{R_2}{R_1}$ $K_2 = \left(\frac{R_1 + R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)$
		$K = -\frac{1}{RC}$
		$K = -RC$

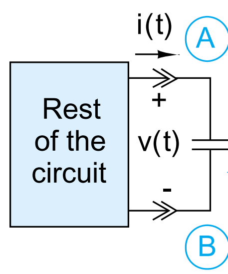
Equivalent Capacitance...





$$C_{EQ} = C_1 + C_2 + ... + C_N$$

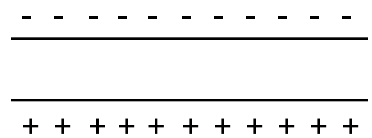




$$\frac{1}{C_{EQ}} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_N}$$

By duality, equivalent Inductance...

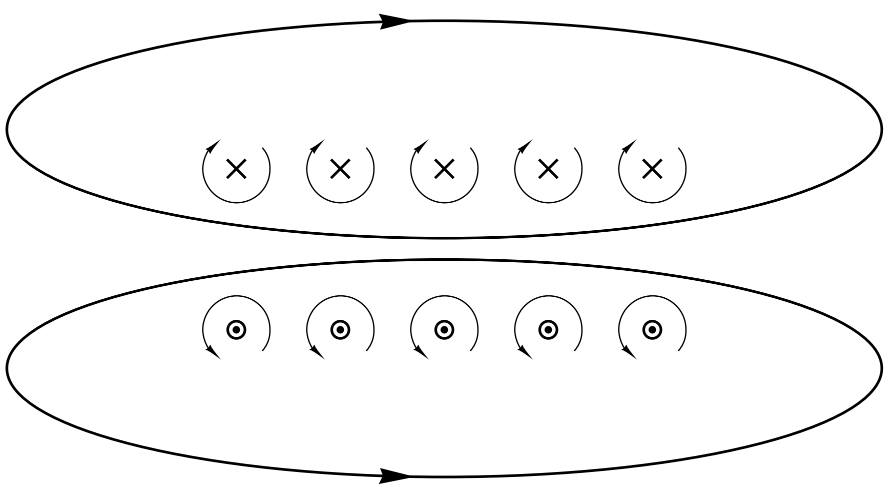
Cross-section of a capacitor



electric field

When there is an electric potential from another source, the potential induces a charge on each plate
When that source is turned off, the existing charge induces a potential across the plates while it dissipates.

Cross-section of an inductor



magnetic field

When current flows from another source, the moving charge induces a magnetic field.
When that source is turned off, the existing magnetic field induces a current in the wires while it dissipates..

Think of inertia- it takes energy to get an object moving, once it is moving it is storing that energy, then as it slows down it dissipates that energy.