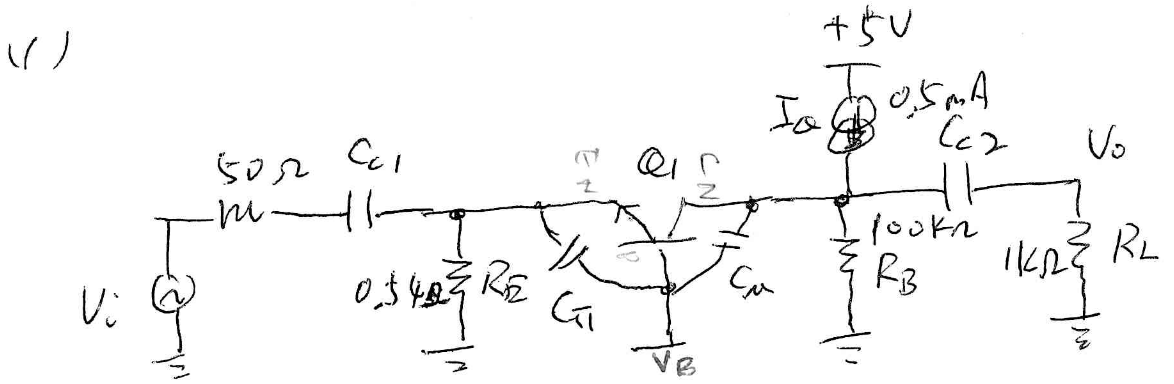
EE2002 Tutorial 12

(1)



Given: $\beta = 100$

$V_A \to \infty$

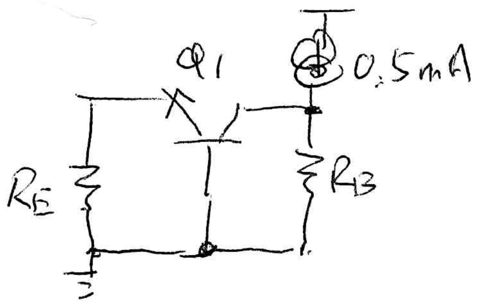
$C_\mu = 1pF$

$f_T = 285\ MHz$

$V_T = 25mV$

Find: ω_H

Step 1: Q point calculations



$I_C \approx 0.5\ mA$

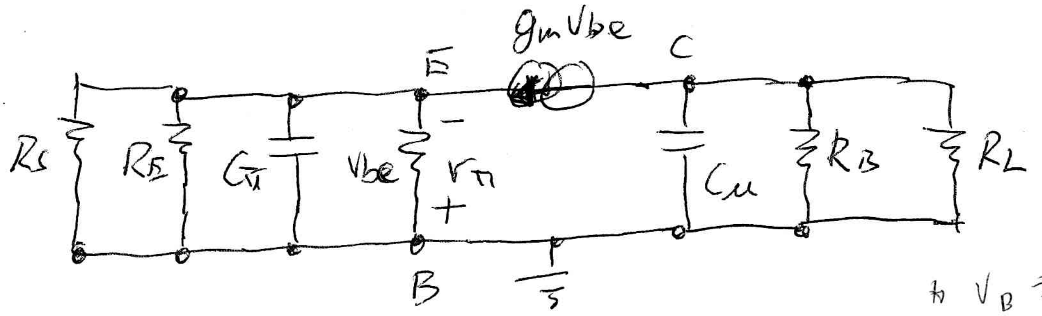
$$g_m = \frac{I_c}{V_T} = \frac{0.5mA}{25mV} = 0.02S$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{0.02S} = 5k\Omega$$

Since $V_A = \infty$, $r_o = \infty$

Step 2: Draw high frequency small-signal equivalent circuit.

