積體電子學題解

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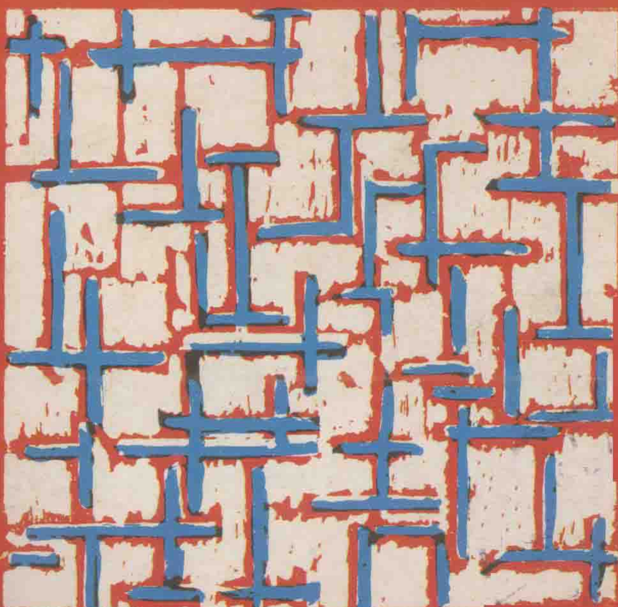
INTEGRATED ELECTRONICS: ANALOG AND DIGITAL CIRCUITS AND SYSTEMS



曉園出版社

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積體電子學詳解

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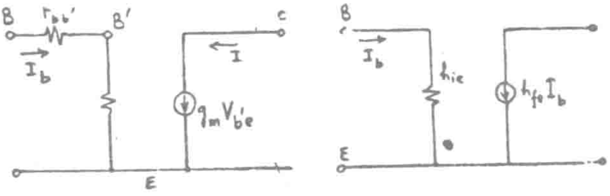
第十一章

11－1　證明：低頻時將拼合 π 之 $r_{b'c}$ 與 r_{ce} 視爲無限大，則約變成共射極 h 參數模型：



From the figure we see $V_{b'e} = I_b\ r_{b'e}$ then

$I = g_m V_{b'e} = g_m r_{b'e} I_b$ but from Eq.(11-16) $r_{b'e} g_m = h_{fe}$

hence $I = h_{fe} I_b$. Also from Eq.(11-9) $h_{ie} = r_{bb'} + r_{b'e}$

11－2　(a)考慮低頻拼合 π 電路，C_e 與 C_c 可忽略不計，其他電路元件則一概不省略，若負載電阻爲 $R_L = 1 / g_L$，試證：

$$K \equiv \frac{V_{ce}}{V_{be}} = \frac{-g_m + g_{be}}{g_{bc} + g_{ce} + g_L}$$

提示：利用定理：C 與 E 間電壓等於短路電流乘以 C 與 E 間所看之阻抗，將輸入電壓 V_{be} 短路〔見（8－36）式〕。

(b)利用米勒定理繪出 C 與 E 間之等效電路。將柯希荷夫電流定律應用於此網路中，證明上述所得之 K 值。

(c)利用米勒定理繪出 B 與 E 間之等效電路，證明：有負載之電流增益爲：

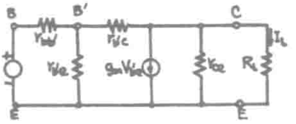
$$A_I = \frac{g_L}{(g_{b'c} + g_{be})/K - g_{b'c}}$$

(d)利用 a 與 c 的結果及拼合 π 與 h 參數間之關係，證明：

$$A_I = \frac{-h_{fe}}{1 + h_{oe} R_L}$$

上式乃直接由低頻 h 參數模型所得之結果〔見（8－18）式〕。〔提示：在 A_I 與 K 中，g_{bc} 與 g_m，g_{be} 比較之下可忽略不計，證明此等近似式。〕

11-2 (a) $K = \dfrac{V_{ce}}{V_{b'e}}$ where



$V_{ce} = I_{sc} Z_{ce}$

with $R_L = 0$,

$I_L = I_{sc} = V_{b'e}\, g_{b'c} - g_m V_{b'e} = (g_{b'c} - g_m) V_{b'e}$

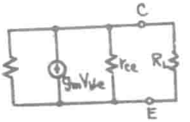
Z_{ce} is the impedance seen between C-E. Thus,

$Z_{ce} = (r_{b'c} \| r_{ce} \| R_L)$ or $Z_{ce} = \dfrac{1}{g_{b'c} + g_{ce} + g_L}$

