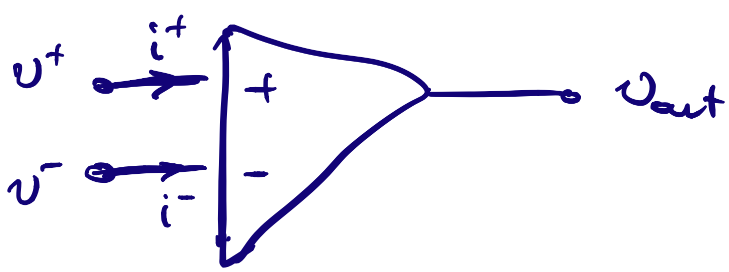
EECS 16A - Module 2

Today: * Quick Review
* Inverting Amplifier
* Cascading Ckt Blocks
* Design Example

Logistics

- OH right after lecture (Panos)
  - same link as Prof. Ranade
- No extension for MT2 Redo

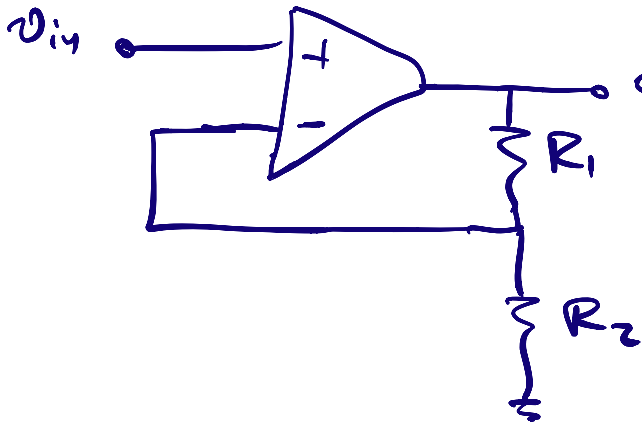
Review: Op-Amp Golden Rules



GR #1 : $i^+ = i^- = 0$ Always

GR #2 : $v^+ = v^-$ For an Op-Amp in Negative Feedback and with infinite gain A

Non-Inverting Amplifier



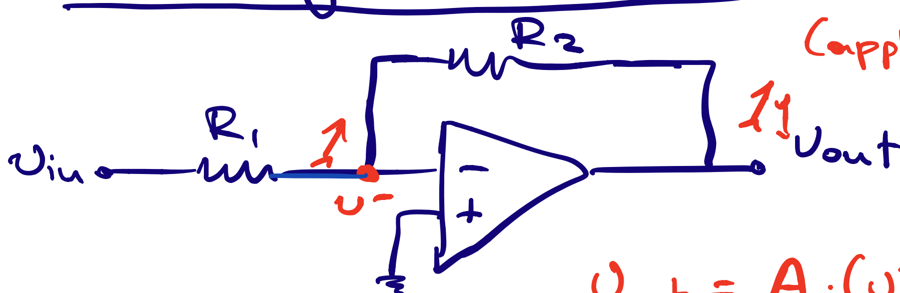
$$v_{out} = \left(1 + \frac{R_1}{R_2}\right) \cdot v_{in}$$

$\left(1 + \frac{R_1}{R_2}\right)$ → Voltage gain

Non-inverting because the voltage gain is always > 0

Inverting Amplifier

(apply disturbance)

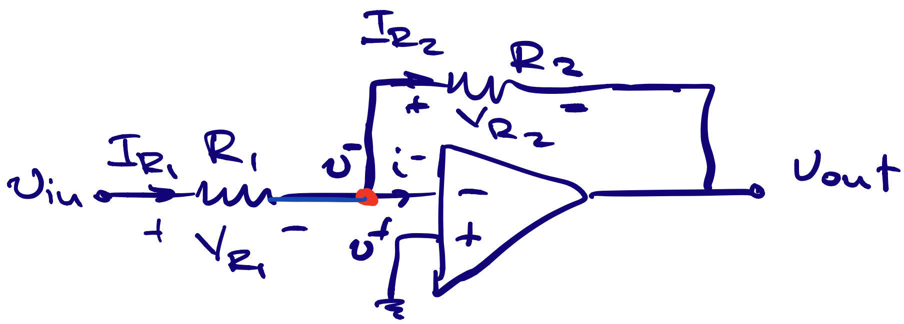


$$v_{out} = A \cdot (v^+ - v^-)$$

if $v_{out} \uparrow \Rightarrow v^- \uparrow \Rightarrow v_{out} \downarrow$

Established Negative Feedback!

