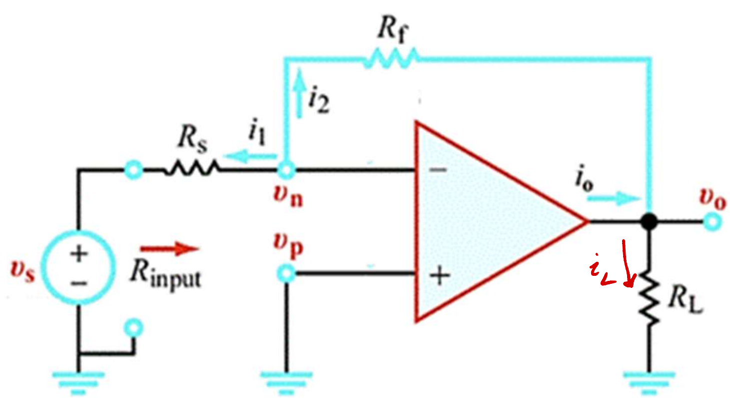
Test # 2 – 214 Hemmer sections 2023. Name JOAQUIN SALAS

Test 2

Special instructions: When equations are asked to be labeled. Use labels like: node, mesh, auxiliary, initial or final condition, KCL, KVL, divider, etc.

1) For the op-amp below, what are the values for the currents i_1, i_2 and i_0 ?



For i_1 and i_2 use KCL

$i_1 + i_2 = 0$

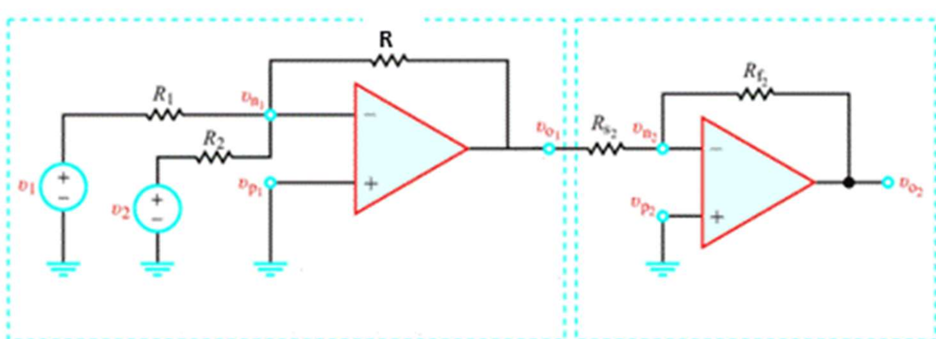
or $\frac{V_n - V_s}{R_s} + \frac{V_n - V_o}{R_f} = 0$

For i_o use KCL AND OHM'S LAW

$i_o = i_L - i_2 = \frac{V_o}{R_L} - \frac{V_n - V_o}{R_f}$

$$\boxed{\begin{aligned} i_1 &= \frac{V_n - V_s}{R_s} \\ i_2 &= \frac{V_n - V_o}{R_f} \\ i_o &= i_L - i_2 = \frac{V_o}{R_L} - \frac{V_n - V_o}{R_f} \end{aligned}}$$

2) What values for R_1, R_2 , R_{f2}, R_{s2} are needed below to have $v_{o_1} = a\, v_1 + b\, v_2$.



① for V_{o_1}

$-\frac{R}{R_1} = a$ and $-\frac{R}{R_2} = b$

② for V_{o_2}

$V_{o_2} = \left(-\frac{R_{f2}}{R_{s2}}\right) V_{o_1}$

$R_1 = -\frac{R}{a}$ and $R_2 = -\frac{R}{b}$

3) Write down and label and label all the equations needed to find v_o for the circuit below.

