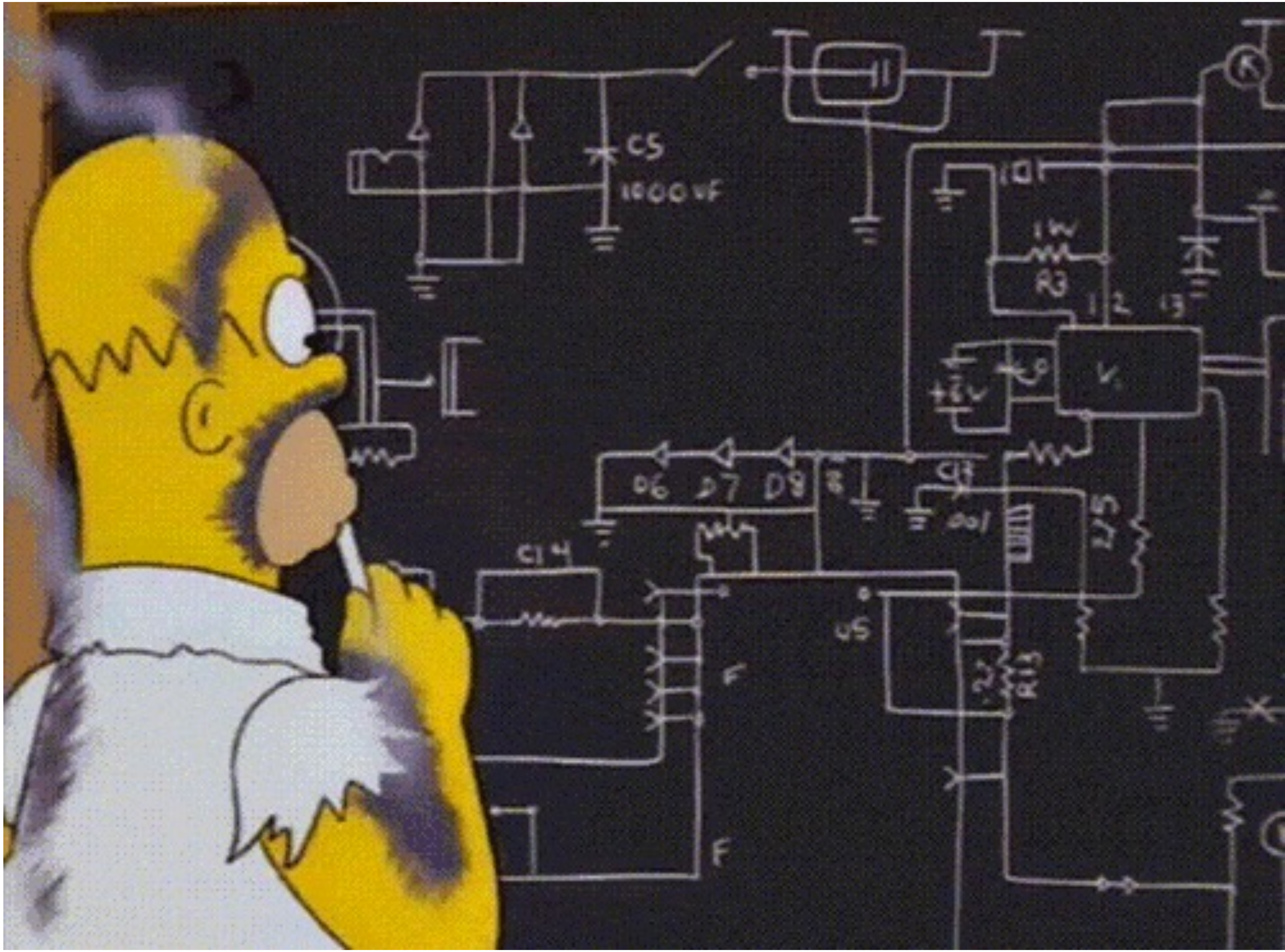
EECS 16A

Spring 2023
Profs. Muller & Waller

Lecture 11B
Circuit Design Examples



Toolbox

KVL: Voltage drops around a loop sum to 0

KCL: All currents coming out of a node sum to 0

$V = IR$

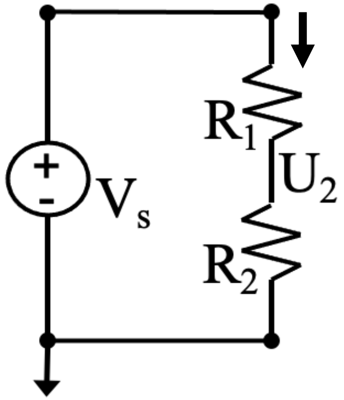
$P = IV$

$R = \frac{\rho L}{A}$

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

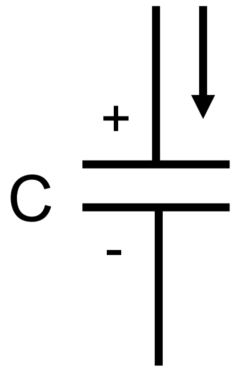
V_{source}(off) → short

I_{source}(off) → open



$I = \frac{V_S}{R_1 + R_2}$

$U_2 = \frac{V_S R_2}{R_1 + R_2}$

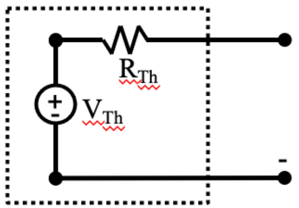


$Q = CV$

$I = C\frac{dV}{dt}$

$C = \frac{\epsilon A}{d}$

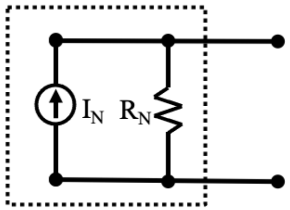
Thevenin Equivalent Circuit



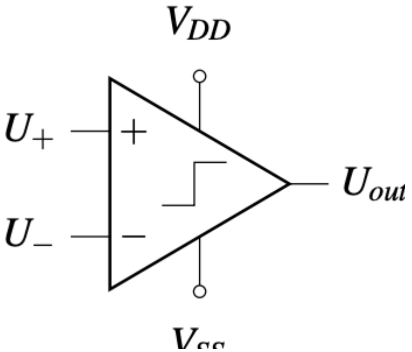
Measure V with open

