HW #1 REVIEW

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EXAMPLE 2.2, pg 63 FIND $\frac{V_O}{V_I} = A_{CL}$

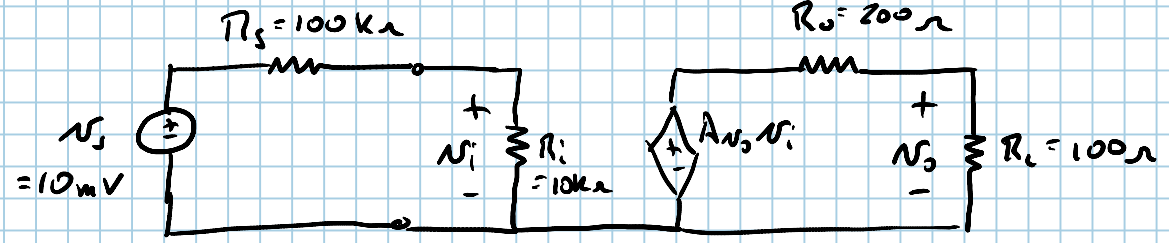
$$\frac{V_I}{R_1} + \frac{R_2}{R_1 R_3} V_I = \frac{1}{R_4}\left[-\frac{R_2}{R_1} V_I - V_O\right]$$

$$-\frac{V_O}{R_4} = V_I\left[\frac{1}{R_1} + \frac{R_2}{R_1 R_3} + \frac{R_2}{R_1 R_4}\right]$$

$$\frac{V_O}{V_I} = -\left[\frac{R_4}{R_1} + \frac{R_2 R_4}{R_1 R_3} + \frac{R_2 R_4}{R_1 R_4}\right] = -\frac{R_2}{R_1}\left[\frac{R_4}{R_2} + \frac{R_4}{R_3} + 1\right]$$

1.52

$A_{V_O} = 1000\ V/V$



(a) $$V_O = \left(\frac{R_L}{R_L + R_O}\right) A_{V_O} V_i, \quad V_i = \left(\frac{R_i}{R_i + R_s}\right) V_s$$

$$V_O = \left(\frac{R_L}{R_L + R_O}\right) A_{V_O} \left(\frac{R_i}{R_i + R_s}\right) V_s = \left(\frac{100}{100 + 200}\right)\left(1000\ V/V\right)\left(\frac{10\,k\Omega}{10k\Omega + 100k\Omega}\right)(0.01\,V)$$

$$\boxed{V_O = 0.303\,V}$$

(b) $\frac{V_O}{V_s}$ ≡ VOLTAGE GAIN FROM SOURCE TO LOAD

$$\frac{V_O}{V_s} = \frac{0.303\,V}{0.01\,V} = 30.3\ V/V = \left(\frac{R_L}{R_L + R_O}\right)\left(\frac{R_i}{R_i + R_s}\right) A_{V_O}$$

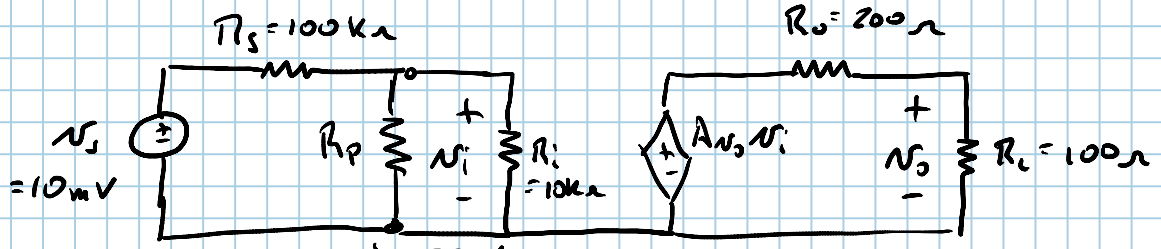
(c) $\frac{v_o}{v_i}$ = GAIN FROM AMPLIFIER INPUT TO LOAD

$$v_i = \left(\frac{R_i}{R_i + R_s}\right) v_s = \left(\frac{10k}{10k + 100k}\right) 10\,mV = 0.909\,mV$$

$$A_{v_i} = \frac{303.03\,mV}{0.909\,mV} = 333.33\,V/V$$

(d) IF $v_o = 0.606\,V$

FIND R_p TO BRING CIRCUIT INTO SPEC.