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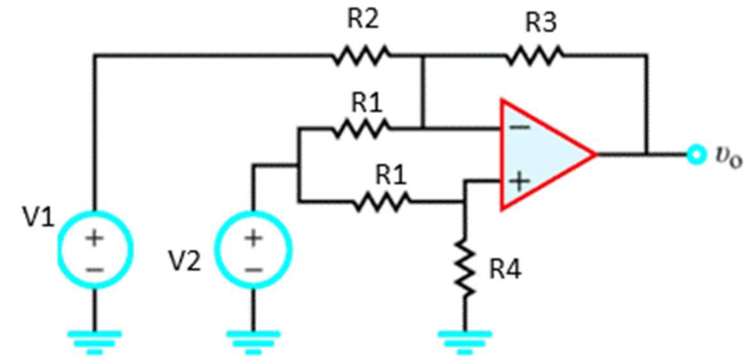


By Voltage Division

Ohm's Law

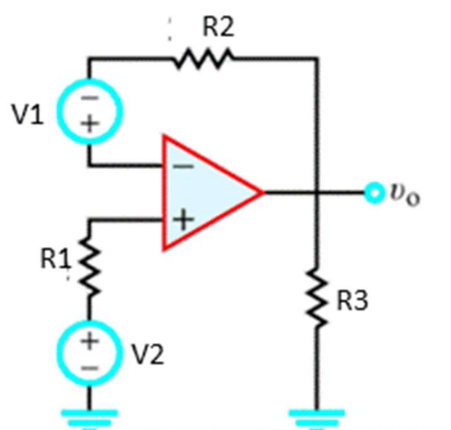
$V_p = V_2 \times \dfrac{R_4}{R_1+R_4}$

$V_n = V_p$ IDeal op-amp constraint

KCL

$\dfrac{V_n - V1}{R_2} + \dfrac{V_n - V_2}{R_1} + \dfrac{V_n - V_o}{R_3} = 0$

4) Write down and label and label all the equations needed to find v_o for the circuit below.



Here, $i_p = 0$.

There's no Voltage drop across R1.

$i_n = 0$

There is no voltage drop across R2.

So,

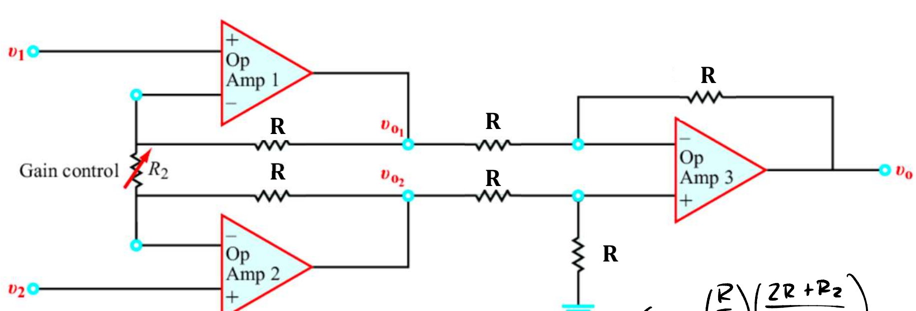
$V_p = V_2$

Subtracting Voltages

$V_o = V_n - V_1$ Ohm's Law

$V_p = V_n$ IDeal OP-AMP CONSTRAINT

5) For the amplifier below, what must be the value of R_2 to produce a gain of G ?



GAIN CONTROL

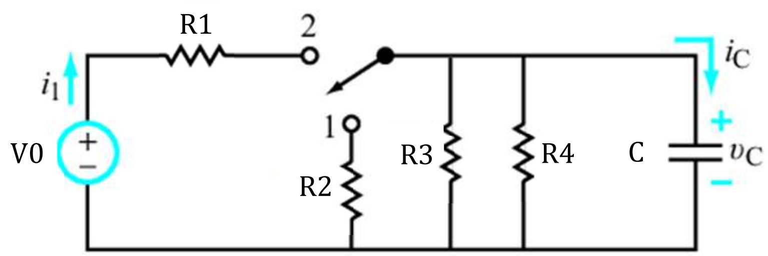
R_2 controls the overall gain of the amp.

$G = 1 + \dfrac{2R}{R_2}$

$G = \left(\dfrac{R}{R}\right)\left(\dfrac{2R+R_2}{R_2}\right)$

$= R_2 = \dfrac{2R}{G-1}$

6) Having been in position 2 for a long time, the switch below moves to position 1 at $t = 0$. Find the initial capacitor current $i_C(0)$ and the time constant τ.