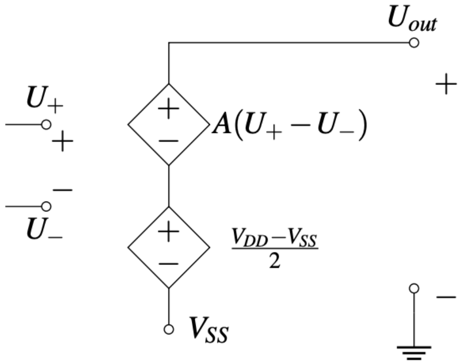
$R_{Th} = V_{Th}/I_N$

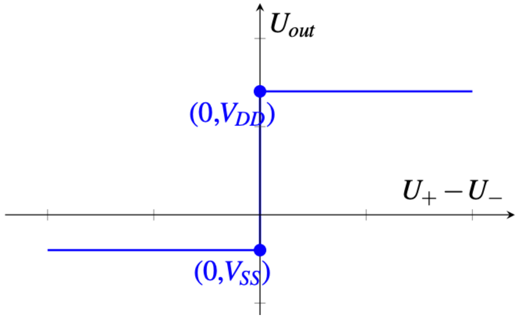
Norton Equivalent Circuit



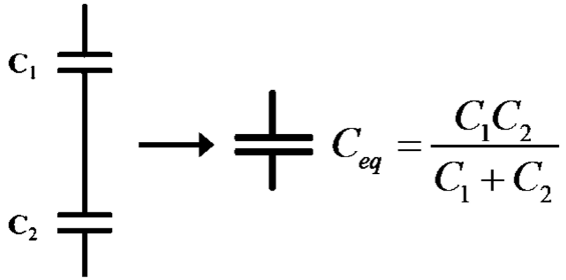
Measure I with short



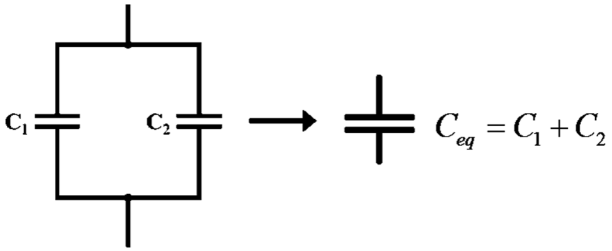




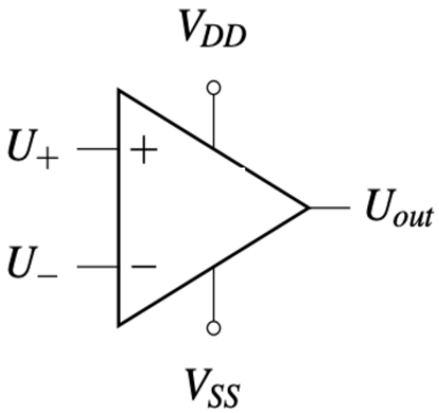
Capacitors in Series

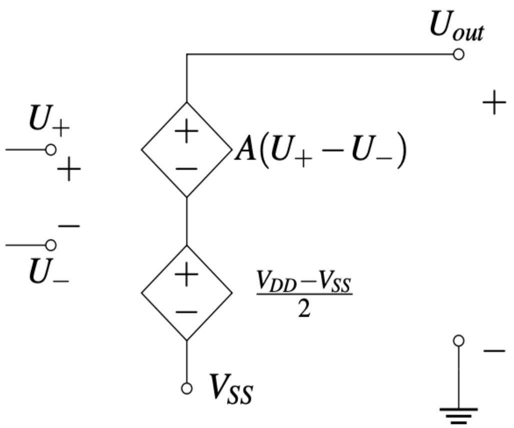


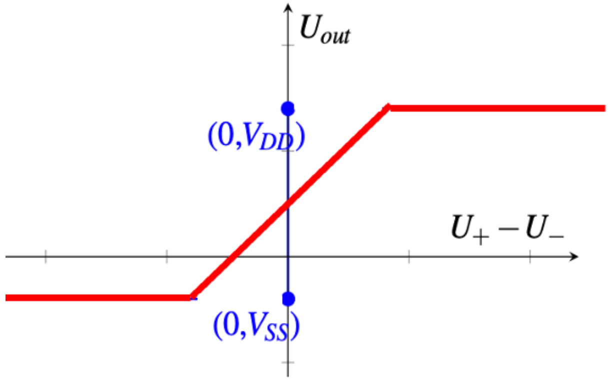
Capacitors in Parallel



Recap: Op Amps





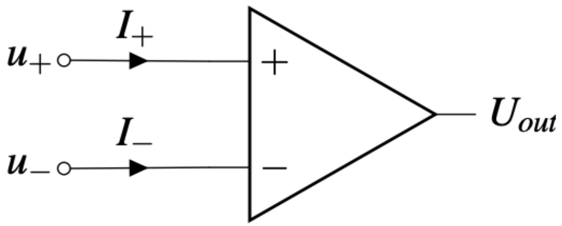


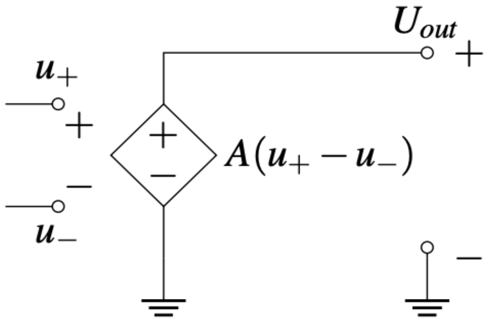
Golden Rules

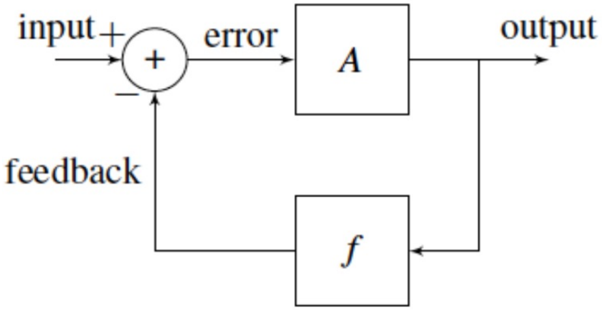
#1: $I_+ = I_- = 0$

#2: $u_+ = u_-$

Only in negative feedback and A= ∞







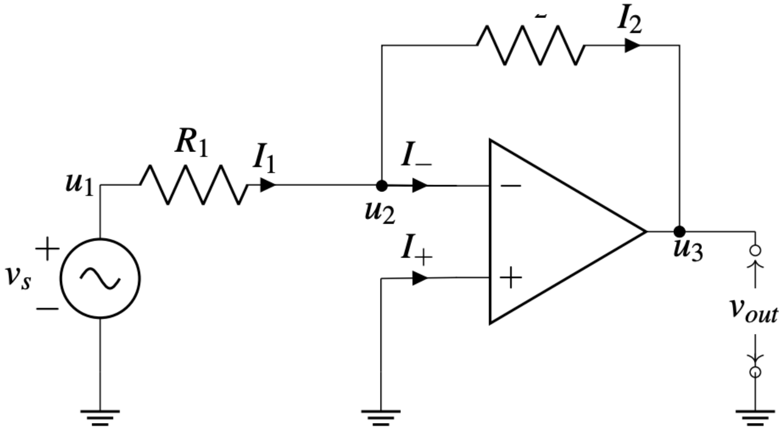
$$\frac{S_{out}}{S_{in}} = \frac{A}{1 + Af}$$