ORIGINAL CIRCUIT:

$$v_i = \left(\frac{R_i}{R_s + R_i}\right) v_s$$

↑ TOO LARGE x2

NEW CIRCUIT:

$$v_i = \left(\frac{R_p // R_i}{R_p // R_i + R_s}\right) v_s$$

$$\frac{1}{2}\left(\frac{R_i}{R_s + R_i}\right) = \frac{R_p // R_i}{R_p // R_i + R_s}$$

$$\frac{1}{2}\left(\frac{10}{110}\right) = \frac{R_p // 10}{R_p // 10 + 100}$$

$$\frac{5}{110} = \frac{R_p // 10}{R_p // 10 + 100}$$

$$\frac{1}{1 + \frac{100}{R_p // 10}} = \frac{5}{110}$$

$$1 + \frac{100}{R_p // 10} = 22$$

$$\frac{100}{R_p // 10} = 21 \Rightarrow R_p // 10 = \frac{100}{21}$$

$$\frac{1}{\frac{1}{R_p} + \frac{1}{10}} = \frac{100}{21} \Rightarrow \frac{1}{R_p} + \frac{1}{10} = \frac{21}{100}$$

$$R_p = 9.09\,k\Omega$$

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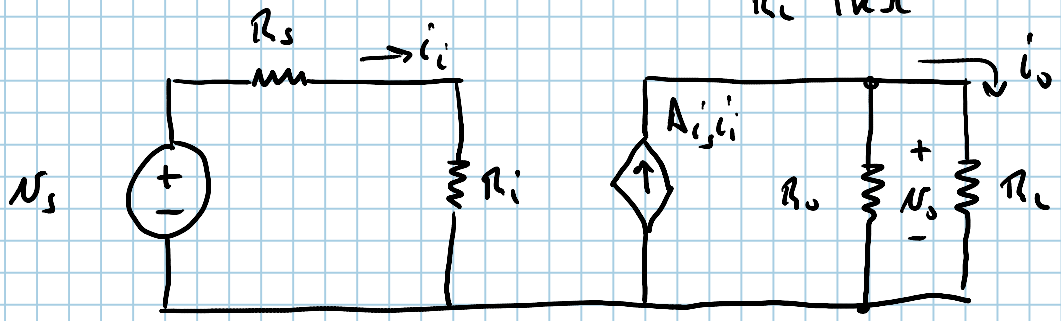
$R_i = 1k\Omega$ $\quad R_o = 10k\Omega$ $\quad R_s = 100k\Omega$ $\quad R_L = 1k\Omega$

$v_s = 100mV$ $\quad A_{i_s} = 100\ A/A$

FIND i_o/i_i, v_o/v_s

POWER GAIN



$$i_i = \frac{v_s}{R_s + R_i} = \frac{0.1V}{101k\Omega} = 990.1\times10^{-6}\ mA$$

$$i_o = \left(\frac{R_o}{R_o + R_L}\right) A_{i_s} i_i = \left(\frac{10k\Omega}{11k\Omega}\right)\left(100\ \tfrac{A}{A}\right)(990.1\times10^{-6}\ mA) = 90\times10^{-3}\ mA$$
$$= 90\ \mu A$$

$$A_i = \frac{i_o}{i_i} = \frac{90\times10^{-6}\ A}{990\times10^{-9}\ A} = 90.9\ A/A$$

IN dB: $A_i = 20\log(90.9) = 39.17\ dB$

$$v_o = i_o R_L = (90\times10^{-3}\ mA)(1k\Omega) = 90\times10^{-3}\ V = 90\ mV$$

$v_s = 100mV$

$$\frac{v_o}{v_s} = \frac{90mV}{100mV} = \boxed{0.9\ V/V}$$

IN dB: $A_v = 20\log(0.9) = \boxed{-0.915\ dB}$

$A_p = A_i A_v = (90.9\ A/A)(0.9\ V/V) = \boxed{81.81\ W/W}$

IN dB: $A_p = 10\log(81.81) = \boxed{19.13\ dB}$

NON-INVERTING AMPLIFIER

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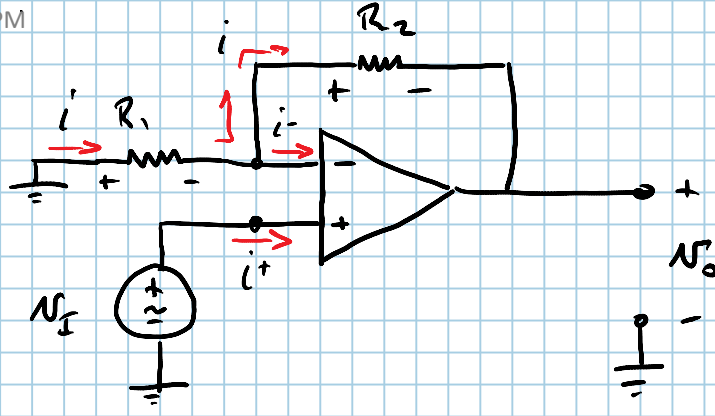


