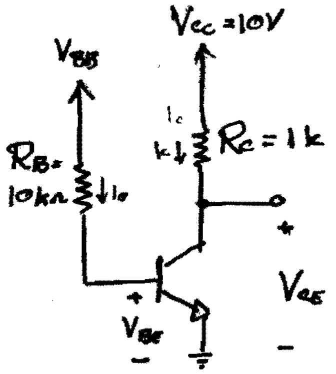
EE320 Homework # 10

① Ex. 8.21



$V_{BB} = 1.7V$

$$I_B = \frac{V_{BB} - V_B}{R_B} = \frac{1.7 - 0.7}{10k}$$
$= 0.1 mA$

$I_C = \beta I_B = 50 \times 0.1 mA = 5\ mA$, $V_C = V_{CC} - R_C I_C = 10 - (1k)(50mA) = \underline{5V}$

So $V_C > V_B$ Verifying that the transistor is operating in Active mode.

ⓐ in order to operate at the edge of saturation, R_C must be increased to make $V_{CE} = 0.3V$

$V_{CE} = V_{BE} - V_{BC} = 0.7 - 0.4 = 0.3V$

AND

$$R_C = \frac{V_{CC} - V_{CE}}{I_C} = \frac{10 - 0.3}{5mA} = \underline{1.94\ k\Omega}$$

ⓑ in order to operate in saturation mode, R_C must be increased so $V_{CE} = 0.2V$ and $\beta_{forced} = 10$

$I_C = \beta_{forced} \times I_B = 10 \times 0.1mA = 1mA$

$$R_C = \frac{V_{CC} - V_{CE}}{I_C} = \frac{10 - 0.2}{1mA} = \underline{9.8\ k\Omega}$$

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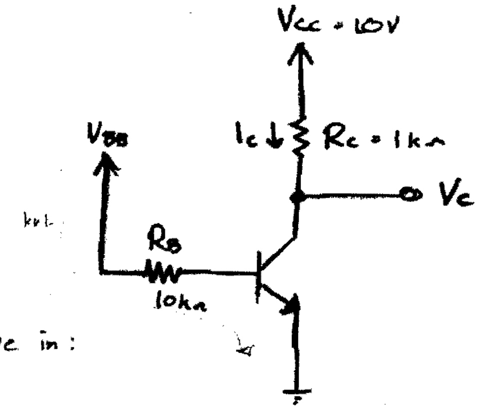
(2) PROBLEM 6.48



V_B that make transistor operate in: $\beta = 50$

(a) Active mode with $V_c = 2V$,

$$I_C = \frac{V_{cc} - V_c}{R_c} = \frac{10-2}{1k} = 8\,mA$$

$$I_B = \frac{I_c}{\beta} = \frac{8mA}{50} = 0.16\,mA$$

kvl

$$V_{BB} = I_B R_B + V_{BE} = 0.16mA \times 10k\Omega + 0.7 = \underline{2.3V}$$

(b) at Edge of Saturation

$V_{CE} = 0.3V$, $V_{BC} = 0.4V$

$$I_c = \frac{V_{cc} - V_{CE}}{R_c} = \frac{10-0.3}{1k} = 9.7\,mA$$

$$I_B = \frac{I_c}{\beta} = \frac{9.7mA}{50} = 0.194\,mA$$

kvl

$$V_{BB} = I_B \times R_B + V_{BE} = 0.194mA \times 10k + 0.7 = \underline{2.64V}$$

(c) in Saturation with $\beta_{forced} = 10$ and

$V_{CE} = 0.2V$

$$I_C = \frac{V_{cc} - V_{CE}}{R_c} = \frac{10-0.2}{1k} = 9.8mA$$

$$I_B = \frac{I_c}{\beta_{forced}} = \frac{9.8mA}{10} = 0.98\,mA$$

$$V_{BB} = I_B R_B + V_{BE} = 0.98mA \times 10k + 0.7V = \underline{10.5V}$$

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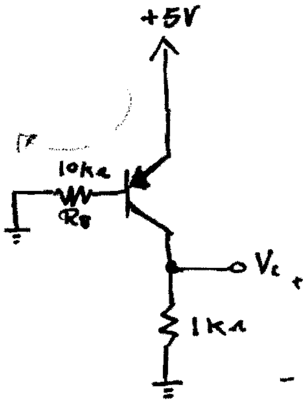
③ Problem 6.50