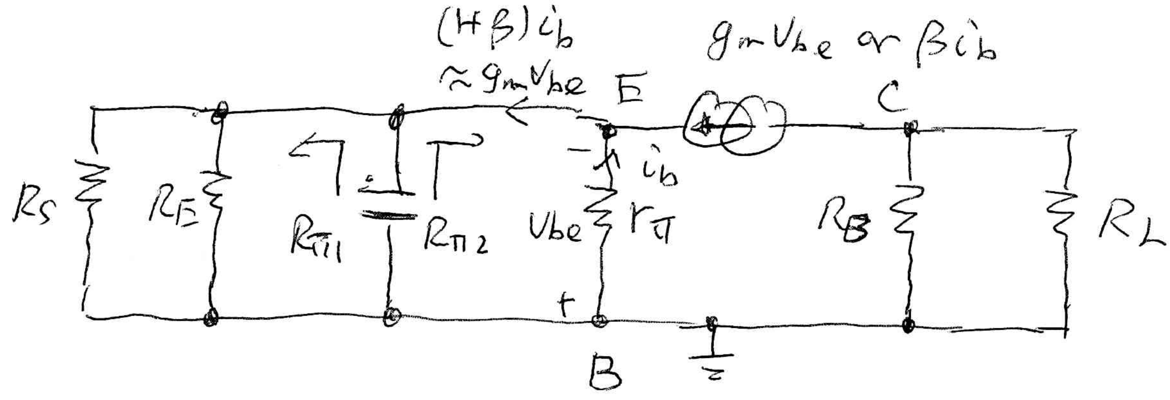
standard AC equivalent:
- (i) Coupling capacitors $C_{c1}, C_{c2} \rightarrow$ short circuit
- (ii) DC voltage source $V_{cc} = 5V \rightarrow$ short circuit



Note that you cannot remove C_π & C_μ.

to $V_B \rightarrow$ gnd for AC circuit.

Step 3: Open circuit C_μ and find $R_{\pi 0}$ seen by C_π

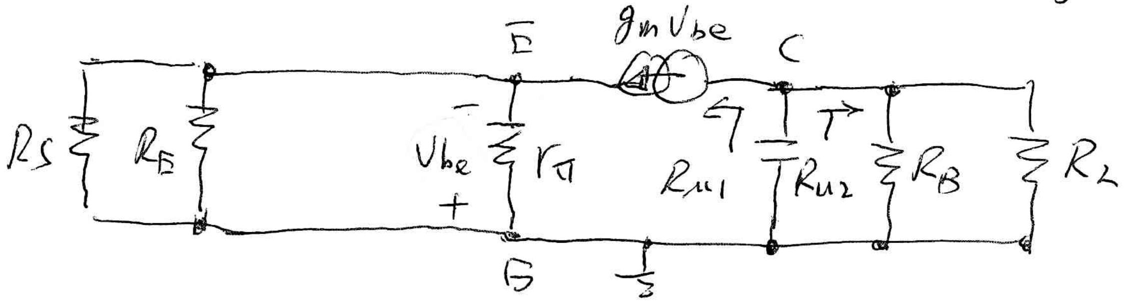


$$R_{\pi 1} = R_S \,//\, R_E$$

$$R_{\pi 2} = \frac{r_\pi}{\beta+1} \quad \text{or} \quad R_\pi \approx \frac{v_{be}}{g_m v_{be}} = \frac{1}{g_m}$$

$$R_{\pi 0} = R_{\pi 1} \,//\, R_{\pi 2} = R_S \,//\, R_E \,//\, \frac{r_\pi}{\beta+1} = 50 \,//\, 500 \,//\, \frac{5000}{101}$$
$$= 24\,\Omega$$

Open circuit C_π and find $R_{\mu 0}$ seen by C_μ



$$v_{be} = -g_m V_{be}\,(R_S \,//\, R_E \,//\, r_\pi) \Rightarrow V_{be} + g_m V_{be}(R_S // R_E // r_\pi) = 0$$