- VIRTUAL SHORT EXISTS
- $V^- = V^+ = V_I$

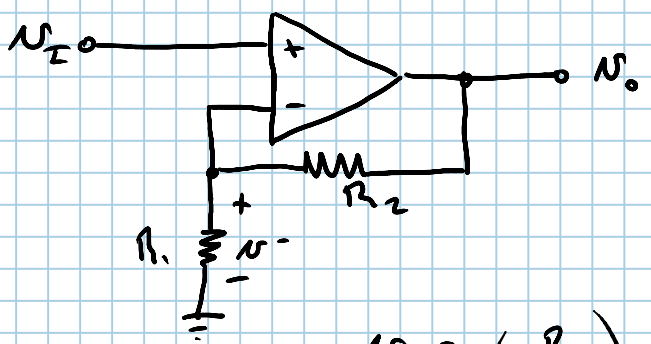
$$i = \frac{0 - V^-}{R_1} = \frac{-V_I}{R_1}$$

$$i' = \frac{V^- - V_o}{R_2} = \frac{V_I - V_o}{R_2}$$

$$i = i' \Rightarrow \frac{-V_I}{R_1} = \frac{V_I - V_o}{R_2}$$

$$\frac{V_o}{R_2} = \frac{V_I}{R_1} + \frac{V_I}{R_2} = V_I\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$V_o = \left(\frac{R_2}{R_1} + 1\right) V_I \Rightarrow A_{CL} = \frac{R_2}{R_1} + 1 = \frac{V_o}{V_I}$$



$$V^- = \left(\frac{R_1}{R_1 + R_2}\right) V_o$$

$$V^+ = V_I = V^- = \left(\frac{R_1}{R_1 + R_2}\right) V_o$$

$$V_I = \left(\frac{R_1}{R_1 + R_2}\right) V_o \Rightarrow V_o = \left(\frac{R_1 + R_2}{R_1}\right) V_I$$

$$V_o = \left(\frac{R_2}{R_1} + 1\right) V_I$$

EFFECTS OF FINITE OPEN-LOOP GAIN

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$(A_{OL} \neq \infty)$

$$v_O = A_{OL}(v^+ - v^-) = A_{OL}\left[v_I - \left(\frac{R_1}{R_1+R_2}\right)v_O\right] = A_{OL}v_I - \left(\frac{R_1}{R_1+R_2}\right)A_{OL}v_O$$

$$v_O + A_{OL}v_O\left(\frac{R_1}{R_1+R_2}\right) = A_{OL}v_I$$

$$v_O = \frac{A_{OL}v_I}{1 + A_{OL}\left(\frac{R_1}{R_1+R_2}\right)} = \left[\frac{1+\frac{R_2}{R_1}}{\frac{\left(1+\frac{R_2}{R_1}\right)}{A_{OL}} + 1}\right]v_I$$

$$\boxed{A_{CL} = \frac{v_O}{v_I} = \frac{1+\frac{R_2}{R_1}}{\frac{\left(1+\frac{R_2}{R_1}\right)}{A_{OL}} + 1}}$$

HW#2: 2.2 2.20
2.8 2.49
2.14 2.50
2.16

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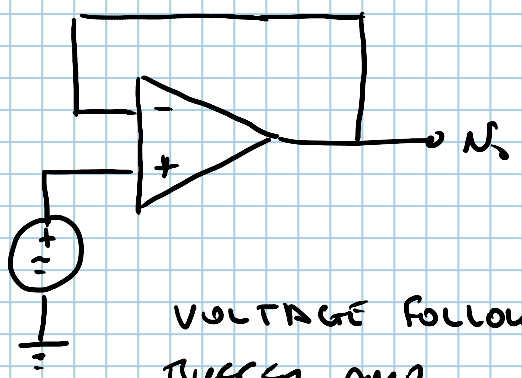


