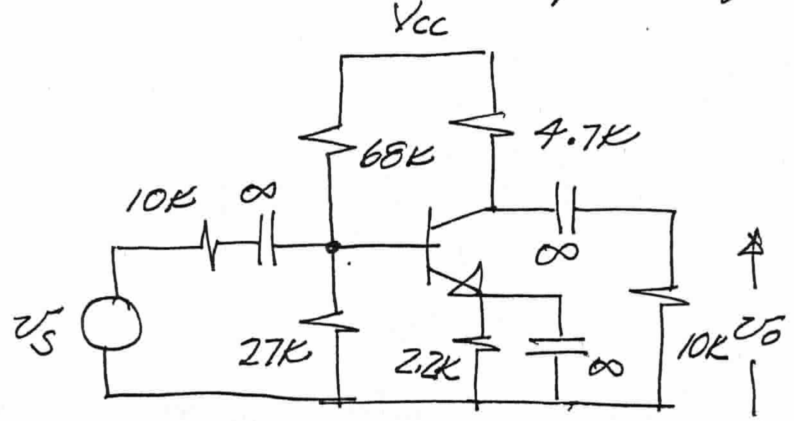
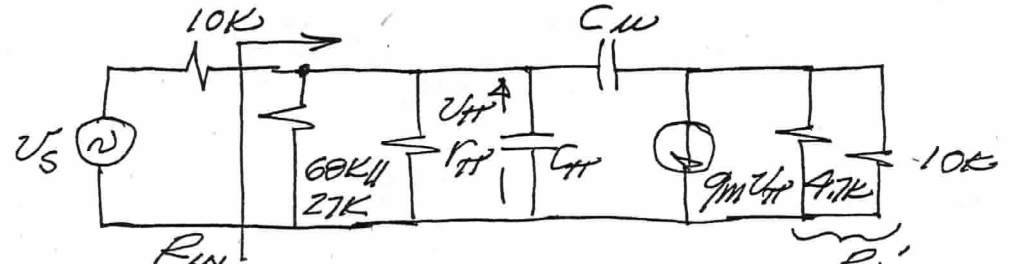
Consider the following voltage amplifier



For the above circuit assume $I_C = 0.8mA$, $\beta = 200$
$f_T = 1GHz$, $C_\mu = 0.8PF$ Assume $r_o \to \infty$ and $r_x = 0$.

Draw the small-signal equivalent circuit -



Determine values for C_μ, C_π, g_m and r_π

$$g_m = \frac{I_C}{V_T} = \underline{\underline{0.032\,S}}, \quad r_\pi = \frac{\beta}{g_m} = \frac{200}{.032} = \underline{\underline{6.25K}}$$

$$2\pi f_T = \omega_T = \frac{g_m}{C_\pi + C_\mu}; \quad (C_\pi + C_\mu)^{-1} = \frac{2\pi(10^9)}{.032};$$

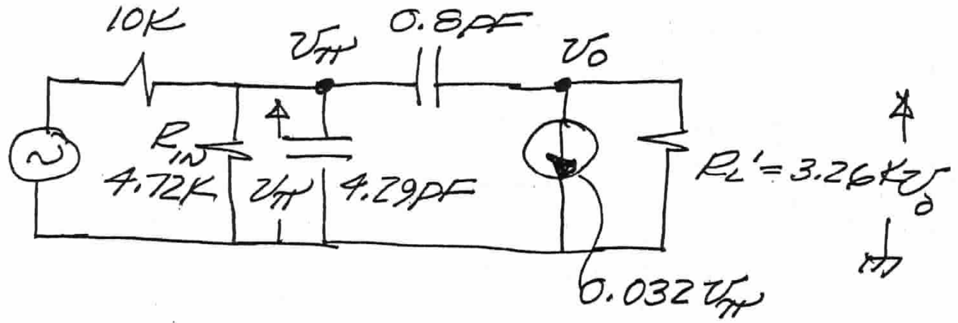
$$C_\pi + C_\mu = 5.09 \times 10^{-12}$$

If $C_\mu = \underline{\underline{0.8\,PF}}$, the $C_\pi = 5.09 - 0.8 = \underline{\underline{4.29\,PF}}$

Calculate R_{IN}

$R_{IN} = 68 // 27K // 6.25K$
$R_{IN} = 4.72K$ $\qquad\qquad$ $R_L' = 10K // 4.7K = 3.2K$

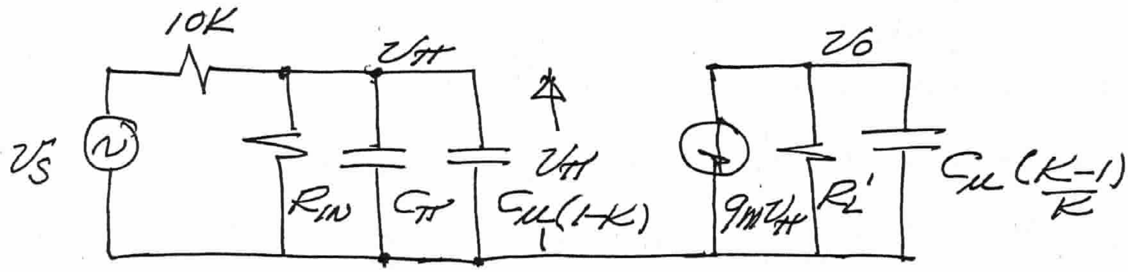
Now the circuit becomes



Now let $\frac{v_0}{v_\pi} \equiv K$ and use Miller's Theorem to reflect $C_\mu = 0.8pF$ across the input & output.

