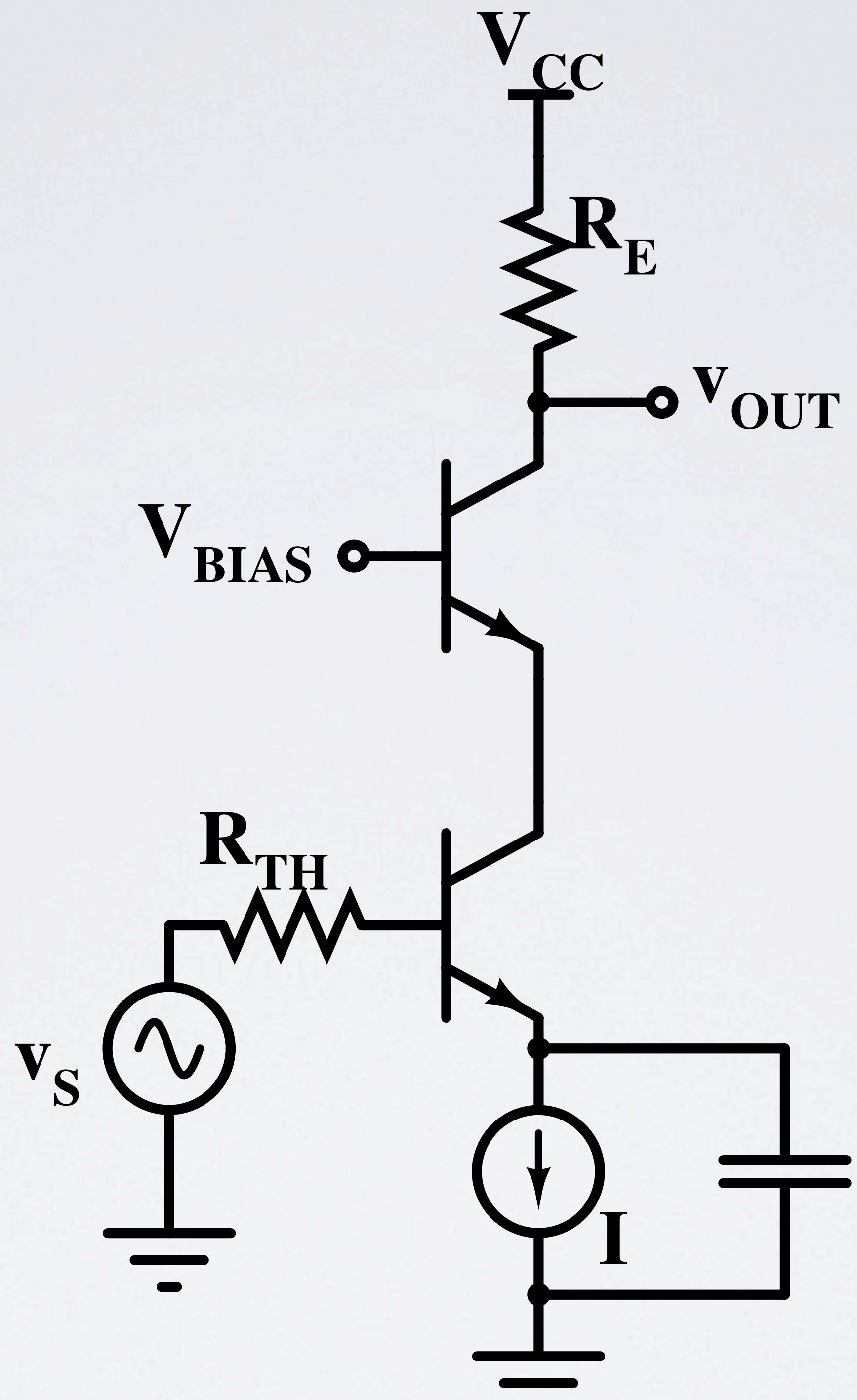
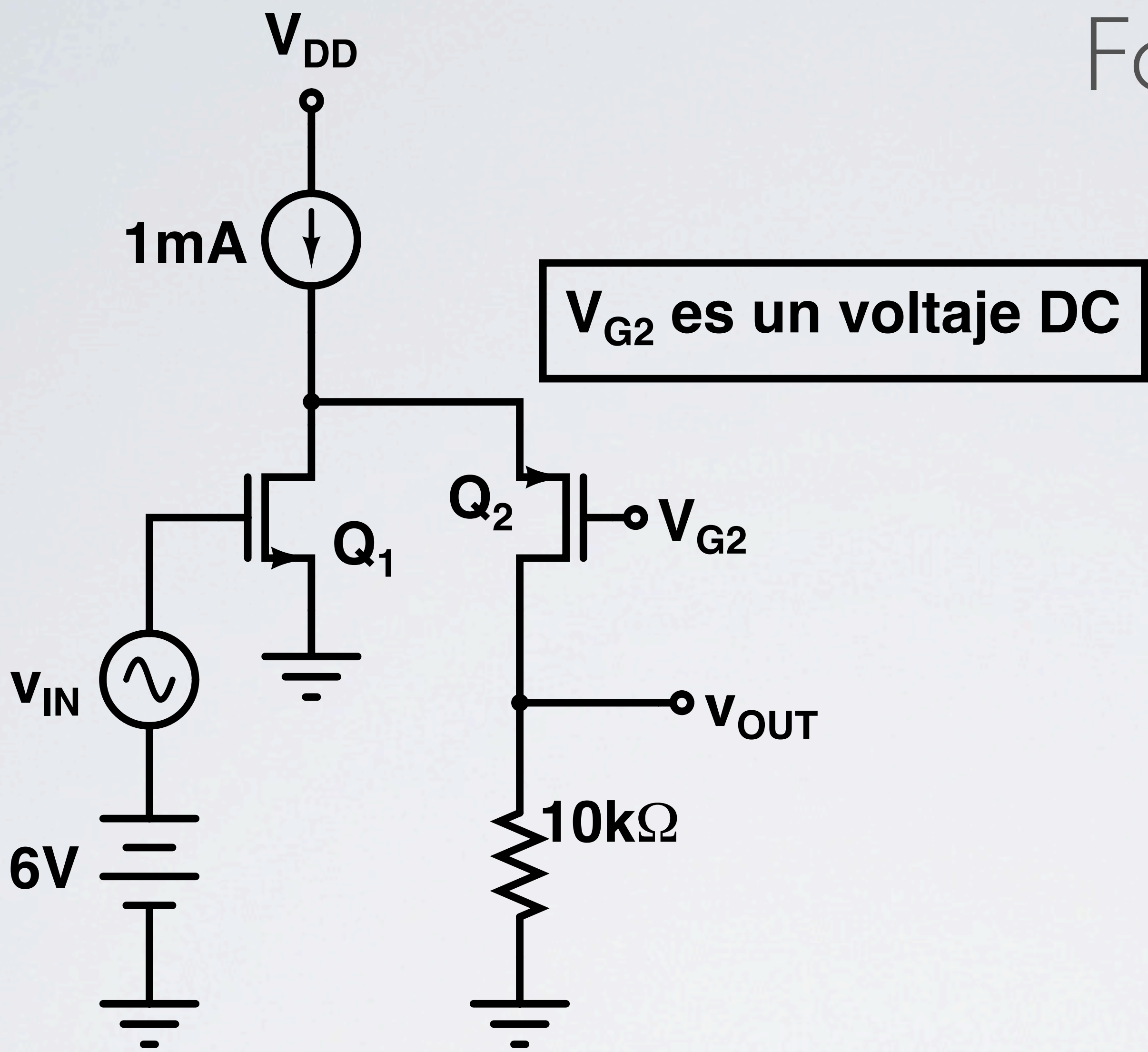
AMPLIFICADORES MULTI-ETAPAS

