Lecture 1 ~ Intro & Thevenin E151B F17

Motivator	Syllabus	Linear Network Theory
↳ why not ADC	↳ Learning Goals Lounts	↳ Superposition
↳ Too fast	↳ Unusual homework	↳ Dependent Sources
↳ Too power hungry	↳ Lab partners	↳ Thevenin
↳ Too delicate	↳ Lab Notebooks *	
↳ why not op-amps	↳ password	
	↳ Lecture Handouts	

Motivator

- Welcome to E151, teaching analog design

→ 1st challenge: why take this class?

↳ Used ADC in E80 and/or MicroPs

↑ Analog to digital converter

↳ Why not put one in front of every analog problem?

→ Too fast
→ Too noisy ~ power hungry
→ Too delicate ~ expensive

} ~ Why is this time? - get there much later

→ 2nd challenge why not op-amps?

~ What analog tools do you know? $\boxed{\text{op-amps}}$

↳ low power output
↳ limited bandwidth, trades w/ gain

} ~ we will answer why this is time

→ Goal is for you to build op-amp ←

How are we going to learn this?

- I want to give you insight into my pedagogical reasoning so you learn better

- 3 parts
  - Learning Goals & Organization
  - Assignments & Logistics
  - Details of one type of assignment: Lab notebook

Learning Goals

5 crucial technical takeaways (know in a year)

↳ really good at doing circuits

↳ Make a small signal model from large signal

↳ Design a single stage amplifier

↳ Comfortable w/ 1st order dynamics

↳ Discuss amplifier design specs

Lots of me

[Brainstorm in groups of 4 for a bit for others]

3-4 follow on goals, maybe more general

↳ Mind & hand ~ how to use theory in a real system

↳ Lab notebooks ~ how to handle documenting your work

1 ↳ Goals: Boss asks what you did

2 ↳ Goals: Boss asks for a graph

[Brainstorm again]

3 ↳ Talk circuits confidently

↙ know lots of detail circuits

(4) ↓ & work with them

→ feel like an analog designer, know what's up

Organization

- Circuit design isn't hard, but it is broad
- Need to know how to solve many types of problems
- Trying to explicitly break these out, see schedule

Large signal ~ I & V (DC) in non-linear ckt.

Small signal ~ I & V (low-freq) around DC op. point

Dynamics ~ I & V (high-freq) on small signal world

Building Blocks ~ supporting circuits & common circuit tricks
↳ mix of large & small signal

- Learn to solve a new class of problems ~ every 3 weeks

Assignments

Homework

- 1 pset per class ~ learning and, engage on your own & then talk it out
- Turn in scan, then self-grade ~ also learning aid, must look @ answ.
- I randomly audit

Labs

- Need to make a notebook (next)
- Done w/ partners (pick today & fill in spreadsheet)
- kind of replace psets: some tricky, open ended puzzles

Projects

- Must also do a report
- lots of needs design, sims, exps → short as possible

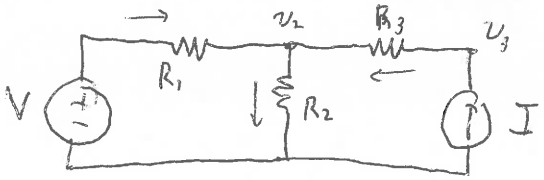
Lab Notebooks

- Go over my good example
- Handwriting makes you smarter
  - ↳ I expect hand drawn ckt diagrams eg
- I used all paper, but tough for tracking digital files
- so we're trying Evernote, all the rage among biologists
- Lab notebook goals
  - replicate exp. under duress (boss meeting)
  - quickly generate or just have good figures
  - Legal document (witness, etc.) (patents)
- Be clear, but remember not to waste time
- Should help both in & out of lab

Lab password: 1-24-5

Break, partners; come back to technical work

- E84 mostly concerned w/ linear circuit theory (& E79 concerned w/ too)
  - You should know how to analyze linear circuits
  - small groups: solve this ckt. 3 ways (find i_2)



① KCL $\quad i_2 = \dfrac{V - v_2}{R_1} + I \quad \& \quad v_2 = i_2 R_2 \longrightarrow i_2 = \dfrac{V}{R_1} - \dfrac{i_2 R_2}{R_1} + I$

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

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

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

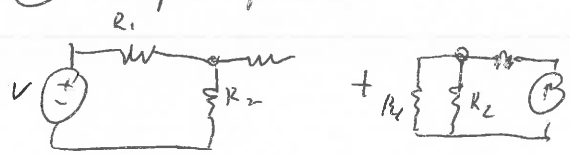
$$v_2 =$$

② KVL $\quad V = i_1 R_1 + (\overset{i_2}{i_1 + I}) R_2$

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

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

③ Superposition



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

Derivation thing: see small sheet if comfort survey looks bad

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

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

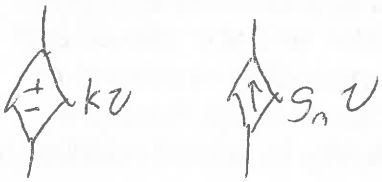
$$\cancel{\begin{bmatrix} v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} 0 & R_2 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}}$$

can find I contrib. indept R_1 & R_2

① make superpos subckts by "turning off" all but 1 s/c (short/open)
② find qty
③ sum across all superpos subckt