$\beta = 50$

Assuming Saturation, $V_{EC} = 0.2V$

$V_{EB} = 0.7V$

$V_{EC} = V_E - V_c$

$0.2 = 5V - V_c$

$V_B = 5 - 0.7 = 4.3V$

$V_c = 4.8$

$I_c = \frac{V_c}{R_c} = \frac{4.8V}{1k} = 4.8mA$

KVL $5 - V_{EB} - I_B \times R_B = 0 \longrightarrow I_B = \frac{5 - V_{BE}}{R_B} = \frac{4.3}{10k} = 0.43 mA$

$\beta_{forced} = \frac{I_C}{I_B} = \frac{4.8}{0.43} = 11.2$ which is $< \beta = 50$ so the transistor is Operating in Saturation mode.

to operate in Edge Saturation

$V_{EC} = 0.3V$ and $I_C / I_B = \beta = 50$

$V_{EC} = V_E - V_c$, ✓

$0.3 = 5 - V_c \longrightarrow V_c = 4.7V$

$I_C = \frac{V_c}{R_c} = 4.7mA$

$I_B = \frac{I_c}{\beta} = 0.094mA$, ✓

Same $V_{EB} = V_E - V_B \longrightarrow V_B = V_E - V_{EB} = 5 - 0.7 = 4.3V$

$R_B = \frac{V_B}{I_B} = \frac{4.3V}{0.094mA} = 45.74 k\Omega$

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④ PROBLEM 10.22

$f_T = 10\,GHz$ and $C_\mu = 0.1\,pF$ when operate at $I_C = 1.0\,mA$

What is C_π in this case, and find g_m. For $\beta = 120$ find r_π and f_β

$$f_T = \frac{g_m}{2\pi(C_\pi + C_\mu)}$$

$$g_m = \frac{I_C}{V_T} = \frac{0.1\,mA}{0.025\,V} = 40\,mA/V$$

$$10 \times 10^9 = \frac{40}{2\pi(C_\pi + 0.1\times10^{-12})}$$ solve for C_π.

$$C_\pi = 0.54\,pF$$

$$r_\pi = \frac{\beta}{g_m} = \frac{120}{40\,mA/V} = 3\,k\Omega$$

$$f_\beta = \frac{f_T}{\beta_0} = \frac{10\times10^9}{120} = 83.3\,MHz$$

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(5) PROBLEM 10.37

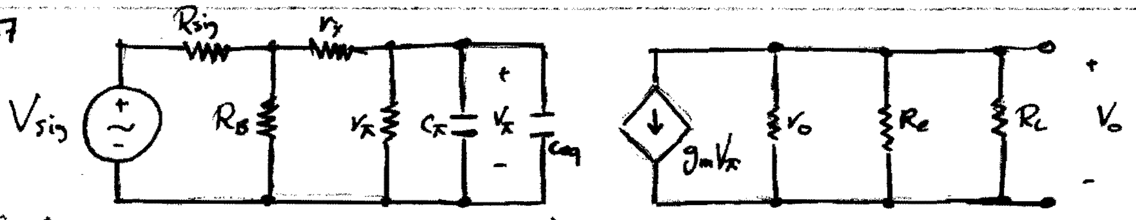


Fig 10.9 (c)

$I_E = 2\,mA$

$$g_m = \frac{I_c}{V_T} = \frac{2\,mA}{0.025} = 80\ mA/V$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{80\,mA/V} = 1.25\,k\Omega$$

$$r_o = \frac{V_A}{I_c} = \frac{100V}{2mA} = 50\,k\Omega$$

$$C_\pi + C_\mu = \frac{g_m}{\omega_T} = \frac{80\times10^{-3}\ A/V}{2\pi\times800\times10^{6}} = 16\,pF$$