Hence, $\dfrac{V_{ce}}{V_{b'e}} = K = \dfrac{-g_m + g_{b'c}}{g_{b'c} + g_{ce} + g_L}$

(b) From the circuit we obtain:

$V_{ce} = -g_m V_{b'e} \dfrac{1}{g_L + g_{ce} + \frac{K-1}{K} g_{b'c}}$

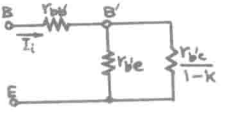


$= KV_{b'e} = \dfrac{-K g_m}{K(g_L + g_{ce} + g_{b'c}) - g_{b'c}}$

or $K(g_{ce} + g_{b'c} + g_L) - g_{b'c} = -g_m \quad \therefore\ K = \dfrac{-g_m + g_{b'c}}{g_{b'c} + g_{ce} + g_L}$

(c) $A_I = \dfrac{I_L}{I_i}$ where $I_L = g_L V_{ce} = g_L K V_{b'e} = \dfrac{g_L K I_i}{g_{b'e} + (1-K) g_{b'c}}$

Hence, $A_I = \dfrac{g_L\ K}{g_{b'e} + g_{b'c} - K g_{b'c}}$



or $A_I = \dfrac{g_L}{(g_{b'c} + g_{b'e})/K - g_{b'c}}$

(d) Note that $g_m >> g_{b'c}$ and $g_{b'e} >> g_{b'c}$.

Thus from parts (a) and (c) we have:

$K \approx \dfrac{-g_m}{g_{b'c} + g_{ce} + g_L}$ and $A_I \approx \dfrac{g_L K}{g_{b'e} - K g_{b'c}} =$

$$\frac{-g_m g_L}{g_{b'e}(g_{b'c}+g_{ce}+g_L)+g_m g_{b'c}} \qquad \text{or}$$

$$A_I \approx \frac{-g_m/g_{b'e}}{1+\frac{1}{g_L}(g_{b'c}+g_{ce}+\frac{g_m}{g_{b'e}}g_{b'c})} = \frac{-h_{fe}}{1+h_{oe}R_L}$$

11－3　已知一個電晶體在室溫下及 $I_C = 10$ 毫安，$V_{CE} = 10$伏特時，其低頻參數如下：

$h_{ie} = 500$ 歐姆　　$h_{oe} = 10^{-5}$ 安培／伏特

$h_{fe} = 100$　　$h_{re} = 10^{-4}$

在同一操作點，$f_T = 50$ 百萬赫，$C_{ob} = 3$ 微微法，試求所有拼合 π 之參數值。

__11-3__ From Eq.(11-16): $g_m = \frac{|I_C|}{V_T} = \frac{10\,mA}{26\,mV} = 385$ mA/V

$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{100}{0.385} = 260\,\Omega$; $r_{bb'} = h_{ie} - r_{b'b} = 500 - 260 = 240\Omega$

$r_{b'c} = \frac{r_{b'e}}{h_{re}} = 260 \times 10^4\,\Omega = 2.6$ M;

$g_{ce} = h_{oe} - (1+h_{fe})g_{b'c} = 4 \times 10^{-6} - \frac{101}{2.6\times10^6} = 0.12 \times 10^{-6}$

or $r_{ce} = 1/g_{ce} = 833K$; $C_e = \frac{g_m}{2\pi f_T} = \frac{385\times10^{-3}}{2\pi\times50\times10^6} = 1224$ pF ;

$C_c = 3$ pF .

11－4　已知一個電晶體在室溫下 $I_C = 5$毫安及 $V_{CE} = 10$ 伏特時，各參數值如下：

$h_{fe} = 100$　　$h_{ie} = 600$ 歐姆

$|A_{ie}| = 10$ 於 $10M$ 赫時　　$C_c = 3$ 微微法

求 f_β，f_T，C_e，$r_{b'e}$，及 $r_{bb'}$。

__11-4__ From Eq.(11-28), $|A_{ie}| = \left|\frac{-h_{fe}}{1+jf/f_\beta}\right| = \frac{h_{fe}}{[1+(f/f_\beta)^2]^{\frac{1}{2}}} = \frac{100}{[1+(f/f_\beta)^2]^{\frac{1}{2}}} = 10$

or $1+(f/f_\beta)^2 = 100$ and $(f/f_\beta)^2 = 99$, or $f/f_\beta = 9.95$ where

$f = 10$ MHz. Thus, $f_\beta = f/9.95 = 10/9.95 = 1.005$ MHz

and $f_T = h_{fe} f_\beta = 100.5$ MHz. From Eq.(11-30),

$$C_e = \frac{g_m}{2\pi f_T} = \frac{|I_C|}{V_T}\,\frac{1}{2\pi f_T} = \frac{5}{26}\,\frac{10^{-6}}{2\pi \times 100.5} = 304 \text{ pF}$$

$$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{100}{5/26} = 520\,\Omega \;;\; r_{bb'} = h_{ie} - r_{b'e} = 600 - 520 = 80\,\Omega$$