INEL 4202 - 9/4/2012 - M.Toledo

CE-CB cascode circuit



Folded cascode



Determine la ganancia de frecuencias intermedias y el ancho de banda (en Hz) del siguiente circuito. Asuma que $C_{gs} = 30pF$, $C_{gd} = 3pF$, $V_{th} = 1V$, $\lambda = 0$ y $K_N = 20\mu A/V^2$.

Respuesta:
Para obtener el punto de operacion de los transistores, observe que

$$1mA = I_{DQ_1} + I_{DQ_2}$$

El voltaje d.c. del *gate* de Q_1 es $6V$, y

$$I_{DQ_1} = K_N \left(v_{GS} - V_{th}\right)^2 = 20\mu A/V^2 \times \left(6V - 1V\right)^2 = 0.5mA$$

asi que

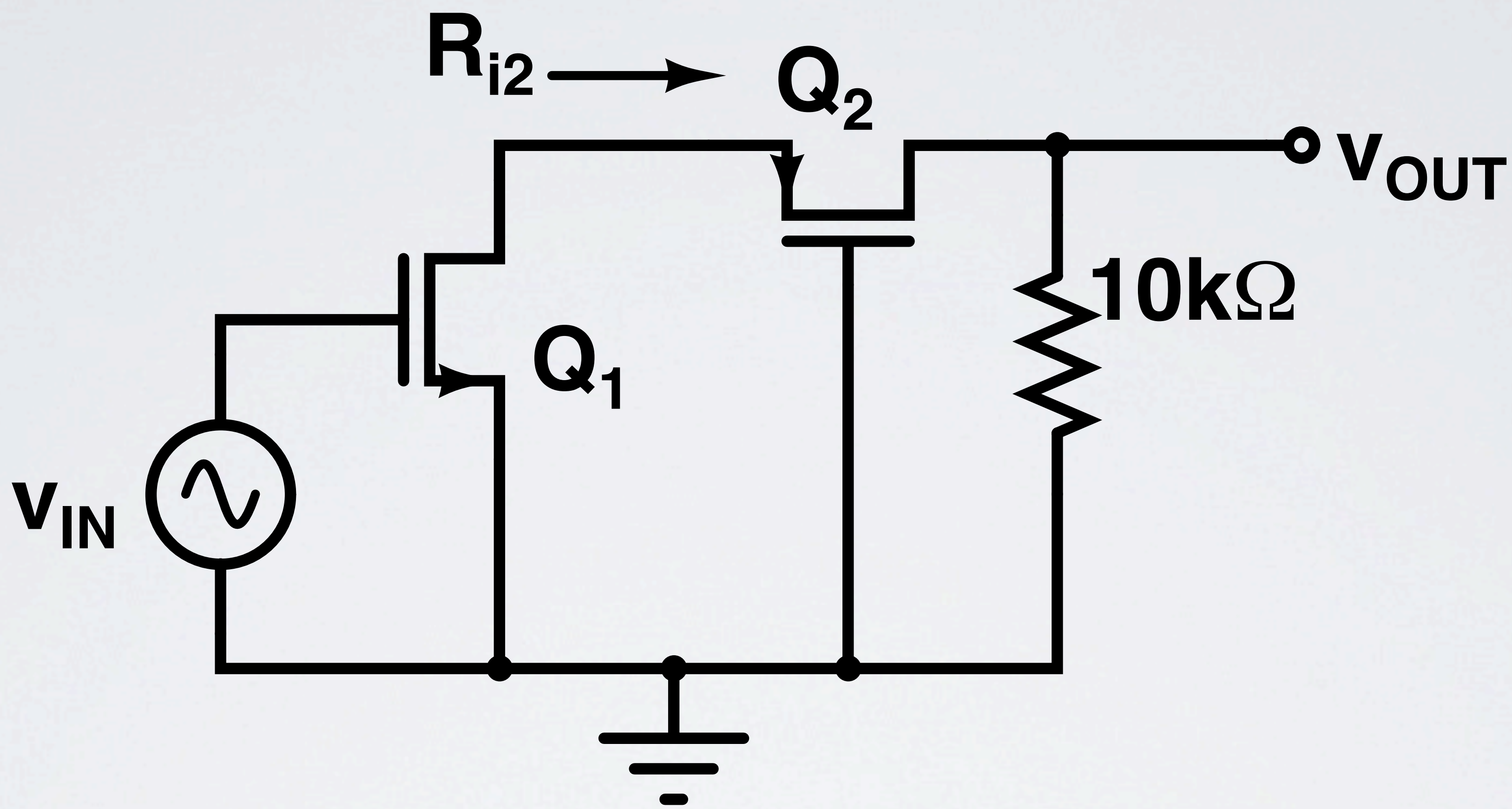
$$I_{DQ_2} = 1mA - 0.5mA = 0.5mA$$

y

$$g_{m1} = g_{m2} = g_m = \sqrt{4K_N I_{DQ}} = \boxed{0.2mA/V}$$

