Lecture 19 - Intro. to nonlinear circuit analysis

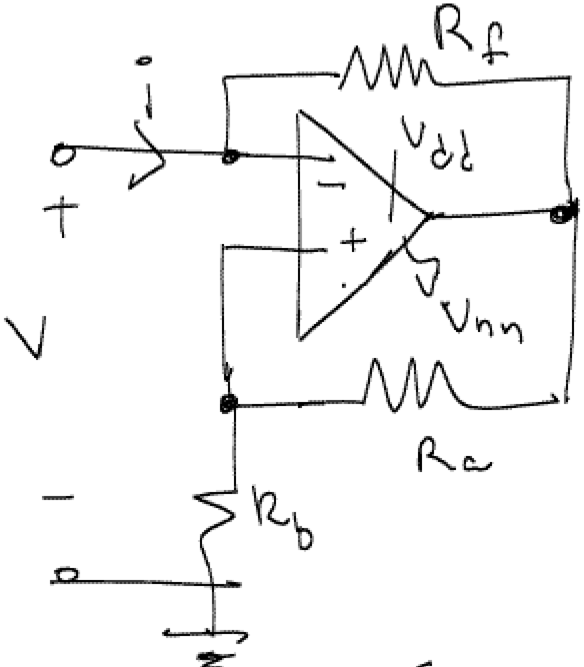
Administrivia

- → Extra HW problem for homework due this week [HW #7 actually, incorrectly numbered HW #8]
- → My Thursday evening office hours are in 277 Cory [5:00-7:00]

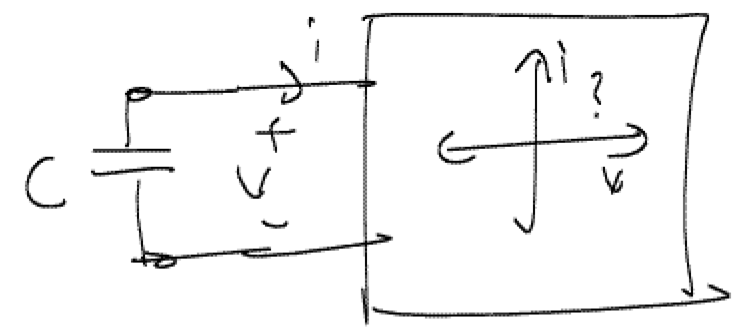
Rest of the semester [6 weeks left!]

- → This week: More op-amps } nonlinear
- → Next week: Diodes intro }
- → Midterm II [op-amps only]
- → Project, Diode circuits, conclusion.

Today: Negative resistance converter. → analysis
[i.e.. this week's lab]

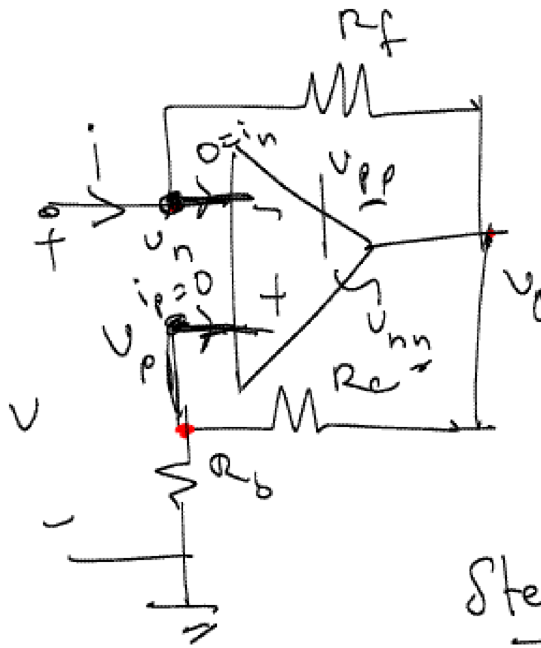


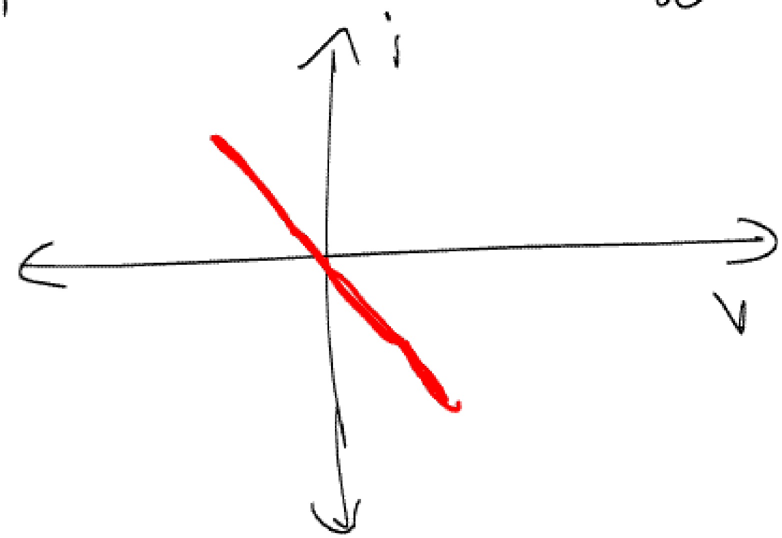
Goal: Plot i vs. v. Once we get i vs. v we will use only this relationship