11－5　一矽製 $p-n-p$ 電晶體之 $f_T = 400\ M$赫，試求其基極厚度。

<u>11-5</u> From Eq.(11-30) we have $\quad f_T = h_{fe} f_\beta = \dfrac{g_m}{2\pi C_e}$ (1)

From Eqs (11-17) and (11-22) we find $C_e = C_{De} = g_m \dfrac{W^2}{2D_B}$ (2)

Substituting (2) in (1) we have

$$f_T = \frac{g_m}{2\pi g_m \frac{W^2}{2D_B}} = \frac{D_B}{\pi W^2} \qquad \text{or} \qquad W^2 = \frac{D_B}{\pi f_T}$$

But for a p-n-p transistor $D_B = D_P = 13\ cm^2/sec$ (Table 2-1)

$$W^2 = \frac{13}{3.14 \times 400 \times 10^6} = \frac{13}{12.56} \times 10^{-8}\ cm^2 = 1.035 \times 10^{-8}\ cm^2$$

or $W = 1.03 \times 10^{-4}$ cm $= 1.03\ \mu$m

11－6　已知一鍺製 $p-n-p$ 電晶體之基極寬度為 10^{-4} 厘米，試求室溫下直流射極電流為 2 毫安時之(a)射極擴散電容，(b) f_T 。

<u>11-6</u> (a) From Eq.(11-22) we have $C_e \approx C_{De} = g_m \dfrac{W^2}{2D_B}$ (1)

Using Eq.(11-3) and Table 2-1 andsubstituting in (1)

we obtain $C_e = \dfrac{I_E}{V_T} \times \dfrac{W^2}{2D_B} = \dfrac{2 \times 10^{-3}}{26 \times 10^{-3}} \times \dfrac{10^{-8}}{2 \times 47} = 8.2$ pF

(b) $f_T = \dfrac{g_m}{2\pi C_e} = \dfrac{|I_C|}{V_T\, 2\pi C_e} = 1500$ MHz

11－7　(a)低頻時共射極之電流增益 β 與共基極之電流增益 α 之關係為

$$\alpha = \frac{\beta}{1+\beta}$$

設在高頻時仍然有效，並利用

$$\beta = -A_i = \frac{\beta_o}{1+j(f/f_\beta)}$$

證明 α 為

$$\alpha = \frac{\alpha_o}{1+j(f/f_\alpha)}$$

其中

$$\alpha_o = \frac{h_{fe}}{1+h_{fe}} \quad 且 \quad f_\alpha = \frac{f_\beta}{1-\alpha_o}$$

(b)利用 a 之結果，證明：$\alpha_o \approx 1$ 時，$f_\alpha \approx f_\beta h_{fe}$ 。

(c)證明：

$$A_i = \frac{-\alpha_o}{1-\alpha_o+jf/f_o}$$

(d) 為闡釋"超額相位"（excess phase），起見以 $\alpha_o \epsilon^{-jmf/f_\alpha}$ 取代 α_o ，證明：$|A_i|=1$ 時之頻率 f_T 可由下式求得：

$$1+x^2 = 2\alpha_o(\cos mx - x\sin mx)$$

其中 $x = f_T/f_\alpha$

(e) 當 $mx \ll 1$ ，將上述三角函數展開並證明

$$f_T \approx \frac{\alpha_o f_\alpha}{[1+2\alpha_o(m+m^2/2)]^{\frac{1}{2}}}$$

(f) 若 $\alpha_o = 1$, $m=0.2$ ，證明 $f_T = f_\alpha/1.2$ 。

<u>11-7</u> (a) $\alpha = \frac{\beta}{1+\beta} = \frac{-A_I}{1-A_I} = \frac{\frac{h_{fe}}{1+jf/f_\beta}}{1+\frac{h_{fe}}{1+jf/f_\beta}} = \frac{h_{fe}}{1+h_{fe}+jf/f_\beta} = \frac{\frac{h_{fe}}{1+h_{fe}}}{1+j\frac{f}{f_\beta(1+h_{fe})}}$

