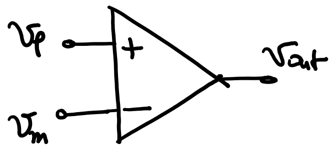
ECE 310- Lecture 38

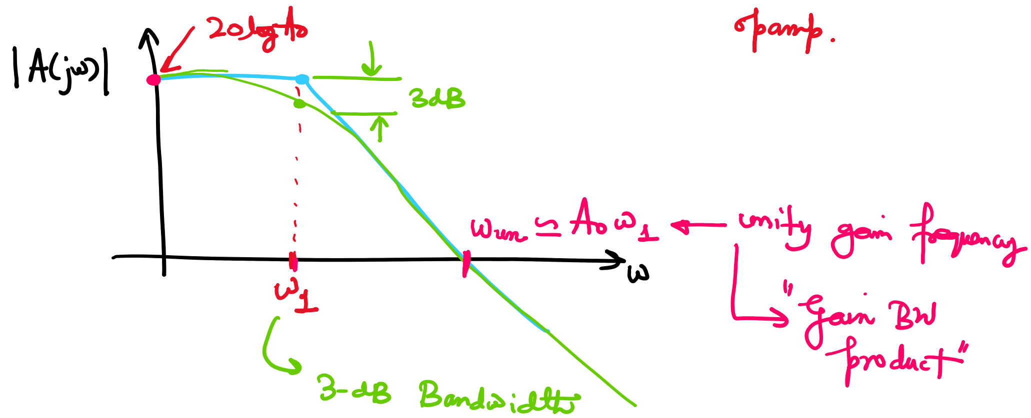
Wednesday, May 2, 2018 10:32 AM



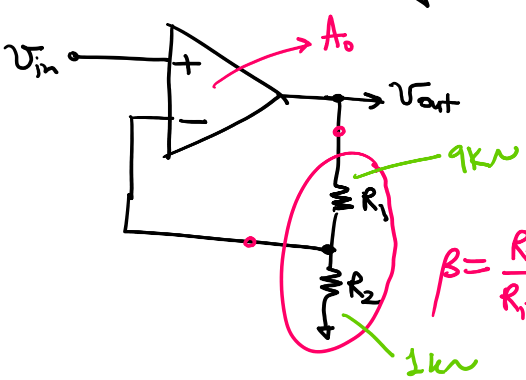
$$A(s) = \frac{V_{out}}{V_p - V_m}(s) = \frac{A_0}{1 + s/\omega_1}$$

A_0 ← DC gain

ω_1 ← 3-dB pole modeling bandwidth limitation of the opamp.



Non-inverting Amplifier



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

Design an amplifier with gain = 10

$$\text{Ideal closed-loop gain} = \frac{1}{\beta} = \frac{R_1 + R_2}{R_2} = 1 + \frac{R_1}{R_2}$$

R_1 → 9k, R_2 ← 1k

* Gain (precision) error < 1%

$$\text{closed-loop gain} \Rightarrow A_{cL} = \underbrace{\frac{1}{\beta}}_{\text{Ideal}} \overbrace{\left(1 - \underbrace{\frac{1}{A_0\beta}}_{\epsilon}\right)}^{\text{error term}}$$

$\epsilon < 0.01$

$$\frac{1}{A_0\beta} < 10^{-2}$$

$$\Rightarrow A_0 > \frac{1}{10^{-2}\cdot\beta} = 10^3$$

We need opamp's DC gain, $A_0 > 10^3$

$20\log_{10}(10^3) = 60$ dB

* How about for 0.01% Error?

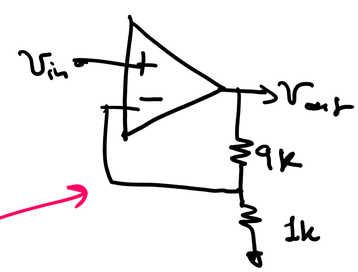
$\epsilon = 10^{-4}$

$$A_0 > \frac{1}{10^{-4}\cdot\beta} = 10^5 \Rightarrow 100\,\text{dB}$$

$$A(s) = \frac{A_0}{1 + s/\omega_1}$$

Amplifier with gain = 10 and 1% error

Closed-loop bandwidth = 100kHz



$$\frac{v_{out}}{v_{in}}(s) = A_{CL}\cdot\frac{1}{1 + \frac{s}{\omega_1(1+A_0\beta)}}$$

