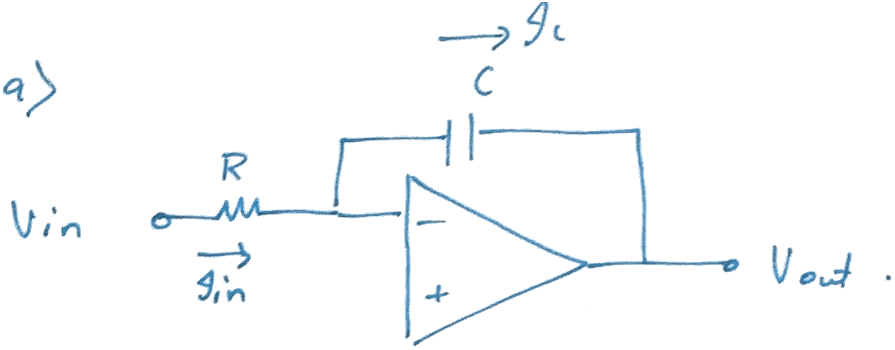
14.1 a)



$$i_{in} = \frac{V_{in}}{R}$$

All the current goes through C.

$$i_{in} \neq i_c = \cancel{\frac{-V_{out}}{X_c}} = \cancel{\frac{V_{in}}{R}}.$$

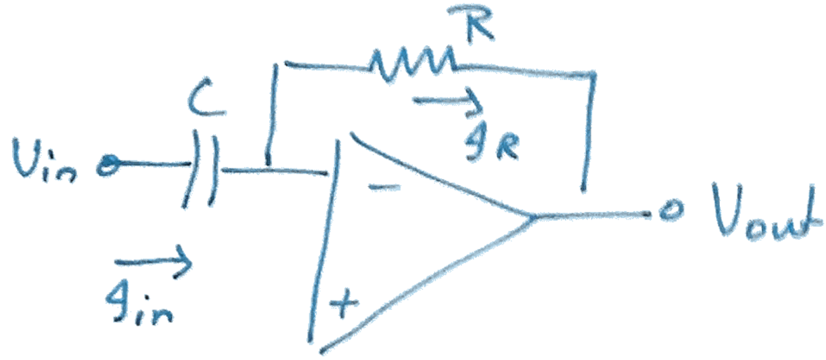
~~Vout =~~ $i_c = C\frac{dV_c}{dt} = C\left(-\frac{dV_o}{dt}\right)$

$$-C\frac{dV_o}{dt} = \frac{V_{in}}{R}$$

$$\frac{dV_o}{dt} = \frac{-1}{RC}V_{in}$$

$$\boxed{V_o = \frac{-1}{RC}\int V_{in}\,dt}$$

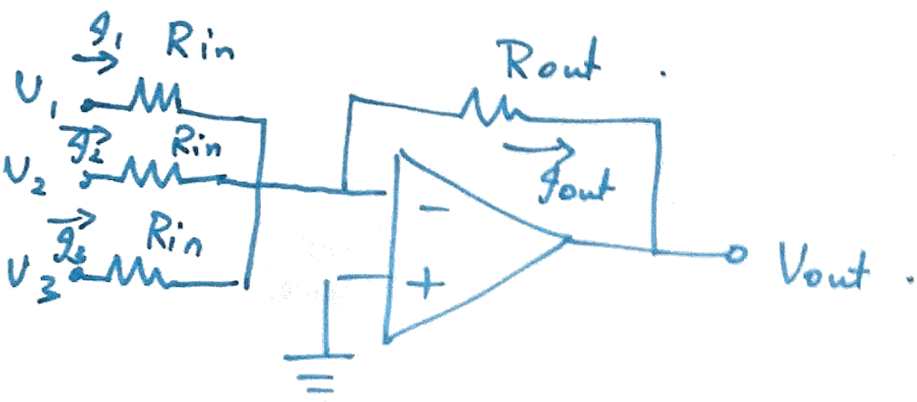
a)



$$i_{in} = i_R$$

$$C\,\frac{dV_c}{dt} = \frac{-V_{out}}{R} \implies C\,\frac{dV_{in}}{dt} = \frac{-V_{out}}{R}$$

