EIT Circuits Review

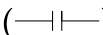
Basics

electric force: $\vec{F} = q\vec{E}$
Coulomb's law: $\vec{E} = q/4\pi\epsilon_0 r^2$
voltage: $V_{ab} = \int_a^b \vec{E} \cdot \mathrm{d}\vec{l} = \vec{E} \cdot \vec{L}$, if const $\vec{E}$

Components

Resistors ()

Ohm's law: $I = V/R$
voltage change across a resistor: $V = IR$
power dissipated in a resistor: $P = I^2 R$
addition in series: $R_{eq} = R_1 + R_2$
addition in parallel: $1/R_{eq} = 1/R_1 + 1/R_2$

Capacitors ()

definition of capacitance: $C = Q/V$
voltage change across a capacitor: $V = Q/C$
current through a capacitor: $I = \mathrm{d}Q/\mathrm{d}t$
energy stored in a capacitor: $E = Q^2/2C$
addition in series: $1/C_{eq} = 1/C_1 + 1/C_2$
addition in parallel: $C_{eq} = C_1 + C_2$

Inductors ()

definition of (self) inductance: $L = V/(\mathrm{d}I/\mathrm{d}t)$
voltage change across an inductor: $V = L(\mathrm{d}I/\mathrm{d}t)$
energy stored in an inductor: $E = LI^2/2$
addition in series: $L_{eq} = L_1 + L_2$
addition in parallel: $1/L_{eq} = 1/L_1 + 1/L_2$

Kirchoff's rules

Junction rule

sum of currents into a junction is equal to sum of the currents out of the junction (conservation of charge)

Loop rule

voltage change around a closed loop is zero (conservation of energy)

Hints

- get as many equations as the unknowns
- use the junction rule first for $(N-1)$ equations (N: number of junctions)
- then use the loop rule with smallest possible loops with least overlap until you have enough equations

AC Circuits

with an alternating-current (AC) voltage or current source, operating at a definite frequency

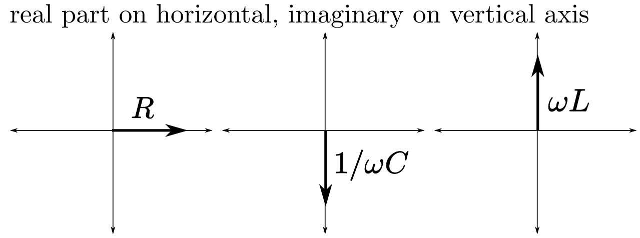
Complex Impedances

generalized and complex replacement for resistance
- resistor: $Z_R = R$
- capacitor: $Z_C = 1/j\omega C$
- inductor: $j\omega L$

generalized version of Ohm's law: $I(t) = V(t)/Z$
or, to ignore phase difference, $I_{\mathrm{rms}} = V_{\mathrm{rms}}/|Z|$
- $\mathrm{Re}[Z]$: resistance; $\mathrm{Im}[Z]$: reactance; $|Z| = \sqrt{Z^* Z}$
- add impedances just as resistances
- power dissipation: $P_{\mathrm{avg}} = I_{\mathrm{rms}}^2 \mathrm{Re}[Z]$; only real component dissipates power

Impedance on Complex Plane (Phasors)

real part on horizontal, imaginary on vertical axis



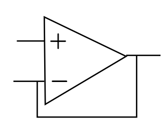
- add Z's in series as (geometric) vector addition
- only horizontal component of Z dissipates power

in polar form, $Z = Re^{i\theta}$
- length of Z: $R = |Z|$
- argument of Z: $\theta = \mathrm{atan}(\mathrm{Im}[Z]/\mathrm{Re}[Z])$

Semiconductor Circuits

Operational Amplifiers

- differential amplifier with a huge gain
- usually used with negative feedback
- golden rules apply with negative feedback



Op-amp Golden Rules

1. input draws no current
2. voltages at the inverting input (V_-) and the noninverting input (V_+) are the same

Topics not covered here:
most basic E&M, such as magnetic fields, electric and magnetic fields with extended bodies, mutual and self inductance; most basic semiconductor circuit topics, such as nonlinear circuit elements (diodes) and active circuit elements (transistors)