E151 Lecture 1 – Intro and Linear Networks Review

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ENGR151

Disclaimer

These are note for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for lecture.

Why Take This Class

- Teaching analog circuit design
- “Analog is dead and digital is king” – some strawman
- Used ADC in E80, why not apply to every analog problem? (board list)
  - Speed, noise, dynamic range, power ← All tightly linked
  - Expensive, complex to design and use, delicate
  - Why is outside the scope of this class … but true
- What other analog tool do you know (op-amp). Why not? (board list)
  - Low power output
  - Limited bandwidth
  - We WILL learn why here ← YOU WILL BUILD ONE

Goals and How We’ll Get There

- Learning goals: you will learn how to build an op-amp (as list)
  - Really good at basics: RC dynamics and KVL/KCL
  - Basic semiconductor physics and intuition for how devices work in circuits
  - Single and multi-stage linear amplifiers
  - Analog building blocks and “talking the talk”
  - Fearless in lab and rational debugging
- Organized as: Large signal / Small signal / Dynamics / Other Stuff
- Learning and note taking
  - Transparent teaching
  - Frequent low stakes assessment and interleaved practice
  - Lecture feels good, but activities are how you make knowledge stick
  - Notes during derivations

How Are We Doing This?

Mon	11:59PM	Turn in Lab Notebook & Problems
Tue	Lecture	Lab debrief
Tue	11:59PM	Turn in warm-up problems
Wed		
Thu	12:01PM Lecture	Turn in self-graded problems Quiz on lecture material (ind, + group)
Fri	Lab	Oscope lesson & work time

- Lab deliverable is notebook: next slide
- Problems don't need to be done before lab, just related
- More later on design project, problems solo, DP + lab partners

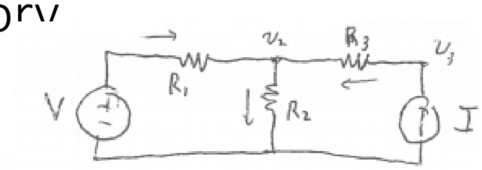
Lab Notebook Demo

- My example posted on the website.
- Necessary features
  - Chronological – that helps you reference when your boss asks a q
  - Informal and handwritten parts – clear, but not a writeup, always evidence
  - Contains necessary data – doesn't have to be at end like this, but highlight
  - Contains convincing evidence of experiments – need to be able to replicate from it
- Notebooks are important: This should help you both in and out of lab

- You need to get right measurements in this class, like 80
- Lab password
- Break to gather partners, come back to tech work.

E84 was Linear Circuit Theory

- Small groups, find i2 3 different ways for



(1) KCL $i_2 = \frac{V - v_2}{R_1} + I$ & $v_2 = i_2 R_2$ → $i_2 = \frac{V}{R_1} - \frac{i_2 R_2}{R_1} + I$

$I = \frac{v_3 - v_2}{R_3}$

$i_2\left(1 + \frac{R_2}{R_1}\right) = \frac{V}{R_1} + I$

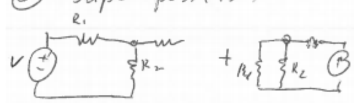
$i_2 = \frac{\frac{V}{R_1} + I}{1 + R_2/R_1}$

(2) KVL $V = i_1 R_1 + (i_1 + I) R_2$

$i_1 = \frac{V - I R_2}{R_1 + R_2}$

$i_2 = \frac{V + I R_1}{R_1 + R_2} = \frac{V/R_1 + I}{1 + R_2/R_1}$

(3) Superposition



$i_2 = \frac{V}{R_1 + R_2} + I \frac{R_1}{R_1 + R_2}$

Split into "superposition subcircuits" and "turn off" supplies
- Splitting into equivalent summed circuits really common in 151
- Why the heck do we "turn off" sources

