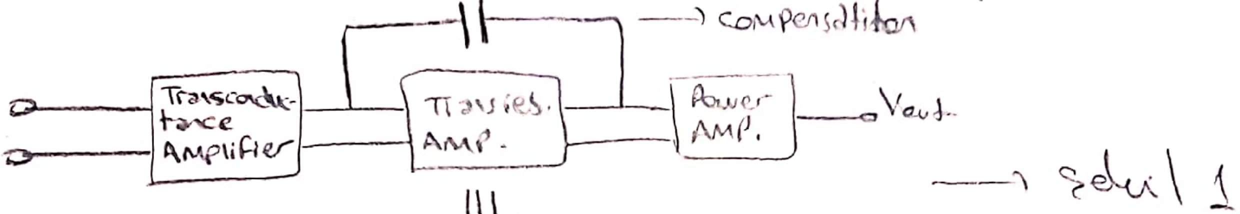
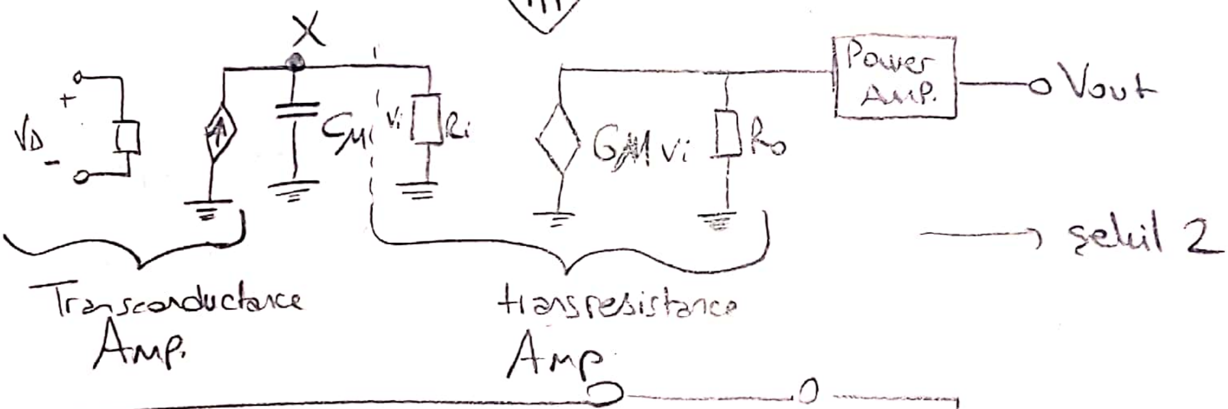
HW-12

Abdullah MENİŞOĞLU
171024001

(Q1.) Derive an expression for the slew rate of an OPAMP, considering that an Opamp consists of a differential amplifier stage followed by a gain stage. What is the relation between the high-frequency cut-off and the slew rate? Is there a trade-off between the slew rate and the phase/gain margins of a compaensated and stable OPAMP? Could you use a compensated Opamp as a comparator, whose responses are expected to be almost instantaneous to step inputs?

Opamp elemanı, Amplifier'ların kaskat bağlanmalarıyla oluşan yapıdır.





Votage gain of the transres. amp. stage

$\underbrace{}_{-G_m R_o}$ $\longrightarrow$ Miller efect $C_m = C_c[1-(-G_m R_o)] = C_c[1+G_m R_o]$ → eq.1

Open Circuit Time Constant Method. (W_H of the Opamp)

$W_H \cong \frac{1}{R_i C_m}$ → C_m eq.1'de hesaplandığından W_H bulunur.

şekil 2'de X ~~node~~ düğümüne KCL uygulanırsa;

$C_m \frac{dv_i}{dt} + \frac{V_i}{R_i} - I_o = 0$ $\qquad \frac{V_i}{R_i} << I_o$ old.