$A_{CL} \rightarrow \frac{1}{\beta}\left(1 - \frac{1}{A_0\beta}\right)$

$\omega_1(1+A_0\beta) \rightarrow$ 3-dB BW for the amplifier

"NOT for the opamp"

Closed-loop BW of the amplifier $= \omega_1(1+A_0\beta) \simeq \omega_1 A_0 \beta$

$\rightarrow \omega_{p,cl} = \omega_1 A_0 \beta$

$\omega_{p,cl} \rightarrow 2\pi \times 100\text{kHz}$

$A_0 \rightarrow 10^3$

$\beta \leftarrow \frac{1}{10}$

$$\swarrow \qquad \rightarrow 10^{-}$$

$2\pi \times 100\,kHz$

$$\Rightarrow \quad 2\pi \times 100\,kHz = \omega_1 \cdot 10^2$$

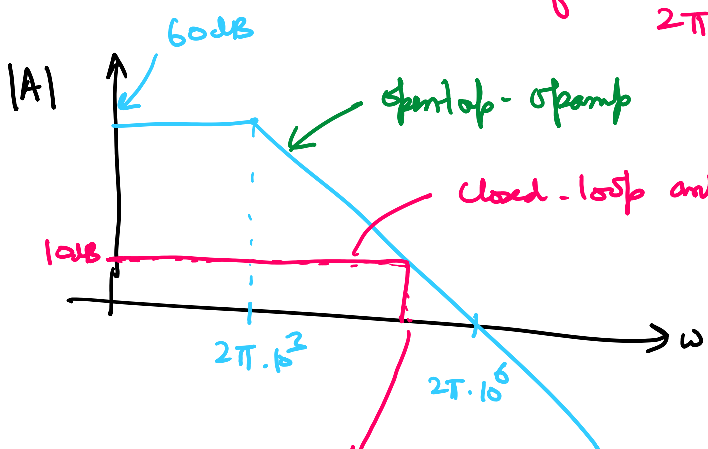
$$\Rightarrow \quad \omega_1 = 2\pi \cdot \frac{10^5}{10^2} = 2\pi \cdot 10^3$$

$$f_1 = \underline{1\,kHz}.$$

$$\omega_{um} = \omega_1 \times A_0 = 2\pi \cdot 10^3 \cdot 10^2$$

$$= 2\pi \times 1\,MHz$$

$$f_{um} = \frac{\omega_{um}}{2\pi} = \boxed{1\,MHz}$$



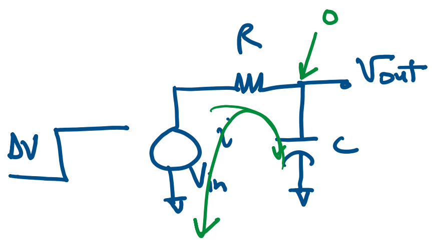
$$\omega_{p,cl} = 2\pi \cdot 10^4 = 2\pi \cdot 100\,kHz$$