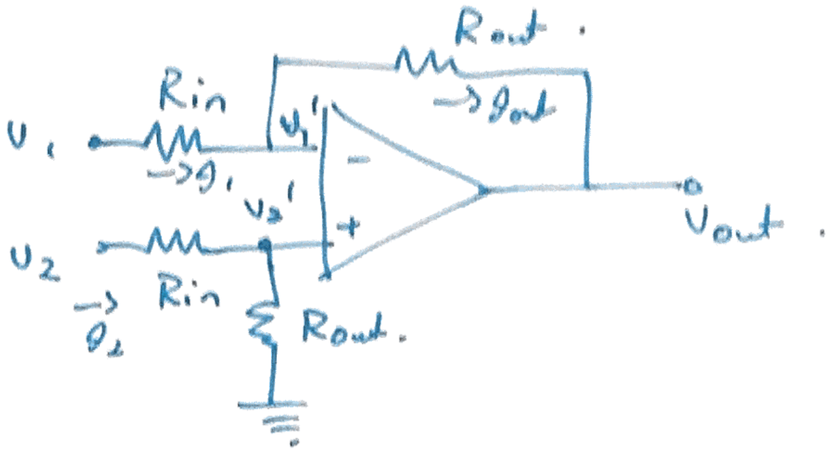
$$\boxed{V_{out} = -RC\,\frac{dV_{in}}{dt}}$$



$i_{out} = i_1 + i_2 + i_3$. (Assuming virtual ground)

$$\frac{-V_{out}}{R_{out}} = \frac{V_1}{R_{in}} + \frac{V_2}{R_{in}} + \frac{V_3}{R_{in}}$$

$$V_{out} = \frac{-R_{out}}{R_{in}}\left(V_1 + V_2 + V_3\right).$$



When $V_2 = 0$, $i_1 = i_{out}$

$$V_{out1} = \frac{-R_{out}}{R_{in}} V_1$$

When $V_1 = 0$, $V_2' = \frac{R_{out}}{R_{in}+R_{out}} V_2$.

$V_1' = V_2'$ and $i_1 = \frac{V_1 - V_1'}{R_{in}} = \frac{-V_1'}{R_{in}} = \frac{-V_2'}{R_{in}}$.

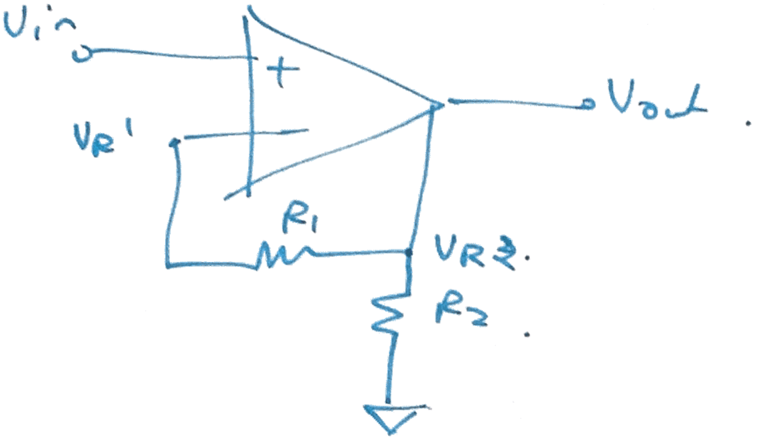
$$i_1 = \frac{-V_2}{R_{in}}\left(\frac{R_{out}}{R_{in}+R_{out}}\right) = i_{out} = \frac{V_1' - V_{out}''}{R_{out}}.$$

$$= \frac{\frac{R_{out}}{R_{in}+R_{out}} V_2 - V_{out}''}{R_{out}} = \frac{V_2}{R_{in}+R_{out}} - \frac{V_{out}''}{R_{out}}.$$

$$V_{out} = V_{out'} + V_{out''} = \frac{-R_{out}}{R_{in}} V_1 + \frac{R_{out}}{R_{in}} V_2 .$$