$\boxed{C_m \frac{dv_i}{dt} \cong I_o}$ eq.2

$$\text{Slew Rate} = \frac{dv_o}{dt} \cong \frac{dv_x}{dt}$$

$V_o \cong V_x$

$$\text{Slew Rate} = \underbrace{\left|\frac{dV_x}{dV_i}\right|}_{G_mR_o} \cdot \underbrace{\frac{dV_i}{dt}}_{\frac{I_o}{C_m}} = \frac{dv_x}{dt}$$

from eq.1

$$\text{Slew Rate} = G_mR_o \cdot \frac{I_o}{C_c(1+G_mR_o)}$$

$$\text{Slew Rate} = \frac{I_o \cdot \cancel{G_mR_o}}{C_c \cdot (\cancel{G_mR_o})} \quad G_mR_o >> 1 \approx \boxed{\frac{I_o}{C_c} = \text{Slew Rate}}$$

$$W_H = \frac{1}{R_iC_m} = \frac{1}{R_i C_c(1+G_mR_o)} \longrightarrow \boxed{\frac{1}{C_c} = W_H \cdot R_i \cdot (1+G_mR_o)} \rightarrow \underline{W_H\, G_mR_o \cdot R_i}$$

eq.4

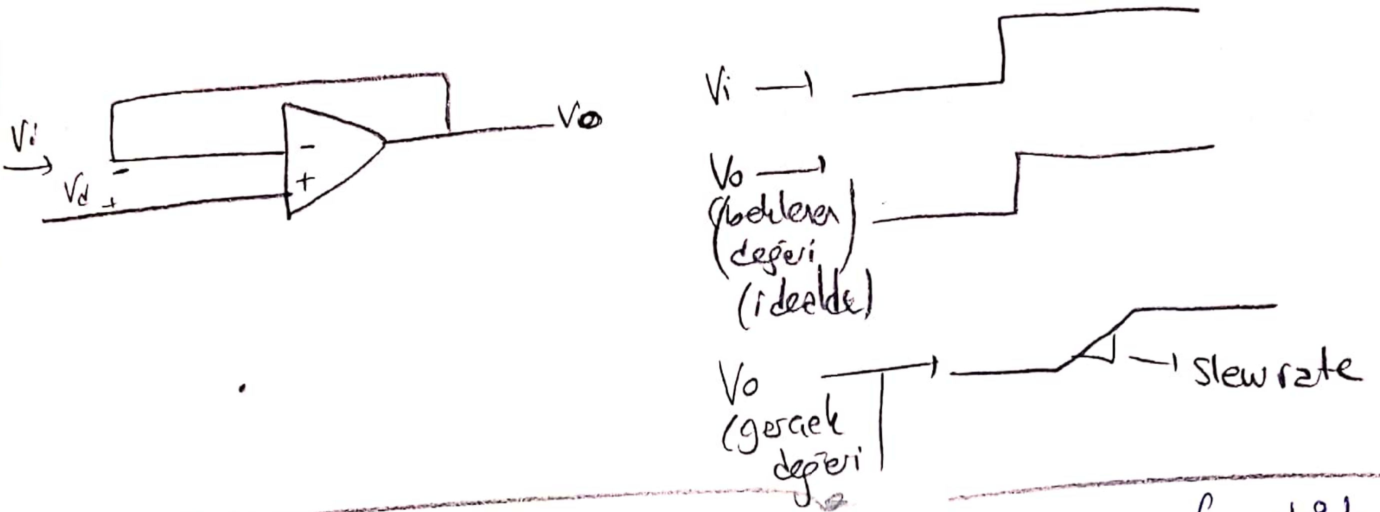
$$\text{Slew Rate} = \frac{I_o}{C_c} = I_o \cdot \frac{1}{C_c} = \boxed{I_o \cdot W_H \cdot G_mR_o \cdot R_i}$$