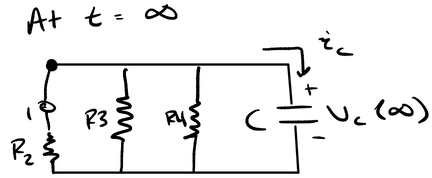


$i_{R_2} = \dfrac{V_c(0)}{R_2}$

$i_{R_{34}} = \dfrac{V_c(0)}{R_{34}}$

$i_c(0) = -i_{R_2} - i_{R_{34}}$

At $t = \infty$



time Constant

$R_{34} = \dfrac{R_3 R_4}{R_3 + R_4}$

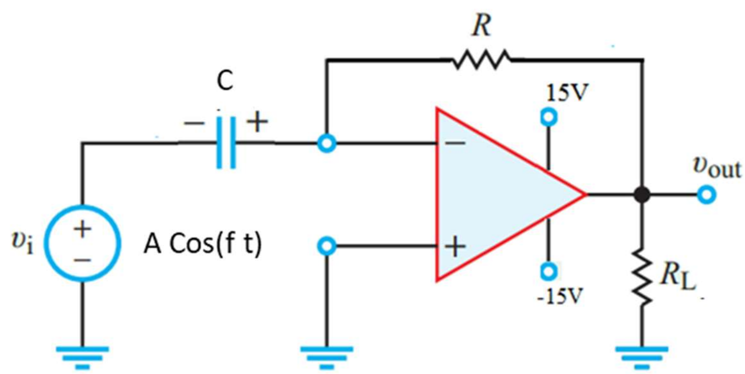
$\tau = \left(\dfrac{R_2 R_{34}}{R_2 + R_{34}}\right) C$

$V_c(0^-) = i_1 R_{34} = \dfrac{V_0 R_{34}}{R_1 + R_{34}}$

Initial Capacitor Current

$i_c(0) = C \dfrac{d}{dt} V_c$

7) For the circuit below, find $v_{out}(t)$.



RC DIFFERENTIATOR

find $V_{out}(t)$

$V_{out} = -RC \dfrac{d}{dt} v_i$

$\rightarrow V_{out} = -RC \times \dfrac{d}{dt}[A \cos(ft)]$

$V_{out} = RCAf \sin(ft)$

8) If the waveform below is input to an inverting op amp differentiator with resistor R and capacitor C, what is the output waveform?

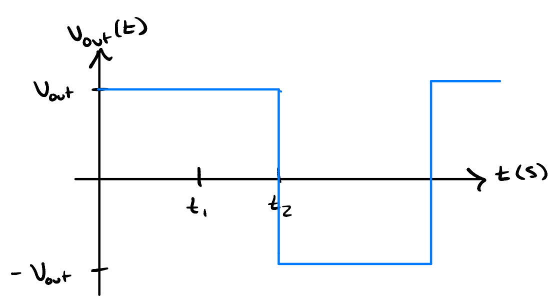
For time segment $t = t_1$ and $t = t_2$, the slope of the Input Signal is $\left(\dfrac{a+b}{t_2}\right)$.

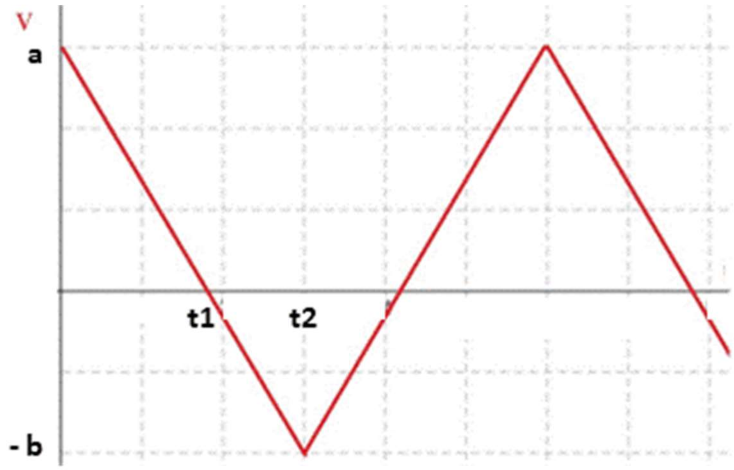
Output Voltage is given by :