Let's analyze this circuit:



KCL on v^-: $I_{R_1} = I_{R_2} + \cancel{i^-}$ → 0 (GR #1)

Ohm's law $\Rightarrow \dfrac{V_{R_1}}{R_1} = \dfrac{V_{R_2}}{R_2}$

$$\Rightarrow \frac{v_{in} - v^-}{R_1} = \frac{v^- - v_{out}}{R_2} \quad (1)$$

GR #2: $v^- = v^+ = 0 \quad (2)$

$$(1) \overset{(2)}{\Rightarrow} \frac{v_{in}}{R_1} = -\frac{v_{out}}{R_2}$$

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

→ Voltage gain

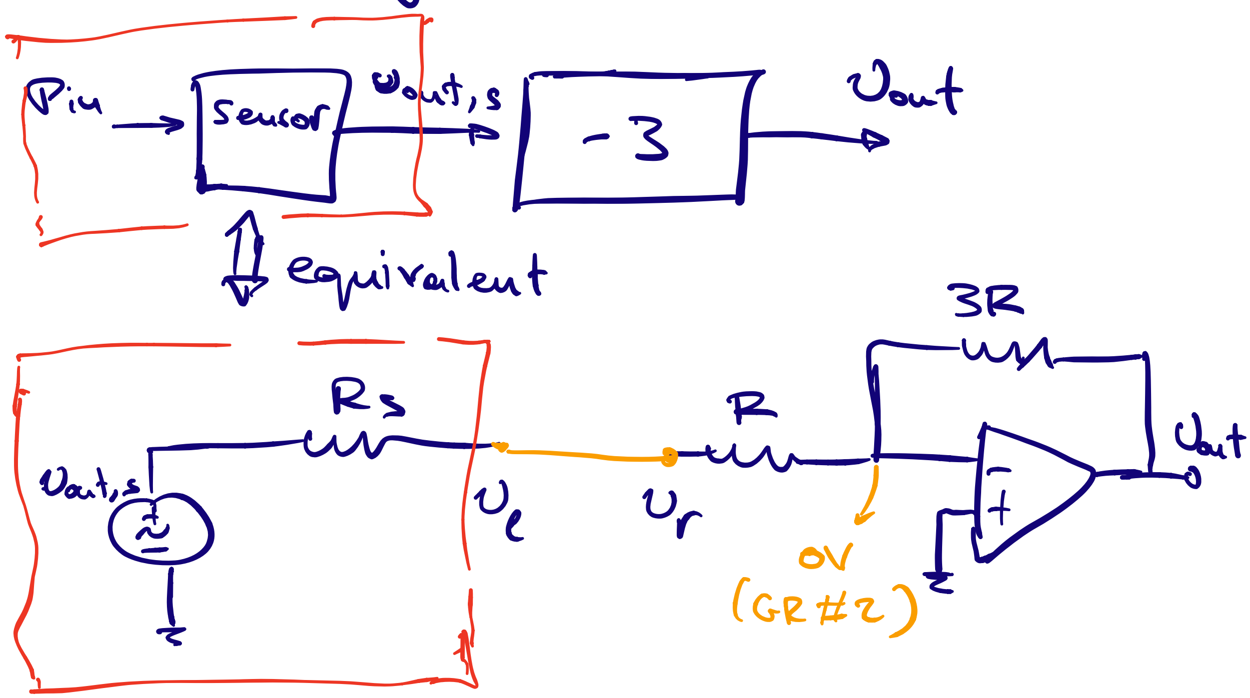
Why negative coefficients?

$$v_{out} = a v_{in_1} + b v_{in_2} + c v_{in_3} + \dots$$

↓ want $b < 0$

Inversion is a very useful operation in general (for signal processing, sensing, matrix-matrix mult)