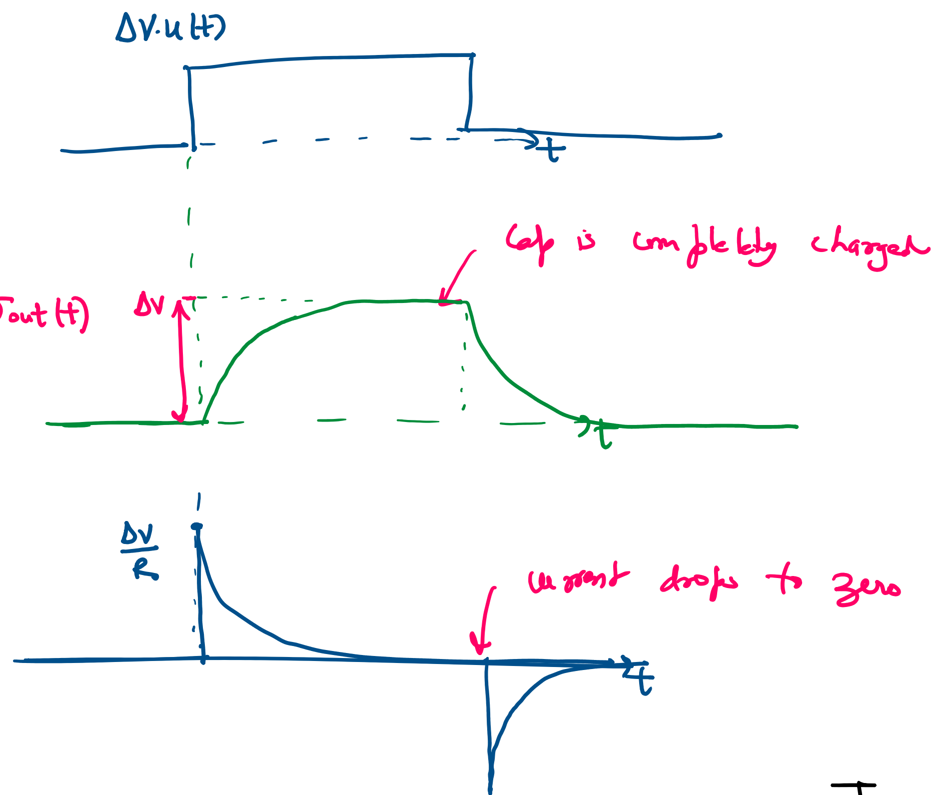
Recap

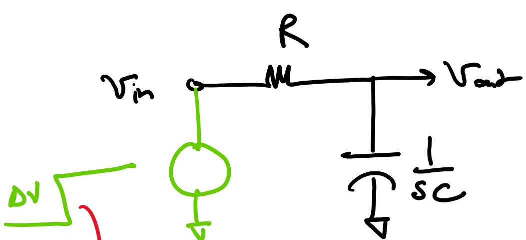
Finite DC gain $\Rightarrow \frac{1}{\beta} \cdot \left(1 - \overbrace{\frac{1}{A_0\beta}}^{\epsilon}\right) \leftarrow$

Closed-loop BW $\Rightarrow \beta\omega_{um} = \beta \cdot (A_0\omega_1) \leftarrow$

DC Offset $\leftarrow$







$\Delta V \cdot u(t) \rightarrow \frac{\Delta V}{s}$

Time constant

$\tau = RC$

$\omega_p = \frac{1}{\tau}$

$$\frac{V_{out}}{V_{in}}(s) = \frac{1/sC}{R + 1/sC} = \frac{1}{1+sRC} = \frac{1}{1+s\tau} = \frac{1}{1+s/\omega_p}$$

$$V_{out}(s) = \frac{1}{(1+s/\omega_p)} \cdot \frac{\Delta V}{s} = \frac{\Delta V}{s(1+s/\omega_p)} = \Delta V\left[\frac{A}{s} + \frac{B}{1+s/\omega_p}\right]$$

$$= \Delta V \frac{\left[A + \frac{As}{\omega_p} + Bs\right]}{s(1+s/\omega_p)}$$

$V_{out}(s) \rightarrow V_{out}(t)$

$$\Rightarrow A + \left(\frac{A}{\omega_p} + B\right)s = 1$$

$\rightarrow \quad A = 1$

$\leftarrow \quad B = -\frac{A}{\omega_p} = -1/\omega_p$

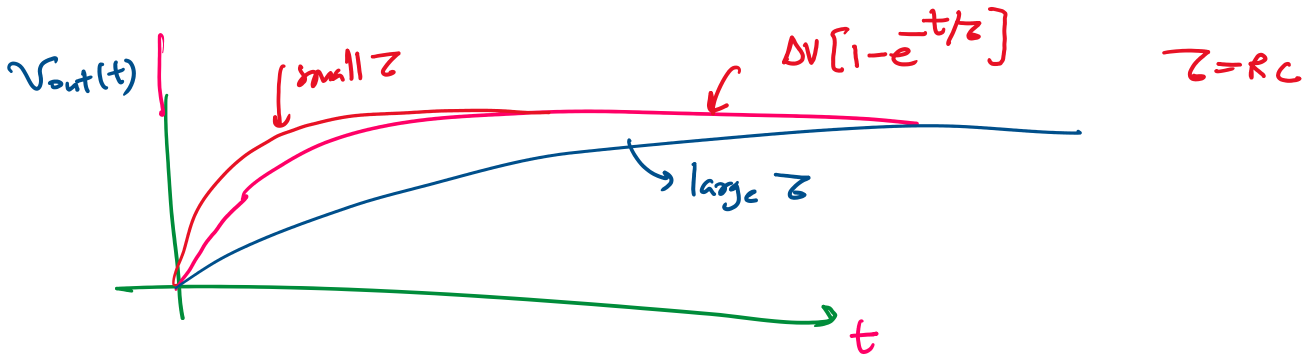
$$V_{out}(s) = \Delta V \cdot \left[\frac{1}{s} - \frac{1}{s + \omega_p} \right]$$