Folded cascode

El esquematico del circuito equivalente en a.c. es:



El circuito consiste de una etapa *common-source* seguida de una *common gate*. La resistencia equivalente en la entrada de la segunda etapa es $R_{i2} = \frac{1}{g_{m2}} = 5k\Omega$.

Debido a que la fuente v_{in} es ideal, la capacitancia parasitica en el *gate* de Q_1 produce un polo en ∞ que no es necesario considerar.

Para $C_{gs,2}$, la resistencia equivalente es R_{i2} y

$$f_{H,gs2} = \frac{1}{2\pi \times 30pF \times 5k\Omega} = \boxed{1.06MHz}$$

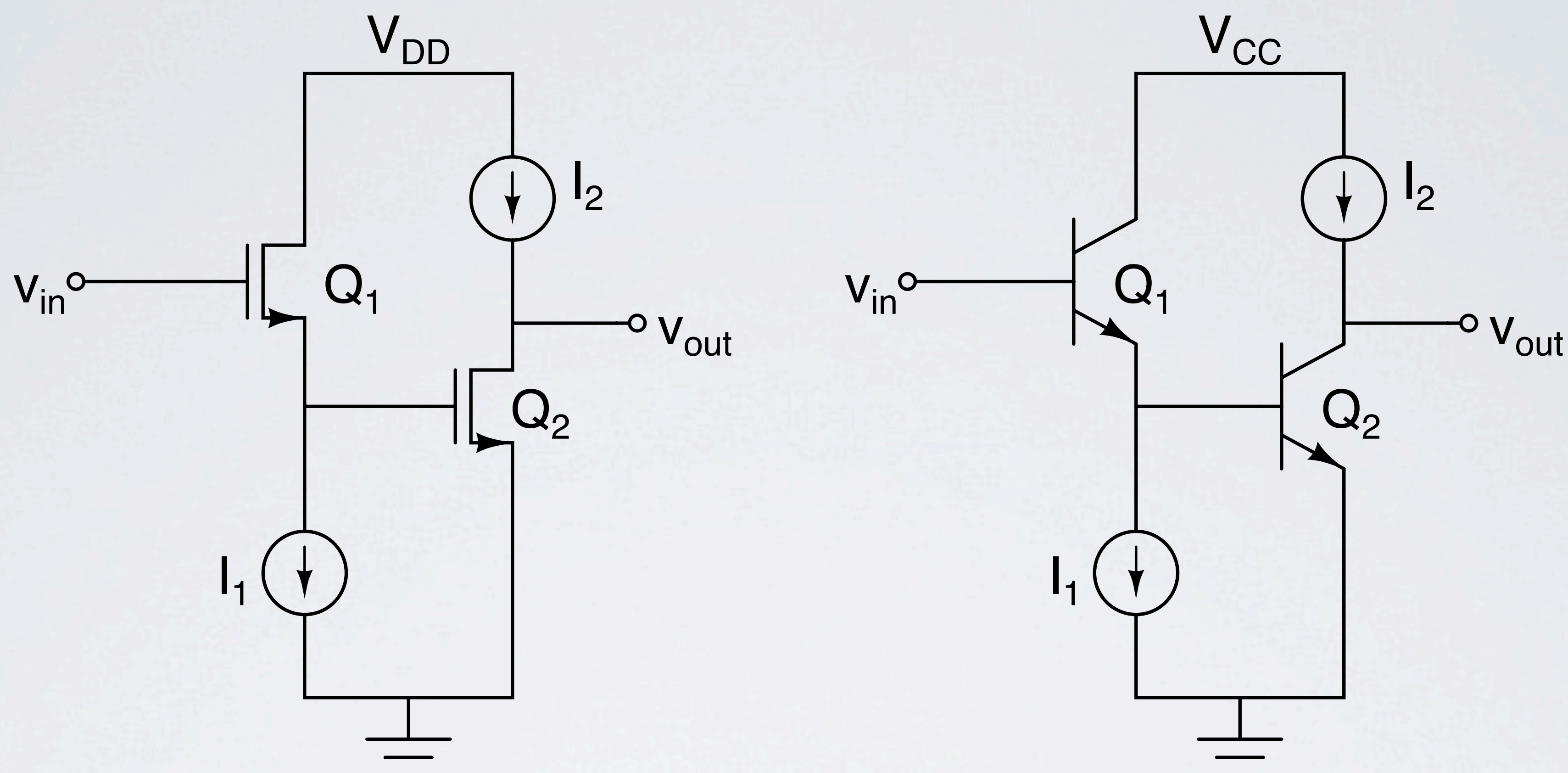
Para $C_{gd,2}$, la resistencia equivalente es $10k\Omega$ y