$= \frac{\alpha_O}{1+j\,f/f_\alpha}$ where $\alpha_O = h_{fe}/(1+h_{fe})$ and

$f_\alpha = f_\beta(1+h_{fe}) = \frac{f_\beta}{1-\alpha_O}$

(b) $\alpha_O = \frac{h_{fe}}{1+h_{fe}} \approx 1$ since $h_{fe} \gg 1$. Then, $f_\alpha \approx f_\beta h_{fe}$

(c) From the results above: $h_{fe} = \frac{\alpha_O}{1-\alpha_O}$ and $f_\beta = f_\alpha(1-\alpha_O)$. Thus, we have

$$A_i = \frac{-h_{fe}}{1+j\,f/f_\beta} = \frac{-\alpha_O/(1-\alpha_O)}{1+j\,f/f_\alpha(1-\alpha_O)} = \frac{-\alpha_O}{1-\alpha_O+j\,f/f_\alpha}$$

(d) Using the expression of part (c),

$$A_i = \frac{-\alpha_O\,e^{-jmf/f_\alpha}}{1-\alpha_O e^{-jmf/f_\alpha}+j\,f/f_\alpha} =$$

$$= \frac{-\alpha_O\cos(m\,f/f_\alpha)+j\,\alpha_O\sin(m\,f/f_\alpha)}{1-\alpha_O\cos(mf/f_\alpha)+j\alpha_O\sin(mf/f_\alpha)+j\,f/f_\alpha}.$$ Note that

when $f = f_T$, $|A_i| = 1$. Thus,

$$|A_i|^2 = 1 = \frac{\alpha_O^2\cos^2(m\,f_T/f_\alpha)+\alpha_O^2\sin^2(mf_T/f_\alpha)}{[1-\alpha_O\cos(m\,f_T/f_\alpha)]^2+[\alpha_O\sin(mf_T/f_\alpha)+f_T/f_\alpha]^2}.$$

Let $x = f_T/f_\alpha$. Then $\alpha_O^2(\cos^2 mx+\sin^2 mx) =$

$1-2\alpha_O\cos mx+\alpha_O^2\cos^2 mx+\alpha_O^2\sin^2 mx+2\alpha_O x\sin mx+x^2$

or $\quad 1+x^2 = 2\,\alpha_O\,(\cos mx - x\sin mx)$

(e) If $mx \ll 1$, then $\cos mx \approx 1-\frac{1}{2}m^2x^2$ and $\sin mx \approx mx$

Thus, $1+x^2 \approx 2\,\alpha_O\,(1-\frac{1}{2}m^2x^2-mx^2)$ or

$x^2 = \left(\frac{f_T}{f_\alpha}\right)^2 \approx \frac{2\alpha_O-1}{1+2\alpha_O m+\alpha_O m^2}$ or $f_T \approx f_\alpha \frac{(2\alpha_O-1)^{\frac{1}{2}}}{[1+2\alpha_O(m+\frac{m^2}{2})]^{\frac{1}{2}}}$. Now

since $\alpha_O \approx 1$ then $(2\alpha-1)^{\frac{1}{2}} \approx \alpha_O$ hence $f_T = \frac{\alpha_O f_\alpha}{[1+2\alpha_O(m+\frac{m^2}{2})]^{\frac{1}{2}}}$

(f) If $\alpha_O = 1$ and $m = 0.2$, then

$$f_T = \frac{1\times f_\alpha}{[1+2\times 1\times(0.2+0.02)]^{\frac{1}{2}}} = \frac{f_\alpha}{(1.44)^{\frac{1}{2}}} = \frac{f_\alpha}{1.2}$$

11－8 (*a*) 以基極爲共同端點重繪共射極之拼合 π 等效電路，同時將輸出端以及集極與基極間分別短路，利用電晶體各參數之典型值證明 C_c，r_{bc}，r_{ce} 可忽略不計。

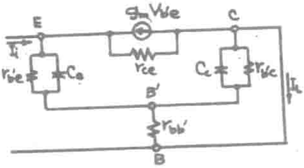
(*b*) 利用 *a* 之結果，證明：共基極短路電流增益爲

$$A_{ib} = \frac{g_m}{g_{be}+g_m+j\omega C_e} = \frac{\alpha_o}{1+jf/f_\alpha}$$

其中

$$\alpha_o=\frac{h_{fe}}{1+h_{fe}} \quad 且 \quad f_\alpha=\frac{g_m}{2\pi C_e\alpha_o}\approx\frac{f_\beta}{1-\alpha_o}$$