(Note: $C > 0$, $R_a, R_b, R_f > 0$, $V_{dd} > 0$, $V_{nn} < 0$)

Note: (1) Circuit has both positive & negative feedback (explain difference on Thursday)



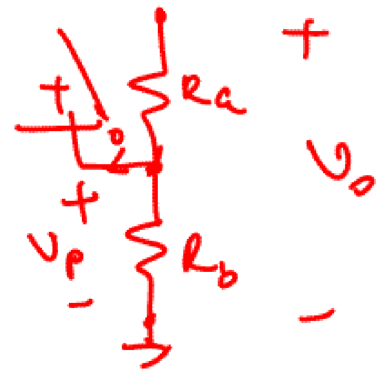


Step (1): Assume op-amp is in linear.

$$\Rightarrow v_o = A(v_p - v_n) \Rightarrow \boxed{v_p \approx v_n}$$

$\therefore$ $\boxed{v_n = v \Rightarrow v_p = v}$. Now, we know $i_n = i_p = 0$

$$\therefore \quad i = \frac{V - V_0}{R_f} \quad \text{— (1)}$$



$$\therefore \quad V_p = \frac{R_b}{R_a + R_b} V_0 \quad \left(\text{voltage divider}\right)$$

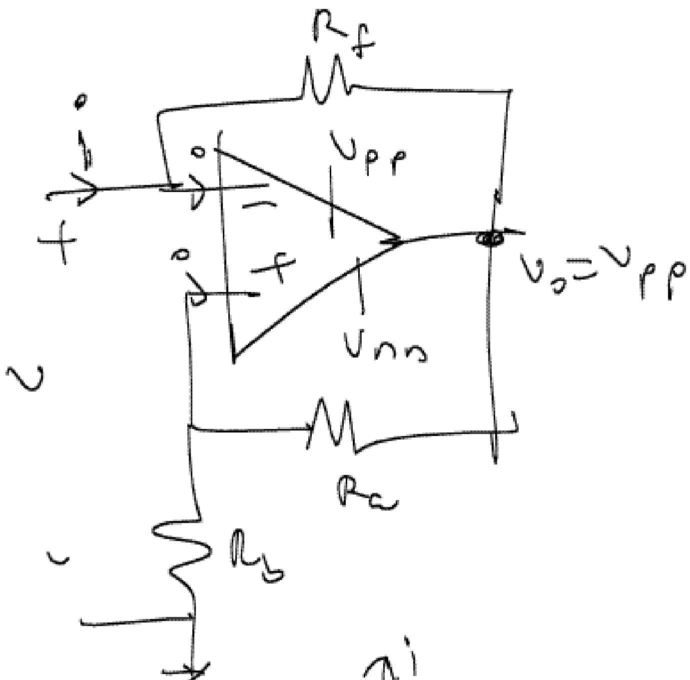
$$\Rightarrow V = \frac{R_b}{R_a + R_b} V_0 \Rightarrow \boxed{V_0 = \frac{R_a + R_b}{R_b} V} \quad \text{— (2)}$$

Substitute (2) in (1) $\Rightarrow$

$$i = \frac{V}{R_f} - \frac{1}{R_f}\left[\frac{R_a + R_b}{R_b} V\right]$$

$$\Rightarrow \boxed{i = \frac{-R_a}{R_f R_b} V}$$

Step (2): Assume op-amp is saturated (positive saturation)

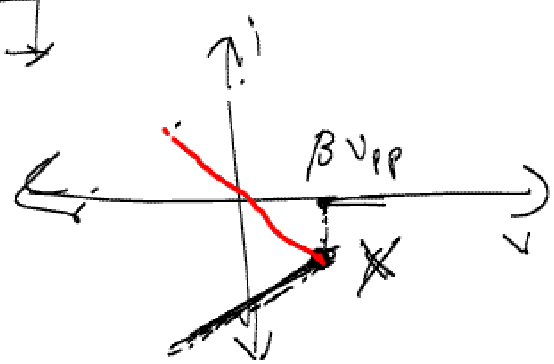


Note: $v_n \neq v_p$ because $v_o = V_{pp}$

$$i = \frac{v - v_o}{R_f}$$

$$i = \frac{v - V_{pp}}{R_f}$$

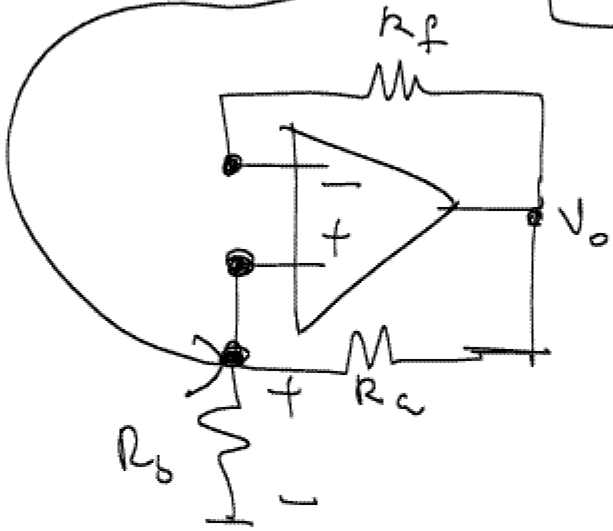
To find X (v_x, i_x)