Common Prefixes used with SI Units			
Prefix	Symbol	Meaning	Order of Magnitude
giga-	G	1 000 000 000	10^9
mega-	M	1 000 000	10^6
kilo-	k	1 000	10^3
hecto-	h	100	10^2
deka-	da	10	10^1
	base unit	1	10^0
deci-	d	0.1	10^{-1}
centi-	c	0.01	10^{-2}
milli-	m	0.001	10^{-3}
micro-	μ	0.000 001	10^{-6}
nano-	n	0.000 000 001	10^{-9}

Recap: Summary of Useful Configurations

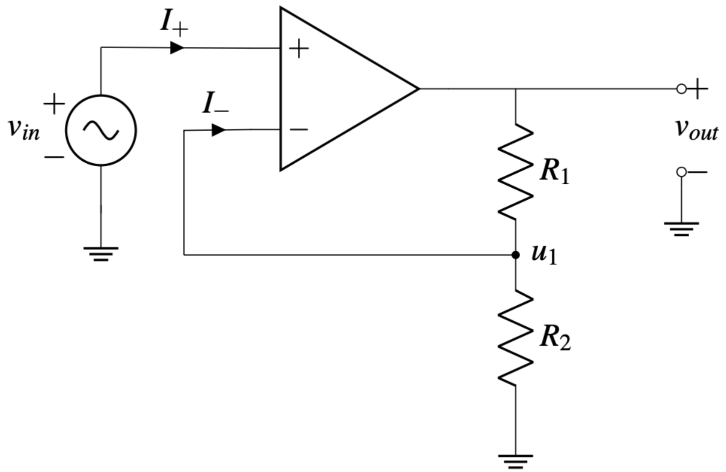
Inverting Amplifier

$$v_{out} = -\frac{R_2}{R_1} \cdot v_{in}$$



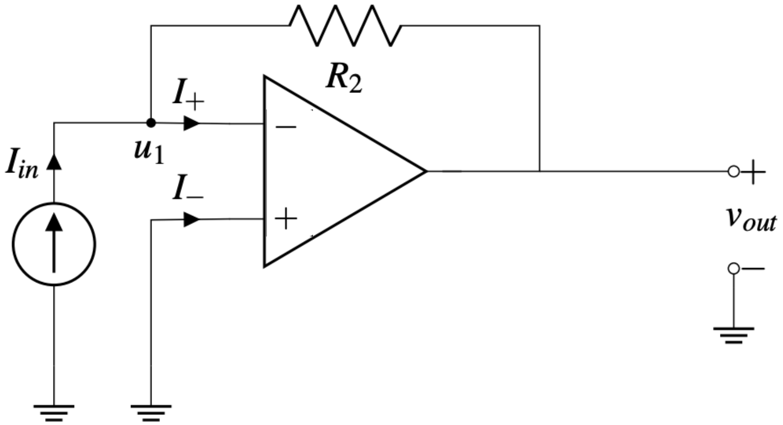
Non-inverting Amplifier

$$v_{out} = \left(1 + \frac{R_1}{R_2}\right) \cdot v_{in}$$

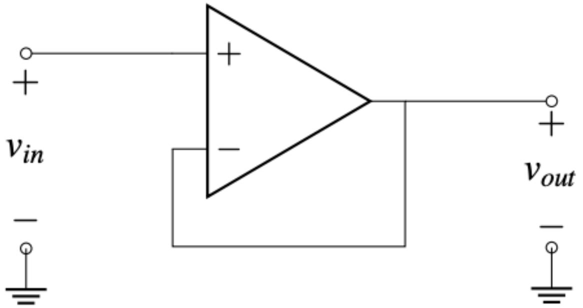


Trans-resistance Amplifier

$$v_{out} = -R_2 \cdot I_{in}$$



Unity Gain Buffer



$$v_{in} = v_{out}$$

Print me!

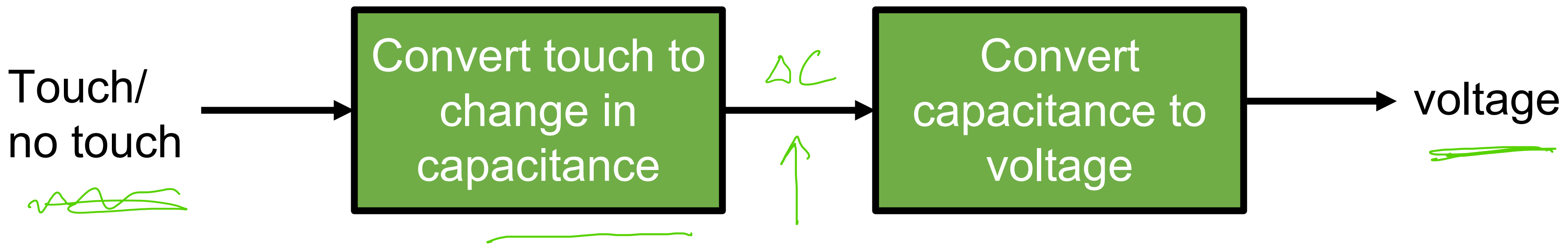
Today: Design!

Step 1: Specification

- Concretely restate the goals of the design
- Cut through all the words and pull out the important features

Step 2: Strategy

- Describe your strategy in the form of a block diagram
- Start by thinking about what you can measure vs. what you want to know



Step 3: Implementation

- Design the circuits and systems described in your strategy
- Choose the best circuit topology for the given constraints (e.g. inputs and outputs)

