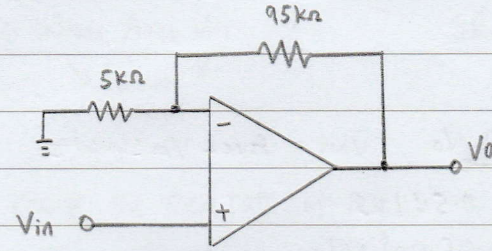
No.: Date:

Esmund Lim AE Tutorial 3

1a)



unity gain frequency $f_0 = 1.2\ \text{MHz}$

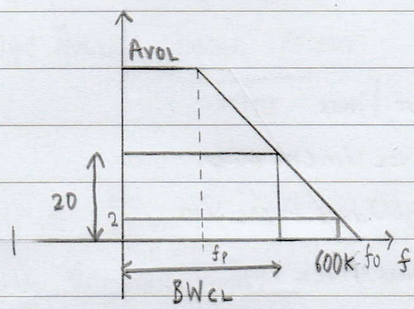
$$A_{VCL} = \frac{5k\Omega + 95k\Omega}{5k\Omega}$$

$$= 20$$

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

$$= \frac{1}{\beta}$$

$$\beta = \frac{R_1}{R_1 + R_2}$$



gain decrease → BW increase

i) $f_0 = A_{VOL}\, f_P$ ← dominant pole frequency

$$= A_1 f_1$$

$$= A_2 f_2$$

$$= \frac{1}{\beta} BW_{CL}$$

$$1.2\ \text{MHz} = 20\ BW_{CL}$$

$$BW_{CL} = 60\ \text{kHz}$$

ii) $\frac{1}{\beta} BW_{CL} = f_0$

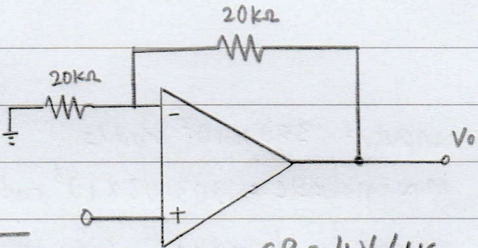
$$\frac{f_0}{BW_{CL}} = \frac{1}{\beta}$$

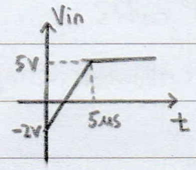
$$\frac{1.2\ \text{MHz}}{600\ \text{kHz}} = 2$$

$$A_{VCL} = \frac{1}{\beta}$$

$$= 2\ V/V$$

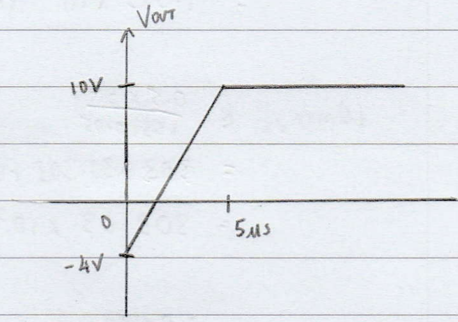
b)





$SR = 4\ V/\mu s$

$f_0 = 2\ \text{MHz}$



$$A_{VCL} = \frac{20k\Omega + 20k\Omega}{20k\Omega}$$

$$= 2$$

$$SR \geq \frac{d}{dt} V_{OUT}\Big|_{max}$$

$$= \frac{10-(-4)}{5\mu s}$$

$$= 2.8 \times 10^6 / s$$

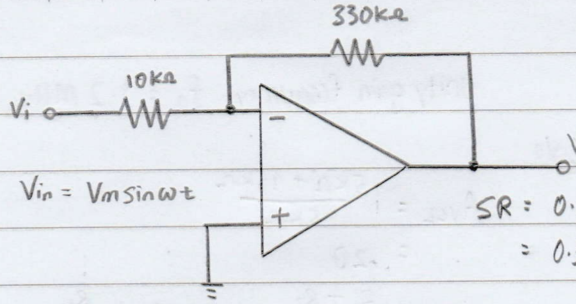
$$= 2.8\ V/\mu s$$

∴ SR is $2.8\ V/\mu s$ which is smaller than the limitation

therefore no distortion of signal will occur

No.: Date:

2)



$V_{in} = V_m \sin \omega t$

$V_{OUT} = A_{VCL} V_m \sin \omega t$ $\quad A_{VCL} = -\left(\frac{330}{10}\right)$
$= -33$

$SR = 0.5 V/\mu s$
$= 0.5 \times 10^6 \ V/s$

$V_1 = 0.01 \sin(10^6 t)$
$V_2 = 0.05 \sin(350\times10^3 t)$
$V_3 = 0.10 \sin(200\times10^3 t)$
$V_4 = 0.20 \sin(50\times10^3 t)$