$$\Rightarrow \frac{-R_a V_x}{R_f R_b} = \frac{V_x - V_{pp}}{R_f}$$

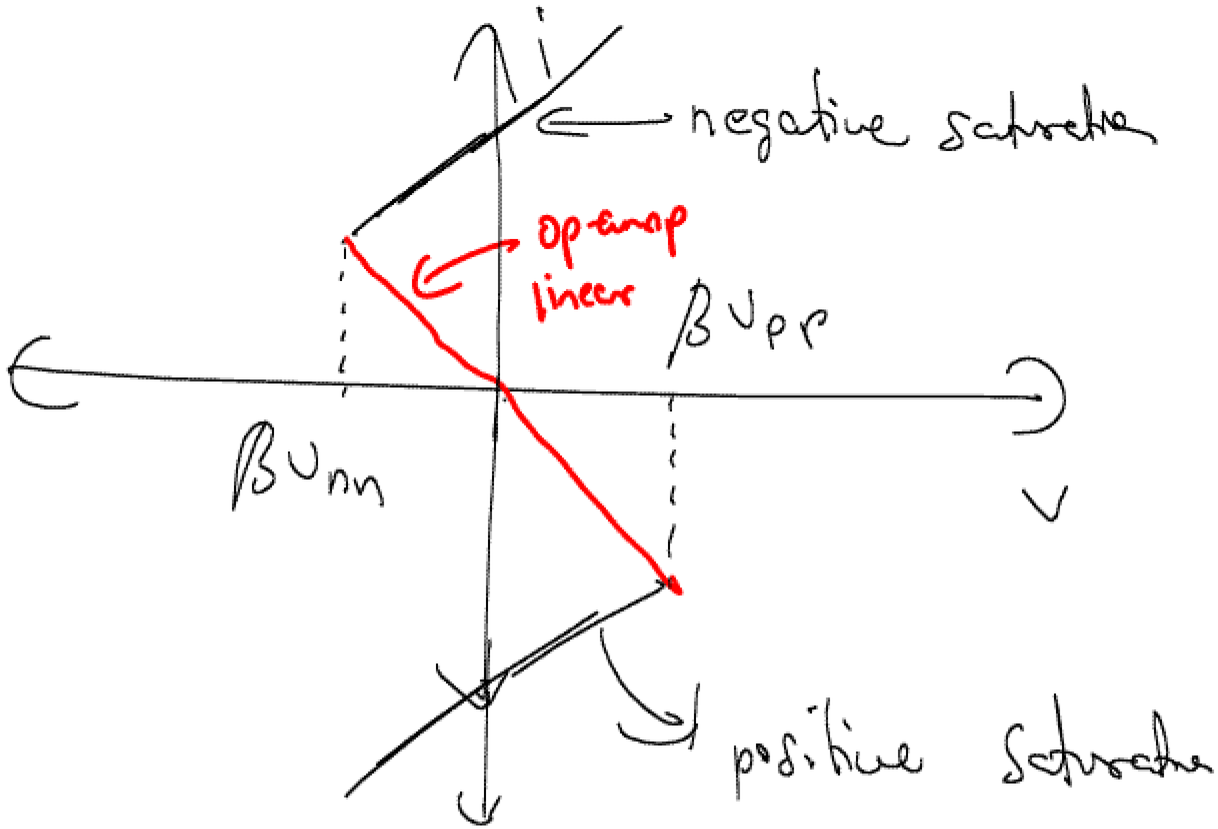
$\Rightarrow \quad -R_a V_x = R_b V_x - R_b V_{pp}$

$$\Rightarrow \quad V_x = \underbrace{\frac{R_b}{R_a + R_b}}_{\beta} V_{pp}$$



Similarly for negative saturation i.e.

$V_o = V_{nn} \quad (V_{nn} < 0)$



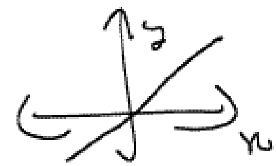
What do you mean by a "linear circuit"
& what is a "non-linear circuit"?

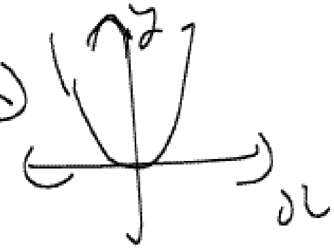
Eg:

$y = x$ ← linear function

$y = x^2$ ← Nonlinear function

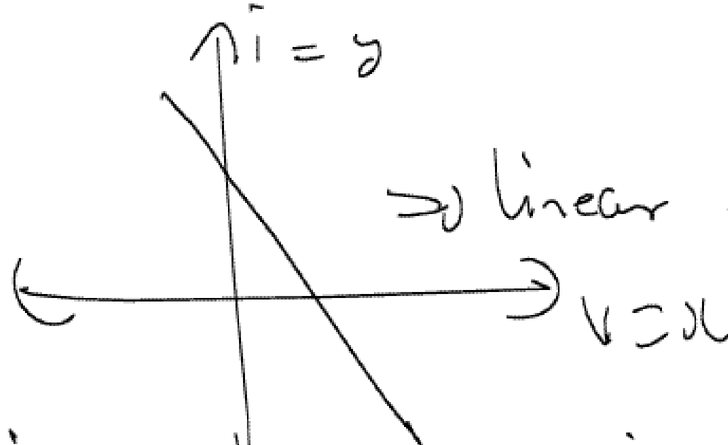
Graphically:





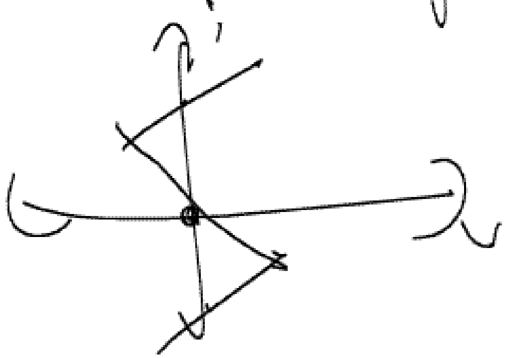
Circuits:

(1)



⇒ linear circuit

(2)



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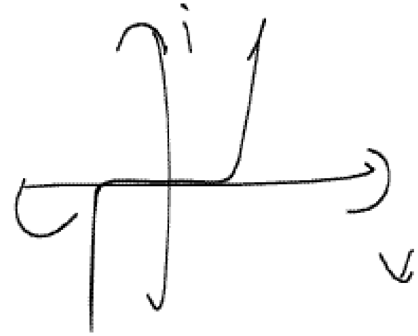
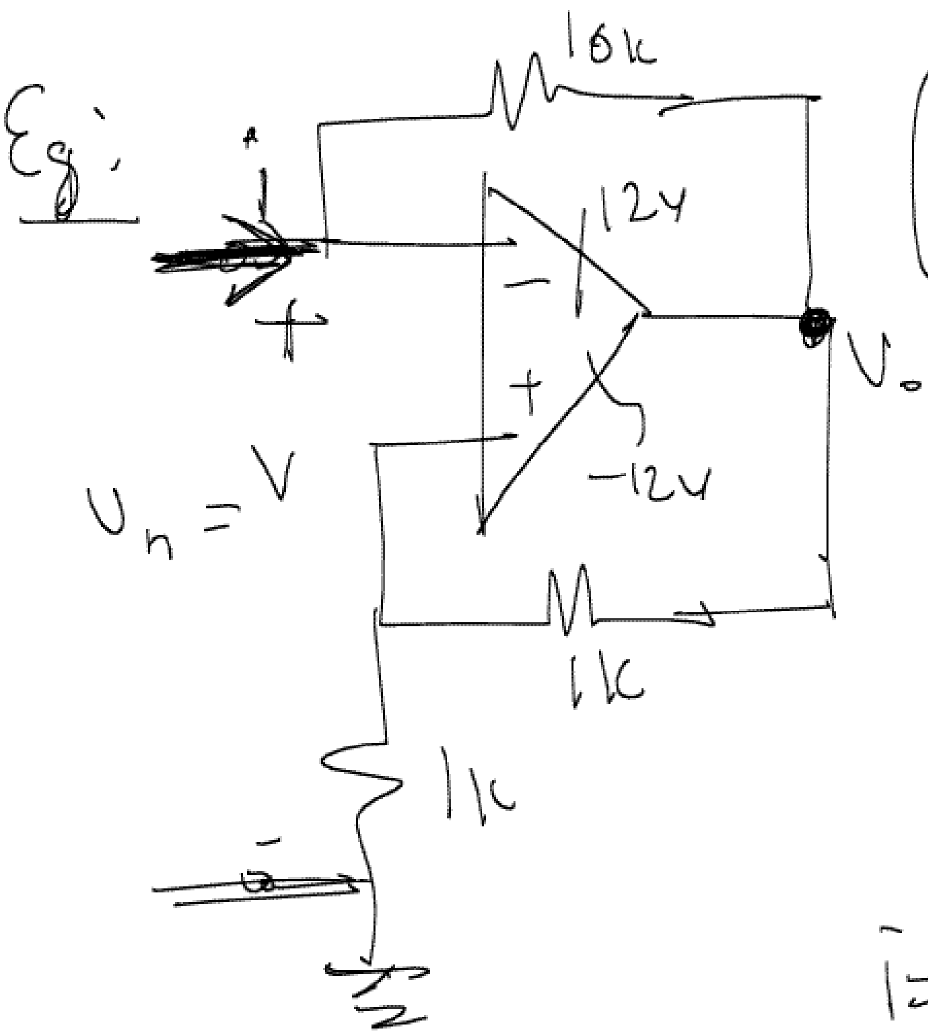
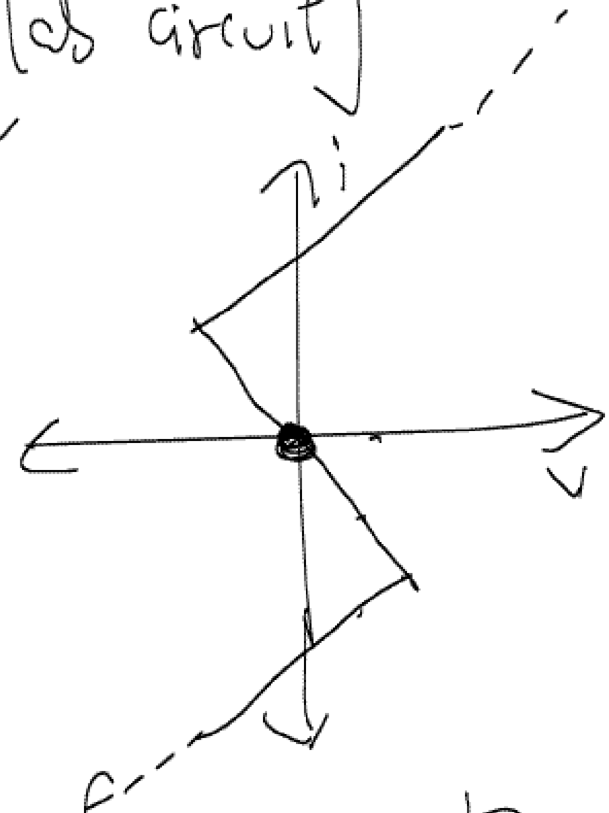