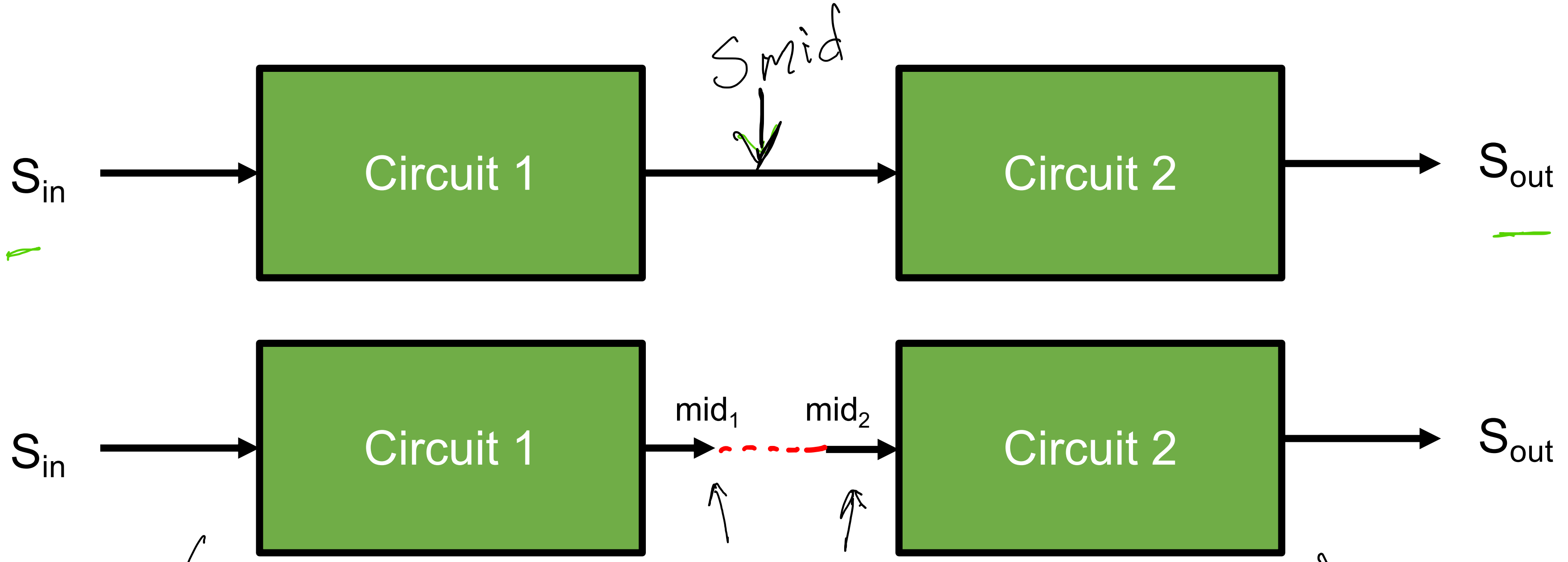
Today: Design!

Step 4: Verification

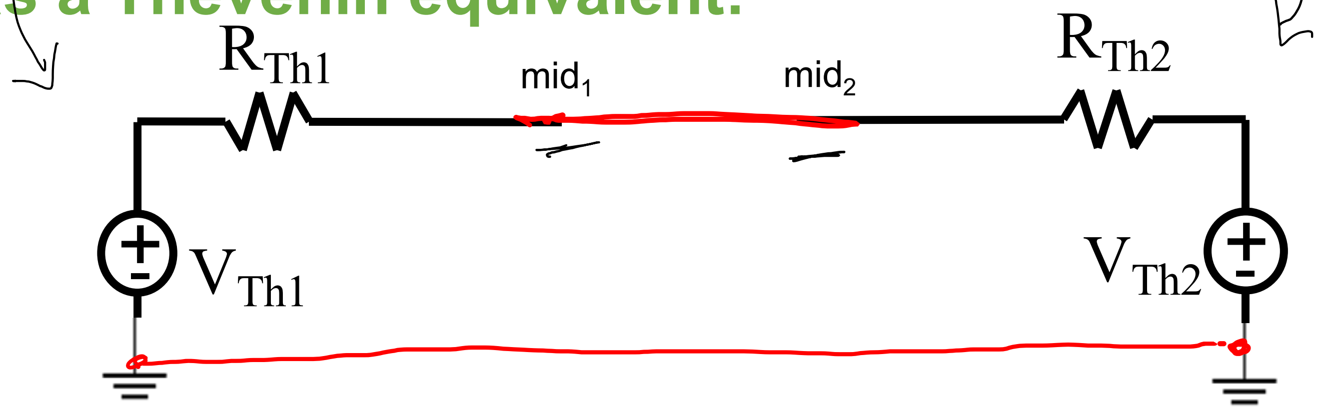
- Check that your design from Step 3 does what you specified in Step 1
- This extremely important step is the easiest to forget or not do thoroughly
- Check block-to-block connections
- Does one block loading another block and cause it to behave differently than expected?
- Are there any contradictions (e.g. forgot to connect power supplies, shorted a component, etc.)

Cascading Blocks

We want to connect two blocks without changing their functionality:



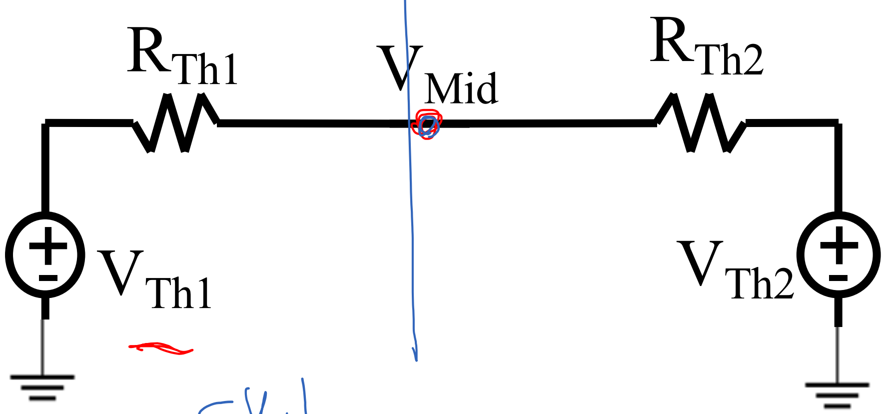
Each circuit has a Thevenin equivalent:

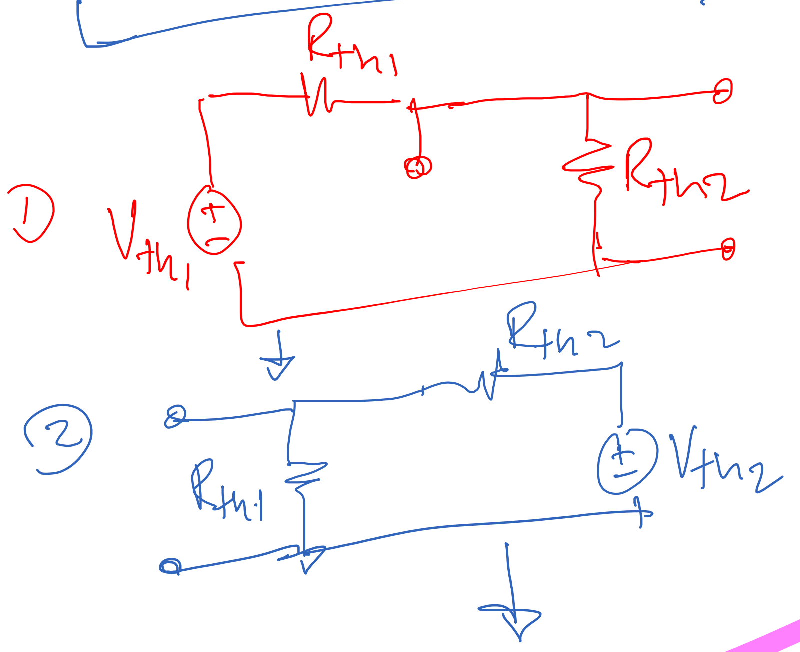


Cascading Blocks

$$V_{mid} = V_{th1}\frac{R_2}{R_1+R_2} + V_{th2}\frac{R_1}{R_1+R_2}$$

After connection:





after

same?

