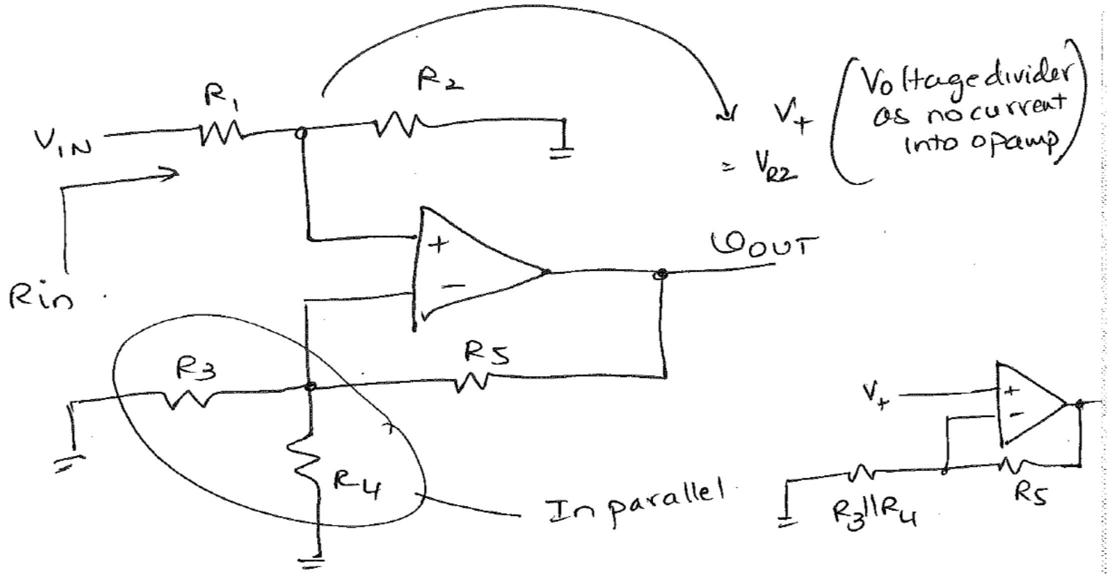
SANTA CLARA UNIVERSITY	ELEN 115 – Spring 2023	S. Krishnan

Homework #3 Solutions

1.



(a)

Noninverting Amplifier.

$$V_+ = V_{IN} * \frac{R_2}{R_1+R_2} \qquad v_{OUT} = \left(1 + \frac{R_5}{R_3 \| R_4}\right) v_+$$

$$\frac{v_{OUT}}{v_{IN}} = \left(\frac{R_2}{R_1+R_2}\right)\left(1 + \frac{R_5}{R_3 \| R_4}\right)$$

$$R_{in} = R_1 + R_2$$

[Current flow into R_1 all to R_2 & GND
none into opamp]

(a) Also can solve by doing KCL @ v_+ & v_-

At v_+: $\frac{v_{IN} - v_+}{R_1} = \frac{v_+ - 0}{R_2} \Rightarrow v_+ = v_{IN} * \frac{R_2}{R_1+R_2}$

At v_-: $\frac{0 - v_-}{R_3} + \frac{0 - v_-}{R_4} + \frac{v_{OUT} - v_-}{R_5} = 0$

$v_+ = v_-$ & so get

(b) $R_1 = 5K \quad R_2 = 10K \quad R_3 = 6K \quad R_4 = 3K \quad R_5 = 4K$

$$\frac{v_{OUT}}{v_{IN}} = \frac{10K}{5K + 10K}\left[1 + \frac{4K}{6K \| 3K}\right] = \frac{2}{3}\left[1 + 2\right] = 2$$