$V_{out} = -RC \dfrac{d}{dt} V_i$

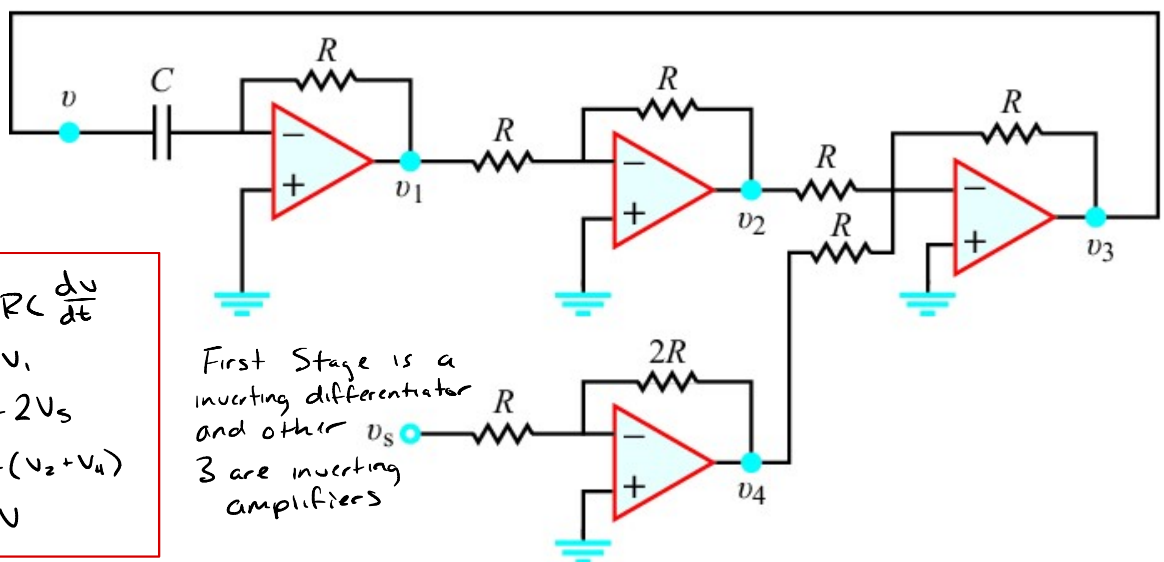
$= -RC \times \left(\dfrac{a+b}{t_2}\right)$

Slope, Op amp differentiator





9) Write down and label all the equations needed to find v_o for the circuit below.



$V_1 = -RC\frac{dv}{dt}$

$V_2 = -V_1$

$V_4 = -2V_s$

$V_3 = -(V_2 + V_4)$

$V_3 = V$

$V_3 = V_1 + 2V_s$

First Stage is a inverting differentiator and other 3 are inverting amplifiers

10) Write down and label all the equations needed to determine υC(t) in the circuit of the figure below for t≥0, given that the switch had been closed for a long time prior to t=0. Hint: You will need equations for the initial and final conditions, the time constant, and then combine them to make the final equation for υC(t).

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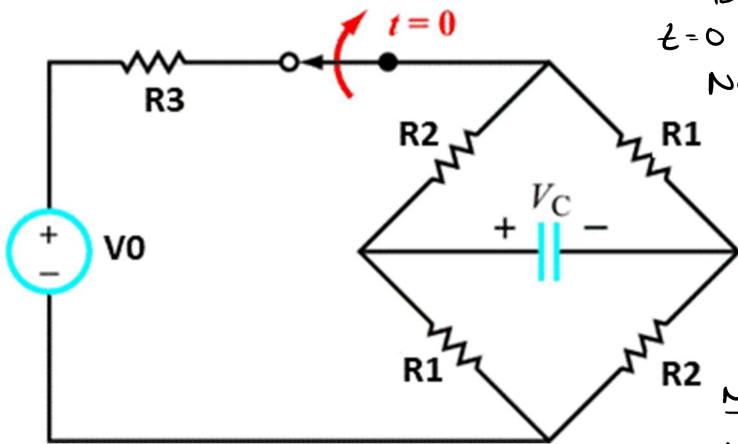


Before opening switch at $t=0$: (Initial)

Node Votage Analysis:

$$\frac{V_1(0^-) - V_0}{R_3} + \frac{V_1(0^-)}{R2+R1} + \frac{V_1(0^-)}{R1+R2} = 0$$

Voltage Division,

$$V_2(0^-) = V_1(0^-)\left(\frac{R1}{R1+R2}\right)$$

$$V_3(0^-) = V_1(0^-)\left(\frac{R_2}{R_2+R_1}\right)$$

Now,

$$V_c(0^-) = V_2(0^-) - V_3(0^-)$$

The circuit at $t = 0^+$: (final)