$C_\mu = 1\,pF$, $C_\pi = 15\,pF$

$r_x = 50\,\Omega$

$R_B = 50k$, $R_c = 4k$

the new $A_M = -\dfrac{R_B}{R_B + R_{sig}} \times \dfrac{r_\pi}{r_\pi + r_x + (R_B \| R_{sig})} (g_m R_L')$

where $R_L' = r_o \| R_c \| R_L$

$= 50k \| 4k \| 5k = 2.13\,k\Omega$

$g_m R_L' = 80\,mA/V \times 2.13\,k\Omega = 170\ V/V$

$$A_M = -\frac{50k}{50k+5k} \times \frac{1.25k}{1.25k + 50 + (50\|5)} \times 170 = -33\ V/V \qquad (-39\,V/V)$$

and

$20\log|A_M| = 30.4\,dB$ ↓ ($\simeq$ 1.6 dB) Compared to the Pervious value of 39 V/V (32 dB) ; to determin f_H we have to find C_{in}

(10.58) → $C_{in} = C_\pi + C_\mu(1 + g_m R_L') = 15 + 1(1+170) = \underline{186\,pF}$

$R_{sig}' = r_\pi \| [r_x + (R_B \| R_{sig})] = 1.25 \| [0.05 + (50\|5)] = \underline{980\,\Omega}$

$$f_H = \frac{1}{2\pi C_{in} R_{in}} = \frac{1}{2\pi\times186\times10^{-12}\times0.98\times10^{3}} = 873\,kHz$$ (Compared to 754 kHz before)

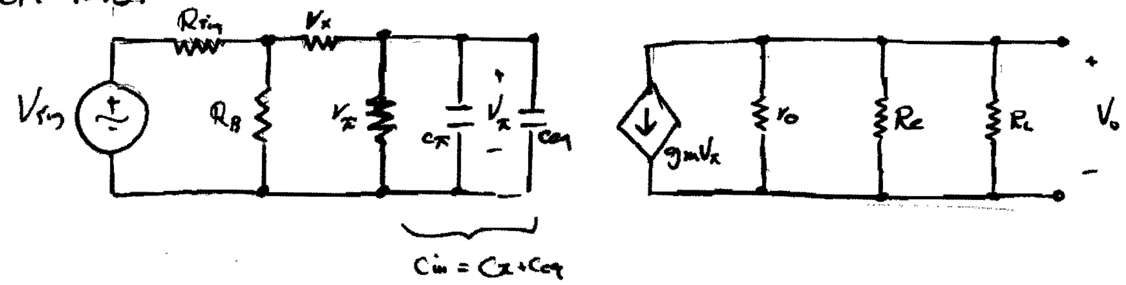
$GB = |A_M| f_H = 33\times873 = \underline{28.8\,MHz}$

bef. $GB = 39\times873 = 29.4\,MHz$

Power dissipation inceased by factor of 2

$P_{dis} = \underbrace{V_{CE}}_{\text{Unchanged}} \cdot I_c$ ↑×2

⑥ PROBLEM 10.37



ⓐ

$$A_M = -\frac{R_B}{R_B + R_{sig}} \frac{r_\pi}{r_\pi + r_x + (R_{sig} \| R_B)} g_m R_L' \qquad (10.54)$$

For $R_B \gg R_{sig}$, $r_x \ll R_{sig}$, $R_{sig} \gg r_x$

$$A_M \simeq -\frac{r_\pi}{R_{sig}} g_m R_L' = -\beta R_L' / R_{sig}$$

ⓑ

$$C_{in} = C_\pi + (g_m R_L' + 1) C_\mu \qquad (10.58)$$

$g_m R_L' \gg 1$ and $g_m R_L' C_\mu \gg C_\pi$

(10.57) $C_{in} \simeq g_m R_L' C_\mu$, $F_H = \frac{1}{2\pi C_{in} R_{sig}'}$

where $R_{sig}' = r_\pi \| [r_x + (R_B \| R_{sig})]$

$\simeq r_\pi \| R_{sig} \simeq r_\pi$

So $f_H = \frac{1}{2\pi g_m R_L' C_\mu r_\pi}$, $\beta = g_m r_\pi \rightarrow f_H = \frac{1}{2\pi C_\mu \beta R_L'}$

ⓒ

$$GB = |A_M| f_H = \beta \frac{R_L'}{R_{sig}} \frac{1}{2\pi C_\mu \beta R_L'} = \frac{1}{2\pi C_\mu R_{sig}}$$