$v_{IN}(t) = 2\sin 2\pi t \qquad v_{OUT}(t) = 2 * v_{IN}$

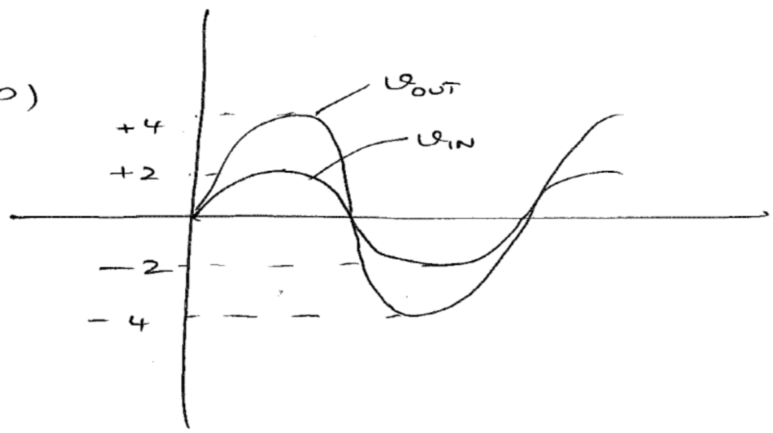
$= 4 \sin 2\pi t$.

(c) v_{OUT} max $= +10$ min $= -10$

$$v_{IN} = \frac{v_{OUT}}{\text{gain}} = \frac{v_{OUT}}{2} \Rightarrow V_{INmax} = \frac{10}{2}$$

$\Rightarrow v_{IN} = 5 \sin 2\pi t$.

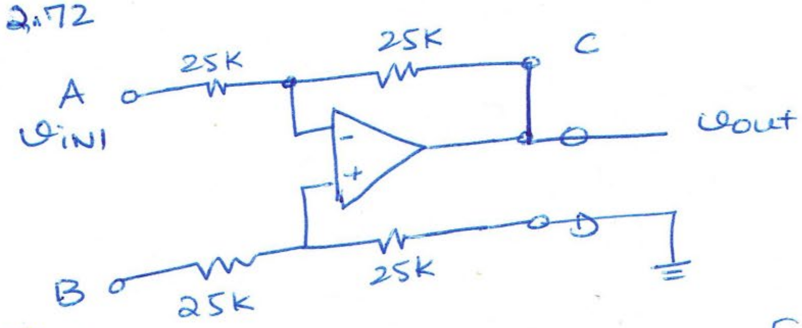
(b)



2. 2.72

2.72

(a)



$$v_{out} = v_{IN2}\frac{25}{25+25}\left[1+\frac{25K}{25K}\right] + v_{IN1}\left[\frac{-25K}{25K}\right]$$

$$v_{OUT} = v_{IN2} - v_{IN1}$$

(b)(i) $-1 \Rightarrow$ inverting amplifier

$B=0 \quad D=0 \quad v_{IN}$ At A $\quad$ C & O connected

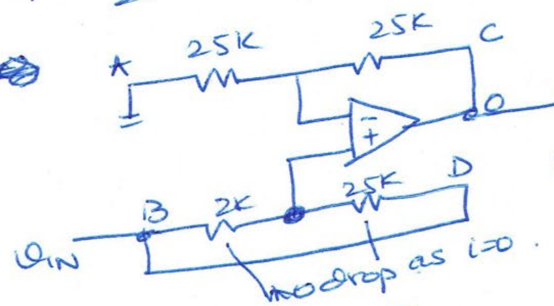
$v_{OUT} = v_{in}\left[-\frac{25}{25}\right] \Rightarrow \frac{v_{OUT}}{v_{IN}} = -1$

(ii) $+1 \Rightarrow$ noninverting amplifier

$A=0 \quad D=0 \quad$ C & O connected v_{IN} @ B

$v_+ = \frac{1}{2}v_{IN} \qquad v_{OUT} = \frac{1}{2}v_{in}\left[1+\frac{25K}{25K}\right] \Rightarrow \frac{v_{OUT}}{v_{in}} =$.