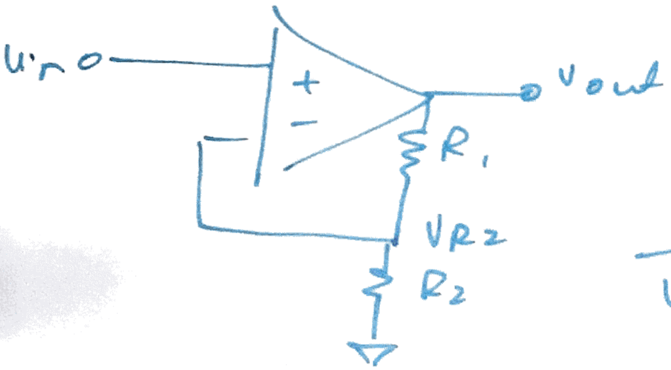
$$\underline{\underline{V_{out} = \frac{R_{out}}{R_{in}} (V_2 - V_1)}}$$

14.1 (b)



$$V_{R2} = V_{out} = V_{R'} \frac{R_2}{(R_1+R_2)} = V_{in} \frac{R_2}{(R_1+R_2)}$$

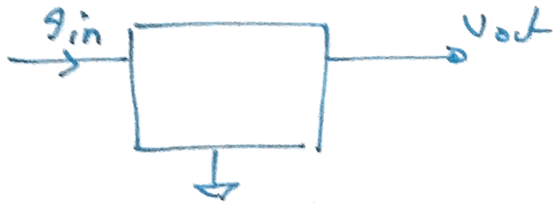
$$\frac{V_{out}}{V_{in}} = \frac{R_2}{(R_1+R_2)}$$ (Not an amplifier)



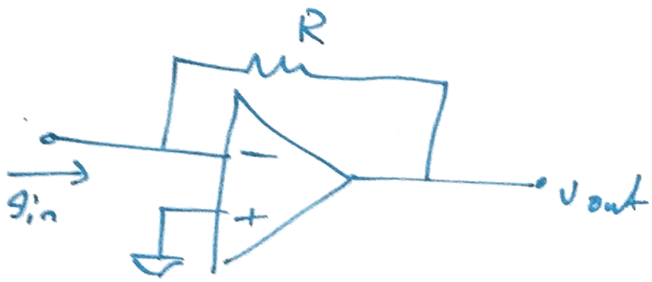
$$V_{R2} = \frac{V_{out} R_2}{R_1+R_2} = V_{in}$$

$$\frac{V_{out}}{V_{in}} = \left(1 + \frac{R_1}{R_2}\right)$$ ← Gain

(c) ~~Gain for~~ a transimpedance amplifier



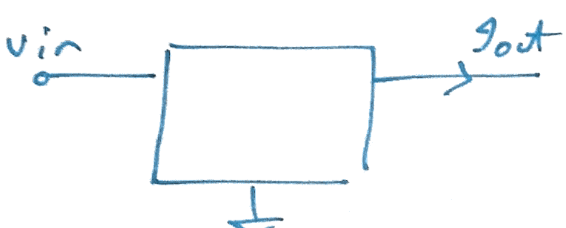
$V_{out} \propto I_{in}$



$$\frac{-V_{out}}{R} = I_{in} .$$

$$\boxed{V_{out} = -I_{in} R}$$

Transconductance amplifier

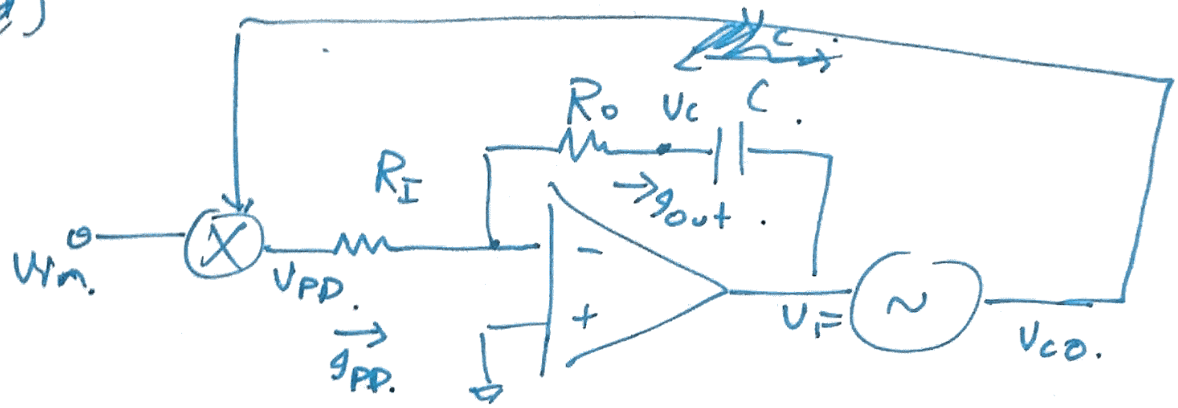


$I_{out} \propto V_{in}$.

