Lecture 1

Today:
* EECS 16B intro
* Logistics
  + Zoom proctoring all exams
  + Lecture Zoom organization (chat and Q&A)
  + Website: eecs16b.org
    + STEM Program, DSP
  + EECS 16A review
* Thévenin & Norton Equivalents
* Intro to transistors

Key circuit elements:

1. + Iel Wire
   Vel = 0
   Iel = ?
   set by ext. clot

2. Resistor
   + Iel
   Vel = R * Iel
   (Ohm's law)

3. "Open" circuit
   + Iel
   Vel = 0
   Iel = ?
   set by the ext. clot
4) Capacitor
\[ Q_{el} = C \cdot V_{el} \]
\[ I_{el} = \frac{dQ_{el}}{dt} = C \cdot \frac{dV_{el}}{dt} \]
\[ C = \text{const in time} \]

5) Voltage source
\[ V_{el} = V_{s} \]
\[ I_{el} = ? \]
\[ \text{set by ext. dots} \]

6) Current source
\[ I_{el} = I_{s} \]
\[ V_{el} = ? \]

Passive sign convention:
\[ + I_{el} \quad \text{over} \quad - V_{el} \]

KCL:
\[ I_{el1} + I_{el2} - I_{el3} = 0 \]
\[ I_{el1} + I_{el2} < I_{el3} \]
KVL: Sum of voltages around the loop is 0.

\[
V_{I1} - V_{I2} - V_{I3} - V_{I4} = 0
\]

\[
V_{I1} = V_{I3}
\]

\[
V_{I1} - V_{I2}^\circ - V_{I3}^\circ - V_{I4}^\circ = 0
\]

\[
V_{I1} = V_{I2}
\]

Op-amp element:

Symbol:

\[
\begin{align*}
V_{DD} &= +\text{rail} \\
V_{SS} &= -\text{rail} \\
&\text{ground}
\end{align*}
\]

New element:

Voltage-controlled voltage source:

\[
\begin{align*}
&\text{Symbol:} \\
&\text{Input:} \\
&\text{Output:} \\
&V_{DD} = V_{I1}^+ - V_{I1}^-
\end{align*}
\]

\[
V_{DD} = V_{I1}^+ - V_{I1}^-
\]

\[
V_{SS} = V_{I2}^+ - V_{I2}^-
\]

\[
V_{out} = \begin{cases} 
V_{dd}, & V^+ > V_{dd} \\
V_{out}, & V^+ < V_{out} < V_{dd} \\
V_{ss}, & V^* < V_{ss} \end{cases}
\]

Negative feedback:

Golden rules:

\[I^+ = I^- = 0\]
GR2: \( U^+ = U^- \) \( \text{(only when NFB \& } A \to \infty) \)

NFB example: Inverting amplifiier

Test NFB:

1. Null indep. sources
2. Apply a change at the output
3. Trace the feedback back to the output
4. Verify that the change is cancelled

\[
\begin{align*}
\text{KCL:} & \quad I_1 + I_2 - I^- = 0 \\
\text{GR1:} & \quad I^- = 0 \\
& \quad I_1 + I_2 = 0 \\
\text{NFB \rightarrow GR2:} & \quad U^+ = U^- \\
& \quad U^+ = 0 \Rightarrow U^- = 0 \\
\text{Ohm's Law:} & \quad I_1 = \frac{V_1}{R_1} = \frac{V_{in} - V^+}{R_1} = \frac{V_{in}}{R_1} \\
& \quad I_2 = \frac{V_2}{R_2} = \frac{V_{out} - V^-}{R_2} = \frac{V_{out}}{R_2} \\
& \quad \frac{V_{in}}{R_1} + \frac{V_{out}}{R_2} = 0
\end{align*}
\]
In circuits, two elements are equivalent if they have the same I-V characteristics.

Need a min of two elements (a resistor and a source) to create any I-V line.

There are equivalent:

Norton equivalent:
To find $V_{th}$:

"Connect" an "open-circuit" across terminals and measure $V_{open-circuit} = V_{th}$.

To find $R_{th}$:

zero-out ("null") input sources, and then apply $V_{test}$ and measure $I_{test}$

or apply $I_{test}$ and measure $V_{test}$

$$R_{th} = \frac{V_{test}}{I_{test}}.$$