Matrix Picture of Circuit Linearity

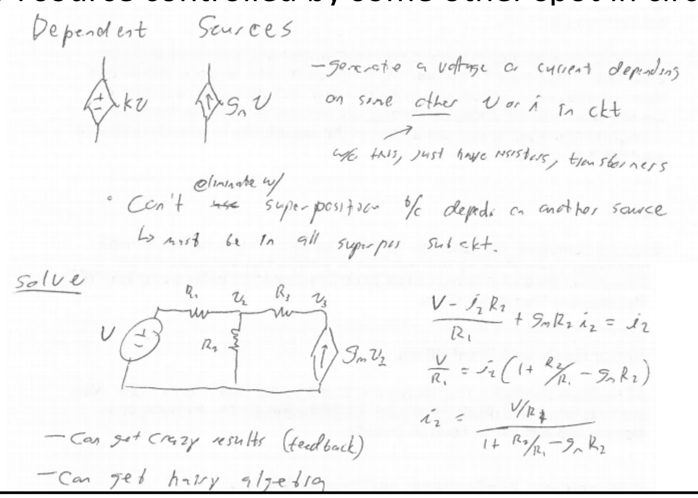
- Split matrix into vectors and turn them off one at a time.

$$\begin{bmatrix} V \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} R_1 & R_2 & 0 \\ 0 & R_2 & 0 \\ 0 & R_2 & R_3 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ I \end{bmatrix} = \begin{bmatrix} R_1 \\ 0 \\ 0 \end{bmatrix} i_1 + \begin{bmatrix} R_2 \\ R_2 \\ R_2 \end{bmatrix} i_1 + \begin{bmatrix} 0 \\ 0 \\ R_3 \end{bmatrix} I$$

Can find I contrib. indept R_1 & R_2
(1) make super-pos subckts by "turning off" all but 1 S/C (short/open)
(2) find qty
(3) sum across all contrib subckt

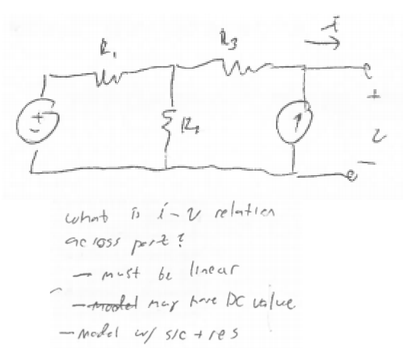
Dependent Sources (I solve)

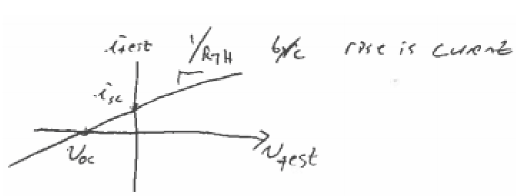
- V source or I source controlled by some other spot in circuit



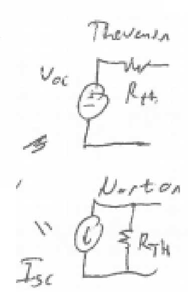
Thevenin

- Don't care about circuits floating in space – want to connect them
- Connecting them to stuff can cause loading, need i-v relationships
- Place we make a connection called a port (where we apply vt) eg:





Norton is V-I curve instead of I-V

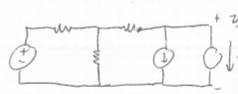


Example Find Thevenin Impedance 2 Ways

- Options: voc/isc (slope), simplify network (why does that work?)
- Then I show 3rd way: test sources (derivative of circuit)

① $v_{oc} = v_3 = I(R_3 + R_1 \| R_2) + V \frac{R_2}{R_1+R_2}$ by super pos $i_{sc} = I + \frac{V}{R_3 + R_1 \| R_2} \cdot \frac{R_2}{R_1+R_2}$

② $R_{TH} = R_3 + R_1 \| R_2$ w/ shorted & opened sources

③ 

- can pick current or voltage test
- ask how much i or v out (find dv_t/di_t)
- i easy here b/c ∥ w/ I
- MUST use this technique w/ dept. src:

$v_t = V \frac{R_2}{R_1+R_2} + (I + i_t)(R_3 + R_1 \| R_2)$

$\frac{dv_t}{di_t} = R_3 + R_1 \| R_3$ (eq to small signal model, setting v & i to 0)

[Super handy for ignoring tricky circuit details!]

MUST SHUT OFF SOURCES for di/dv. (Small wiggles go to die)