$V_{mid1} = V_{th1}$

I=0 open ckt

Before

Ideal Isolation:

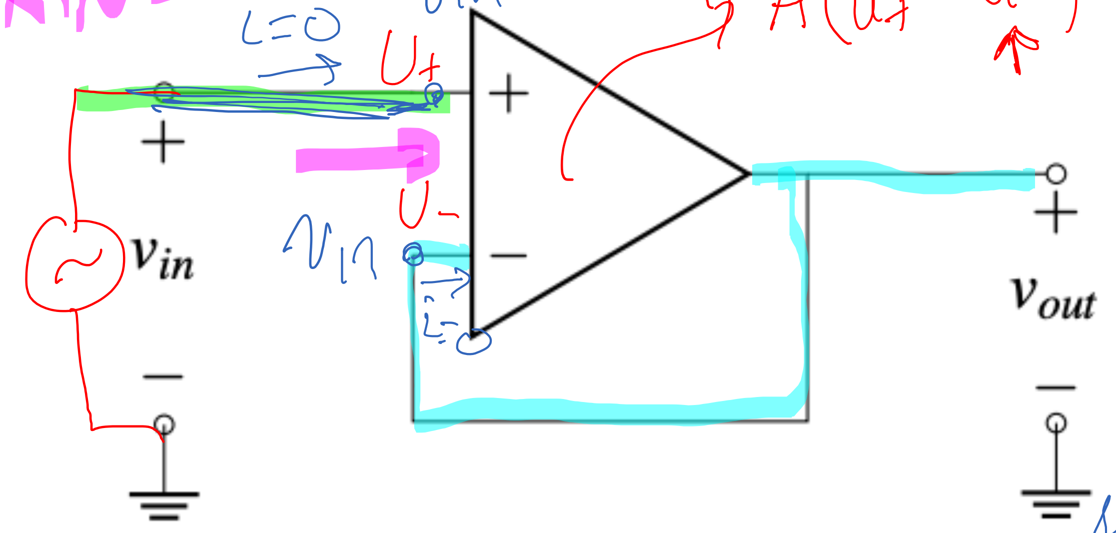
- From the perspective of Circuit 1: R_{th2} → Open Circuit $R_{th2} = \infty$ ← V_{th1} // V_{mid}
- From the perspective of Circuit 2: R_{th1} → 0 Ohms (just the voltage source)

* like an op amp!