$SR \geq \frac{d}{dt} V_{OUT}\Big|_{max}$
$\frac{d}{dt} V_{OUT} = \omega A_{VCL} V_m \cos \omega t$
$\left|\frac{d}{dt} V_{OUT}\right|_{max} = \omega_{max} A_{VCL} V_m$
$SR \geq \omega_{max} A_{VCL} V_m$

$\omega_{max\,V_1} \leq \frac{SR}{A_{VCL} V_m}$
$= \frac{0.5\times10^6}{|33|\,0.01}$
$= 1515151.515$
$= 1.515 \times 10^6$ rad/s

input $= 1\times10^6$ rad/s
Max allowable $= 1.5\times10^6$ rad/s
No distortion

$\omega_{max\,V_2} \leq \frac{0.5\times10^6}{|33|\,0.05}$
$= 303030.303$ rad/s
$= 303.03 \times 10^3$ rad/s

input $= 350\times10^3$ rad/s
max allowable $= 303.03\times10^3$ rad/s
signal is distorted (max allowable < input)

$\omega_{max\,V_3} \leq \frac{0.5\times10^6}{|33|\,0.10}$
$= 151515.1515$ rad/s
$= 151.51\times10^3$ rad/s

input $= 200\times10^3$ rad/s
max allowable $= 151.51\times10^3$ rad/s
Signal is distorted (max allowable < input)

$\omega_{max\,V_4} \leq \frac{0.5\times10^6}{|33|\,0.2}$
$= 75757.57576$ rad/s
$= 75.76\times10^3$ rad/s

input $= 50\times10^3$ rad/s
max allowable $= 75.76\times10^3$ rad/s
No distortion

The output due to V_2 and V_3 will be distorted

b) $SR \geq \omega_{max} A_{VCL} V_m$

cannot change

either change the slew rate of A_{VCL}

Change SR = change op-amp

change A_{VCL} = $\underbrace{\text{change resistor}}_{\text{better}}$

$SR_{V_2} \geq 350 \times 10^3 \, |33| \, (0.05)$

$= 0.5775 \, V/\mu s$

$SR_{V_3} \geq 200 \times 10^3 \, |33| \, (0.1)$

$= 0.66 \, V/\mu s$

choose op-amp with $0.66 V/\mu s$ SR

ii) $A_{VCL} \leq \dfrac{SR}{\omega_{max} V_m}$

$A_{VCL\,V_2} \leq \dfrac{0.5 \times 10^6}{350 \times 10^3 (0.05)}$

$= 28.57142857$

$= 28.57$

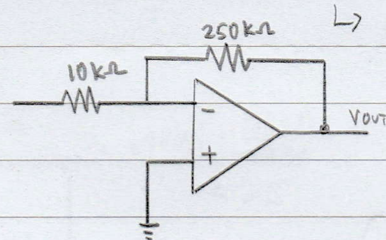
$A_{VCL\,V_3} \leq \dfrac{0.5 \times 10^6}{200 \times 10^3 (0.1)}$

$= 25$

Reduce the A_{VCL} of the present amplifier to 25V/V

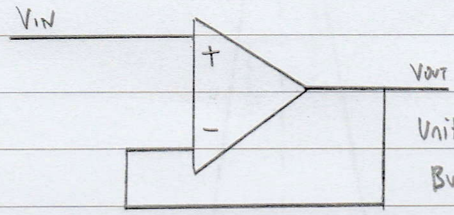
* gain larger, slope = steeper

↳ exceed slew rate



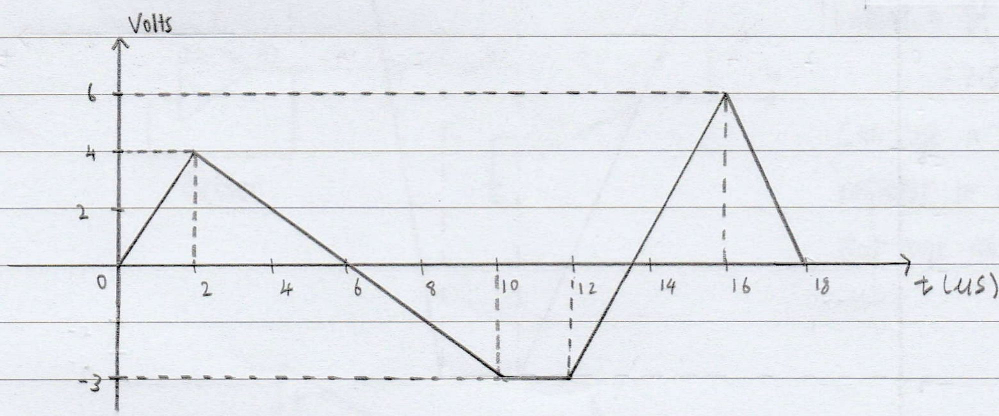
change resistor instead of the whole op-amp