$$f_{H,gd2} = \frac{1}{2\pi \times 3pF \times 10k\Omega} = \boxed{5.3MHz}$$

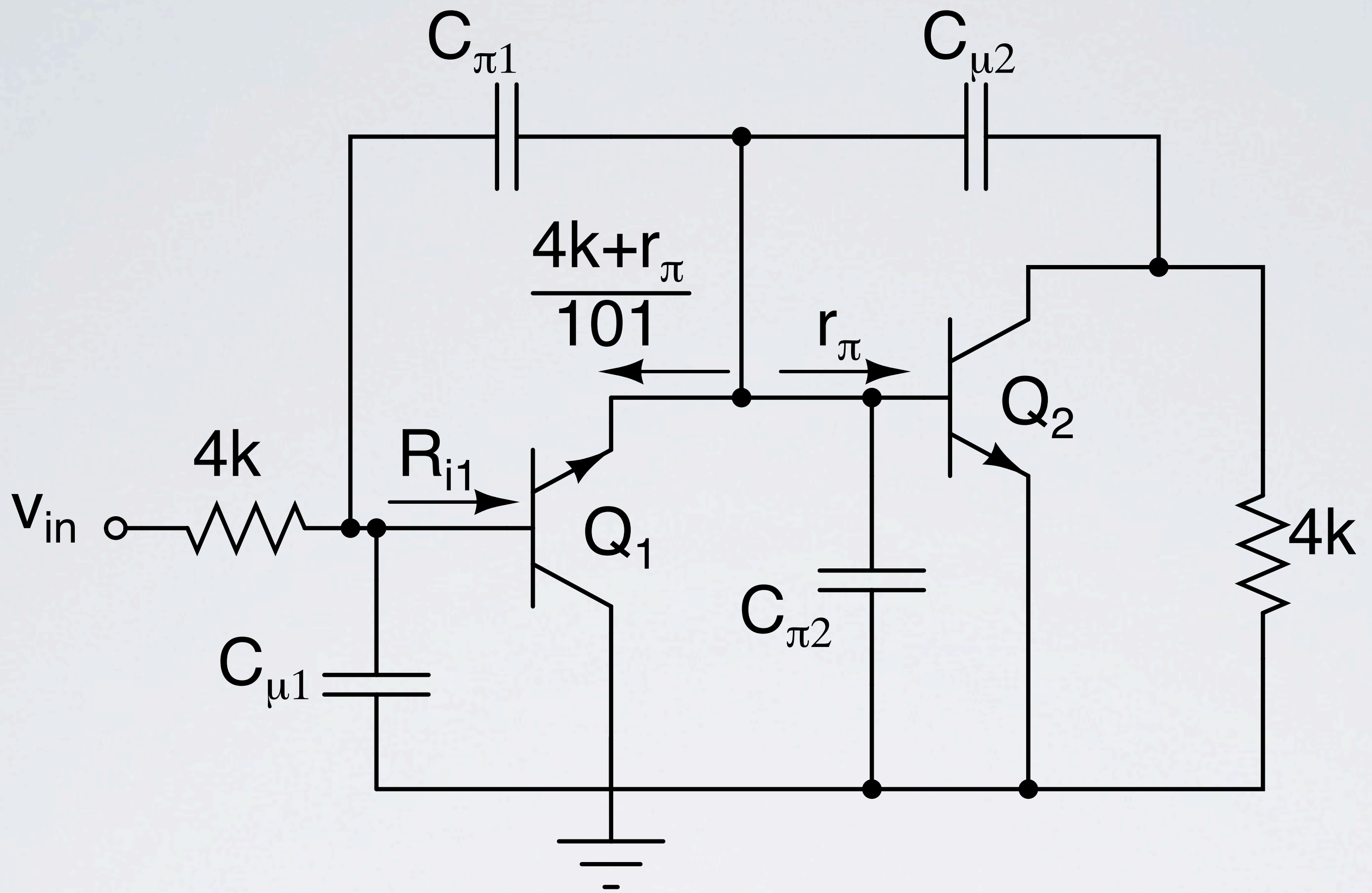
El polo dominante es $1.06MHz$ y determina el ancho de banda.

La ganancia para frecuencias intermedias es

$$A_v = \frac{v_{d2}}{v_{g1}} = (-g_m R_{i2})(g_m R_L) = (-1)(0.2mA/V \times 10k\Omega) = \boxed{-2V/V}$$



Example: CC-CE amp. - $I_1 = I_2 = 1mA$, $\beta = 100$, $f_T = 400MHz$, $C_\mu = 2pF$, $R_{sig} = R_L = 4k\Omega$,. Find A_M and estimate f_H



$$R_{i1} = r_{\pi 1} + (\beta+1) r_{\pi 2}$$

Example: CC-CE amp. - $I_1 = I_2 = 1mA$, $\beta = 100$, $f_T = 400MHz$, $C_\mu = 2pF$, $R_{sig} = R_L = 4k\Omega$,. Find A_M and estimate f_H

ANSWER: $f_T = \beta/2\pi(C_\pi + C_\mu)r_\pi$ -> $C\pi = 13.9pF$; $A_M = -155V/V$, $R_{\mu 1}=3.9k\Omega$, $R_{\pi 1} = 63\Omega$, $R_{\pi 2} = 63\Omega$, $R_{\mu 2} = 14k\Omega$, $f_H \cong 4.2MHz$

See procedure, applying Miller's Theorem, on next 4 pages.

Example: CC-CE amp. - $I_1 = I_2 = 1mA$, $\beta = 100$, $f_T = 400MHz$, $C_\mu = 2pF$, $R_{sig} = R_L = 4k\Omega$,. Find A_M and estimate f_H

$C_{\mu 1}$ sees:

$$R_{\pi 1} = 4K \,||\, [r_{\pi 1} + (\beta+1) r_{\pi 2}]$$

$$= 4K \,||\, [2.5K + 101(2.5K)] = 4K \,||\, 255K$$

$$= 3.9K \Rightarrow f_1 = \frac{1}{2\pi(3.9k)(2\ pF)} \simeq \boxed{20\ MHz}$$

$C_{\mu 2}$ can be changed using Miller's theorem.