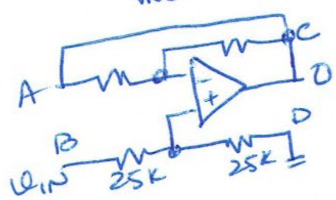
(iii)



$v_{out} = \left(1+\frac{25K}{25K}\right)v_{IN}$

$\frac{v_{out}}{v_{in}} = 2$

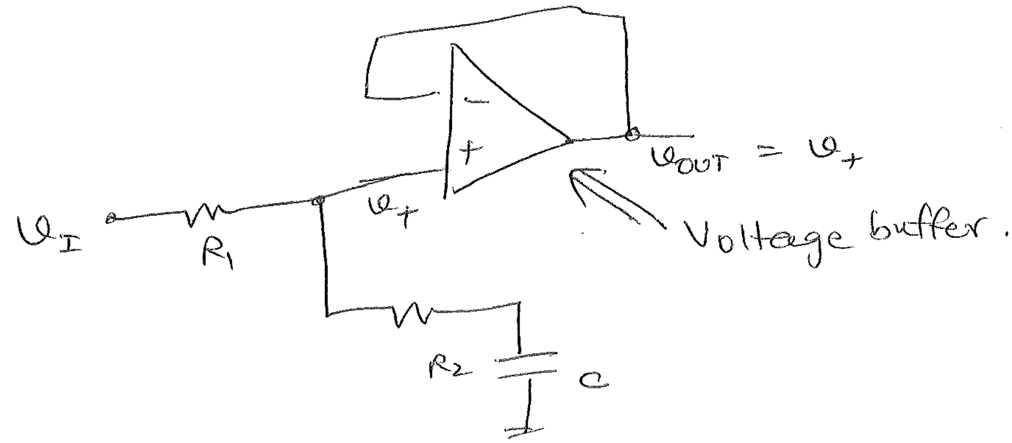
(iv)



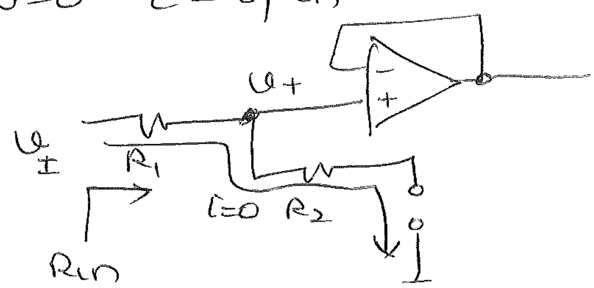
$v_+ = v_{IN}\left[\frac{25K}{25K+25K}\right] = \frac{v_{IN}}{2}$

$v_o = v_- = v_+ \Rightarrow \frac{v_o}{v_{IN}} = 1/2$

3.



(a) $\omega = 0 \quad C = \text{open}$



$i = 0 \Rightarrow R_{in} = \infty$

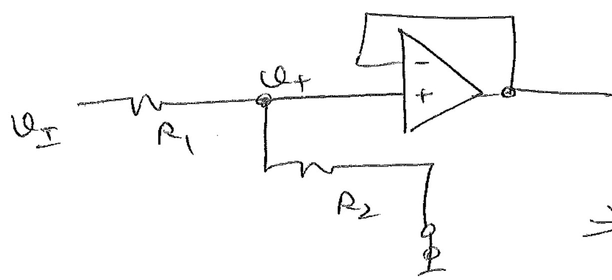
$\Rightarrow v_+ = v_I$

$\Rightarrow v_o = v_+ = v_I$

$\frac{v_o}{v_I} = 1.$

(b) $\omega = \infty \quad C = \text{short}.$

$i = \frac{v_I - 0}{R_1 + R_2} \Rightarrow R_{in} = R_1 + R_2$

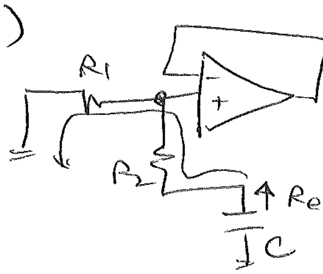


$v_+ = \frac{R_2}{R_1 + R_2} v_I$

$\Rightarrow v_o = v_I * \frac{R_2}{R_1 + R_2}$

$\Rightarrow \frac{v_o}{v_I} = \frac{R_2}{R_1 + R_2}.$

(c)