$V_{mid} = V_{th1}$

Unity Gain Buffer → Ideal Isolation

$R_{IN} = \infty$



$A(u_+ - u_-) = V_{out}$

* #1: $I_+ = I_- = 0$

* #2: $u_+ = u_-$

Only in negative feedback and A= ∞

① turn off ind. source

② disturb the output

✓ negative FB

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

$A_v = \frac{V_{out}}{v_{in}}$

$V_{out} = A_v \cdot v_{in}$

$u_+ = v_{in}$

$u_- = v_{in}$ $\quad u_- = V_{out}$

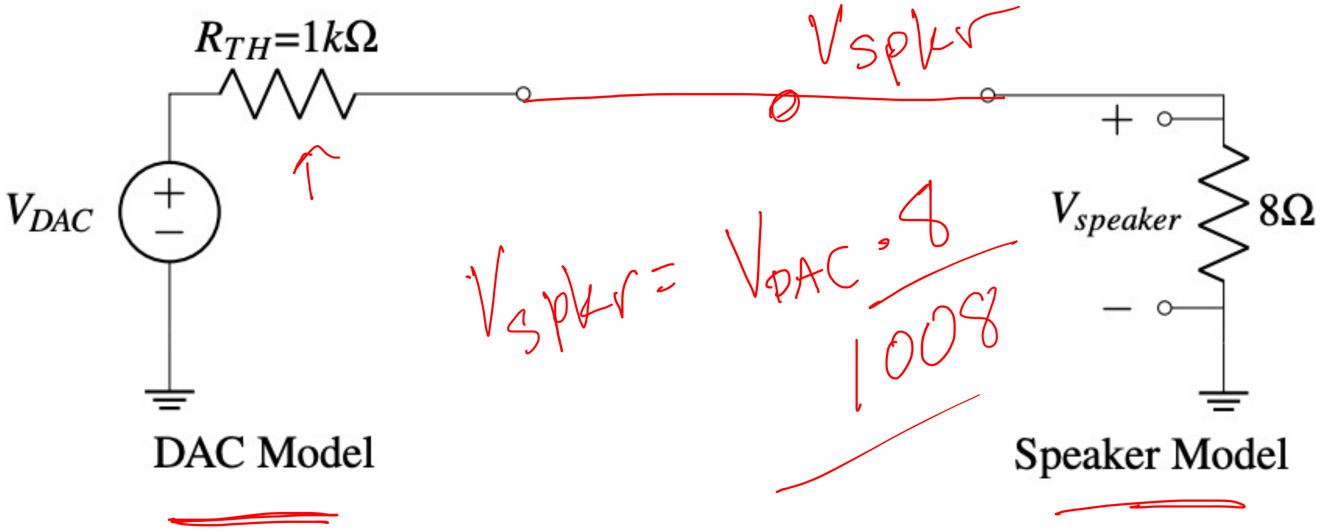
$u_- = \boxed{V_{out} = v_{in}}$

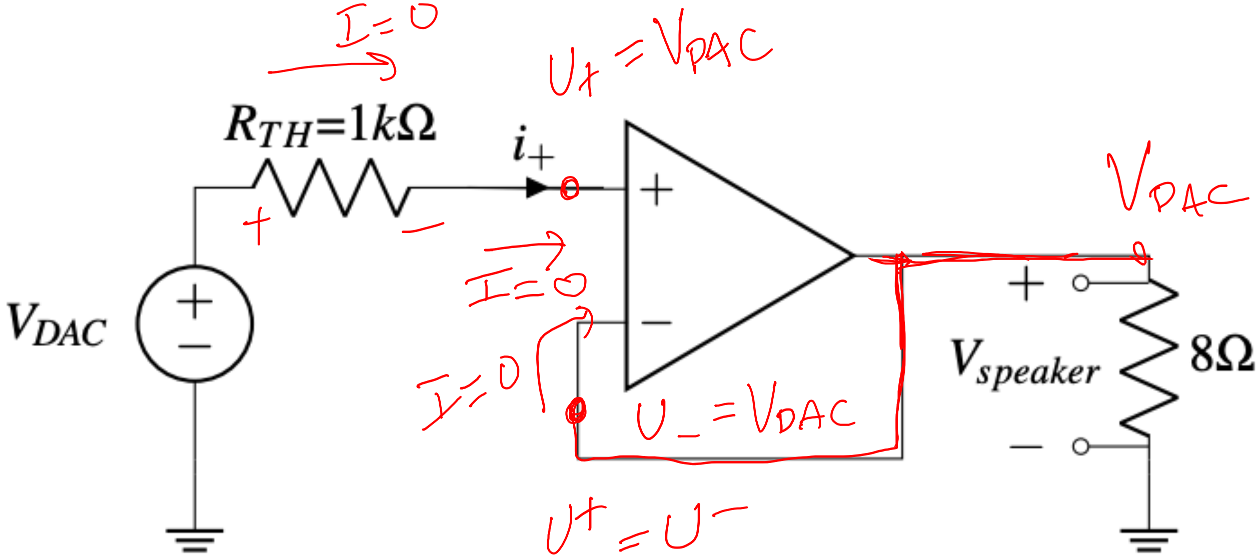
$\therefore \boxed{A_v = \frac{V_{out}}{v_{in}} = 1}$

* $R_{in} = \infty$ or open circuit * $R_{out} = 0\ \Omega$ or short ckt

Unity Gain Buffer → tradeoffs

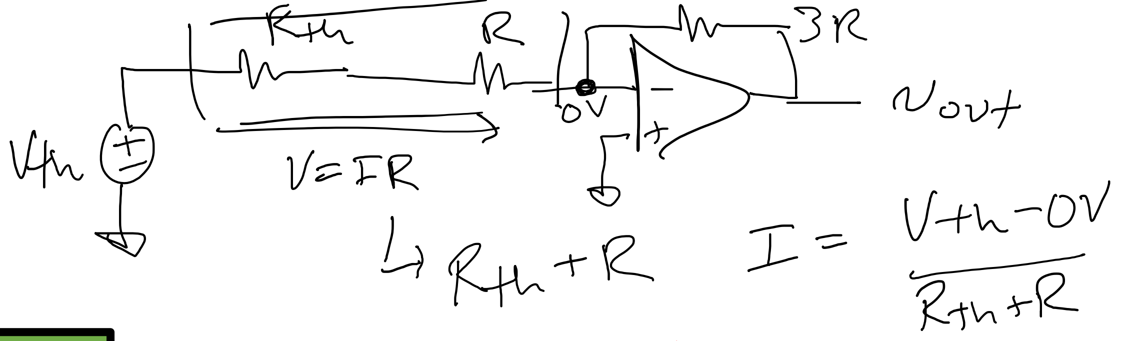
(UGB)
+ ideal isolation
+ no change in gain
− power
− area/volume
− complexity