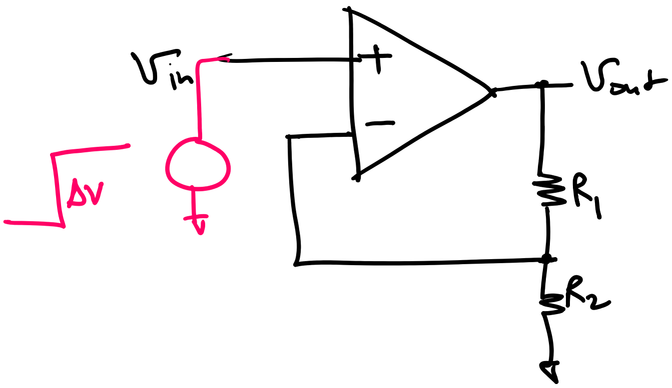
$$V_{out}(t) = \Delta V \cdot \left[u(t) - e^{-\omega_p t} u(t) \right]$$

$$= \boxed{\Delta V \left[1 - e^{-\omega_p t} \right] u(t).}$$

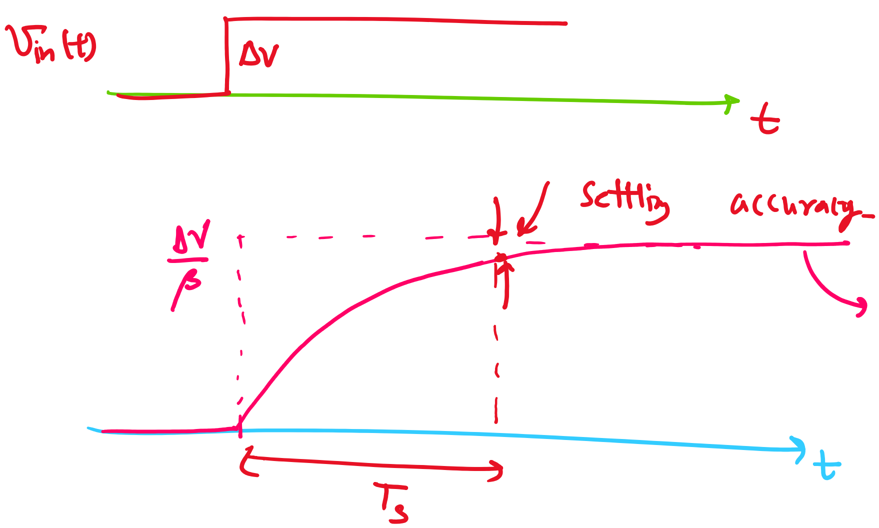
$$= \Delta V \left[1 - e^{-t/\tau} \right] u(t)$$

RC charging/discharge waveform.





$$\frac{V_{out}}{V_{in}}(s) = \frac{1}{\beta}\cdot\frac{1}{\left(1+\frac{s}{\beta\omega_{un}}\right)}$$ → 3-dB BW



$$\frac{\Delta V}{\beta}\cdot\left[1-e^{-t/\tau}\right]u(t)$$

$$\tau = \frac{1}{\omega_{p,cl}} = \frac{1}{\beta\omega_{un}}$$

Small τ ⇒ large $\omega_{p,cl}$

⇒ large $\beta\omega_{un}$

$$V_{out}(t) = \frac{\Delta V}{\beta}\left[1-e^{-2\pi\beta f_{un}t}\right]u(t)$$

$$V_{out}(t) = \frac{\Delta V}{\beta}\left[1 - e^{-LT/\beta f_{unit} t}\right] u(t)$$

large $\omega_{p,cL}$ for faster settling.