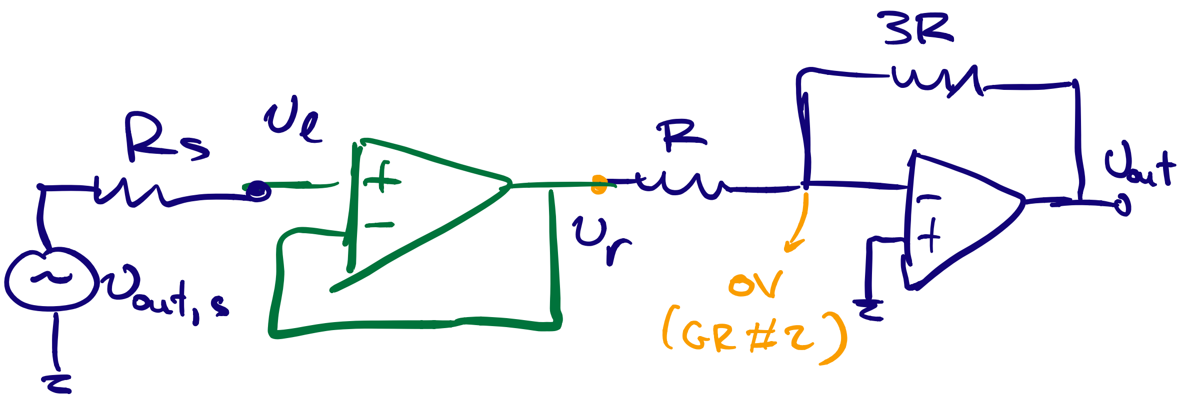
Cascading Circuit Blocks



Before connection: $v_\ell = v_{out,s}$ ✓

After connection: $v_\ell = v_r = \frac{R}{R+R_s} v_{out,s} \neq v_{out,s}$:(

Solution: Add a buffer!



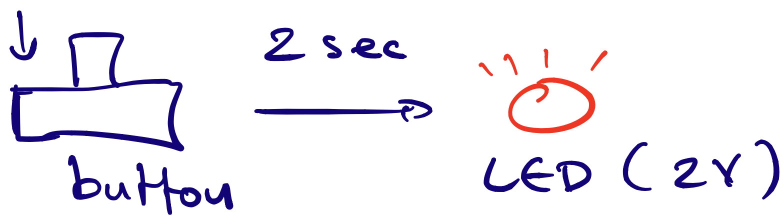
(GR #2)

$$v_r = v_- = v_+ = v_e = v_{out,s}$$:) ✓

Takeaway: Safe way to connect ckt blocks is by adding buffers in-between

DESIGN EXAMPLE

Countdown Timer Circuit

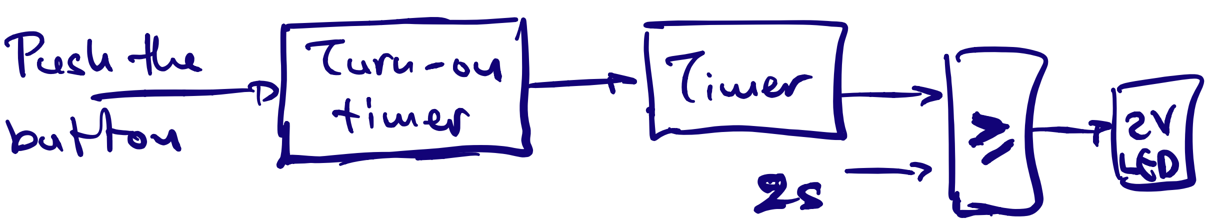


Step 1 : (Specification)

Build a circuit that after a button is pushed measures 2s and then applies 2V on an LED.

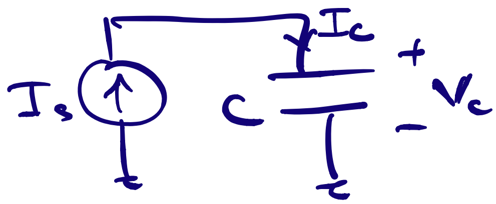
Assumption: You can only press the button once.