$R_{eq} = R_1 + R_2$

$f_0 = \frac{1}{2\pi R_{eq} C} = \frac{1}{2\pi (R_1 + R_2) C}$

$R_1 = 1K \quad R_2 = 500\Omega \quad C = 1\mu F$. $\pm 5V$ sat voltage.

$$f_0 = \frac{1}{2\pi(1.5K)1\mu F} = 106.10 Hz$$

$$\frac{v_0}{v_1} = 1 \qquad \cancel{f_0}\ f < 106.1 Hz$$

$$\frac{v_0}{v_1} = \frac{500}{500+1000} = \frac{1}{3} \qquad f > 106.1 Hz.$$

(i) $v_{IN}(t) = 2 + 5\sin 2\pi t$.

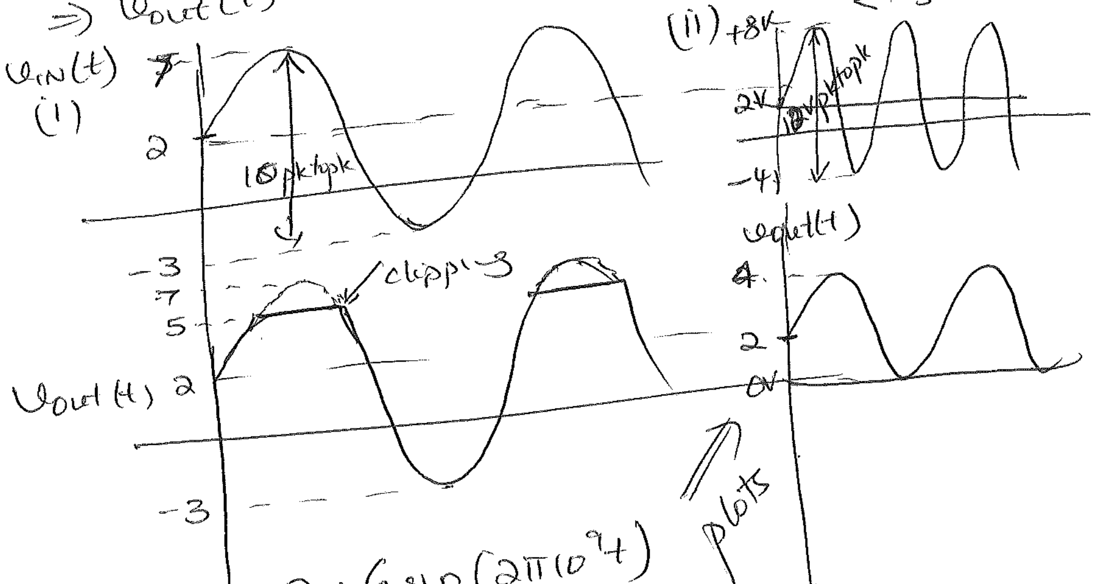
$2 \rightarrow f=0$; $5\sin 2\pi t \rightarrow f = 1Hz$. $\omega = 2\pi$, $\omega = 2\pi f$

$\Rightarrow$ Both 0 & 1Hz get multiplied by gain = 1

$\Rightarrow v_{out}(t) = 2 + 5\sin 2\pi t$

Max $2+5 = 7$ $>+5$ will get clipped

min $2-5 = -3$ <-5 No clipping



(ii) $v_{IN}(t) = 2 + 6\sin(2\pi 10^9 t)$

$2 \rightarrow f=0 \rightarrow *1$; $6\sin(2\pi 10^9 t) \rightarrow f = 10^9 Hz \rightarrow * 1/3$

$v_{out}(t) = 2*1 + \frac{1}{3}*6\sin 2\pi 10^9 t$
$= 2 + 2\sin 2\pi 10^9 t$

4 $<+5$ no clipping; 0 >-5