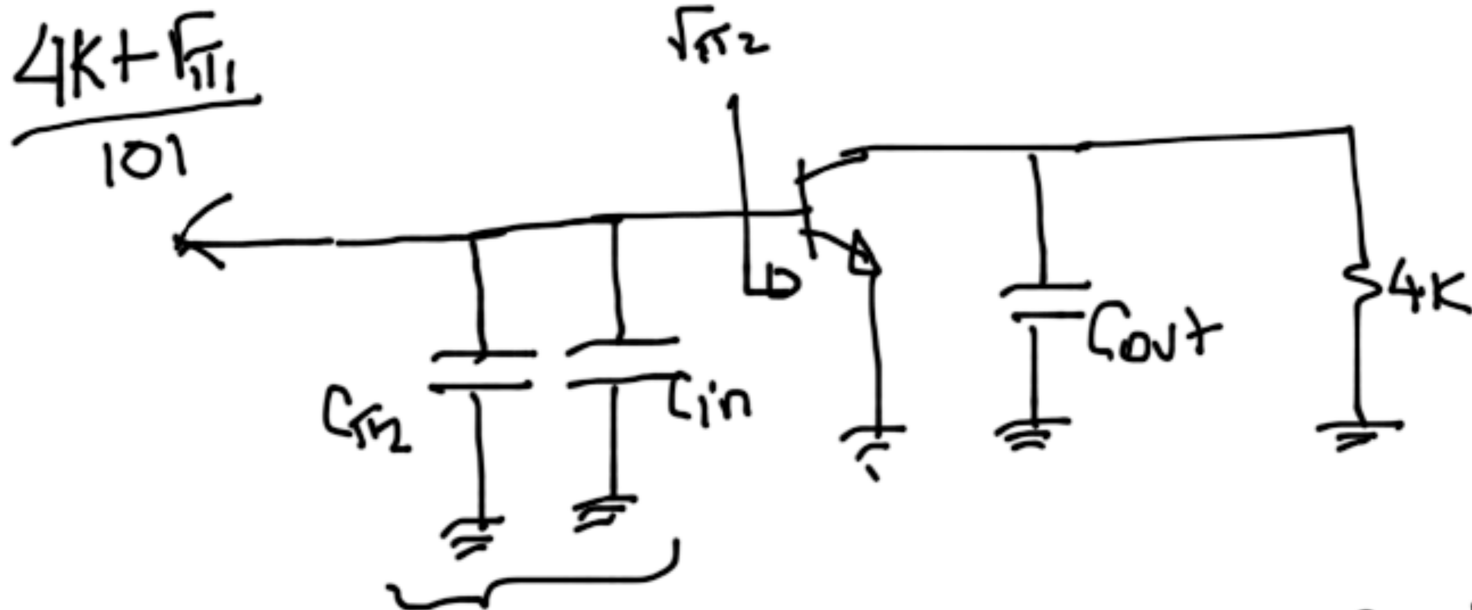
$$\text{Miller's gain} = -g_m R_L =$$

$$= -(40\ mA/V)(4K\Omega)$$

$$= -160$$

$$C_{in} = (1+160)C_{\mu 2} = 324\ pF$$

$$C_{out} \simeq C_\mu = 2\ pF$$



$$C_{eq} = C_{\pi 2} + C_{in} = 324\,pF + 13.9\,pF$$

$$\simeq 338\,pF$$

C_{eq} sees a resistance

$$\frac{4K + r_{\pi 1}}{101} \parallel r_{\pi 2} = 64\,\Omega \parallel 2.5K\,\Omega$$

$$= 63\,\Omega \Rightarrow$$

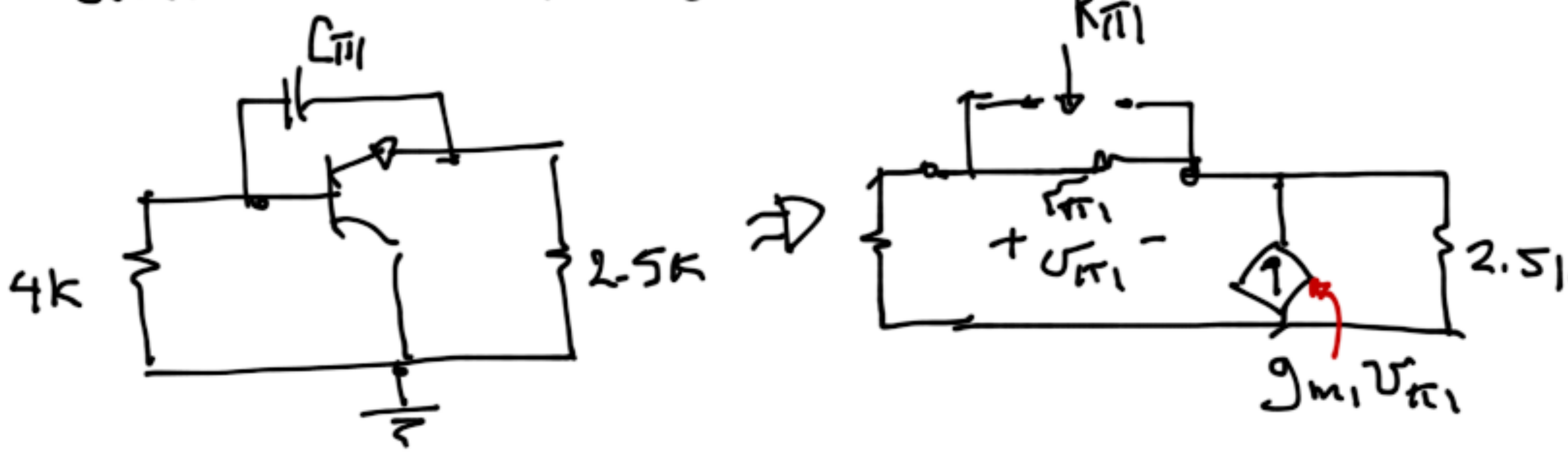
$$f_2 = \frac{1}{2\pi(63)(338pF)} = \boxed{7.5\,MHz}$$