11-8 (a) The impedance of $C_c = 3$ pF is $-j100$ at 530 MHz which is far above the frequency range this circuit is used. Thus, C_c may be neglected. $r_{b'c} = 4M$ is in parallel with $r_{bb'} = 100\,\Omega$ and thus may be omitted. $r_{ce} = 80K$ is in parallel with $(r_{b'e}+r_{bb'}) = 1.1K$ and may also be neglected.



(b) With C_c, $r_{b'c}$ and r_{ce} left out in the circuit of part (a), we have: $A_{ib}=\frac{I_L}{I_i}$ where $I_L=-g_mV_{b'e}$ and

$$V_{b'e}=-(I_i+g_mV_{b'e})Z_e=\frac{-(I_i+g_mV_{b'e})}{g_{b'e}+j\omega C_e} \quad \text{or}$$

$$V_{b'e}=\frac{-I_i}{g_{b'e}+g_m+j\omega C_e} \quad \therefore A_{ib}=\frac{g_m}{g_{b'e}+g_m+j\omega C_e}.$$ Using

$$\text{Eq.(11-16)},\ A_{ib}=\frac{h_{fe}/r_{b'e}}{\frac{1}{r_{b'e}}+\frac{h_{fe}}{r_{b'e}}+j\omega C_e}=\frac{h_{fe}}{1+h_{fe}+j\omega r_{b'e}C_e}=$$

$$\frac{\frac{h_{fe}}{1+h_{fe}}}{1+j2\pi fC_e\frac{r_{b'e}}{1+h_{fe}}} \quad \text{or} \quad A_{ib}=\frac{\alpha_o}{1+jf/f_\alpha} \quad \text{where } \alpha_o=\frac{h_{fe}}{1+h_{fe}} \quad \text{and}$$

$$f_\alpha=\frac{1+h_{fe}}{2\pi r_{b'e}C_e} \quad \text{or} \quad f_\alpha=\frac{1}{2\pi\frac{r_{b'e}}{h_{fe}}\left(\frac{h_{fe}}{1+h_{fe}}\right)C_e}=\frac{g_m}{2\pi C_e\alpha_o}.$$ Also

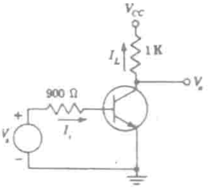
$$f_\alpha=\frac{\frac{1}{2\pi r_{b'e}C_e}}{\frac{1}{1+h_{fe}}}\approx\frac{\frac{1}{2\pi r_{b'e}(C_e+C_c)}}{1-\frac{h_{fe}}{1+h_{fe}}}=\frac{f_\beta}{1-\alpha_o} \quad \text{using Eq.(11-29)}$$

11-9 圖示電路中電晶體之拼合π參數見 11-1 節，試以米勒定理及近

似分析，求

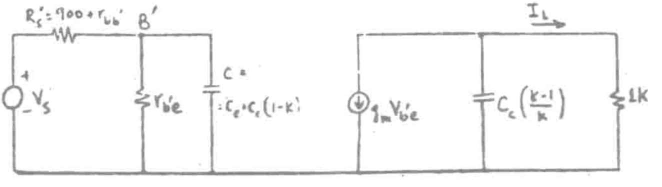
(a) 電流增益 $A_I = I_L / I_i$ 之上 3 分貝頻率。

(b) 在 a 中所求之頻率時電壓增益 $A_{Vs} = V_o / V_s$ 之振幅。

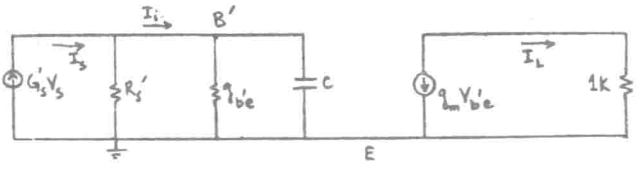


第 11-9 題圖

11-9 Assuming $|K| = |\frac{V_{ce}}{V_{b'e}}| >> 1$ and using Miller's theorem we obtain the equivalent circuit shown.