$I_{in} = I_{R2} = I_{out}$.

$$\frac{V_{in}}{R_1} = \frac{-V_{out}}{R_2} = I_{out} .$$

14.1) (d)



$$i_{PD} = i_{out}.$$

$$\frac{V_{PD}}{R_I} = \frac{C\,dV_c}{dt}$$

$$= C\frac{d}{dt}\left[V_c - V_F\right]$$

$$\frac{V_{PD}}{R_I C} = \frac{dV_c}{dt} - \frac{dV_F}{dt}$$

$$\frac{dV_F}{dt} = \frac{dV_c}{dt} - \frac{V_{PD}}{R_I C}$$

$$\boxed{\frac{dV_F}{dt} = \frac{-R_o}{R_I}\frac{dV_{PD}}{dt} - \frac{V_{PD}}{R_I C}.}$$

$$V_c = -i_{out} R_o.$$

$$V_c = \frac{V_{PD}}{R_I}(-R_o)$$

$$V_c = \frac{-R_o}{R_I} V_{PD}$$

14.5) SNR $= 20 \log_{10}\left(\frac{V_{RMS\ signal}}{V_{RMS\ noise}}\right)$

$V_{RMS\ noise} = 1$ LSB

$V_{RMS\ signal} =$ Full scale signal $= 2^N$ LSB.

N = Resolution of ADC

For an 8-bit ADC SNR $= 20 \log_{10}(2^8)$

$= \underline{48.164}$ dB

For an 16-bit ADC SNR $= \underline{96.32}$ dB

Averaging

Upon averaging $(SNR)_{8\,bit} = 96.32 = 20 \log_{10}\left(\frac{V_{RMS\ Av\ sign}}{V_{RMS\ noise}}\right)$

$$\left(\frac{V_{RMS\ sign}}{V_{RMS\ noise}}\right)_{Aver} = 2^{16} = 2^8 \cdot 2^8 = 2^8\left(\frac{V_{RMS\ signal}}{V_{RMS\ noise}}\right)$$

$$= \frac{V_{RMS\ signal}}{V_{RMS\ noise}/2^8}$$

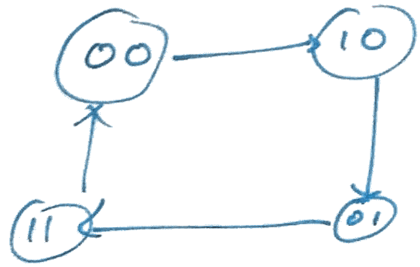
No. of averages $= 2^8 = \underline{256}$