Algebraic Topology
Expander Graphs
Counting Starting Poker Hands
Cyclic Codes

Dependent Sources

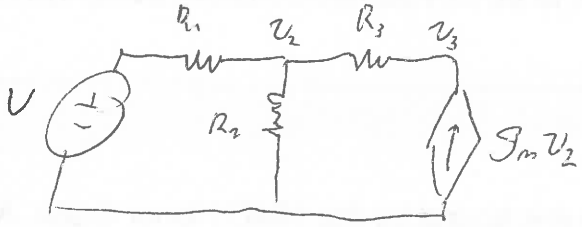


- generate a voltage or current depending on some other v or i in ckt

w/o this, just have resistors, transformers

- Can't ~~use~~ eliminate w/ superposition b/c depends on another source
  ↳ must be in all superpos subckt.

Solve



$$\frac{V - i_2 R_2}{R_1} + g_m R_2 i_2 = i_2$$

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

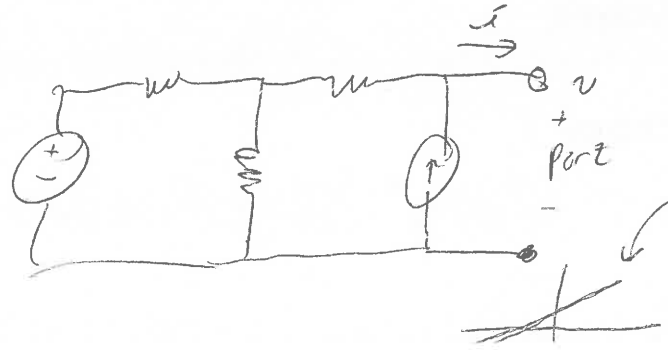
$$i_2 = \frac{V/R_1}{1 + R_2/R_1 - g_m R_2}$$

- Can get crazy results (feedback)
- Can get hairy algebra

Thevenin

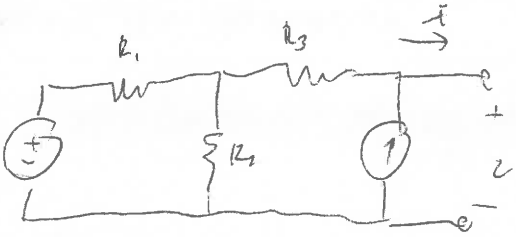
- Don't care about circuits in the void of space
- Only care if we measure it (should be defined) (check up to stuff)
- measuring it causes "loading" ~ E80 used op-amps to bypass
- place we measure is called a "port"

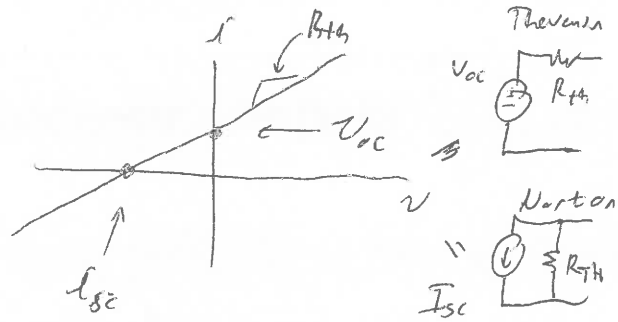
e.g.:



what is $i - v$ relation across port?

- must be linear
- ~~model~~ may have DC value
- model w/ s/c + res





- Two intercepts of i v relation: open ckt voltage (@ 0 current)
  short ckt current (@ 0 voltage)

- Slope is called Thevenin resistance

Find R_{TH} 3 ways:

- options ① $\frac{v_{oc}}{i_{sc}}$, ② simplify network, ③ test source

① $v_{oc} = v_3 = I(R_3 + R_1 \| R_2) + V \frac{R_2}{R_1 + R_2}$ by superpos

$$i_{sc} = I + V \frac{R_2 \| R_3}{R_1 + R_2 \| R_3} \cdot \frac{1}{R_3 + R_2 \| R_3}$$

$$= I + \frac{V}{R_3 + R_1 \| R_2} \cdot \frac{R_2}{R_1 + R_2}$$

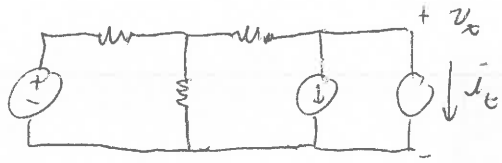
$$= \frac{1}{R_1 + \frac{R_2 R_3}{R_2 + R_3}} \cdot \frac{R_2 R_3}{R_2 + R_3}$$

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

$$= \frac{1}{R_3(R_1 + R_2) + R_1 R_2} \cdot R_2$$

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)
- (easy here b/c ‖ w/ I
- MUST use this technique w/ dept. sic:

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

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

[super handy for ignoring tricky circuit details!]