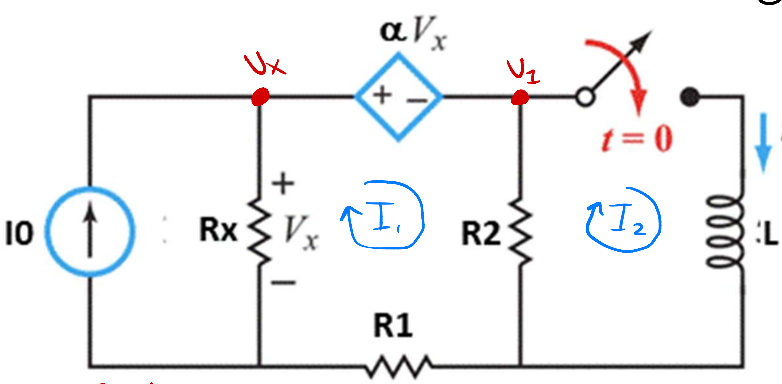
$R_{eq} = (R1+R2) \parallel (R1+R2)$

τ = time Constant = $R_{eq} \times C$

$V_c(\infty) = 0$

Final Equation: $V_c(t) = V_c(\infty) + \left[V_c(0) - V_c(\infty)\right]e^{-\frac{t}{\tau}}$

11) Write down and label all the equations needed to determine iL(t) in the circuit below for t≥0. Hint: You will need equations for the initial and final conditions, the time constant, and then combine them to make the final equation for iL(t). Note that to find time constant you will need to find the Thevenin equivalent of a circuit with a dependent source.



① Simplify into Equivalent RL Circuit using Thevenin Equivalent to the left of the switch:

At supernodes V_x and V_1:

$$-I_0 + \frac{V_x}{R_x} + \frac{V_1}{R_1+R_2} = 0$$

$I_2 = \alpha V_x$

Voltage Division:

$$V_{oc} = V_1\left(\frac{R_2}{R_1+R_2}\right) \rightarrow V_{TH} = V_{oc}$$

Mesh Analysis

$$R_x I_1 + \alpha V_x + R2(I_1 - I_2) + R1(I_1) = 0$$

$$R_{TH} = \frac{V_{ex}}{I_{ex}} = \frac{V_{ex}}{-I_2} \quad \text{AND} \quad I_N = \frac{V_{TH}}{R_{TH}}$$

Final Equation

$$i_L(t) = i_L(\infty) + \left[i_L(0) - i_L(\infty)\right]e^{-t/\tau} \quad \text{AND} \quad \tau = \frac{L}{R_{TH}}$$

12) Write down and label all the equations needed to determine iL(t)in the circuit below for t≥0 when it is driven with the voltage waveform shown. Hint: You will have a driven and transient solution.

Using the triangular - source Excitation

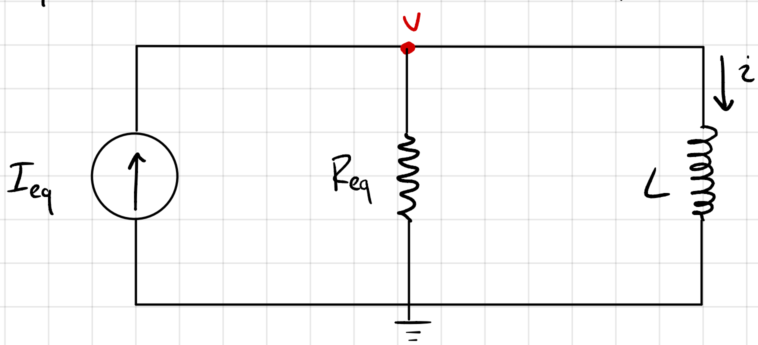
$$\text{Equation} = \int xe^{ax}dx = \frac{e^{ax}}{a^2}(ax-1)$$

12)

① Find R_{eq}

$$R_{eq} = R_3 + \frac{R_1 \times R_2}{R_1 + R_2} \quad \text{AND} \quad \tau = \frac{L}{R_{eq}} = \tau^{-1}$$