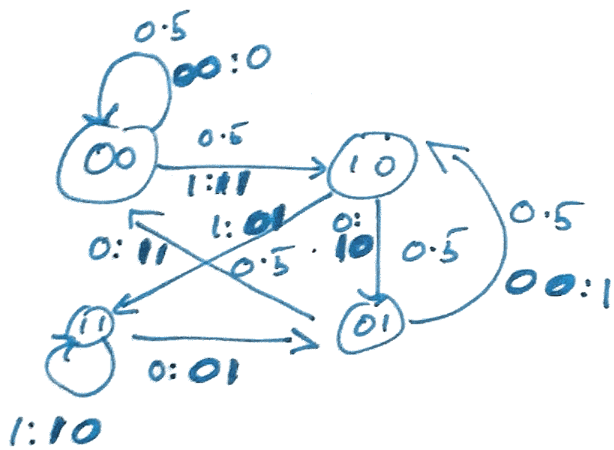
14.6 }

1 0

$\boxed{\begin{matrix}0 & 1\\ 1 & 1\end{matrix}}$

00 10 01 11 00

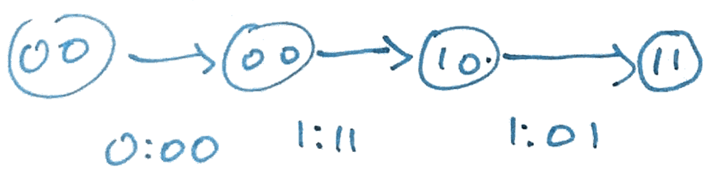




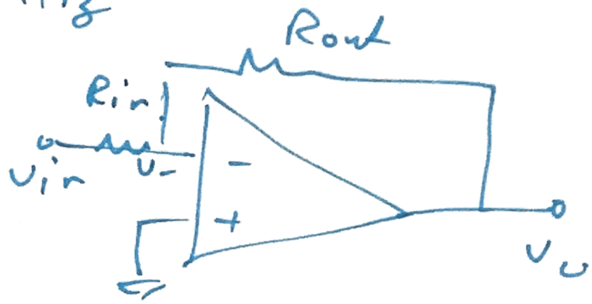
00

10

~~00 → 10 → 01~~



14.2) Given $\omega_1 \approx G_{ol}\,\omega_{ol} = 10\ MHz$



$(G_{ol})_{dB} = 100\ dB$

$(G_{ol}) = 10^5$

$$G(\omega) = \frac{G_{ol}}{1 + i\frac{\omega}{\omega_{ol}}}$$

Gain with feed back $= \dfrac{R_{out}}{R_{in}}$ & $G(\omega) = \dfrac{G_{ol}}{1 + i\frac{\omega}{\omega_{ol}}}$

$$\cancel{G(\omega) = \frac{G_{ol}\,\omega_{ol}}{\omega_{ol} + i\omega} = \frac{10^5}{1 + i\frac{\omega}{\omega_{ol}}}}$$

$$V_o = -V_-\,G(\omega)$$

$$\frac{V_{in} - V_-}{R_{in}} = \frac{V_- - V_o}{R_{out}} \Rightarrow \frac{V_{in}}{R_{in}} + \frac{V_o}{R_{out}} = V_-\left(\frac{1}{R_{in}} + \frac{1}{R_{out}}\right)$$

$$V_- = \frac{V_{in}R_{out} + V_oR_{in}}{R_{in} + R_{out}}$$

$$\therefore\ V_o = -\left(\frac{V_{in}R_{out} + V_oR_{in}}{R_{in} + R_{out}}\right)G(\omega) \Rightarrow$$

$$\cancel{V_o\left(1 - \frac{R_{in}}{R_{in} + R_{out}}\right) = \frac{V_{in}R_{out}}{R_{in} + R_{out}}}$$

$$\cancel{V_o\left(\frac{R_{out}}{R_{in}+R_{out}}\right) = \left(\frac{V_{in}\,R_{out}}{R_{in}+R_{out}}\right)}$$

$$V_o\left(1+\frac{R_{in}\,G(\omega)}{R_{in}+R_{out}}\right) = \frac{-V_{in}\,R_{out}\,G(\omega)}{R_{in}+R_{out}}$$

$$V_o\left(\frac{R_{in}+R_{out}+R_{in}\,G(\omega)}{R_{in}+R_{out}}\right) = \frac{-V_{in}\,R_{out}\,G(\omega)}{R_{in}+R_{out}}$$

$$\frac{V_o}{V_{in}} = \frac{-R_{out}\,G(\omega)}{R_{in}+R_{out}+R_{in}\,G(\omega)}$$

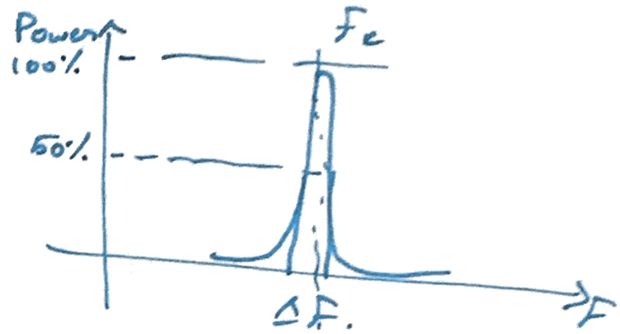
$$= \frac{-\frac{R_{out}}{R_{in}}\,G(\omega)}{\frac{R_{out}}{R_{in}}+1+G(\omega)}.$$