$Z'_{IN} = \frac{Z}{1-K}$ $\quad Z''_{OUT} = Z\left(\frac{K}{K-1}\right)$ $\quad$ where $Z = \frac{1}{j\omega C_\mu}$

$\therefore Z_{IN}' = \frac{1}{j\omega C_\mu(1-K)}$ $\quad$ and $Z'' = \frac{1}{j\omega C_\mu}\left(\frac{K}{K-1}\right)$



If $K \gg 1$ the $C_\mu\left(\frac{K-1}{K}\right) \approx C_\mu$ assume $\frac{1}{\omega C_\mu} \gg R_L'$ where ω is maybe $10\,\omega_{3db}$. If we make this assumption and find it is valid. then $v_0 = -g_m v_\pi R_L'$.

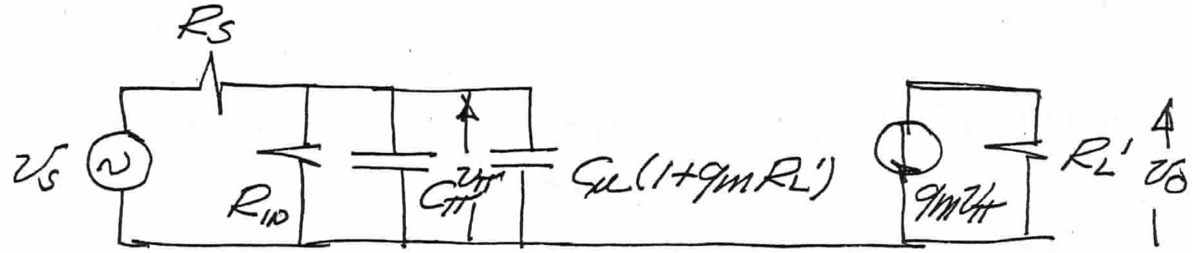
NOTE: for $\frac{1}{\omega C_\mu} = R_L' \Rightarrow \omega = \frac{1}{R_L' C_\mu} = \frac{1}{3.26\times10^3 (0.8)(10^{-12})}$

$= \frac{10^9}{2.6} = 0.38\times10^9$ rad/sec

$f = 6\times10^7$ Hz.

With the the assumption we can ignore the effects of C_μ on the output, then the circuit simplifies as follows.

$$K = \frac{v_o}{v_\pi} = \frac{-g_m R_L' \cancel{v_\pi}}{\cancel{v_\pi}} = -g_m R_L'$$

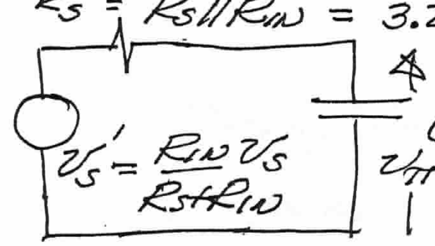


$$\frac{v_o}{v_s} = \frac{v_o}{v_\pi} \cdot \frac{v_\pi}{v_s}$$

$$= \frac{-g_m R_L' \cancel{v_\pi}}{\cancel{v_\pi}} \cdot \frac{v_\pi}{v_s}$$

For $\frac{v_\pi}{v_s}$ use Thevenin equiv.

$R_s' = R_S \| R_{IN} = 3.2K$



$v_s' = \frac{R_{IN} v_s}{R_S + R_{IN}}$

$v_s' = 0.32 v_s$

$C_T = C_\pi + C_\mu(1 + g_m R_L')$

$= 4.29pF + 0.8pF[1 + 0.032(3.2K)]$

$= 4.29pF + 82.7pF = \underline{\underline{87pF}} = C_T$

$$v_\pi = \frac{\frac{1}{j\omega C_T}}{R_s' + \frac{1}{j\omega C_T}} v_s'$$

$$v_\pi = \frac{1}{1 + j\omega R_s' C_T} \cdot 0.32 v_s$$

$$\frac{v_\pi}{v_s} = \frac{0.32}{1 + j\omega R_s' C_T}$$

Thus $\frac{v_o}{v_s} = \frac{-g_m R_L'(0.32)}{1 + j\omega R_s' C_T}$

For $\omega = 0$, the midband gain (low freq gain) is $-g_m R_L'(0.32)$

$= -0.032(3.2K)(0.32) = -32.8\ V/V.$

the ω_{3db} for this amp is $\frac{1}{R_S' C_T}$ as seen by inspection of $\frac{V_o}{V_s} = \frac{-32.8}{1 + j\omega R_S' C_T}$. ie that value of ω where $\omega R_S' C_T = 1$

Hence $\omega_{3db} = \frac{1}{R_S' C_T} = \frac{1}{3.2K\ 87pF}$

$\omega_{3db} = \frac{10^9}{278.4}$

$\omega_{3db} = 3.59 \times 10^6$ rad/sec

OR

$f_{3db} = 5.71 \times 10^5$ Hz.

NOTE: $\left|\frac{1}{\omega C_\mu}\right|$ at $f_{3db} = \frac{1}{3.59 \times 10^6 (0.8) 10^{-12}} = \frac{1}{\omega C_\mu}$

$= \frac{10^6}{2.87} = 348\ K\Omega$

Thus $348K \gg R_L'$ and our assumption to ignore effects of C_μ on the output is a good one.

Also note: Due to the Miller effect, $C_\mu(1 + g_m R_L') = 82.7pF$ which is much larger than C_π.

Hence a small capacitor C_μ affects the 3db freq. in a big way if the voltage gain (K) is high.

To conclude:

To estimate the 3 dB radian frequency, determine the effective input resistance R_s'; using Thevenin equivalents, determine the total capacitance, C_T, using Miller's Theorem, and then

$$\omega_{3db} = \frac{1}{R_s' C_T}$$