from eq.4

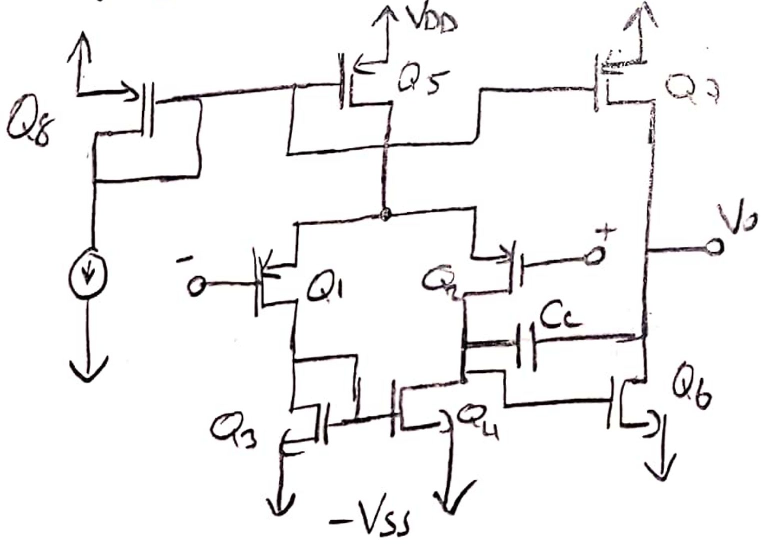
Eger Cc(compensation capacitance) ~~d~~ degeri artarsa, faz ve kazanc marginleri opampin daha stabil oldugunu gösterir.

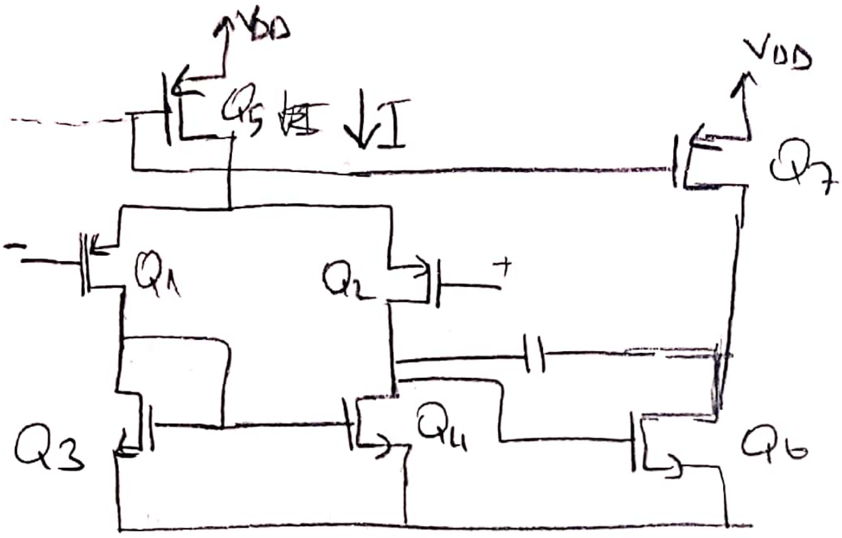
Slew Rate'in ideal degeri sonsuzdur. $\frac{I_o}{K_c} \approx \infty$ ise $C_c \to 0$ ideal degerdir. Slew Rate'i ideal duruma getirmek istedigimizde Compensation efektini kaybetmeliyiz. Bu iliskiye trade-off iliski denir. Slew rate'in idealligi ya da opampin stabilitesi arasinda secim yapmaliyiz. Hangisi tasarima daha uygun ise Cc degeri ona uygun secilmelidir.

CamScanner ile tarandı



Q2. The CMOS opamp of Fig 9.1 is fabricated in a process for which $V'_{An} = 25\,V/\mu m$ and $|V'_{Ap}| = 20\,V/\mu m$. Find A_1, A_2, and A_v if all devices are $0.8\,\mu m$ long and are operated at equal overdrive voltages of 0.25-V magnitude. Also, determine the opamp output resistance obtained when the second stage is biased at 0.4 mA. What do you expect the output resistance of a unity-gain voltage amplifier to be, using this opamp?