$$V_{be}\left[1 + g_m (R_S // R_E // r_\pi)\right] = 0$$

Since $1 + g_m (R_S // R_E // r_\pi) \neq 0$, $V_{be} = 0$

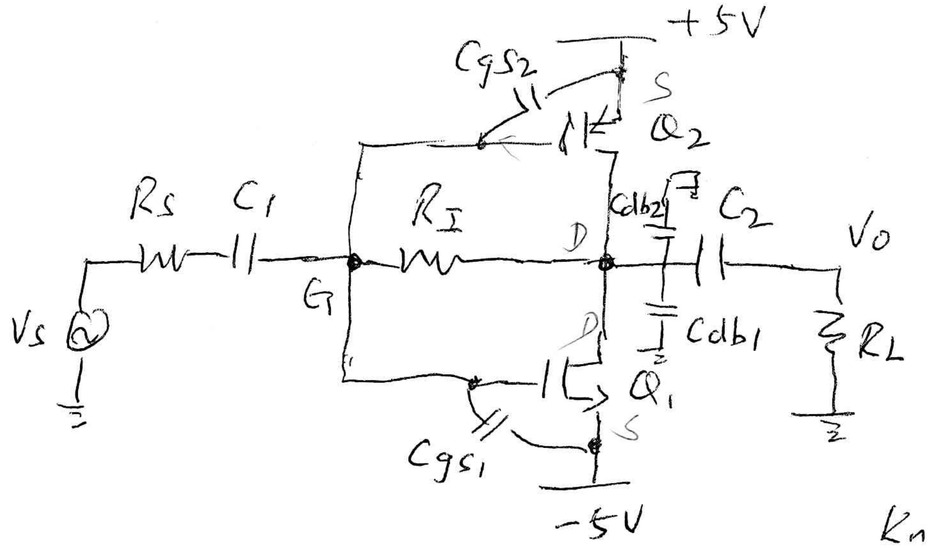
$\Rightarrow g_m V_{be} = 0$, Hence, $R_{\mu 1} = \infty$

$R_{\mu 2} = R_B \,//\, R_L = 100\,k\Omega \,//\, 1\,k\Omega = 990\,\Omega$, $R_{\mu 0} = R_{\mu 1} // R_{\mu 2} = 990\,\Omega$

By OCTC method, $\omega_H = \dfrac{1}{R_{\pi 0} C_\pi + R_{\mu 0} C_\mu}$

$$\omega_H = \frac{1}{24 \times 10p + 990 \times 1p} = \underline{813\ M\ rad/s} \quad \#$$

(2)



Find ω_L

Given: $R_S = 1 k\Omega$

$C_1 = 1\mu F$

$C_2 = 1\mu F$

$R_I = 5 M\Omega$

$R_L = 10 k\Omega$

$K_n = K_p = 50 \mu A/V^2$

$V_{Tn} = |V_{Tp}| = 2V$

$\lambda = 0.005 V^{-1}$

Step 1: Find the biasing point

$V_{SG2} + V_{GS1} = 10V \Rightarrow V_{GS} = 5V$

$I_{D1} = \frac{K_n}{2}(V_{GS} - V_{TN})^2 (1+\lambda V_{DS}) \simeq \frac{K_n}{2}(V_{GS} - V_{TN})^2 = \frac{50\mu A/V^2}{2}(5V - 2V)^2$

$= 225 \mu A$

$g_{m1} = g_{m2} = g_m = \sqrt{2K_n I_D (1+\lambda V_{DS})} \simeq \sqrt{2K_n I_D} = \sqrt{2 \times 50\mu A/V \times 225\mu A}$