Step 2 : (Strategy)

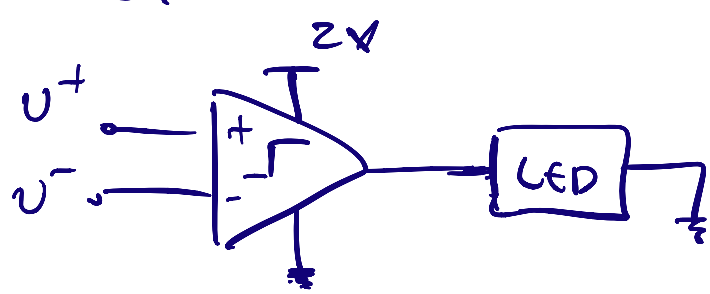


Step 3 : (Implementation)

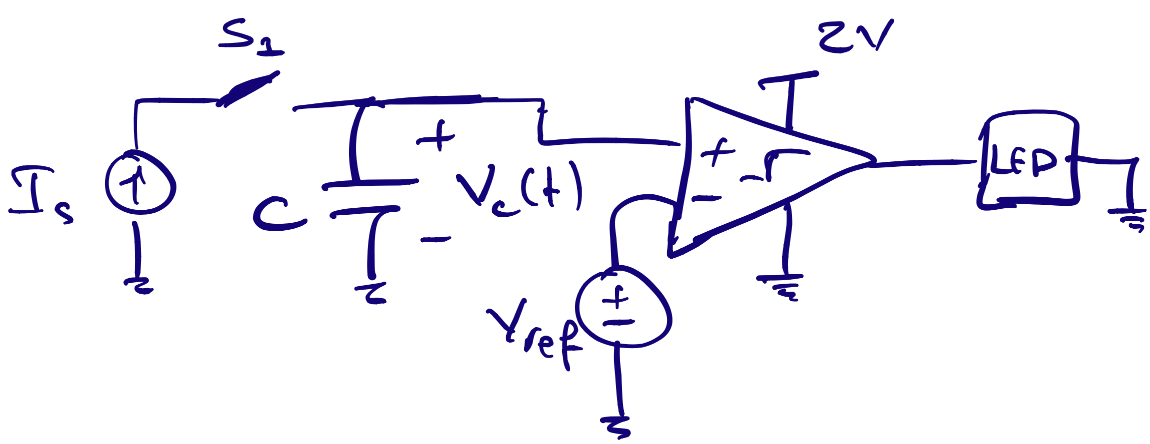
Turn-on ckt :  (switch)

Timer : 

$$I_c = C \cdot \frac{dV_c}{dt} \Rightarrow V_c(t) = \frac{I_s}{C} t + V_c(0)$$

$\geq$: 

Putting it all together:



Set $V_{ref} = V_c(2)$

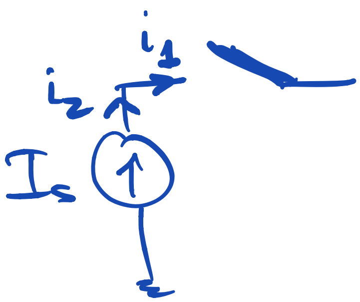
Step 4: (verify)

$$V_c(t) = \frac{I_s}{C} t + V_c(0)$$

Prob. #1

↳ ? unknown!

Before button pushed:



KCL: $i_1 = i_2$

$i_1 = 0$ (open-ckt definition)