$\rightarrow \; I_{D5} = 2I_{D4} = I \qquad V_{G6} \approx V_{D4} \approx V_{D3}$

$$I_{D6} = \frac{(W/L)_6}{(W/L)_4} I_{D4} = \frac{(W/L)_6}{(W/L)_4}\frac{I}{2} = I_{D6}$$

$$I_{D7} = \frac{(W/L)_7}{(W/L)_5} I_{D5} = \frac{(W/L)_7}{(W/L)_5} I$$

$$I_{D6} = I_{D7}$$

$$\frac{(W/L)_6}{(W/L)_4}\frac{I}{2} = \frac{(W/L)_7}{(W/L)_5} I \rightarrow \frac{(W/L)_6}{(W/L)_4} = 2\cdot\frac{(W/L)_7}{(W/L)_5}$$

$\boxed{I_{D4} = I_{D1}' = \frac{0.4}{2} mA = 0.2 mA} \qquad \boxed{I_{D6} = I_{D7} = 0.4 mA} \qquad I_{D5} = I_{D7}$

$$g_{m1} = \frac{2I_{D1}}{V_{GS1} - V_{th}} = \frac{2I_{D1}}{V_{overdrive}} = \frac{2\cdot 0.2\times10^{-3}}{0.25} = 1.6 mS$$

$$g_{m6} = \frac{2I_{D6}}{V_{GS6} - V_{TH,n}} = \frac{2\cdot(0.4)\times10^{-3}}{0.25 V} = 3.2 mS$$

$$r_{op} = \frac{V_{A,P}}{I_D} \Rightarrow \quad r_{o2} = \frac{V_{A,P}}{0.2mA} \qquad r_{o4} = \frac{V_{A,n}}{0.2mA}$$

$$r_{o,6} = \frac{V_{A,n}}{0.4mA} \qquad r_{o,7} = \frac{V_{A,P}}{0.4mA}$$

$V_{A,n} = V'_{A,n} \cdot L = 25V/\mu m \cdot 0.8\mu m = 20V$

$V_{A,p} = V'_{A,p} \cdot L = 20V/\mu m \cdot 0.8\mu m = 16V$

$r_{o2} = \dfrac{V_{A,p}}{I_{D2}} = \dfrac{16}{0.2\times10^{-3}} = 80k\Omega$ $\quad r_{o6} = \dfrac{V_{A,n}}{I_{D6}} = \dfrac{20V}{0.4\times10^{-3}} = 50k\Omega$

$r_{o4} = \dfrac{V_{A,n}}{I_{D4}} = \dfrac{20V}{0.2\times10^{-3}A} = 100k\Omega$ $\quad r_{o7} = \dfrac{V_{A,p}}{I_{D,7}} = \dfrac{16V}{0.4\times10^{-3}} = 40k\Omega$

$A \rightarrow$ Voltage Gain $= \underbrace{A_1}_{\text{differential Stage}} \cdot \underbrace{A_2}_{\text{Common Source Stage}}$

$A = \left[-\underbrace{g_{m1}}_{1.6mS} \cdot (\underbrace{r_{o2}}_{80k\Omega} \| \underbrace{r_{o4}}_{100k\Omega})\right] \cdot \left[-\underbrace{g_{m6}}_{3.2mS}(\underbrace{r_{o6}}_{50k\Omega} \| \underbrace{r_{o7}}_{40k\Omega})\right]$

$A = \left[(-1.6\times10^{-3}) \cdot \left(\dfrac{80 \cdot 100}{180} k\Omega\right) \cdot (-3.2\times10^{-3}) \cdot \left(\dfrac{50 \cdot 40}{90} k\Omega\right)\right]$

$A = [(-1.6) \cdot (44.44) \cdot (-3.2) \cdot (22.22)]$

$\boxed{A = 5056.739 \ V/V}$

$1 = \dfrac{A}{1+A\beta} \longrightarrow A = 1 + A\beta \longrightarrow \boxed{1 + A\beta = 5056.739}$

$\beta = 0.99980$

$R_{out} = r_{o6} \| r_{o7} = 22.22k\Omega$

$R_{out,f} = \dfrac{r_{o6} \| r_{o7}}{1+A\beta} = \dfrac{22.22k\Omega}{5056.739} = 4.3945\Omega$

feedback ile çıkış empedansı $\approx$ 5000 kat daha azalmıştır

CamScanner ile tarandı