QUIZ NO. 9 - SOLUTION

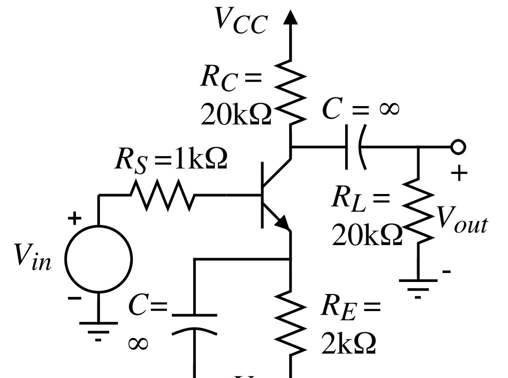
(Average score = 8.6/10 of those taking the quiz)

Assume that the small-signal parameters of the BJT amplifier shown are g_m = 10mS, r_π = 1kΩ, r_x = 0, $r_o = \infty$, C_π = 10pF, and C_μ = 1pF.

a.) Find the midband voltage gain of this amplifier, V_{out}/V_{in}.

b.) Find the value of the upper -3dB frequency, f_H, in Hz, first using the Miller approximation and secondly using the open-circuit time constant approach.

c.) Which of the two answers for f_H in part b.) is the most accurate and why?



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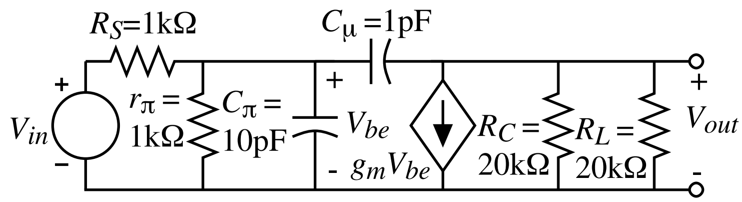
Solution

a.) The small-signal model for all three parts of this problem is shown.



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The MBG is,

$$\frac{V_{out}(0)}{V_{in}(0)} = -g_m(R_C||R_L)\left(\frac{r_\pi}{r_\pi + R_S}\right) = \underline{\underline{-50 \text{ V/V}}}$$

b.) The Miller approximation gives the following capacitance between gate and source.

$$C_{eq} = C_\pi + [1- g_m(R_C||R_L)]\ C_\mu = 10\text{pF} + (1+100)1\text{pF} = 111\text{pF}.$$

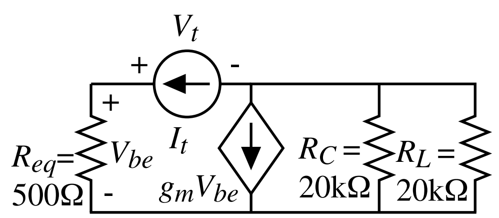
$$\therefore\ \omega_H = \frac{1}{(R_S||r_\pi)C_{eq}} = \frac{1}{0.5\text{K}\cdot 111\text{pF}} = 18.02 \text{ Mrads/sec.} \rightarrow f_H = \frac{18.02\text{x}10^6}{2\pi} = \underline{\underline{2.87\text{MHz}}}$$

The OCTC approach requires finding $R_{c\pi O}$ and $R_{c\mu O}$.

These are found as,

$R_{c\pi O} = R_i = 500\Omega$

$R_{c\mu O}$ = ?



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$$V_t = V_{be} + (I_t + g_m V_{be})10\text{k}\Omega = I_t R_{eq} + (I_t + g_m I_t R_{eq})10\text{k}\Omega$$

$$\therefore \quad R_{c\mu O} = \frac{V_t}{I_t} = R_{eq} + (1+ g_m R_{eq})10\text{k}\Omega = 500\Omega + (1+5)10\text{k}\Omega = 60.5\text{k}\Omega$$

$$\therefore \quad \omega_H = \frac{1}{R_{c\pi O}C_\pi + R_{c\mu O}C_\mu} = \frac{1}{500\cdot 10\text{pF} + 60.5\text{K}\cdot 1\text{pF}} = 15.27\text{x}10^6 \text{ rads/sec.}$$

Thus, $f_H = \frac{15.27\text{x}10^6}{2\pi} = \underline{\underline{2.43\text{MHz}}}$ However, since the RC products are poles we can solve for the poles as $(1/R_{c\pi O}\ C_\pi)^{-1}$=200 Mrads/sec and $1/R_{c\propto O}\ C_\propto)^{-1}$=16.53 Mrads/sec. The dominant pole is –16.53 Mrads/sec which give f_H = $\underline{\underline{2.63\text{MHz}}}$

c.) The answer given by the OCTC method is probably more correct because the impedance of C_μ at ω_H for the Miller approach turns out to be $(1/18.02\text{ x}10^6\cdot 10^{-12})$ = 55.5kΩ which is not all that much greater than $R_L||R_C$ = 10kΩ.