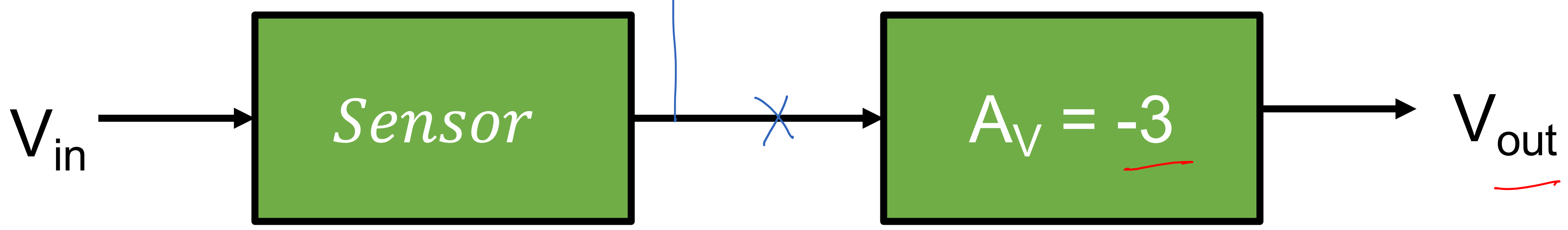


* Vspeaker = VDAC

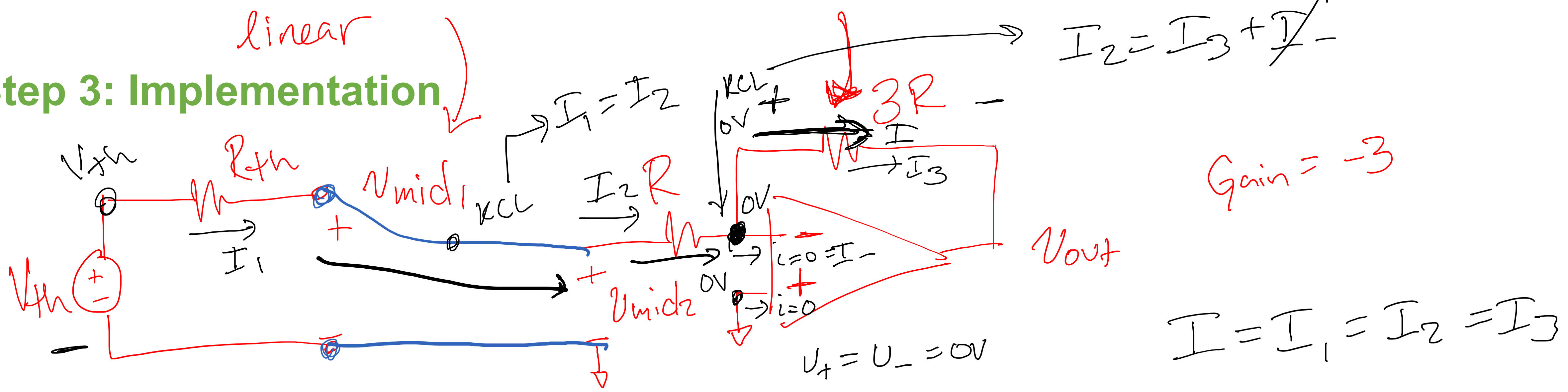
Design Example 1



Step 2: Strategy



Step 3: Implementation



Step 4: Verification

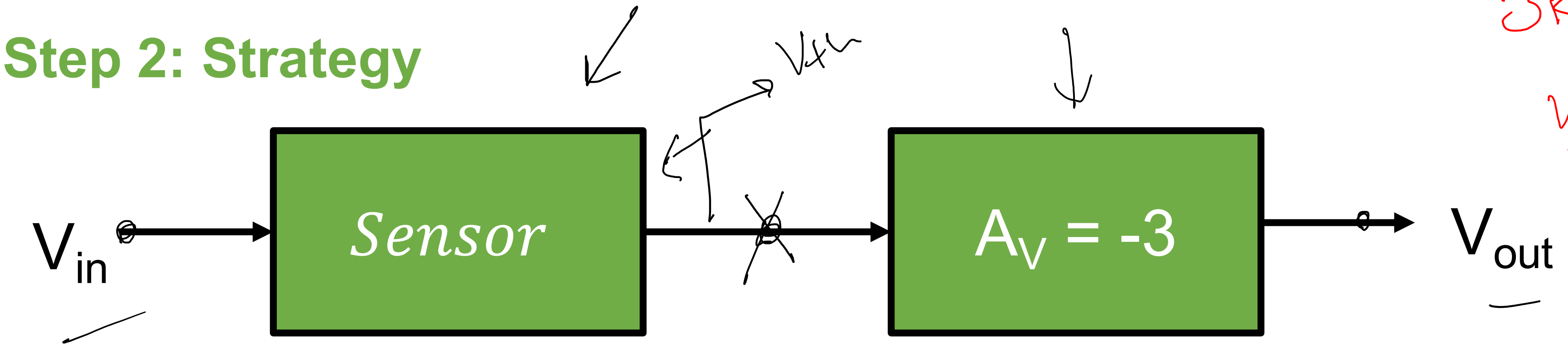
Design Example 1

$$\frac{-V_{out}}{3R} = \frac{V_{th}}{R_{th}+R}$$

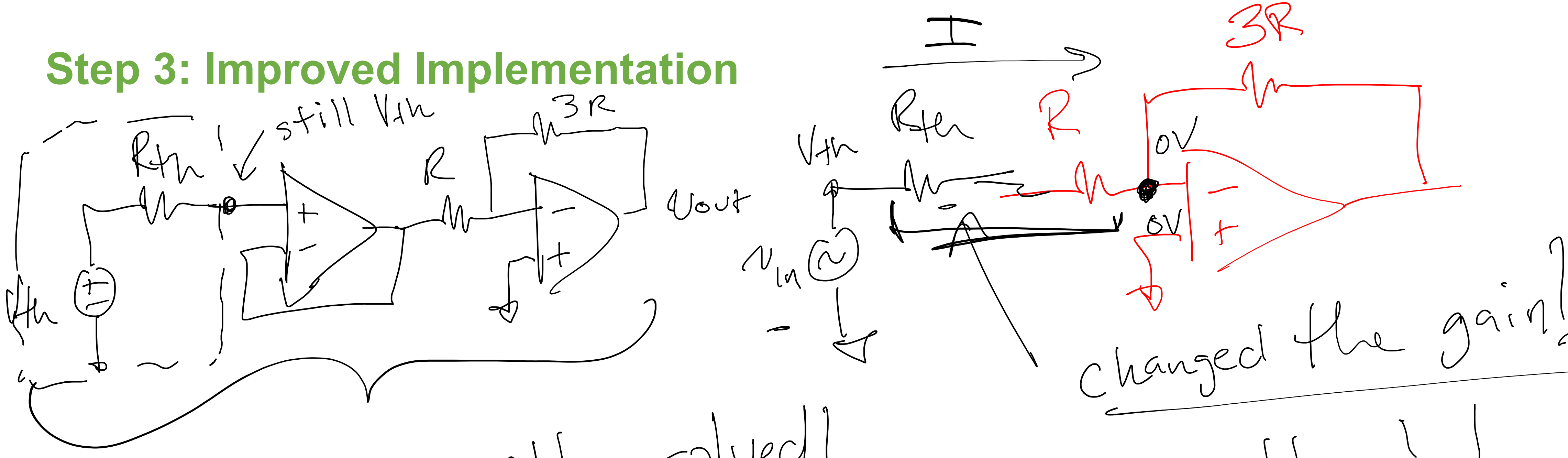
$$\frac{V_{out}}{V_{th}} = \frac{-3R}{R_{th}+R}$$

wanted 3!

Step 2: Strategy



Step 3: Improved Implementation



changed the gain!

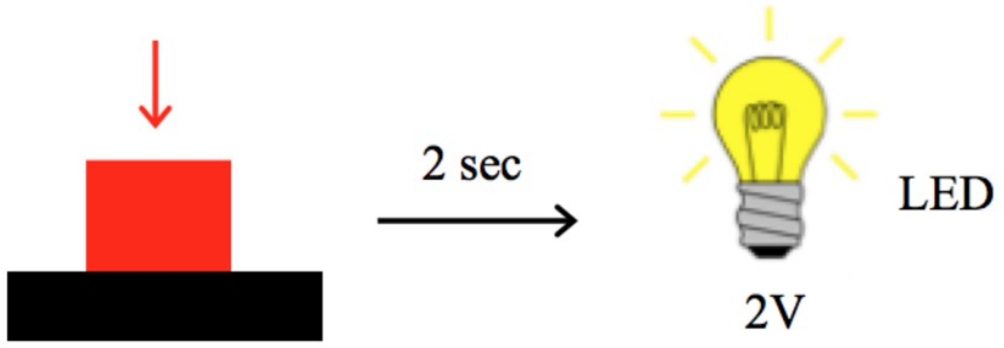
Step 4: Verification

problem solved!

problem!!

Design Example 2

Your boss comes to you and asks you to build a countdown timer that will turn on an LED 2 seconds after a button is pressed. She tells you that the LED turns on when 2V is applied across it.

