EE16A Lecture 11 - Module 2/3

* current source (design example)
* more examples with caps & op-amps
* Module 3 - locationing intro - Laura welcome back!

How do we build a current source out of op-amps, R's and voltage supplies?

---

step 1: Restate objectives: Build a current source - - a device that has a constant current I flowing through regardless of the voltage across it.

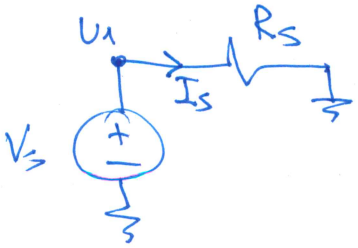
step 2: Strategy

Ohm's law $V_{elem} = I_{elem} R_{elem}$

$I_{elem} = \frac{V_{elem}}{R_{elem}}$

step 3: Implement:

Attempt #1:

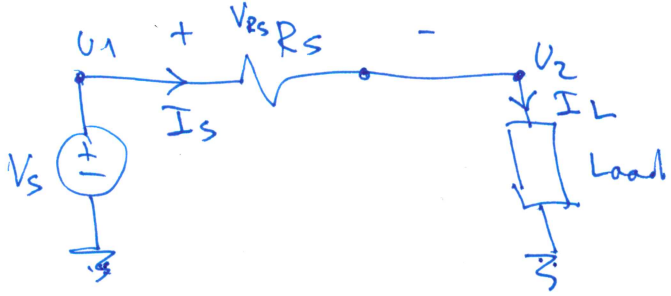


$V_1 = V_S$

$V_1 = I_S \cdot R_S = V_S$

$$I_S = \frac{V_S}{R_S}$$

(12)



(KCL) $I_S = I_L$

$$I_S = \frac{U_1 - U_2}{R_S} = \frac{V_S - U_2}{R_S}$$

to make I_S only a f-n of V_S, R_S

$\Downarrow$

$V_2 = 0$

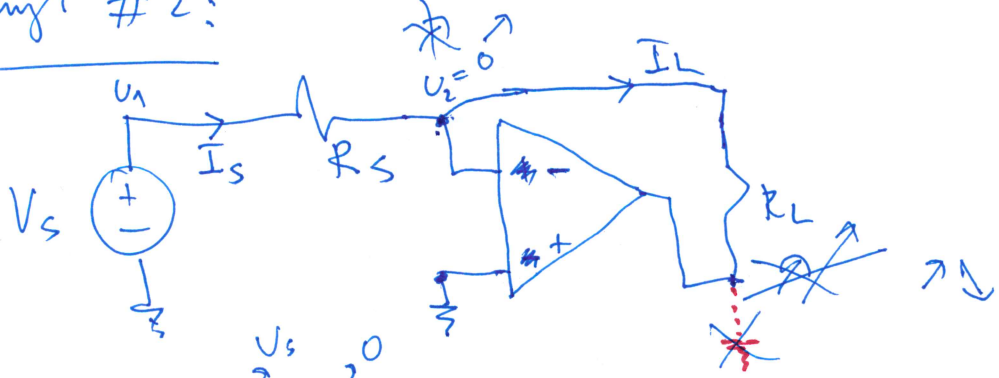
$\Downarrow$

$I_L = 0$

$\Downarrow$

$I_S = 0$

Attempt #2:



$I_L = I_S$

$$I_S = \frac{V_S - 0}{R_S} = \frac{V_S}{R_S}$$

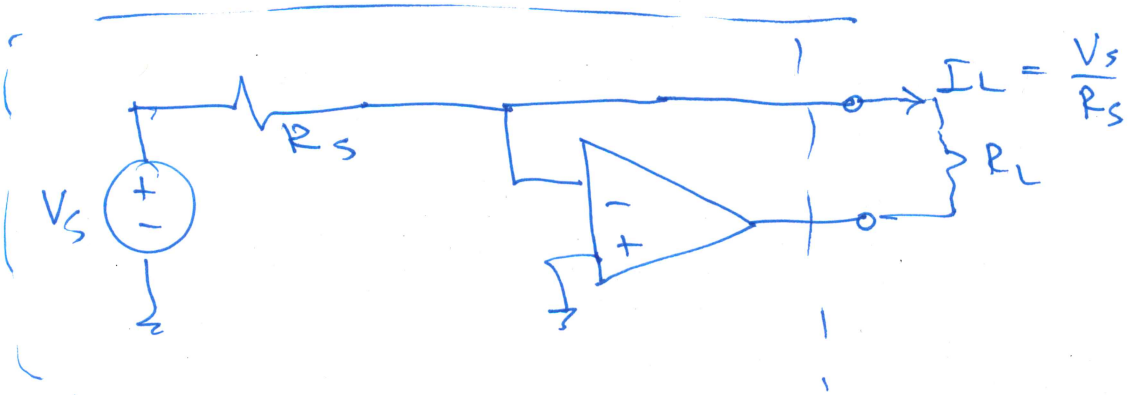
Almost a CS:

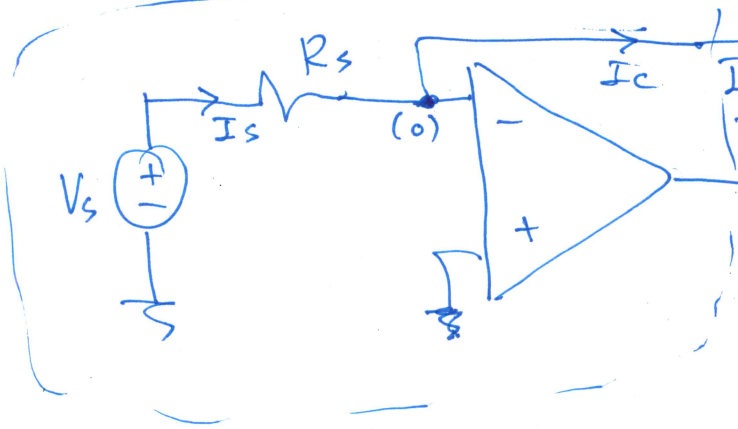
(1) Don't connect to ground externally

(2) Whatever you connect - must keep the op-amp in NFB.

(2)

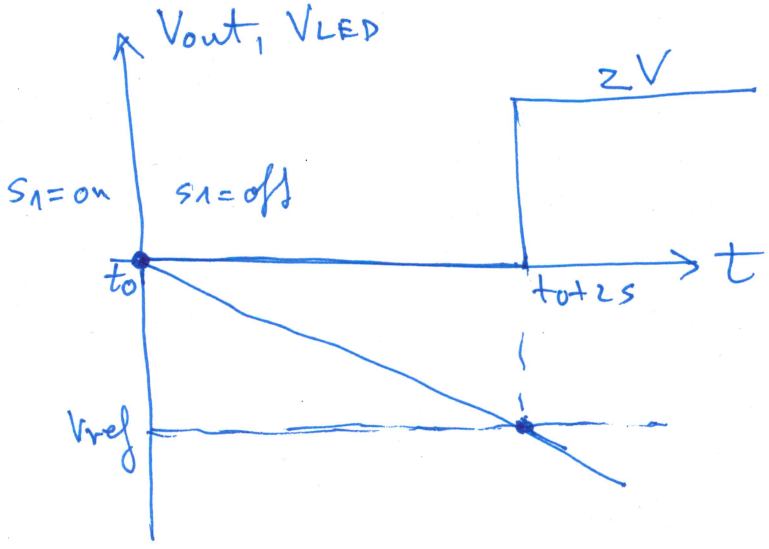
CS :