② Equivalent Circuit for $0 \le t \le t_1$



$$V_s(t) = 4t\,(V)$$

$$I_{eq} = \frac{v}{R_{eq}} + i$$

$$v = L\frac{di}{dt} \text{ So,}$$

$$\frac{L}{R_{eq}}\frac{di}{dt} + i = I_{eq}$$

Multiply both sides by e^{at}, integrate $t=0$ to t. $\rightarrow$ $\frac{di}{dt} + \frac{R_{eq}}{L} i = \frac{R_{eq} I_{eq}}{L}$

$$\rightarrow \int_0^t \left(\frac{di}{dt} + \frac{R_{eq}}{L} i\right) e^{at}\, dt = \int_0^t \frac{R_{eq}}{L} e^{at}\, dt$$

$$\rightarrow \int_0^t \frac{di}{dt}(e^{at})\,dt + \frac{R_{eq}}{L}\int_0^t i e^{at}\, dt = 2\int_0^t t e^{at}\, dt$$

$$\rightarrow \int_0^t \frac{d}{dt}(i e^{at})\,dt = \int_0^t \frac{1}{a} t e^{at}\, dt$$

$$\rightarrow i e^{at}\Big|_0^t = \int_0^t \frac{1}{a} t e^{at}\, dt$$

Apply $\int x e^{ax} dx = \frac{e^{ax}}{a^2}(ax-1)$, $i(t)e^{at} - i(0)$ for $0 \le t \le t_1$

Because V_s was zero before $t=0$

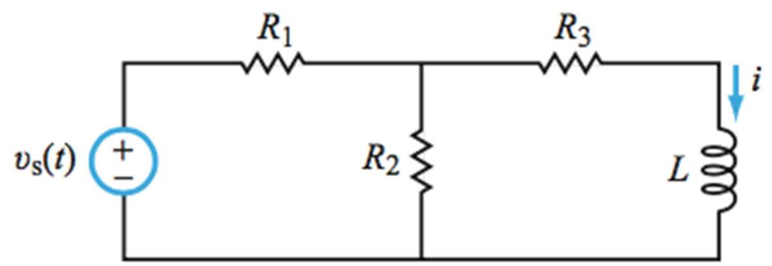
$$i(0) = i(0^-) = 0$$

2. Time Segment $t \ge t_1$

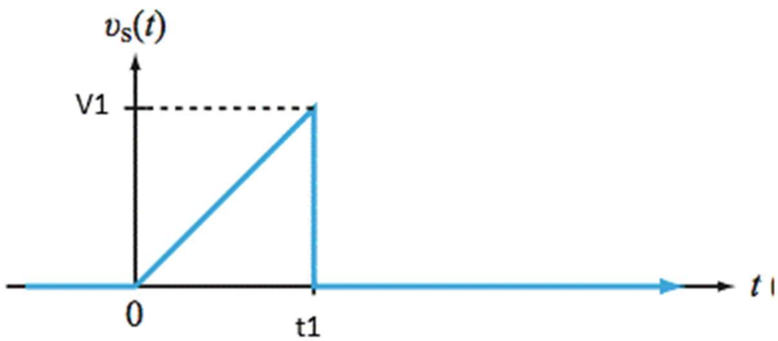
At $t = t_1$, $\quad i(t = t_1)$ Plug into Equation Above

For $t > t_1$,

$$\tau = \frac{L}{R_{eq}}$$



(a) Circuit



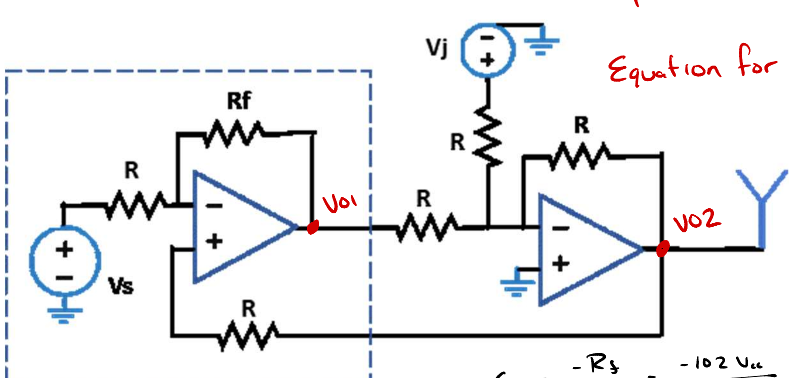
Extra credit 1) Consider a dual stage op amp amplifier, shown below that drives a transmitter antenna. The first amplifier is high gain and operates inside a protective enclosure. The second op amp is lower gain but can produce a higher output power and is placed outside the enclosure. As shown, feedback is applied by sampling the second op amp output and applying it to the input of the first op amp. Consider the case when a jamming signal is applied to the outside amplifier. For simplicity model this as a voltage vj applied through a resistor Rj, as shown below. Assume the jammer voltage is 100 times larger that Vcc for the op amps. Write down and label all the equations needed to find the minimum gain of the first op amp that is needed to bring the second op amp out of saturation.