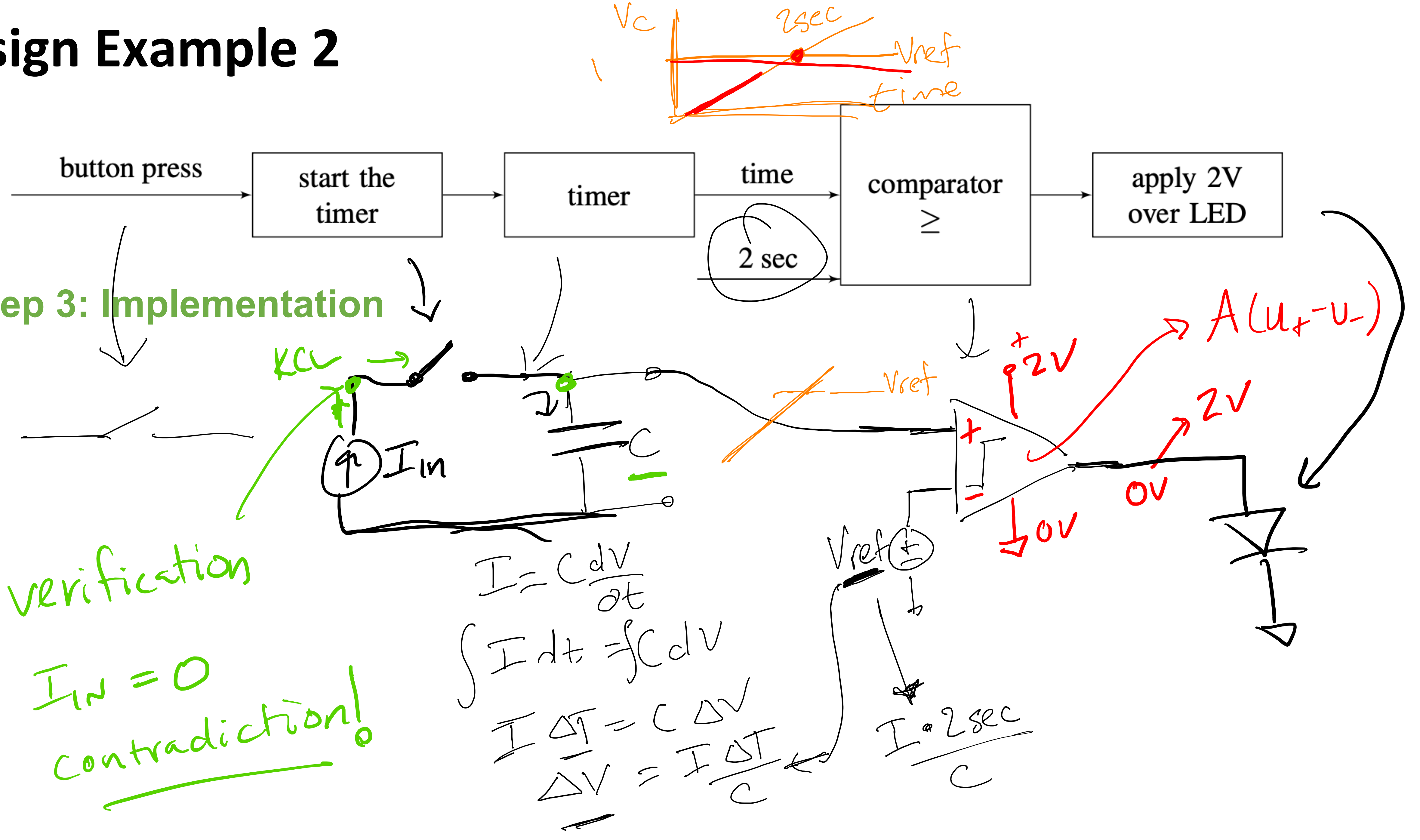


Step 1: Specification: Press button, measure 2 seconds, and then apply 2V across an LED.

Step 2: Strategy

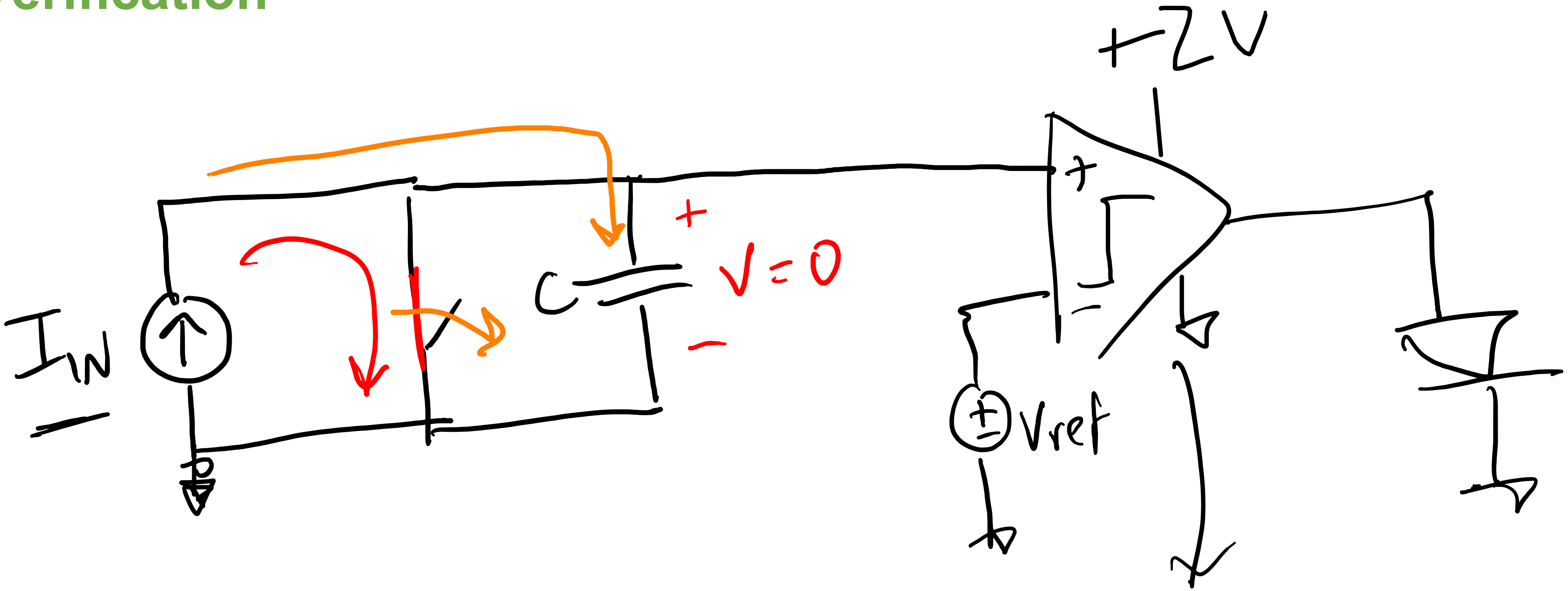
Design Example 2

Step 3: Implementation



Design Example 2

Step 4: Verification



- You can pretty much design a circuit to do anything
  - Play music
  - Recharge your batteries
  - Talk to a satellite
  - Run ChatGPT
  - Call your mom
  - Read your mind
  - *Your ideas here…*

The End

Just kidding. Like circuits? EECS16A → EECS16B → EE105 → EE140 & EECS151 → EE194