V_o

VOLTAGE FOLLOWER
BUFFER AMP
UNITY-GAIN AMP

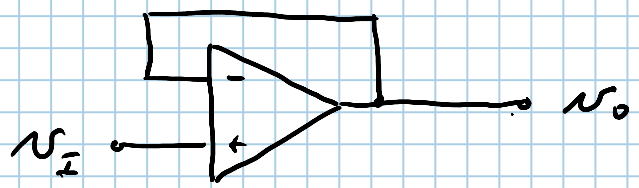
$$V_o = \left(\frac{R_2}{R_1} + 1\right) V_I$$

IF $R_1 = \infty$, $R_2 = 0$

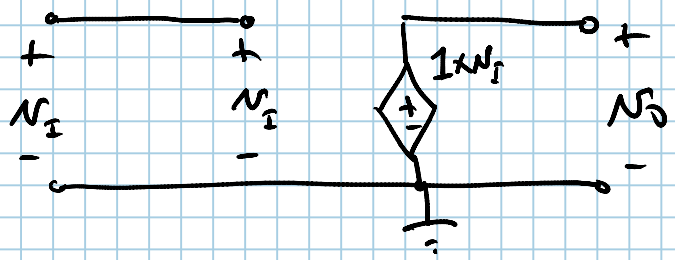
$$V_o = \left(\frac{0}{\infty} + 1\right) V_I$$

$$V_o = V_I$$

$$\boxed{\frac{V_o}{V_I} = 1}$$



V_I V_o



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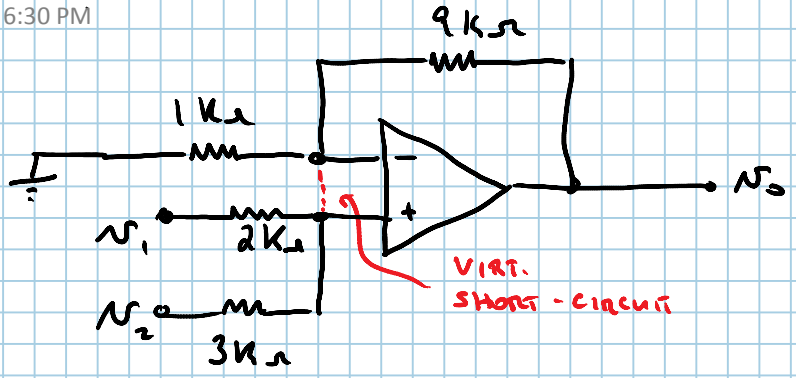
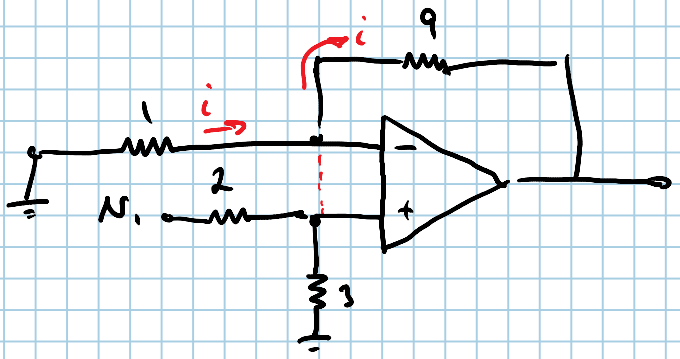
EXAMPLE

USE SUPERPOSITION TO FIND v_o



(A) SHORT v_2 TO GND



$$v^+ = \left(\frac{3}{2+3}\right) v_1 = \frac{3}{5} v_1$$

$$v^- = v^+ = \frac{3}{5} v_1$$

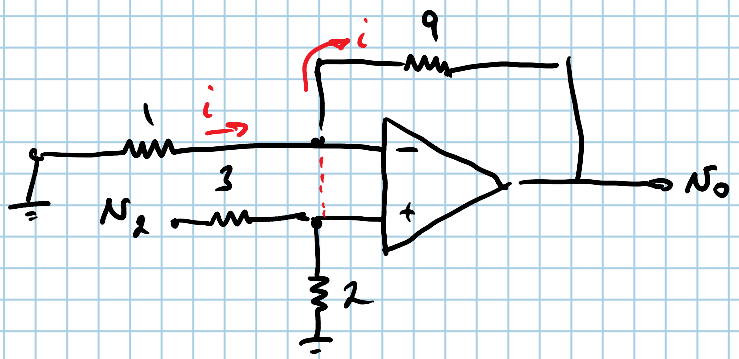
$$i = \frac{0 - v^-}{1} = \frac{-\frac{3}{5} v_1}{1} = -\frac{3}{5} v_1$$