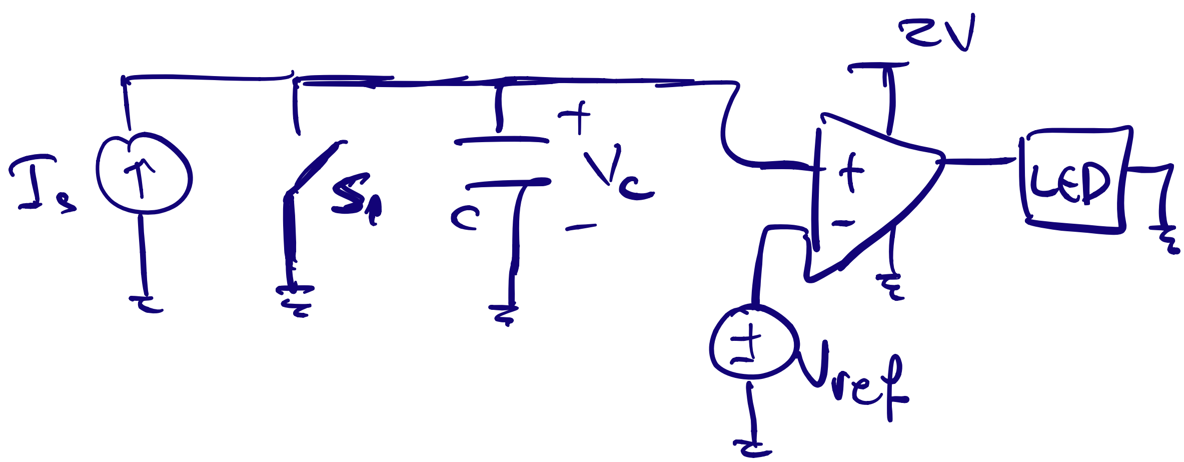
$i_2 = I_s \neq 0$

↳ $I_s = 0$: contradiction inconsistency

Prob. #2

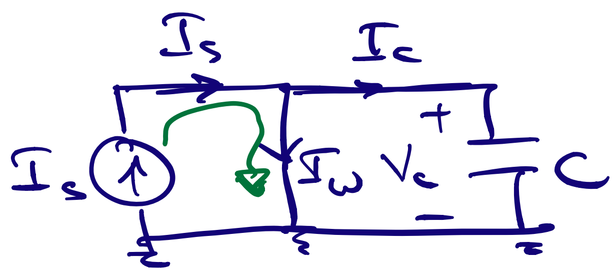
Solution: Connect the switch to ground.

Revisit Step 3:



NOTE: Now the switch is CLOSED BEFORE the button is pushed and OPEN after it is pushed

Before the button is pushed:



$V_c = 0 = \text{constant}$

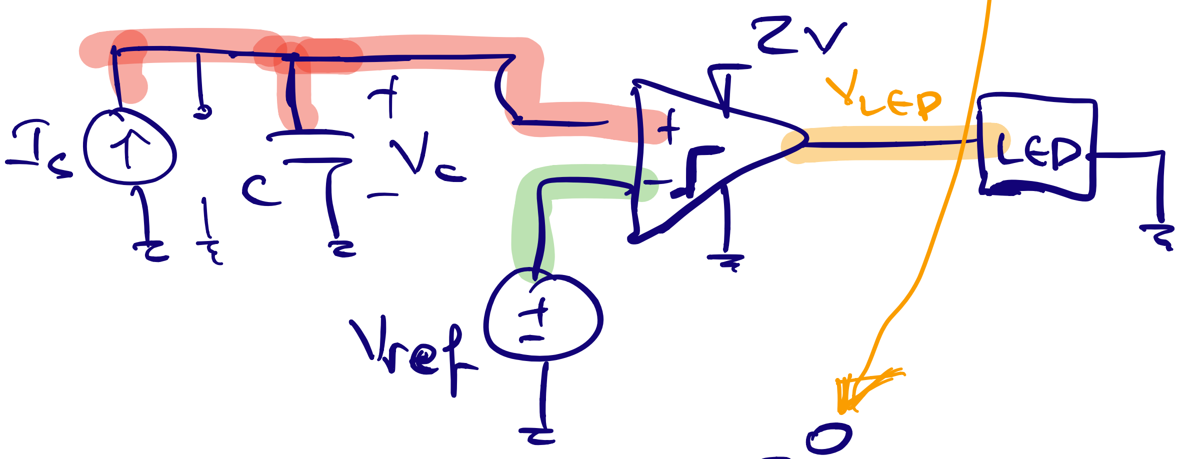
$I_c = C \cdot \frac{dV}{dt} \rightarrow 0$

KCL:

$I_s = I_w + I_c$, but $I_c = 0$

$\Rightarrow I_w = I_s$ (path of least resistance)

After the button is pushed



$$V_c(t) = \frac{I_s}{C} t + \cancel{V_c(0)}^{\,0}$$

$$V_{ref} = V_c(2) = \frac{I_s}{C} \cdot 2$$