As explained in Sec. 11-8 we can neglect $C_C(1 - \frac{1}{K})$ and then at midband $K = -g_m R_L = (-50\ mA/V) \times 1\ K = -50$. Also $C = C_e + 51\ C_C = 100 + 153 = 253\ pF$. We call $R'_s = 900 + r_{bb'} = 1K$ and we obtain the indicated equivalent circuit using Norton's theorem.



Now $I_1 = I_S \dfrac{g_{b'e} + sC}{G'_s + g_{b'e} + sC}$ and $A_I = \dfrac{I_L}{I_1} = -\dfrac{g_m V_{b'e}}{I_1}$ but

$I_1 = V_{b'e}(g_{b'e} + sC)$ hence $A_I = \dfrac{-g_m}{g_{b'e} + sC}$ (1). Using Eq. (11-

16) (1) becomes $A_I = \dfrac{-h_{fe}}{1+s\dfrac{C}{g_{b'e}}} = \dfrac{-h_{fe}}{1+j\ f/f_I}$ where

$$f_I = \frac{g_{b'e}}{2\pi C} = \frac{1}{2\pi \times 1 \times 10^3 \times 253 \times 10^{-12}} = \frac{1}{1.582} \times 10^6 = 0.63 \text{ MHz}$$

(b) From Eq.(11-47) $f_H = \dfrac{1}{2\pi RC}$ where $C = 253$ pF and

$R = (R_S + r_{bb'}) \| r_{b'e}$ from Eq.(11-40), hence $R = \dfrac{10^3 \times 10^3}{2 \times 10^3} = 500\Omega$

Then $f_H = \dfrac{1}{2\pi \times 500 \times 254 \times 10^{-12}} = 1.26$ MHz. Using Eq.(11-41)

we have $A_{VS} = \dfrac{-g_m R_L G'_S/(G'_S + g_{b'e})}{1 + j\ f/f_H}$ or

$$|A_{VS}| = \frac{g_m R_L G'_S}{G'_S + g_{b'e}} \left(\sqrt{1 + \frac{f^2}{f_H^2}}\right)^{-1} \quad (1) \text{ where}$$

$G'_S = \dfrac{1}{R_S + r_{bb'}} = 1 \times 10^{-3}$ mho then

$\dfrac{g_m R_L G'_S}{G'_S + g_{b'e}} = \dfrac{50 \times 10^{-3} \times 1 \times 10^3 \times 1 \times 10^{-3}}{1 \times 10^{-3} + 1 \times 10^{-3}} = 25$ and at $f = f_I$ we have from (1)

$$|A_{VS}| = 25 \times \frac{1}{\sqrt{1 + \left(\frac{0.63}{1.26}\right)^2}} = 25 \times \frac{1}{\sqrt{1.25}} = \frac{25}{1.12} = 22.4 .$$

11-10 茲有一單級共射極電晶體放大器，其負載電阻 R_L 與電容 C_L 並聯

(a) 證明：內部電壓增益 $K = V_{ce} / V_{b'e}$ 爲

$$K \approx \frac{-g_m R_L}{1 + j\omega\,(C_c + C_L)\,R_L}$$

(b) 證明：3分貝頻率爲

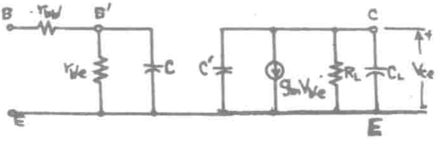
$$f_H = \frac{1}{2\pi\,(C_c + C_L)\,R_L}$$

其先決條件爲：

$$g_{b'e}R_L(C_e+C_L) \gg C_e + C_c(1+g_m R_L)$$

11-10 Applying Miller's theorem we get: where $C = C_e + C_c(1-K)$ and $C' \approx C_c$.

(a) $K = \frac{V_{ce}}{V_{b'e}} = \frac{1}{V_{b'e}}\left[\frac{-g_m V_{b'e} R_L}{1+j\omega R_L(C_c+C_L)}\right]$ or $K = \frac{-g_m R_L}{1+j\omega(C_c+C_L)R_L}$



(b) From the circuit we see that there are two time constants $R_L(C_c+C_L)$, and $r_{b'e}[C_e + C_c(1-K)]$. If

$$R_L(C_c+C_L) \gg \frac{1}{g_{b'e}}[C_e + C_c(1-K)] = r_{b'e}[C_e + C_c(1+g_m R_L)]$$