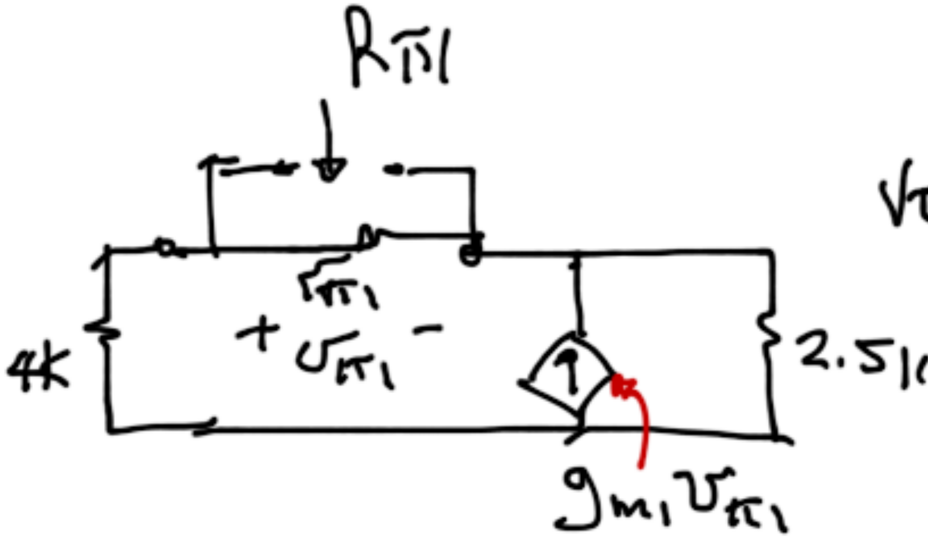
C_{out} sees $4k\Omega$

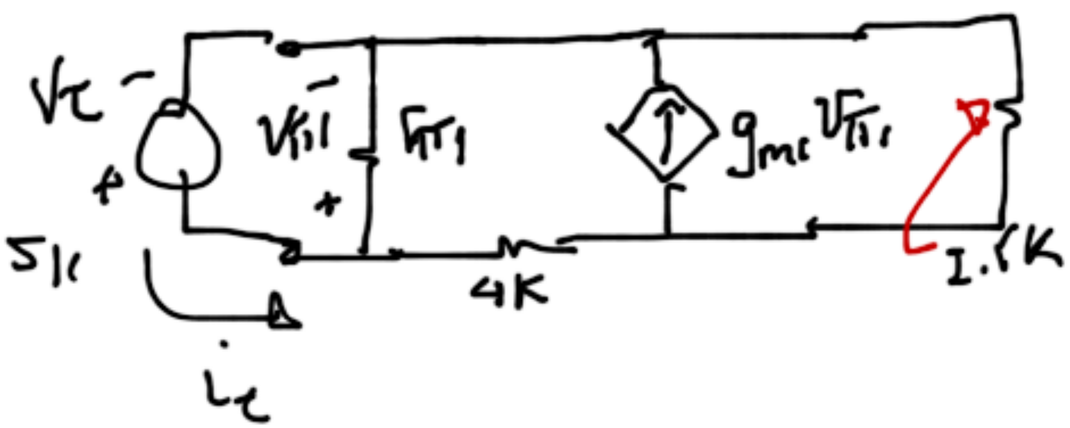
$$f_3 = \frac{1}{2\pi(4k\Omega)(2pF)} = \boxed{19.9\,MHz}$$

It remains to find the resistance seen by $C_{\pi 1}$.

Replace 2nd stage by input imp. $= r_{\pi 2}$ and other caps by open circuits







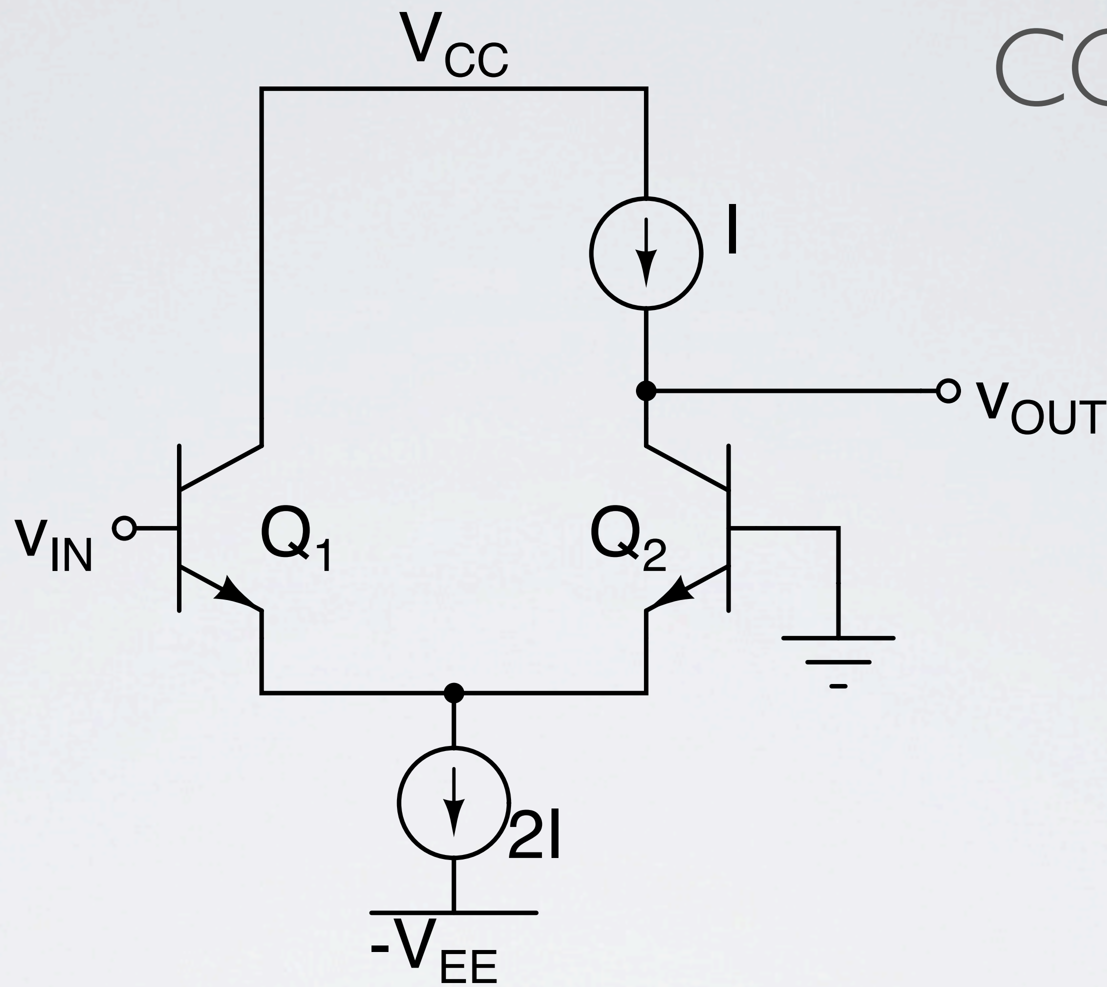
$$v_t = v_{\pi 1} = i_t(4K) + 2.5K\,(i_t - g_{m1} v_{\pi 1})$$

