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

- 2nd challenge: why not op-amps?
  - What analog tools do you know? [op-amps]
    - Low power output
    - Limited bandwidth, trade of gain
    - We will answer why

  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 on course type & assignments: lab notebook

Learning Goals
- 5 crucial technical takeaways (know in a year)
  1. Be really good at doing circuits
  2. Make a small signal model from a large signal
  3. Design a single stage amplifier
  4. Comfortable with 1st order dynamics
  5. Discuss amplifier design specs

(Brainstorm in groups of 4 for a bit, for others)

3 sub-goals: more general
- Mind your 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 sketch
3) Talk circuits confidently
   - Know lots of detail circuits
   - 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 \sim \text{I and V (DC) in non-linear circuit.}
Small signal \sim \text{I and V (low freq.) around DC op. point}
Dynamics \sim \text{I and V (high freq.) or small signal case}

Building Blocks - supporting circuits a common event tricks to mix large and small signal

Assignments

Homework
- 1 set per class \sim learning and engage on your own
then talk it out

- Turn in scan, then self-grade \sim also learning aid, must look at scan

- I randomly audit

Labs
- Need to make a notebook (net +)
- Done w/ partners (pick today + fill in spreadsheet)
- Kind of replace uets: some tricky, open ended puzzles

Projects
- Must also do - report
- lots of needs design, sim, exprs \sim short is possible
Lab Notebooks
- Go over my good example
- Handwriting makes you smarter
  - I expect hand drawn ckt diagrams etc.
- 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 (loss reading)
  - Quickly generate or just have good figures
  - Be clear, but remember not to waste time
  - Should help both in 2 out of 1 lab

Lab password: 1-24-5

Break, partnership, come back to technical work
E151/3 E17  Lecture 1 - Intro & Thru

* 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 (6 and \( x_2 \))

\[ V \]
\[ V \]
\[ R_1 \]
\[ R_2 \]
\[ R_3 \]
\[ I \]

\[
\begin{align*}
\dot{x}_2 &= \frac{V - V_2}{R_1} + I = \frac{x_2 R_2}{R_3} \\
I &= \frac{V_3 - V_2}{R_3} \\
x_2 &= \frac{V}{R_1 + \frac{R_2}{R_1} + I} \\
\end{align*}
\]

\[
\begin{align*}
\dot{x}_1 &= \frac{V - IR_2}{R_1 + R_2} \\
\dot{x}_L &= \frac{V + IR_1}{R_1 + R_2} = \frac{VR_1}{1 + R_2/R_1} \\
\end{align*}
\]

\[ \text{Superposition} \]

\[ V \]
\[ R_1 \\
\]
\[ R_2 \\
\]
\[ R_3 \\
\]

\[ \dot{x}_2 = \frac{V}{R_1 + R_2} + I \frac{R_1}{R_1 + R_2} \]

Derivation thing: see small sheet if can get super lords

\[
\begin{bmatrix}
V_1 \\
V_2 \\
V_3 \\
\end{bmatrix} = \begin{bmatrix}
R_1 & R_2 & 0 \\
0 & 0 & R_2 \\
R_2 & 0 & R_3 \\
\end{bmatrix} \begin{bmatrix}
x_1 \\
x_2 \\
x_3 \\
\end{bmatrix}
\]

Can find \( I \) contribute. Ignore \( R_1 + R_2 \)

\[ \text{for get} \]

\[ \text{(8) same across all superior subject} \]
Dependent Sources

- Generate a voltage or current depending on some other $V$ or $i$ in ckt
- Can't use superposition b/c depend on another source
- Must be in all superpos sub ckt.

Solve

\[ V - \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + 2 \frac{V}{R_4} = i_2 \]

\[ \frac{V}{R_1} = i_2 (1 + \frac{R_2}{R_1} - 2 \frac{R_2}{R_1}) \]

\[ i_2 = \frac{V}{R_1} \frac{1}{1 + \frac{R_2}{R_1} - 2 \frac{R_2}{R_1}} \]

Thevenin

- Don't care about circuits in the word ab sparse
- Only care if we measure $i$ (6-cord defined) check up + stuff
- Measuring $i$ causes "loading" ~ E80 used op-smps 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/ $v$ and $i$
- Two intercepts of $i$ vs $v$ relations: open ckt voltage (@ 0 current) start ckt current (@ 0 voltage)

- Slope is called Thuean resistance

For $R_{th}$ 3 ways:
- options 0 $\frac{V_{oc}}{I_{sc}}$ simplify network, test source

1. $V_{oc} = V_3 = I \left( R_3 + R_1 || R_2 \right) + V \frac{R_2}{R_1 + R_2}$ by superposition

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

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

3. $V = \frac{R_2}{R_1 + R_2} + (I + i)^2 \left( R_3 + R_1 || R_2 \right)$ can pick current or voltage test ask how much $i$ or $v$ at (work done)

- easy here $V$ & $I$

$\frac{\Delta V}{\Delta I} = R_1 + R_1 || R_3$ (eq to small signal model, setting $V_2 = 0$

Super handy for tracing trouble circuit details!