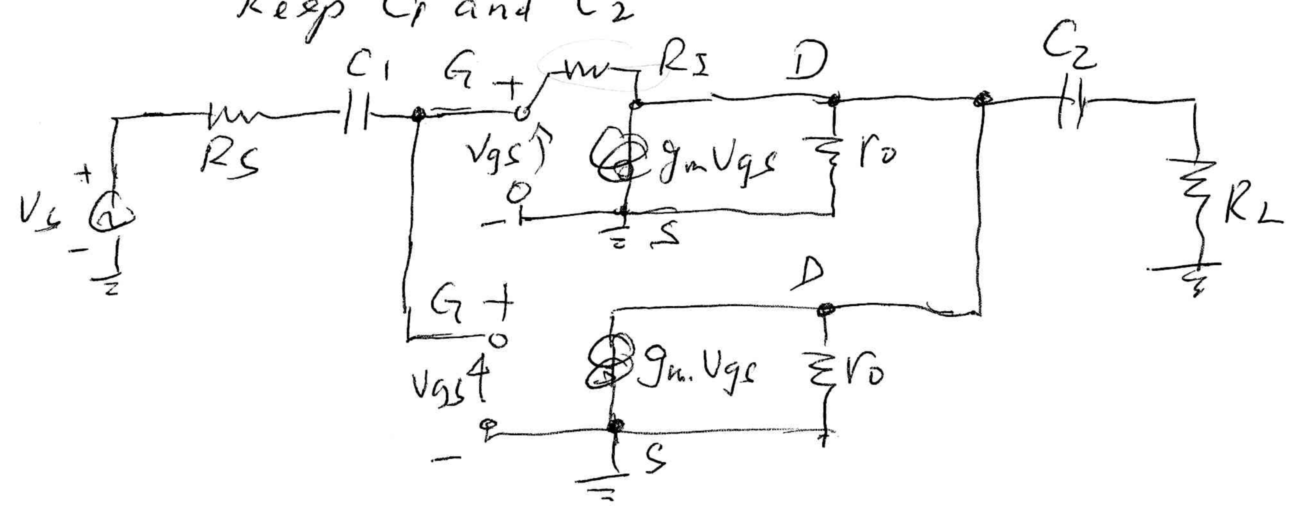
$= 150 \mu A/V$

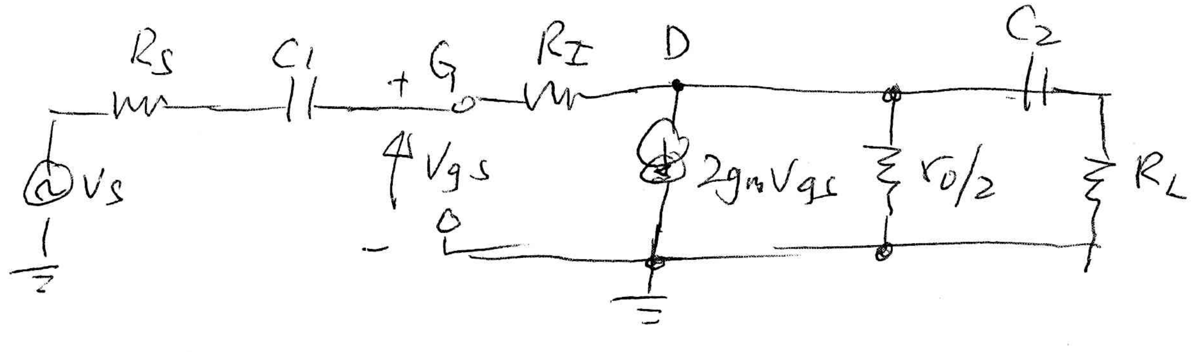
$r_{o1} = r_{o2} = r_o = \frac{1}{\lambda I_D} = 0.888 M\Omega$

Step 2: Draw low-frequency small-signal equivalent circuit.

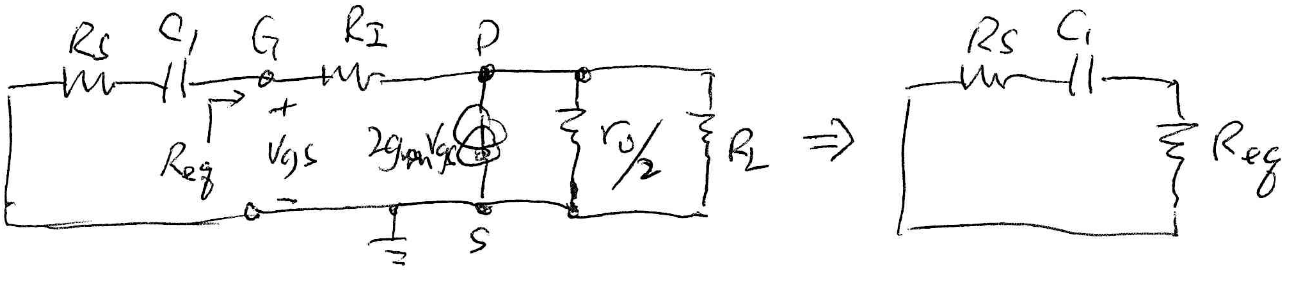
Remove parasitic caps: C_{gs1}, C_{gs2}, C_{db1}, C_{db2}