$$i = \frac{v^- - v_o}{9} = \frac{\frac{3}{5} v_1 - v_o}{9}$$

$$i = i \Rightarrow \frac{\frac{3}{5} v_1 - v_o}{9} = -\frac{3}{5} v_1$$

$$\boxed{v_o = 6 v_1}$$

(B) SHORT v_1 TO GND, FIND v_o W.R.T. v_2



$$v^+ = \left(\frac{2}{2+3}\right) v_2 = \frac{2}{5} v_2$$

$$v^- = v^+ = \frac{2}{5} v_2$$

$$i = \frac{0 - v^-}{1} = \frac{0 - \frac{2}{5} v_2}{1} = -\frac{2}{5} v_2$$

$$i = \frac{v^- - v_o}{9} = \frac{\frac{2}{5} v_2 - v_o}{9}$$

$$i = i \Rightarrow \frac{\frac{2}{5} v_2 - v_o}{9} = -\frac{2}{5} v_2$$

$$\boxed{v_o = 4 v_2}$$

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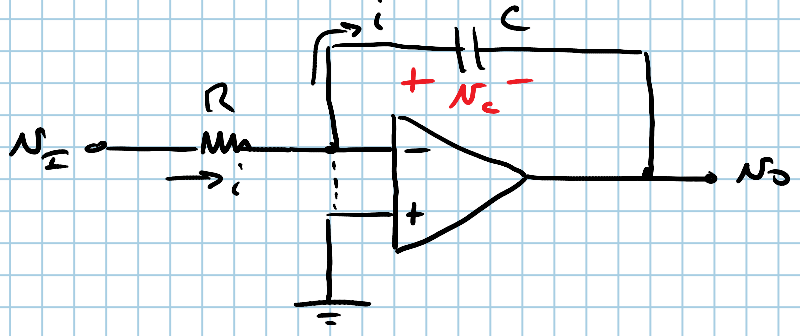
$$V_o = V_{o_A} + V_{o_B} = \boxed{6V_1 + 4V_2}$$



INTEGRATOR

$$i = \frac{V_I - 0}{R} = \frac{V_I}{R}$$

$$i = C\frac{dV_c}{dt}, \quad V_c = 0 - V_o$$

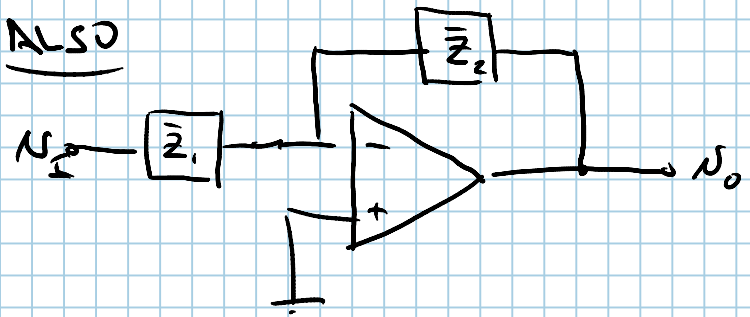
$$i = C\frac{d}{dt}(-V_o) = -C\frac{dV_o}{dt}$$

$$i = i \Rightarrow \quad -C\frac{dV_o}{dt} = \frac{V_I}{R}$$

$$\int dV_o = \frac{-1}{RC}\int V_I\,dt$$

$$\boxed{V_o = \frac{-1}{RC}\int V_I(t)\,dt}$$

ALSO



$$V_o = -\left(\frac{\bar{Z}_2}{Z_1}\right)V_I$$

$$\bar{Z}_2 = \frac{1}{j\omega C} = \frac{1}{sC}, \quad s = j\omega$$

$$\bar{Z}_1 = R$$

$$\frac{V_o}{V_I} = -\frac{\bar{Z}_2}{\bar{Z}_1} = -\frac{\frac{1}{sC}}{R} = -\frac{1}{sRC} = -\frac{1}{j\omega RC}$$

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$$\frac{V_o}{V_I} = \frac{-1}{j\omega RC}, \qquad \left|\frac{V_o}{V_I}\right| = \frac{1}{\omega RC} \qquad \omega \to 0$$