$$\frac{v_t}{i_t} = \frac{6.5K}{1 + g_{m1}\,2.5K} = \frac{6.5K}{101} = 64\,\Omega$$

$$f_4 = \frac{1}{2\pi\,(13.9\,pF)(64\,\Omega)} = \boxed{179\,MHz}$$

$$f_H \simeq \frac{1}{\frac{1}{179} + \frac{1}{19.9} + \frac{1}{7.5} + \frac{1}{20}}\,MHz = \boxed{9.2\,MHz}$$

CC-CB



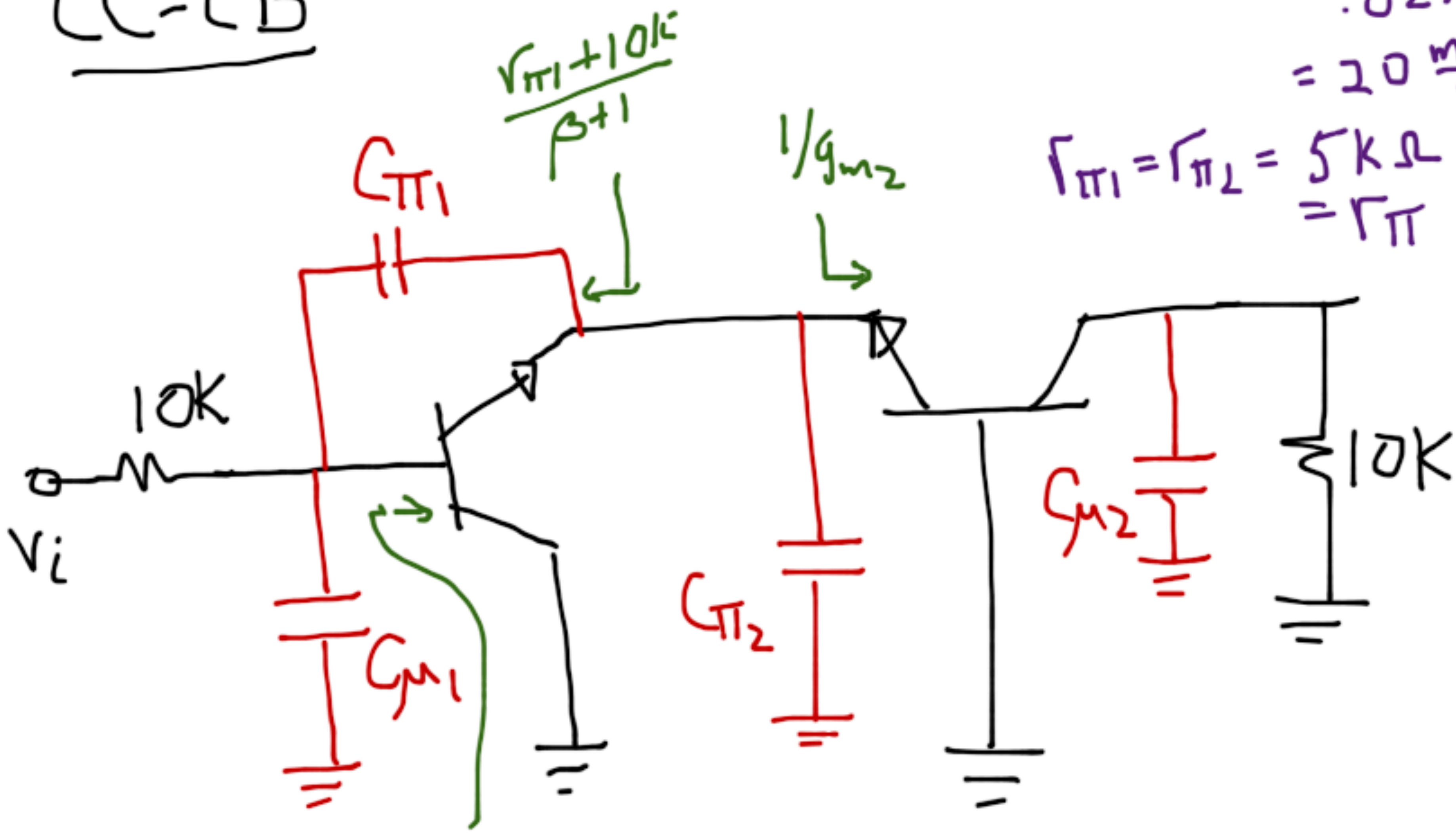
For the above amplifier, let $I = 0.5mA$, $\beta = 100$, $C_\pi = 6pF$, $C_\mu = 2pF$ and $R_{sig} = R_L = 10k\Omega$.