(since $K = K_o = -g_m R_L$), then f_H is determined by the larger time constant. From part (a) we get:

$$f_H = \frac{\omega_H}{2\pi} \approx \frac{1}{2\pi}\,\frac{1}{(C_c+C_L)R_L}$$

11-11 茲有一單級共射極電晶體放大器，其拼合 π 參數值如11－1節所列之平均值，試求電源電阻 R_s 以使其3分貝頻率 f_H 爲(a) $R_s = 0$ 時之一半，(b) $R_s = \infty$時之二倍？此等R_s 值與負載 R_L 之大小有無關係？利用米勒定理及近似分析法。

11-11 From Eq.(11-47), $f_H = \frac{1}{2\pi RC}$ where $R = \frac{R_s + r_{bb'}}{R_s + h_{ie}} r_{b'e} \cdots$ Eq.(11-40), and $C = C_e + C_c(1+g_m R_L) \ldots$ Eq.(11-39).

(a) If $R_s = 0$, $f_H = \frac{1}{2\pi}\,\frac{h_{ie}}{r_{bb'} r_{b'e}}\,\frac{1}{C_e + C_1(1+g_m R_L)}$. Now find R_s

such that $f'_H = \frac{1}{2} f_H$

$$f'_H = \frac{1}{2\pi}\,\frac{R_s + h_{ie}}{(R_s + r_{bb'}) r_{b'e}}\,\frac{1}{C_e + C_c(1+g_m R_L)} =$$

$$\frac{1}{2}\left[\frac{1}{2\pi}\,\frac{h_{ie}}{r_{bb'}\,r_{b'e}}\,\frac{1}{C_e+C_c(1+g_mR_L)}\right] \text{ where } h_{ie}=r_{bb'}+r_{b'e}$$

or $\dfrac{R_s+h_{ie}}{(R_s+r_{bb'})r_{b'e}}=\dfrac{1}{2}\,\dfrac{h_{ie}}{r_{bb'}\,r_{b'e}}$ $\therefore R_s=\dfrac{h_{ie}\,r_{bb'}}{h_{ie}-2r_{bb'}}=$

$$\frac{(r_{bb'}+r_{b'e})r_{bb'}}{r_{b'e}-r_{bb'}}=\frac{1100\times100}{900}=122\,\Omega$$

(b) If $R_s=\infty$, $f_H=\dfrac{1}{2\pi}\,\dfrac{1}{r_{b'e}}\,\dfrac{1}{C_e+C_c(1+g_mR_L)}$. To find R_s for

$f'_H=2f_H$, $\dfrac{f'_H}{f_H}=2=\dfrac{(R_s+h_{ie})r_{b'e}}{(R_s+r_{bb'})r_{b'e}}$ or $2R_s+2r_{bb'}=R_s+h_{ie}=$

$R_s+r_{bb'}+r_{b'e}$

or $R_s=r_{b'e}-r_{bb'}=1000-100=900\,\Omega$. Note that the above values of R_s do not depend on R_L.

11-12 一單級共射極放大器於 $R_L=500$ 歐姆時之電壓增益頻帶寬爲 $f_H=5M$赫，設：$h_{fe}=100$，$g_m=100$ 毫安／伏特，$r_{bb'}=100$ 歐姆，$C_c=1$ 微微法，$f_T=400$ 百萬赫。

(a) 試求能得所需頻帶寬之電源電阻值。

(b) 用 a 所求之 R_s 值，求中頻電壓增益 V_o/V_s。

〔提示：利用近似分析法〕。

11-12 (a) From Eq.(11-23) we find

$$C_e=\frac{g_m}{2\pi f_T}=\frac{100\times10^{-3}}{6.28\times400\times10^6}=0.0405\times10^{-9}$$

From Eq.(11-16) we have $r_{b'e}=\dfrac{h_{fe}}{g_m}=1\,K$. From Eq.(11-39) we have $C=C_e+C_c(1+g_mR_L)=$

$$=40+1(1+100\times10^{-3}\times\tfrac{1}{2}\times10^3)=91\text{ pF.}$$

Let $R'_s=R_s+r_{bb'}$ and $R=R'_s\,\|\,r_{b'e}$ then from Eq.(11-47)

we have $f_H=\dfrac{1}{2\pi RC}$ or $R=\dfrac{1}{2\pi f_HC}=\dfrac{1}{6.28\times5\times10^6\times91\times10^{-12}}$

$=0.35\times10^3=350\,\Omega$

$$\text{hence } \frac{R'_s \times r_{b'e}}{R'_s + r_{b'e}} = 0.350\,K \quad \text{or } 0.650R' = 0.350$$