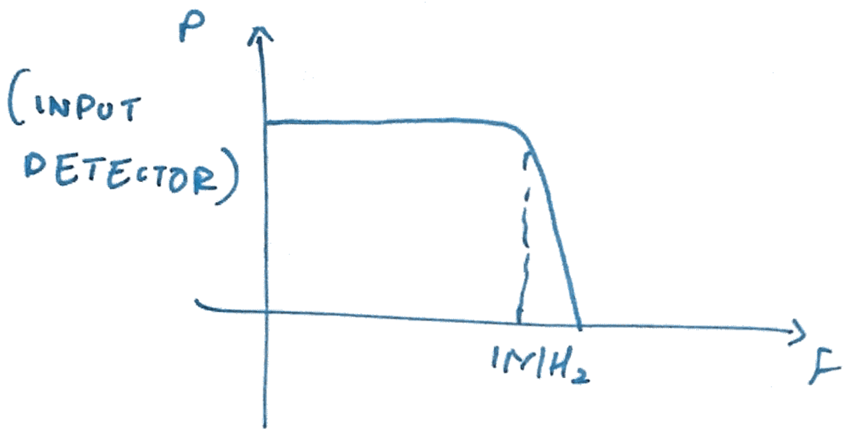
$$= \frac{-\frac{R_{out}}{R_{in}}\,\frac{G_{ol}}{1+i\,\omega/\omega_{ol}}}{1+\frac{G_{ol}}{1+i\,\omega/\omega_{ol}}+\frac{R_{out}}{R_{in}}}$$

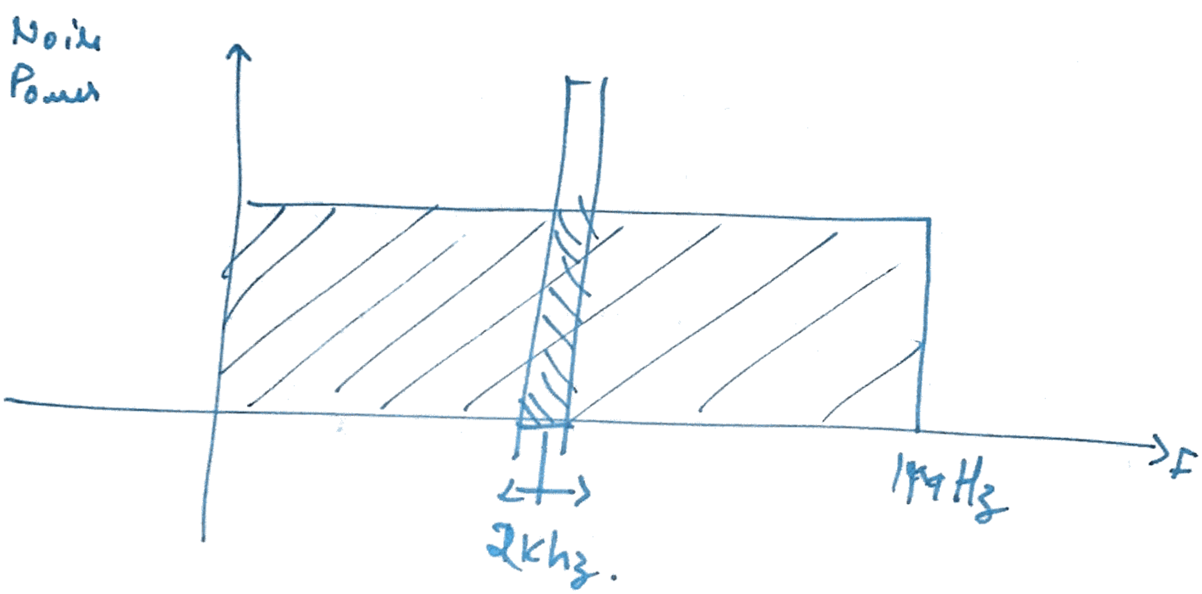
14.3

$$F_0 = 100\ kHz, \quad Q = 50 = \frac{F_c}{\Delta F}$$

$$\Delta F = \frac{100\,kHz}{50} = 2\,kHz.$$







Reduction factor at bandpass filter. $= \dfrac{1\,MHz}{2\,kHz} = 500$