] Nonlinear

Eg:



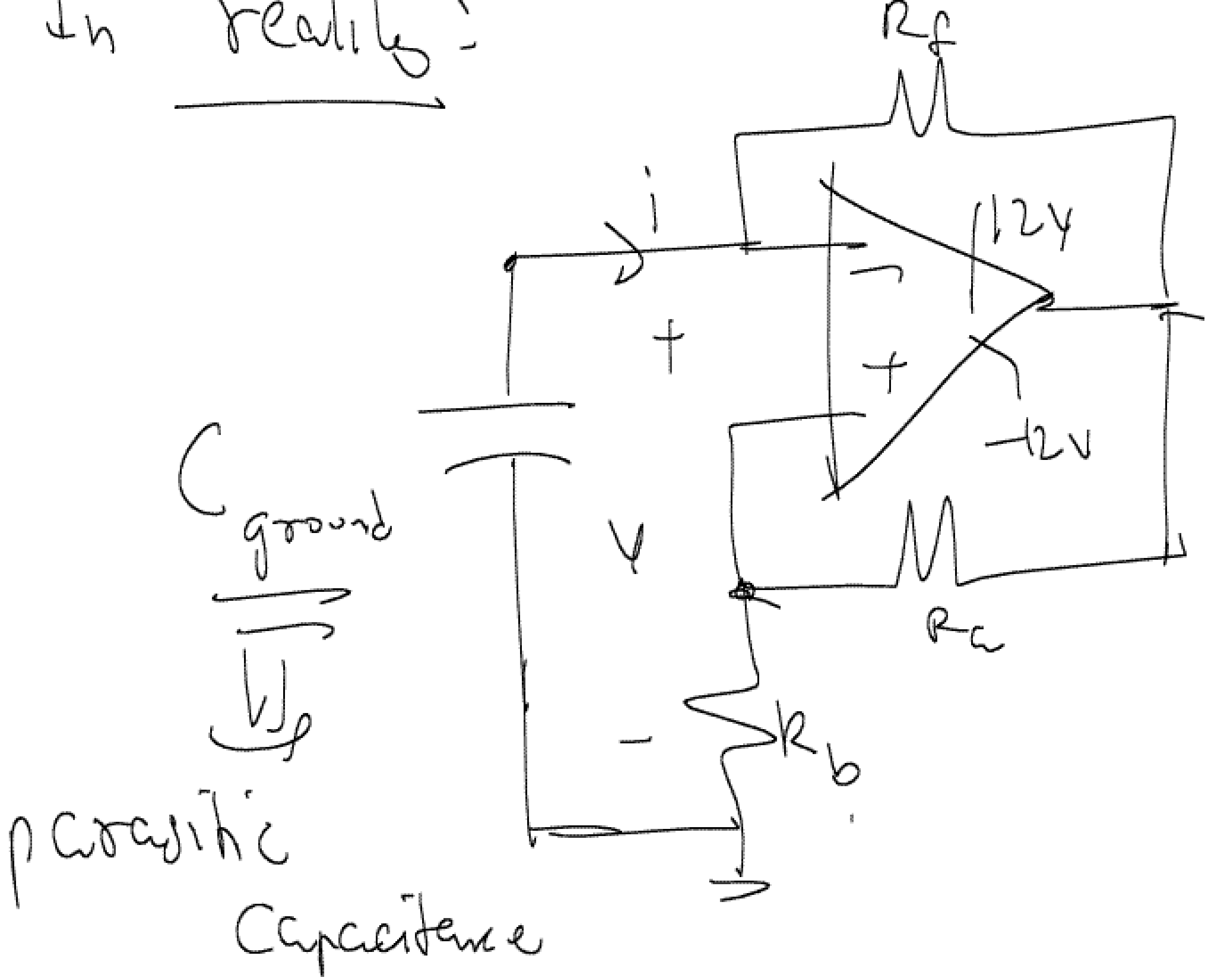
(lab circuit)