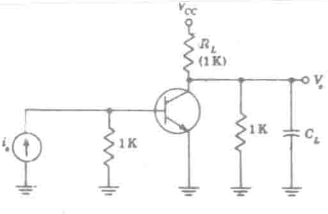
$$R'_s = 0.539\,K = 539\,\Omega \quad \text{and } R_s = R'_s - r_{bb'} = 539 - 100 = 439\,\Omega$$

(b) For $s = j\omega$ and $\omega = 0$ for the midband gain Eq.(11-41)

becomes $A_{Vs} = -\dfrac{g_m R_L G_s}{G'_s + g_{b'e}}$ where $G'_s = \dfrac{1}{R'_s}$ hence

$$A_{Vs} = -\frac{100\times10^{-3}\times0.5\times10^{3}\times1.86\times10^{-3}}{1.86\times10^{-3}+1\times10^{-3}} = \frac{-50\times1.86}{2.86} = -32.5$$

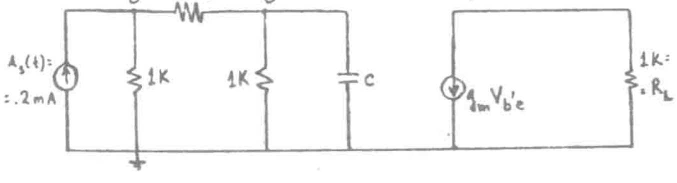
11-13 圖示電路中電晶體之拼合π參數如11－1節所列，輸入至放大器者係大小爲0.2毫安之突變電流，試求下列情況之輸出電壓之時間函數：(a)當 $C_L = 0$時，輸出時間常數忽略不計。(b)當 $C_L = 0.1$ 微法時，輸入時間常數忽略不計。



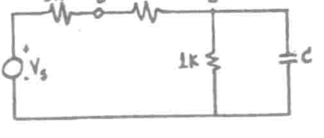
第 11-13 題圖

11-13 (a) We shall use approximate analysis. Applying Miller's theorem we obtain the circuit shown. Where

$$C = C_e + (1+g_m R_L)C_c = 100 + (1+50)\times 3 = 253\text{ pF}$$

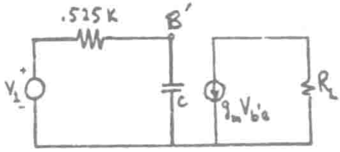


Applying Thevenin's theorem to the circuit to the left of B we have



$V_S = 0.2\,u(t)\,V$

(u(t) unit step function) and $R' = 1\,K$. Applying Thevenin's theorem to the circuit the left of B' we have



$$V_1 = V_S \frac{1}{2.1} = 0.0952\,u(t)$$

and $R_1 = 1.1 \| 1 = 0.525\,K$. Then the time constant of the input circuit is $R_1C = 0.525\times10^3\times253\times10^{-12} = 0.133\,\mu sec$

Hence $v_{b'e} = 0.0952\,(1 - e^{-t/0.133})$ with t given in μsec

Consequently

$$v_o = -g_m R_L\, v_{b'e} = -50\times 0.0952\,(1-e^{-t/0.133}) =$$

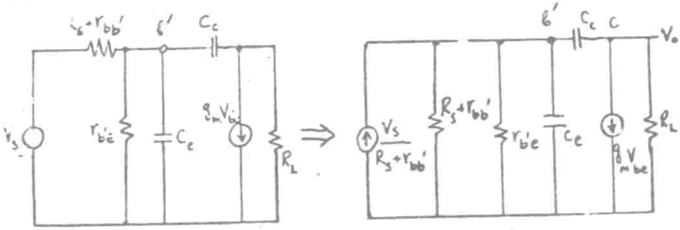
$$= -4.76\,(1 - e^{-t/0.133})$$

(b) For this case we can consider $g_m v_{b'e}$ as a unit step since the time constant of the output $R_L C_C = 10^3 \times 10^{-7} = 10^{-4} \gg R_1 C = 0.133\times 10^{-6}$. Hence $v_o = -50\times0.182\,(1-e^{-t/10^{-4}}) = -4.76\,(1 - e^{-t/10^{-4}})$ with t given in seconds.

11－14 (*a*) 試證 11－8節中之單級共射極放大器之節點方程式。

(*b*) 求式 (11－37) 所表之電壓增益 V_o/V_i 。

<u>11-14</u>



(a) (b)

(a) By applying Norton's theorem we obtain the circuit