$V_{out} + V_{time} = 0$

$V_{out} = -V_{time}$



$I_S = \frac{V_S}{R_S}$

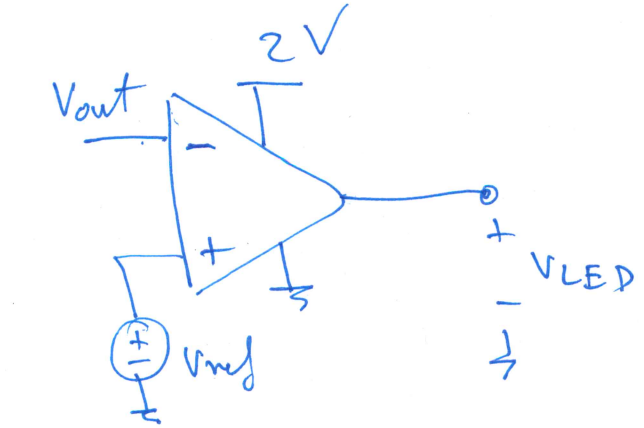
$I_C = I_S$

$I_C = C_{time} \cdot \frac{dV_{time}}{dt}$

$\frac{V_S}{R_S} = -C_{time} \cdot \frac{dV_{out}}{dt}$

$V_{out}(t) = -\frac{V_S}{R_S C_{time}} \cdot (t-t_0) + (V_{out}(t_0))$

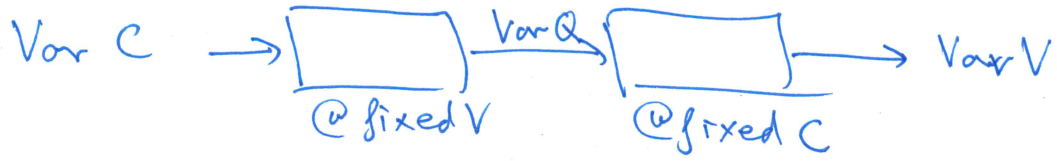
$V_{out}(t_0) = 0$

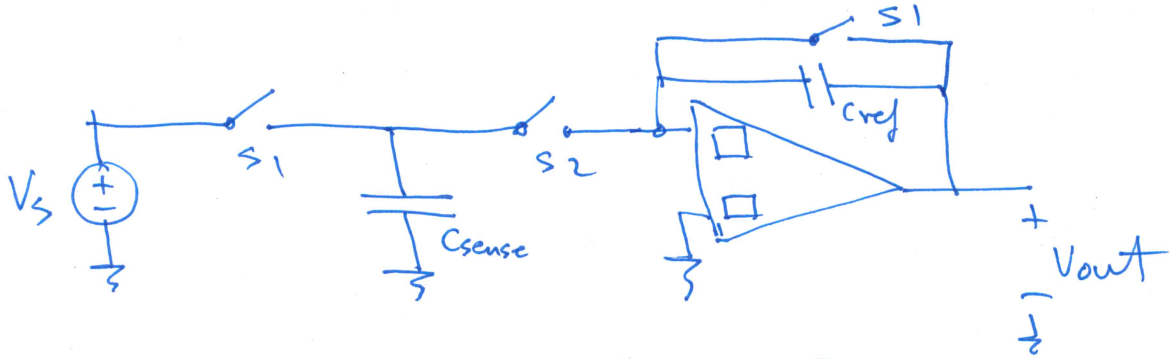


L4

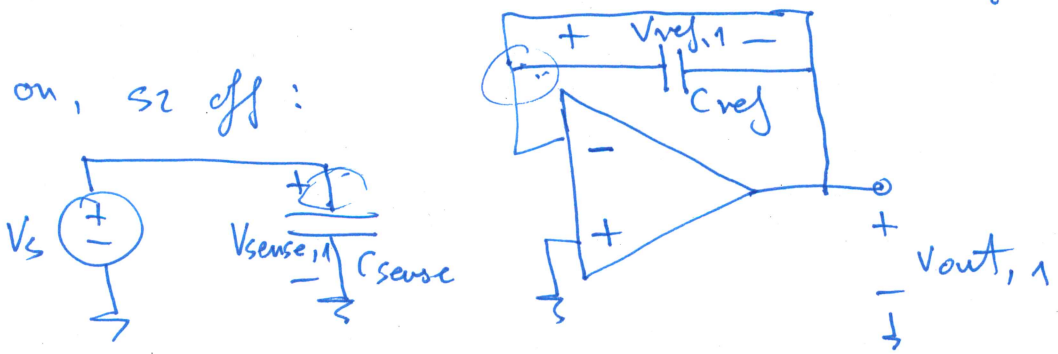
Q-amps with caps:

Remember the touchscreen





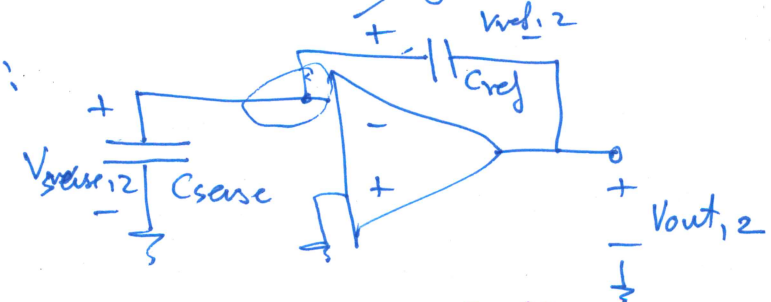
S1 on, S2 off:



$$Q_{sense,1} = C_{sense} \cdot V_{sense,1} = C_{sense} \cdot V_s$$

$$Q_{ref,1} = C_{ref} \cdot V_{ref,1} = 0$$

S1 off, S2 on:



$$Q_{sense,2} = C_{sense} \cdot V_{sense,2} \to 0 \quad (\#2\ GP)$$

$$Q_{ref,2} = C_{ref} \cdot V_{ref,2} = -C_{ref} \cdot V_{out,2}$$

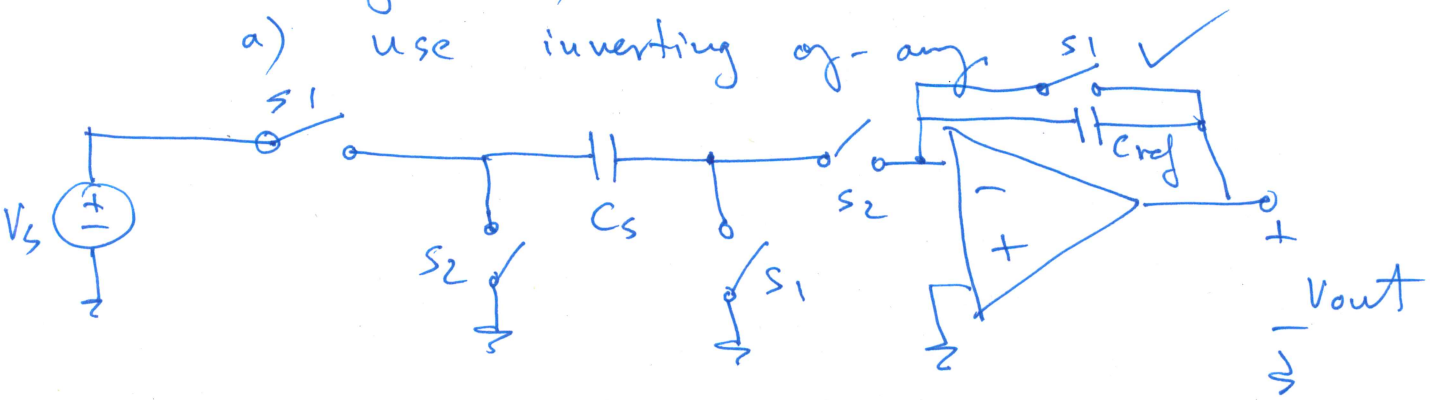
$$Q_{sense,1} + \cancel{Q_{ref,1}}^{0} = \cancel{Q_{sense,2}}^{0} + Q_{ref,2}$$

$$C_{sens} \cdot V_S = - C_{ref} \cdot V_{out,2}$$

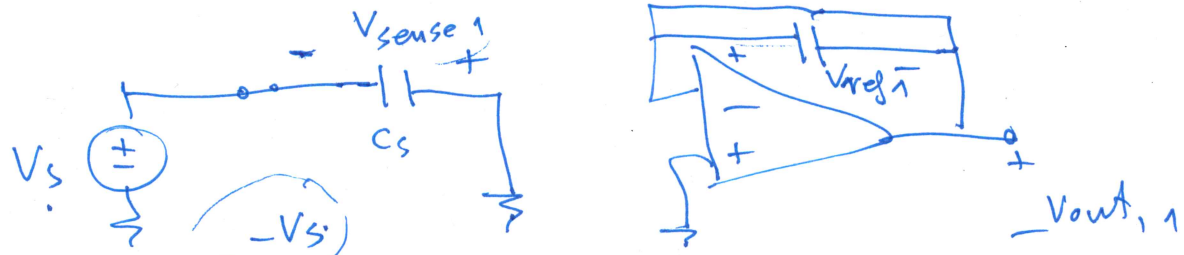
$$\boxed{V_{out,2} = - \frac{C_{sense}}{C_{ref}} \cdot V_S}$$

Get rid of (-1)

a) use inverting op-amp

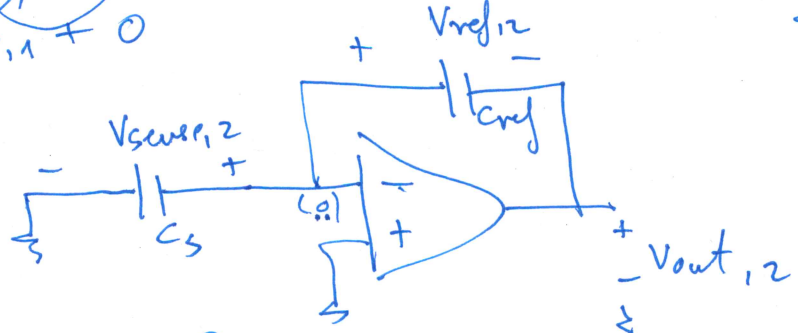


S1 on:



$$Q_{tot,1} = C_S \cdot V_{sense,1} + 0$$

S2 on:



$$Q_{tot,2} = C_S \cdot \cancel{V_{sense,2}}^{0} + C_{ref} \cdot \cancel{V_{ref,2}}^{(-V_{out,2})}$$

$$= - C_{ref} \cdot V_{out,2}$$

$$Q_{tot,1} = Q_{tot,2} \Rightarrow C_S \cdot (-V_S) = - C_{ref} \cdot V_{out,2}$$

$$\boxed{V_{out,2} = \frac{C_S}{C_{ref}} \cdot V_S}$$