Keep C_1 and C_2





Step 3 : Find R_{1S} seen by C_1 by shorting other capacitors



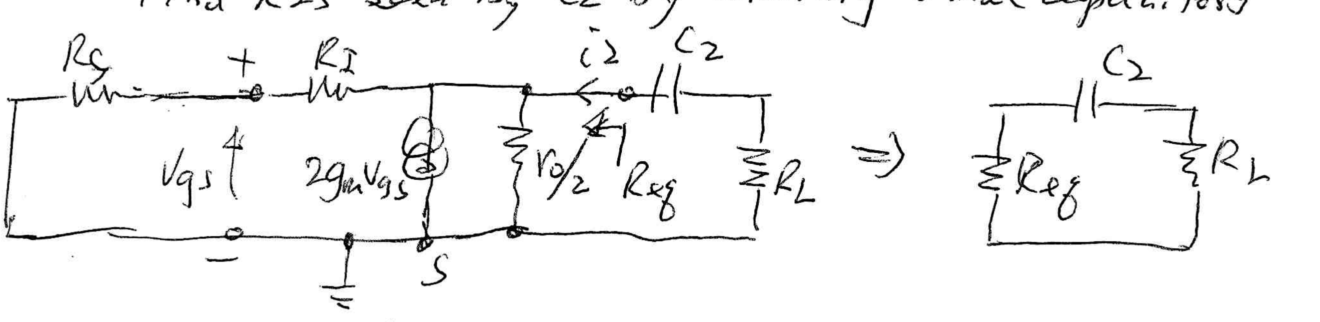
$$\frac{V_g - V_d}{R_I} = 2g_mV_g + \frac{V_d}{r_o/2} + \frac{V_d}{R_L} \Rightarrow \left(\frac{1}{R_I} - 2g_m\right)V_g = \left(\frac{2}{r_o} + \frac{1}{R_L} + \frac{1}{R_I}\right)V_d$$

For $r_o = 0.888M$, $R_L = 10k\Omega$, $R_I = 5M$, $g_m = 150\mu A/V$,

we get $V_d = -294V_g$, $R_{eq} = \frac{V_g}{\frac{V_g - V_d}{R_I}} = \frac{V_g R_I}{V_g + 2.94V_g} = \frac{5M}{3.94} = 1.27M\Omega$.

$\therefore R_{1S} = R_{eq} + R_S = 1.27M + 1M = 2.27M\Omega$

Find R_{2S} seen by C_2 by shorting other capacitors



$$i_2' = 2g_mV_g + \frac{V_d}{r_o/2} + \frac{V_d - V_g}{R_I} \Rightarrow R_{eq} = \frac{V_d}{i_2'} = \frac{V_d}{2g_mV_g + \frac{2V_d}{r_o} + \frac{V_d - V_g}{R_I}}$$

$\because V_g = \frac{R_S}{R_S + R_I} \cdot V_d = \frac{1M}{1M+5M} V_d$ $V_d = 6V_g$

$$\therefore R_{eq} = 6V_g \Big/ \left(2\times 150\mu A/V \times V_g + \frac{12V_g}{0.888M} + \frac{5V_g}{5M}\right)$$

$R_{2S} = R_{eq} + R_L = 19.08k + 10k\Omega = 29.08k\Omega$, By SCTC method

$$\omega_L = \sum_{i=1}^{n} \frac{1}{R_{iS}C_i} \Rightarrow \omega_L = \frac{1}{2.27M\times 1\mu} + \frac{1}{29.08k\times 1\mu} = \underline{34.9\ rad/s}\ \#$$