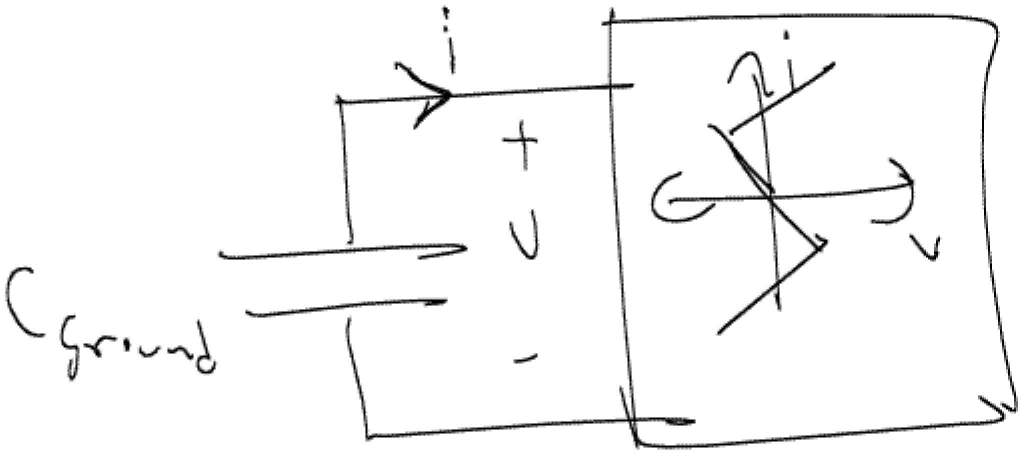


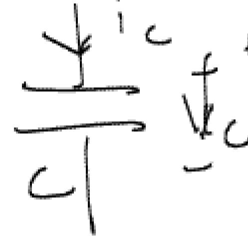
i=0 (open-circuit) ⇒ v=0

(ideally)

In <u>reality</u>:







$$i_c = C\frac{dv_c}{dt}$$

$$i = -C_{ground}\frac{dv}{dt}$$

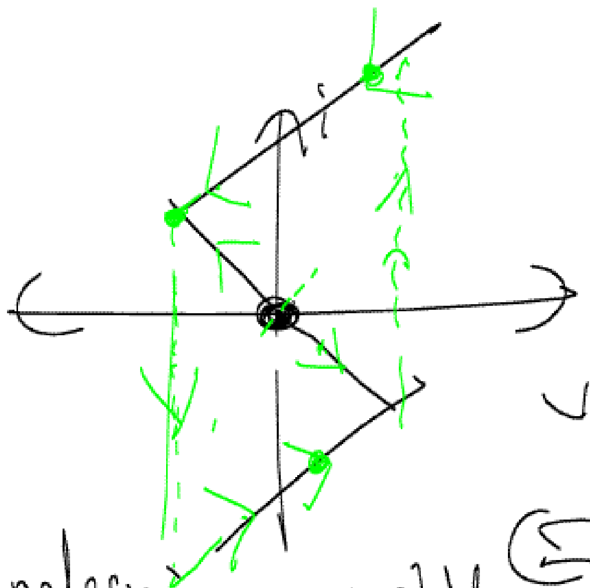
We now talk about (1) equilibrium points

