- Syllabus - handout
- Website - on ECE Classweb
  - will not be using the WebCT site right now
- We will use Prof. Najmabadi's notes (on web site)

Introduction (review)

Circuit theory - 9 fundamental circuit elements

- Resistor $v = Ri$
- Capacitor $i = C\frac{dv}{dt}$ or $V = \frac{1}{j\omega C} I$
- Inductor $v = L\frac{di}{dt}$ or $V = j\omega L I$
- Independent voltage source $v =$ constant
- Independent current source $i =$ constant
- Four dependent sources voltage → voltage, current ⇄ current

- Kirchoff's voltage law from Faraday's law

$$\nabla \times \vec{E} = \frac{-\partial \vec{B}}{\partial t} = 0 \quad \text{(steady state)}$$

Stoke's theorem

$$\oint_c \vec{E} \cdot d\vec{l} = 0$$ → sum of voltage drops around a closed path is 0

- Kirchoff's current law from charge-current continuity relation

$$\nabla \cdot \vec{J} = \frac{-\partial \rho_v}{\partial t} = 0 \quad \text{(steady state)}$$

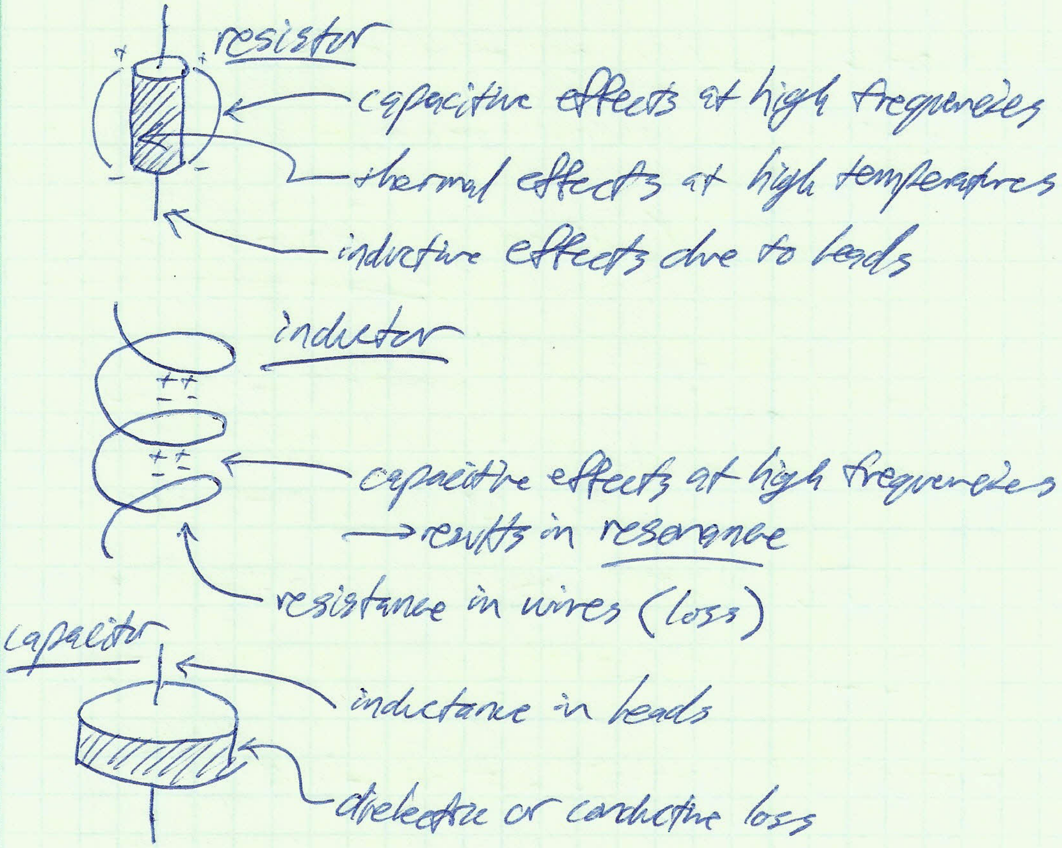
divergence theorem

$$\oint_s \vec{J} \cdot d\vec{s} = 0$$

$$\sum_n I_n = 0$$ → sum of currents leaving a node is 0

Applicability of circuit models

real vs. ideal elements



- Real device in lab is approximated by ideal device over a certain range of conditions
- Circuit theory allows us to use simple models instead of solving full electromagnetic/thermal/etc. problem
- Many of these effects can be included by adding parasitic elements
- KVL and KCL always apply
  - only question is whether you have modeled the real device properly

Basics of solving circuit problems

for a circuit with N_e elements, N_n nodes, N_ℓ loops

- KVL + KCL : 2N equations
- Node voltage method : $N_n - 1 - N_{IVS}$ equations
  - 1 ← ground
  - N_{IVS} ← ind. voltage sources
- Mesh current method : $N_\ell - N_{ICS}$ equations
  - N_{ICS} ← ind. current sources

Frequency Domain

time domain – explicit time dependence

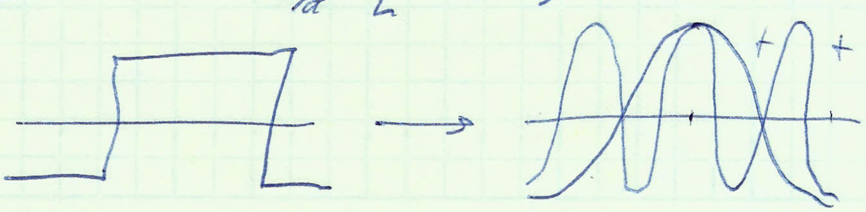
frequency domain – phasors = magnitude/phase at given frequency