Equation for V_o1: $\frac{V_n - V_s}{R} + \frac{V_n - V_o1}{R_f} = 0$

Equation for V_o2:

$V_o2 = -\left(\frac{R_f}{R}V_s + V_{o2}\right) - 100V_{cc}$ NODE ANALYSIS

$V_{cc} > -\frac{R_f}{R}V_s$ $R_f < \left|\frac{-102V_{cc}R}{V_s}\right|$



$V_n = V_p = V_o$ IDEAL OP AMP

$G_1 = \frac{-R_f}{R} = \frac{-102V_{cc}}{V_s}$

GIVEN CONDITION

$V_{o2} < V_{cc}$

For this Stage

$\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_1}$

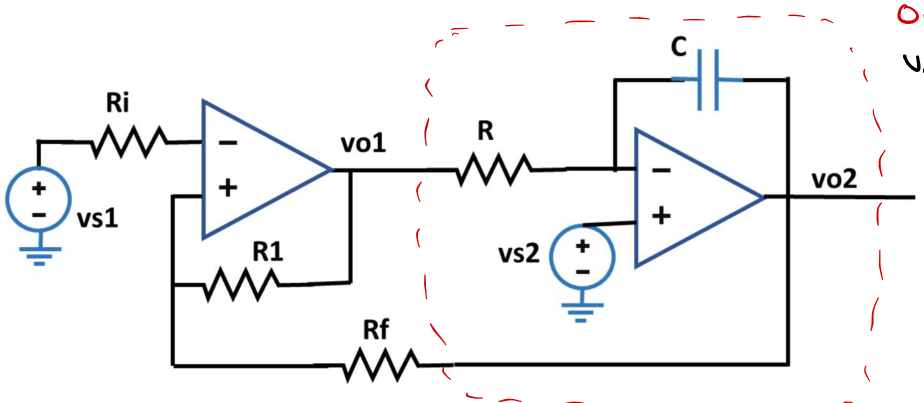
Minimum Gain

$G = \left(1 + \frac{R}{R_f}\right)$

Minimum Gain to bring 2nd Op amp to saturation

$A1 = \frac{-20V}{V_j}$

Extra credit 2) The dual op amp circuit below has two outputs vo1 and vo2. Note that the first op amp has positive feedback and so is saturated to +Vcc or –Vcc. Because of this the two input voltages, vn1 and vp1, are not necessarily equal. Begin with Vs1=0=Vs2. Write down and label all the equations to determine the ratio of Rf to R1 needed for the second op amp to produce a signal of maximum amplitude almost equal to Vcc.



Op-amp 2 - Integrator

$$V_{o2} = v(0) - \int_0^t i_2 \, dt \, \frac{1}{C}$$

$$= v(0) - \frac{V_{o1}}{RC} t$$

Op-amp 1

$$\frac{V_{s1} - V_{o1}}{R_1} + \frac{V_{s1} - V_{o2}}{R_f} = 0$$

Starting at $t=0$, $V_{o1} = V_{cc}$, $V_{o2} = 0$

$V_{o2} = -V_{cc} \frac{t}{\tau}$, $\tau = RC$

$$V_{p1} = (R_1 \| R_f)\left(\frac{V_{o1}}{R_1} + \frac{V_{o2}}{R_f}\right)$$

$$V_{p1} = (R_1 \| R_f)\left(\frac{V_{cc}}{R_1} - \frac{V_{cc}}{R_f} t/\tau\right)$$

Now,

$V_{s1} = 0 = V_{s2}$ $\qquad$ $V_{o1} = -\frac{R_1}{R_f} V_{o2}$

$\frac{V_{o1}}{R} = V_{o2}$ $\qquad$ $V_{o1} = V_{cc}$

$$\boxed{-\frac{V_{cc}}{V_{o2}} = \frac{R_1}{R_f}}$$