Find A_M, the frequencies of the poles, and and estimate of f_H.

CC-CB

$g_m = g_{m1} = g_{m2} = \frac{.5\,mA}{.025\,V} = 20\,\frac{mA}{V}$

$r_{\pi1} = r_{\pi2} = 5\,k\Omega = r_\pi$



$R_{ib_1} = r_{\pi1} + (\beta+1)\frac{1}{g_{m2}} \simeq 2r_\pi = 10k\Omega$

R_e

$C_{\mu 1} \rightarrow R_{\mu 1} = 10k\Omega \,||\, 2r_\pi = 5k\Omega$

$$f_1 = \frac{1}{2\pi(5k\Omega)(2pF)} = \boxed{15.9MHz}$$

$C_{\pi 2} \rightarrow R_{\pi 2} = \frac{1}{g_{m2}} \,||\, \frac{r_{\pi 1} + 10k}{101} = 50\Omega \,||\, 149\Omega$

$= 37.4\Omega$

$$f_2 = \frac{1}{2\pi(6pF)(37.4\Omega)} = \boxed{709MHz}$$

$C_{\mu 2} \rightarrow R_{\mu 2} = 10K$

$$f_3 = \frac{1}{2\pi(2pF)(10k\Omega)} = \boxed{7.95MHz}$$

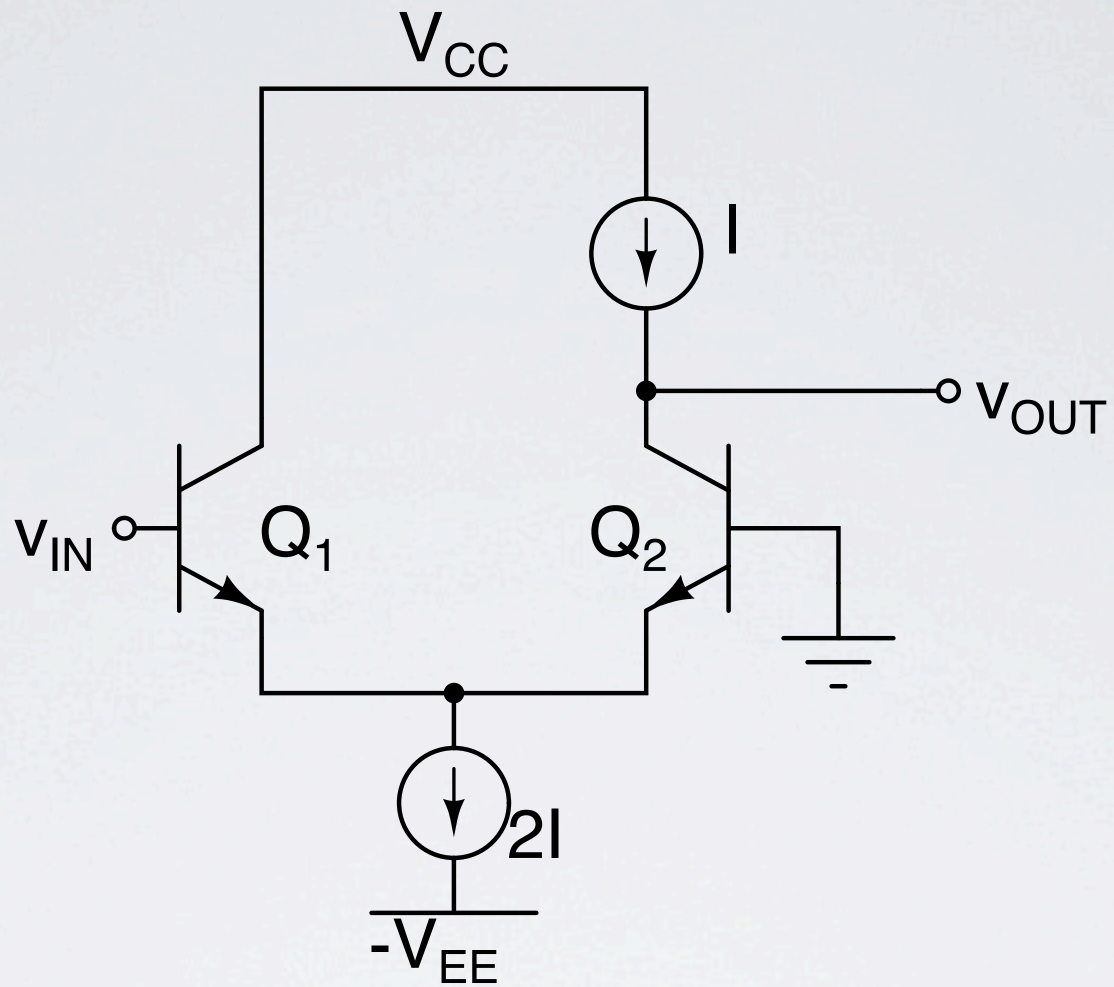
$C_{\pi 1}$ → See previous example

$$R_{\pi 1} = \frac{r_{\pi 2} + R_{sig}}{1 + g_m r_{\pi 2}} \| r_{\pi 1} = \frac{15K}{101} \| 5k = 144\,\Omega$$

$$f_4 = \frac{1}{2\pi (6pF)(144\,\Omega)} = \boxed{183\,MHz}$$

f_2 & f_4 → very high freq. → can be ignored

$$f_H \simeq \frac{1}{\frac{1}{7.95} + \frac{1}{15.9}} MHz = \boxed{5.3\,MHz}$$



For the above amplifier, let I = 0.5mA, β = 100, C_π = 6pF, C_μ = 2pF and R_{sig} = R_L = 10kΩ.

Find A_M, the frequencies of the poles, and and estimate of f_H.

ANSWER: 50V/V; 16MHz and 8MHz; $f_H \simeq$ 5MHz