$i = C\frac{dv}{dt} \longrightarrow V = \frac{1}{j\omega C} I$

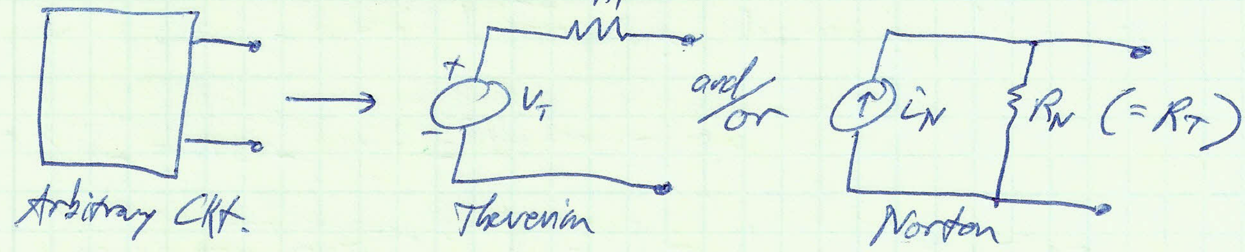
$v = L\frac{di}{dt} \longrightarrow V = j\omega L I$

- linear circuits driven by sources with frequency ω
  → all currents and voltages will have frequency ω
  → for multiple frequencies, each response can be added up (superposition) so overall response is the sum of responses at each frequency
- Any periodic signal can be written as sum of sinusoidal functions using Fourier series expansion

Square wave : $v(t) = \frac{4V_m}{\pi}\left[\sin(\omega_0 t) + \frac{1}{3}\sin(3\omega_0 t) + \frac{1}{5}\sin(5\omega_0 t) + \dots\right]$



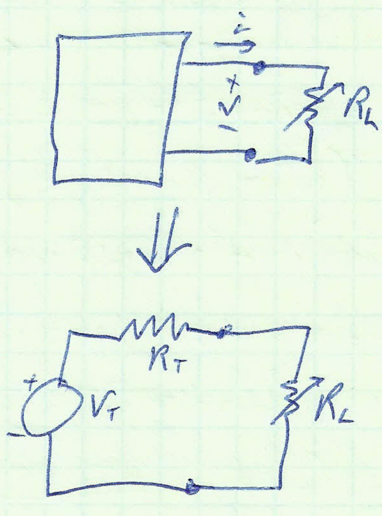
Thevenin + Norton Equivalents

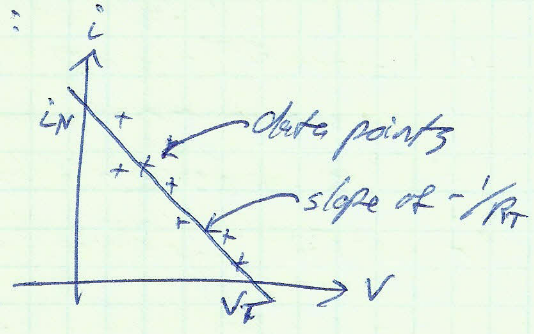


(use Z_T instead of R_T for frequency domain)

- How to find the Thevenin/Norton equivalents:
  - Zero the independent sources and calculate R_T
  - Find V_{oc} (open-circuit voltage) or i_{sc} (short-circuit current)
- How to <u>measure</u> the Thevenin/Norton equivalents:
  - can't just short out the circuit (may damage it)
  - can't attach ohm-meter while circuit is turned on
  - measurement of open-circuit voltage affected by impedance of meter

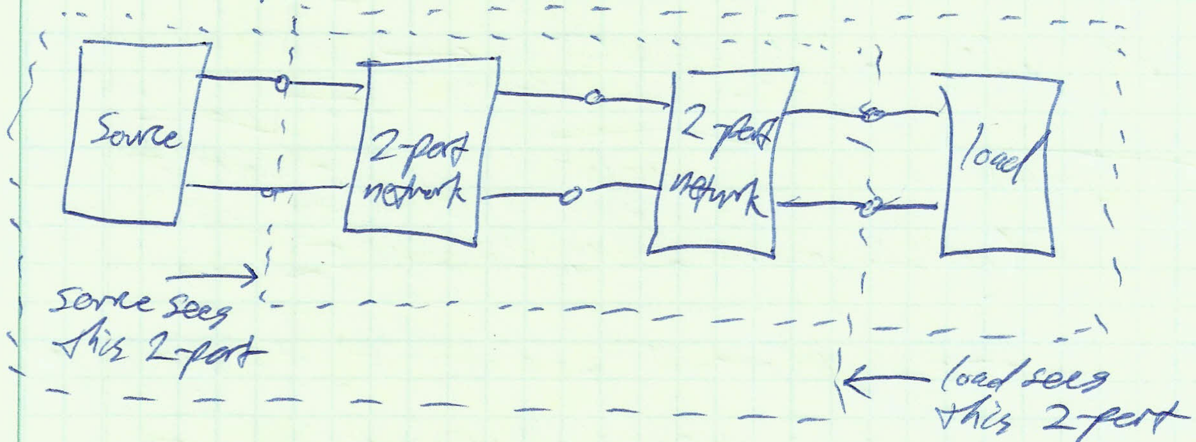
Instead, use variable resistor:





Cascading Circuits

Two-port networks



- We often don't solve complete circuits, but treat them as sub-circuits
  - example: multi-stage amplifiers

Accuracy of Measurements:

- Instruments and devices in this lab will have a tolerance – ϵ
- Value A can actually be anywhere in range of $A(1 \pm \epsilon)$
- Typical tolerance for resistors may be 1% or 5%
  - a $1\,k\Omega$ resistor may be anywhere from 950 to $1050\,\Omega$
- Do not report more digits than appropriate for a given measurement.