3a)



Unity gain amplifier

Buffer



a) $SR \geq \frac{d}{dt} V_{OUT}|_{max}$

$= \dfrac{6-0}{2\mu s}$

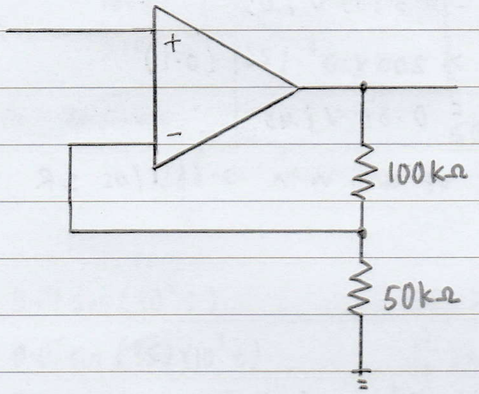
$= 3 V/\mu s$

The minimum SR is $3V/\mu s$

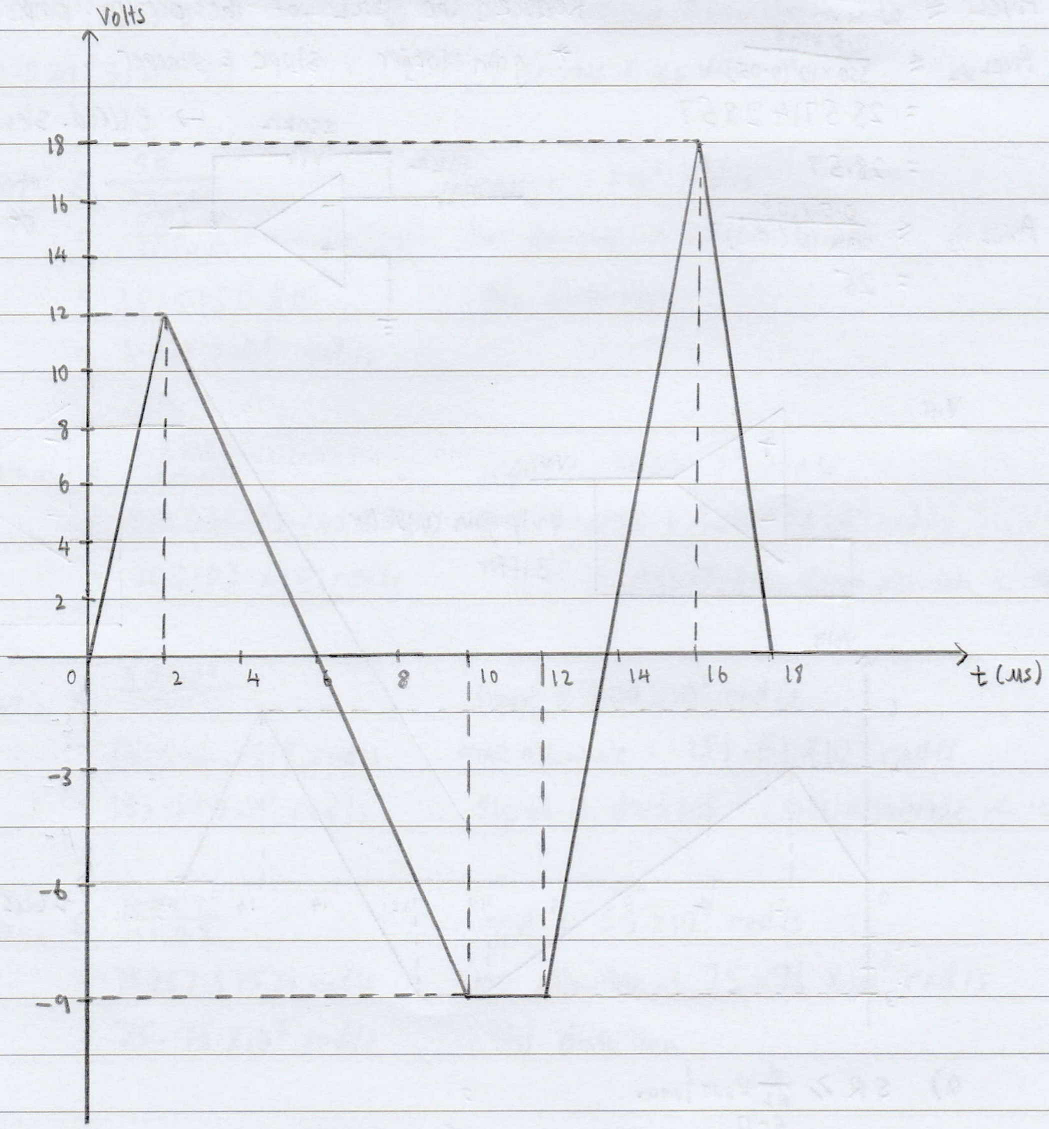
The slew rate that we need for this op-amp must be at least $3V/\mu s$

