Lecture 1

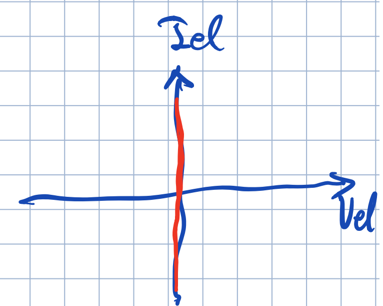
Today:
- * EECS 16B intro
- * Logistics
  - + Zoom proctoring all exams
  - + Lecture zoom organization (chat and Q&A)
  - + website: eecs16b.org
    - + STEM Program, DSP
- * EECS 16A review
- * Thevenin & Norton Equivalents
- * Intro to transistors

Key circuit elements:

① Wire

$V_{el} = 0$

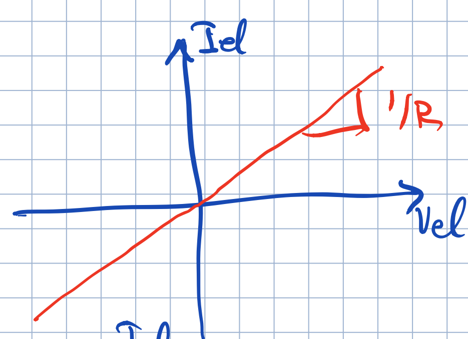
$I_{el} = ?$ set by ext. ckt



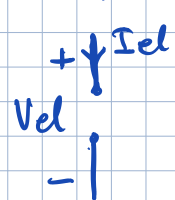
② Resistor

$V_{el} = R \cdot I_{el}$

(Ohm's law)



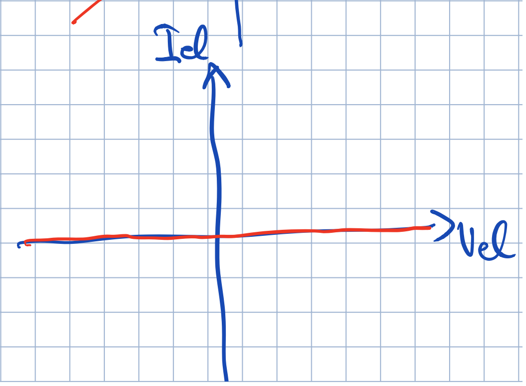
③ "Open" circuit



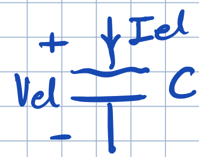
$I_{el} = 0$

$V_{el} = ?$

set by the ext. ckt



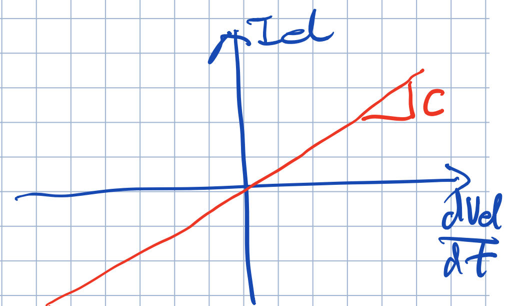
④ Capacitor



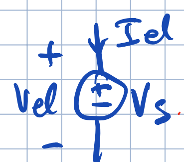
$$Q_{el} = C \cdot V_{el}$$

know: $I_{el} = \frac{dQ_{el}}{dt} = C \frac{dV_{el}}{dt}$

C = const in time



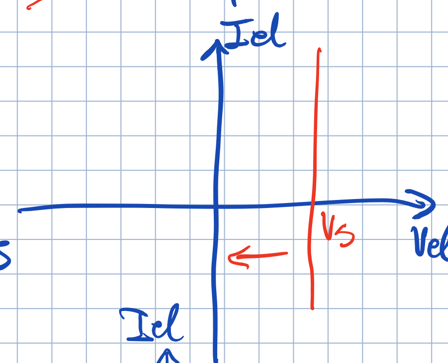
⑤ Voltage source



$V_{el} = V_s$

$I_{el} = ?$

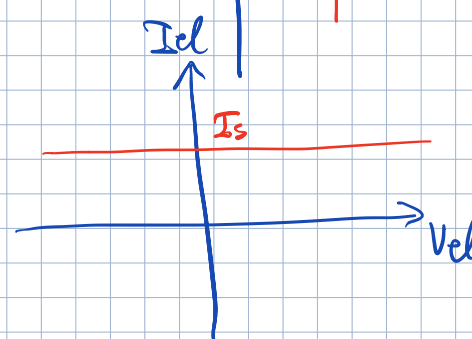
set by ext. ckts



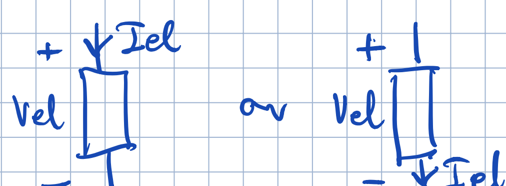
⑥ Current source

$I_{el} = I_s$

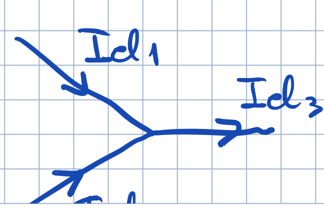
$V_{el} = ?$



Passive sign convention:



KCL:

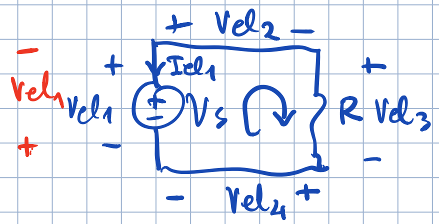


$$I_{el_1} + I_{el_2} - I_{el_3} = 0$$

$$I_{el_1} + I_{el_2} = I_{el_3}$$

$\rightarrow I_{el_2}$

KVL: Sum of voltages around the loop is 0.



$$V_{el_1} - V_{el_2} - V_{el_3} - V_{el_4} = 0 \quad (V_{el_2} \to 0,\ V_{el_4} \to 0)$$

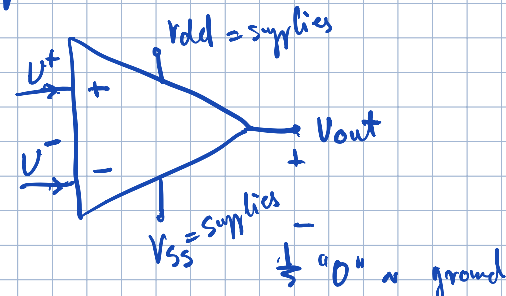
$$V_{el_1} = V_{el_3}$$

$$-V_{el_1} - V_{el_2} - V_{el_3} - V_{el_4} = 0 \quad (V_{el_2} \to 0,\ V_{el_4} \to 0)$$

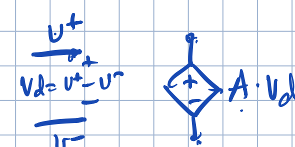
$$-V_{el_1} = V_{el_3}$$

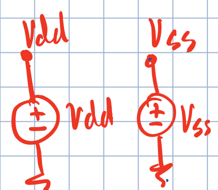
Op-amp element:

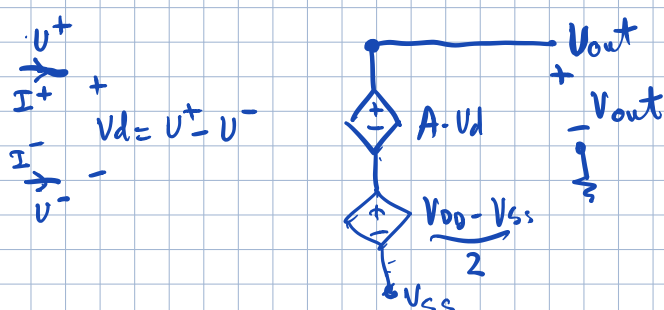
Symbol:



New element: voltage-controlled voltage source

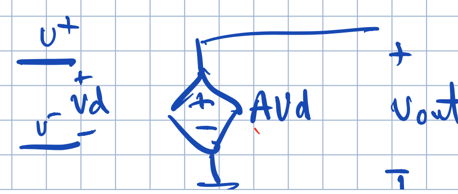






$$V_{out} = \begin{cases} V_{dd}, & V^* > V_{dd} \\ \underbrace{V_{ss} + \frac{V_{dd} - V_{ss}}{2} + A \cdot V_d}_{V^*}, & V_{ss} \le V^* \le V_{dd} \\ V_{ss}, & V^* \le V_{ss} \end{cases}$$

Negative feedback:

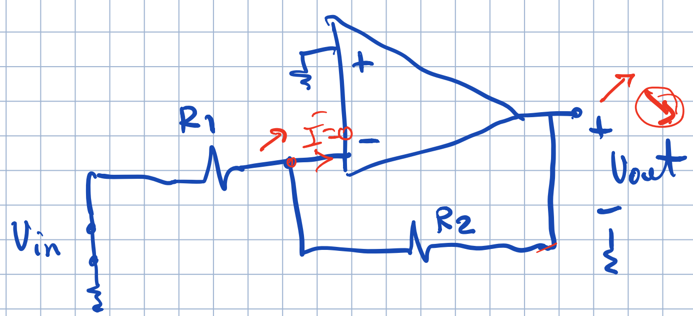


Golden rules:

GR1: $I^+ = I^- = 0$

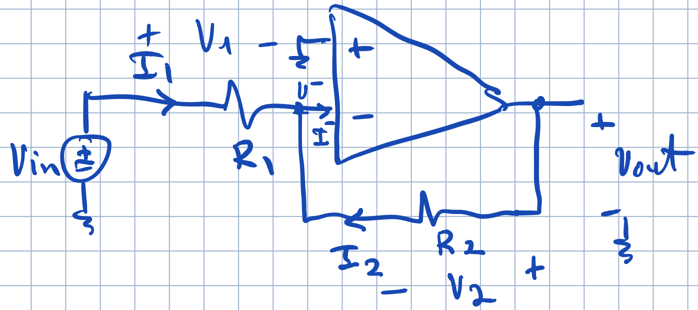
GR2: $U^+ = U^-$ (only when NFB & $A \to \infty$)

NFB example: Inverting amplifier



Test NFB:

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



$$V_{out} = f(V_{in}) = ?$$

$$V_{out} = -\frac{R_2}{R_1} V_{in}$$

KCL: $I_1 + I_2 - I^- = 0$

GR1: $I^- = 0$

$$\Downarrow$$

$$I_1 + I_2 = 0$$

NFB → GR2: $U^+ = U^-$

$$U^+ = 0 \Rightarrow U^- = 0$$

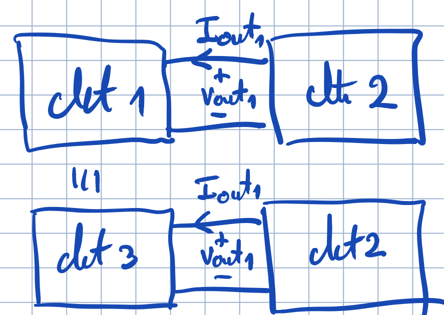
Ohm's law: $I_1 = \frac{V_1}{R_1} = \frac{V_{in} - \cancel{U^-}^{\,0}}{R_1} = \frac{V_{in}}{R_1}$

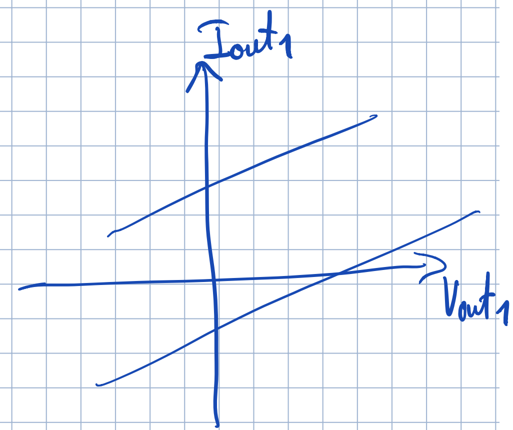
$$I_2 = \frac{V_2}{R_2} = \frac{V_{out} - \cancel{U^-}^{\,0}}{R_2} = \frac{V_{out}}{R_2}$$

$$\frac{V_{in}}{R_1} + \frac{V_{out}}{R_2} = 0$$

$$V_{out} = -\frac{R_2}{R_1} V_{in}$$

Equivalence:

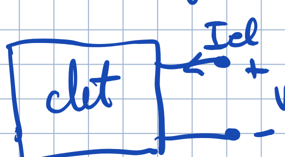




In ckts, two elements are equivalent if they have the same I-V characteristics.

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

Thevenin equivalent:



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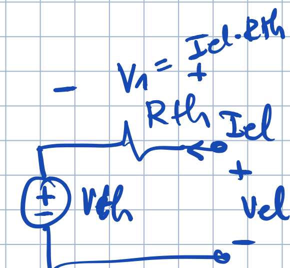
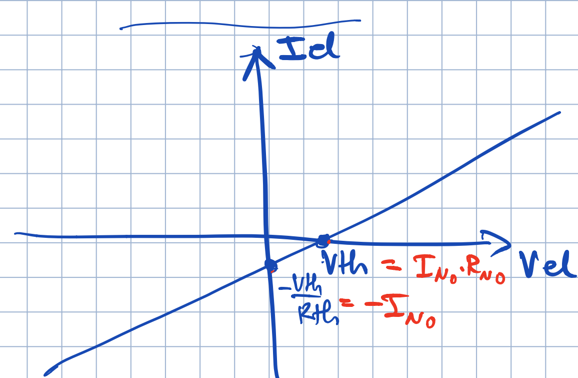
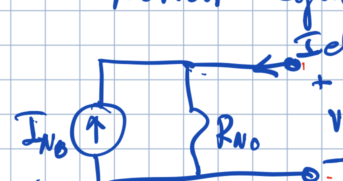




$$V_{el} = V_{th} + I_{el} \cdot R_{th}$$

$$I_{el} = \frac{V_{el} - V_{th}}{R_{th}}$$

Norton equivalent:



To find Vth:

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

To find Rth:

zero-out ("null") indep. sources, and then apply Vtest and measure Itest or apply Itest and measure Vtest

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