(2) stability

(1) Equilibrium points: $f'(t) = 0$

$$\Rightarrow \frac{dv}{dt} = 0$$

$$\Rightarrow \frac{-i}{C_{ground}} = 0 \Rightarrow \boxed{i = 0}$$

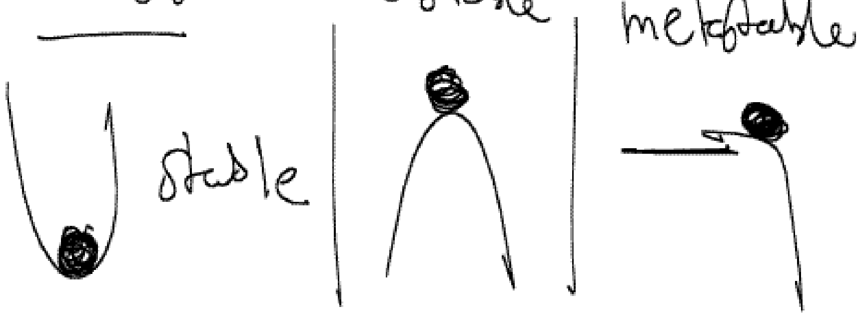


(2) Stability: $i = -C_{ground}\frac{dv}{dt}$ $[C_{ground} > 0]$

(3) $i > 0$, $v'(t) < 0$

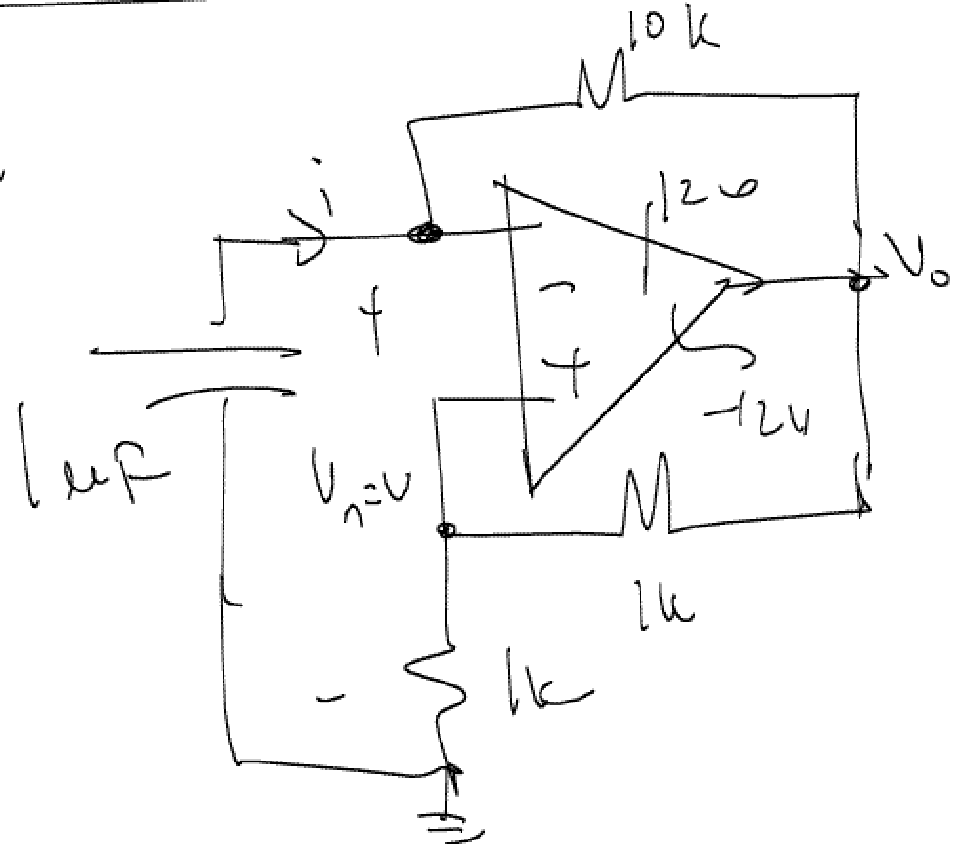
(4) $i < 0$, $v'(t) > 0$

Analogy

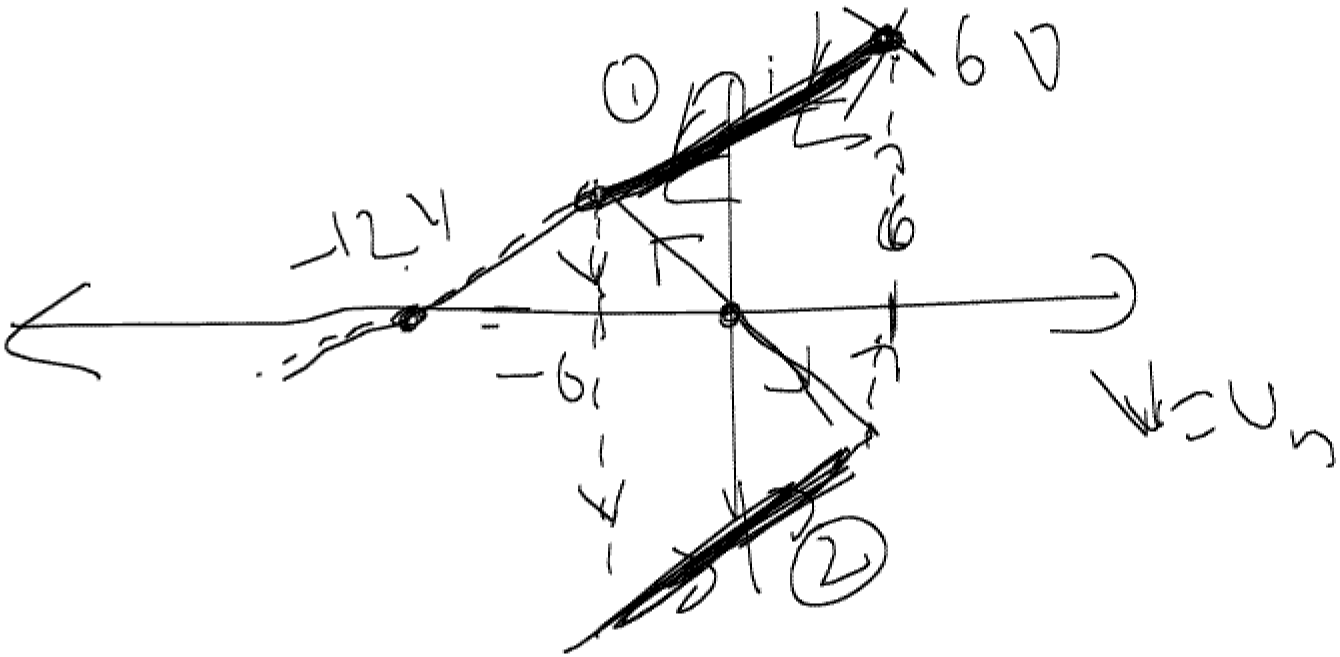


Using the stability eqns. [(a) & (b)] ⇒ dynamic route

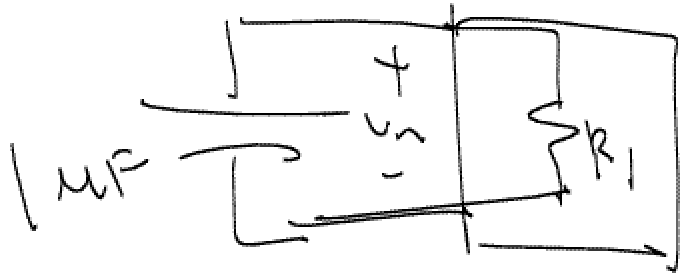
Analysis:



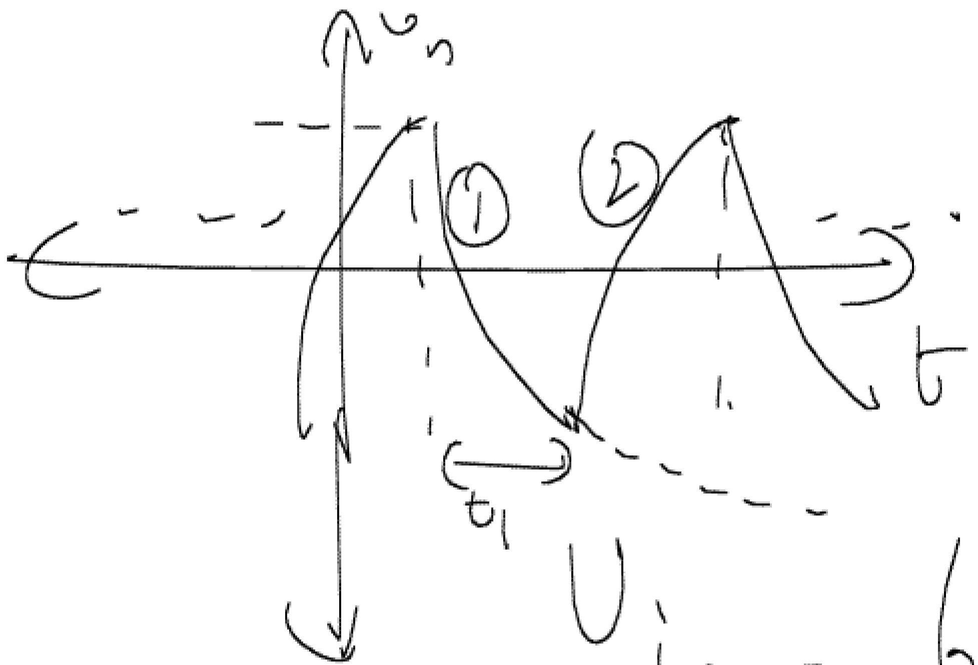
Goal: Find $v_n(t)$, $v_o(t)$



Assume $V_n(0) = 0$ V ⇒ you quickly move out of the linear op-amp region



$$v_{n_{(1)}} = v_{f_{(1)}} + \left(v_{i_{(1)}} - v_{f_{(1)}}\right) e^{-t/R_1 C}$$



$$v_{i_{(1)}} = 6\,V \qquad v_{f_{(1)}} = -12\,V$$

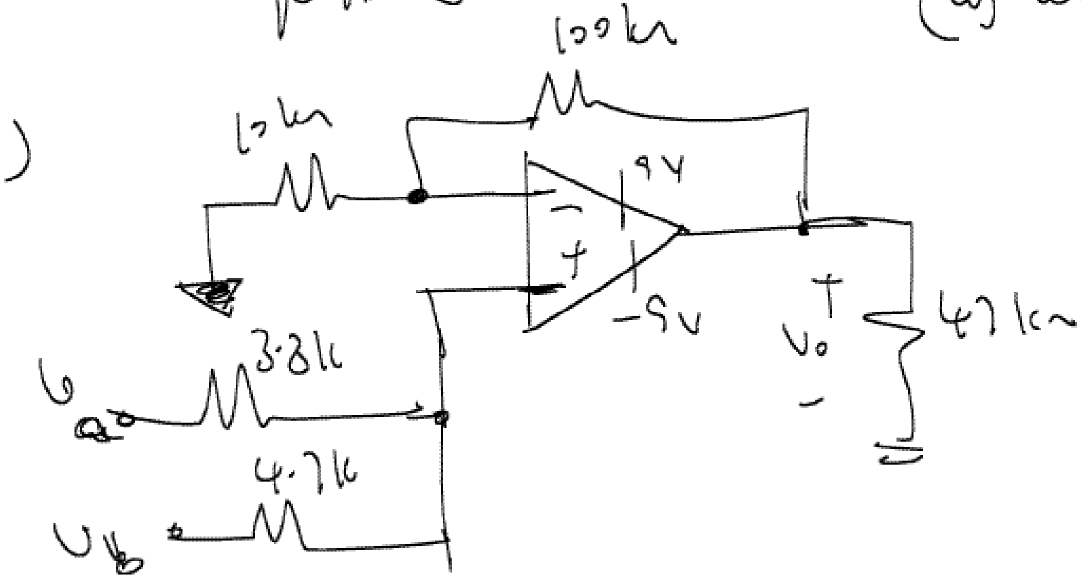
$R_1 = \frac{1}{\Delta}$ → will finish next lecture.

Now: HW question (5.25)

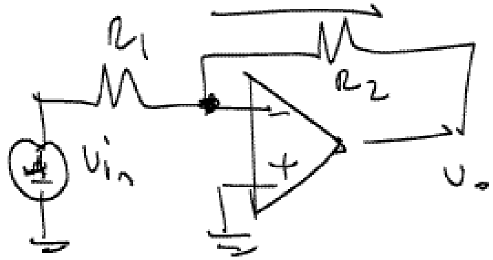
(a) What kind of amplifier?

non-inverting summing amplifier

i.e., $V_o \to f(v_a, v_b)$

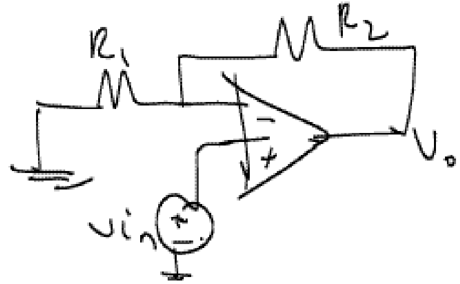


Inverting



$$v_o = -\frac{R_2}{R_1} v_{in}$$

Non-inverting



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

(Q:) What are the weighting factors associated with v_a & v_b?

$$V_o = \underline{\alpha} v_a + \underline{\beta} v_b$$

↳ weighting factors

Why is a summing amplifier useful