No.: .... Date: ....

b)



$$A_{VCL} = \frac{50k\Omega + 100k\Omega}{50k\Omega}$$
$$= 3$$

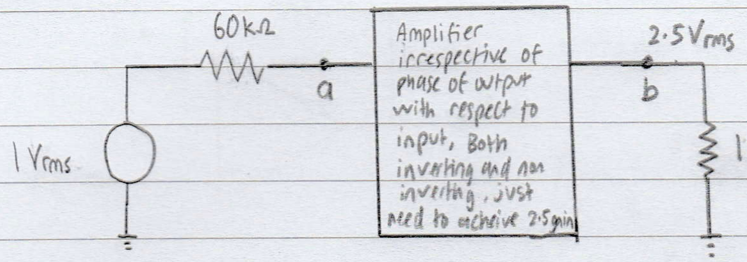


$$SR \geq \frac{d}{dt} V_{OUT}|_{max}$$
$$= \frac{18-0}{2us}$$
$$= 9V/us$$

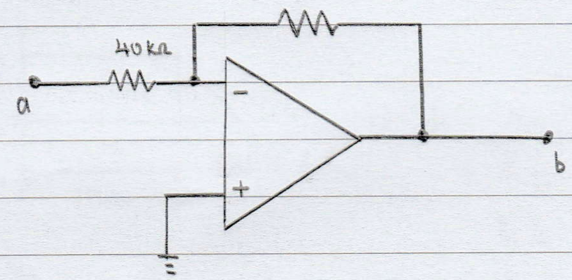
The minimum SR is 9V/us

No.: Date:

4)

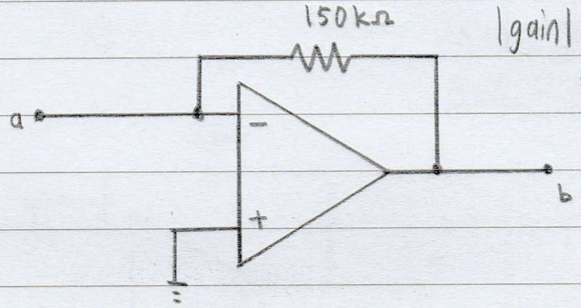


a)



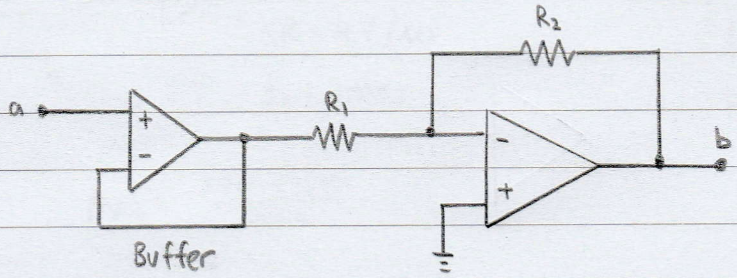
$|gain| = \frac{250k\Omega}{40k\Omega + 60k\Omega}$
$= 2.5$

These designs are very restrictive as the gain is pre-determine by the 60kΩ resistor, and it reduces the variety of values of resistor we could use for designing the op-amp



$|gain| = \frac{150k\Omega}{60k\Omega}$
$= 2.5$

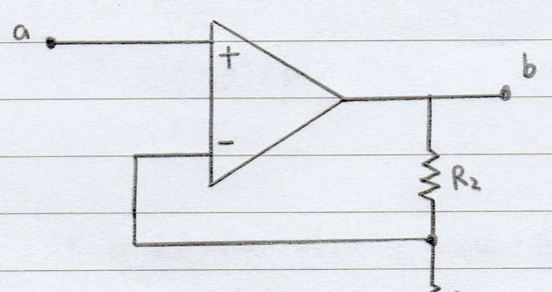
b)



$|gain| = \frac{R_2}{R_1}$
$= 2.5$

Can use a lot of values of resistor to acheive gain of 2.5 But one more op-amp is used

c)



$|gain| = 1 + \frac{R_2}{R_1}$
$\frac{R_2}{R_1} = 1.5$

Best solution (60kΩ does not play a part in finding of gain)