第二章　选频网络

注意：①有部分答案有差异；
②3-1 题是 2-1 题；
③只有计算题答案和部分问答题；
④答案不齐全。

$3-1$　$\because f_0 = 1MHz$

$$2\Delta f_{0.7} = 1\times10^6 - 990\times10^3 = 10(kHz)$$

$$Q = \frac{f_0}{2\Delta f_{0.7}} = \frac{1\times10^6}{10\times10^3} = 100$$

$$R = 10\Omega$$

$$L = \frac{QR}{\omega_0} = \frac{100\times10}{2\times3.14\times10^6} = 159(\mu H)$$

$$C = \frac{1}{\omega_0^2 L} = \frac{1}{(2\times3.14\times10^6)^2\times159\times10^{-6}} = 159(pF)$$

$3-2$　$\because$ (1)　$\omega_{01} = \frac{1}{\sqrt{L_1C_1}}$　$\omega_{02} = \frac{1}{\sqrt{L_2C_2}}$　，　　.

(2)　$\omega_{01} = \frac{1}{\sqrt{L_1C_1}}$　$\omega_{02} = \frac{1}{\sqrt{L_2C_2}}$　，　　.

(3)　$\omega_{01} = \frac{1}{\sqrt{L_1C_1}}$　$\omega_{02} = \frac{1}{\sqrt{L_2C_2}}$　，　　.

$3-3$　$\because$

$$Z = \frac{(R+j\omega_0L)(R+\frac{1}{j\omega_0C})}{R+j\omega_0L+R+\frac{1}{j\omega_0C}} = \frac{R^2+\frac{L}{C}+j\omega_0LR(1-\frac{1}{\omega_0^2LC})}{2R+j\omega_0L(1-\frac{1}{\omega_0^2LC})} = \frac{R^2+\frac{L}{C}}{2R} = R$$

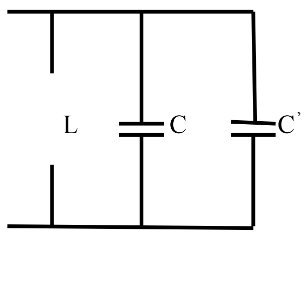
$3-4$　$\because$1)　$(15+C)\times1605^2 = (450+C)535^2$　$C = 40pF$

$(12+C)\times1605^2 = (100+C)535^2$　$C = -1pF($　　　　$)$

。

$$2)L = \frac{1}{\omega_0^2(C+C')} = \frac{1}{(2\times3.14\times535\times10^3)^2\times(450+40)\times10^{-12}} = 180(\mu H)$$

3)



$$3-5\quad \because\ Q_0=\frac{1}{\omega_0 C_0 R}=\frac{1}{2\times3.14\times1.5\times10^6\times100\times10^{-12}\times5}=212$$

$$L_0=\frac{1}{\omega_0^2 C_0}=\frac{1}{\left(2\times3.14\times1.5\times10^6\right)^2 100\times10^{-12}}=112(\mu H)$$

$$I_{om}=\frac{V_{om}}{R}=\frac{1\times10^{-3}}{5}=0.2(mA)$$

$$V_{Lom}=V_{Com}=Q_0V_{Sm}=212\times1\times10^{-3}=212(mV)$$

$$3-6\quad \because\ L=\frac{1}{\omega_0^2 C}=\frac{1}{\left(2\times3.14\times10^6\right)^2\times100\times10^{-12}}=253(\mu H)$$

$$Q_0=\frac{V_C}{V_S}=\frac{10}{0.1}=100$$

$$\frac{C\cdot C_X}{C+C_X}=\frac{1}{\omega_0^2 L}=\frac{1}{\left(2\times3.14\times10^6\right)^2\times253\times10^{-6}}=100(pF)\rightarrow C_X=200pF$$

$$R_X=\frac{\omega_0 L}{Q}-\frac{\omega_0 L}{Q_0}=\frac{2\times3.14\times10^6\times253\times10^{-6}}{2.5/0.1}-\frac{2\times3.14\times10^6\times253\times10^{-6}}{100}=47.7(\Omega)$$

$$Z_X=R_X-j\frac{1}{\omega_0 C_X}=47.7-j\frac{1}{2\times3.14\times10^6\times200\times10^{-12}}=47.7-j796(\Omega)$$

$$3-7\quad \because\ L=\frac{1}{\omega_0^2 C}=\frac{1}{\left(2\times3.14\times5\times10^6\right)\times50\times10^{-12}}=20.2(\mu H)$$

$$Q_0=\frac{f_0}{2\Delta f_{0.7}}=\frac{5\times10^6}{150\times10^3}=\frac{100}{3}$$

$$\xi=Q_0\frac{2\Delta f}{f_0}=\frac{100}{3}\times\frac{2\times(5.5-5)\times10^6}{5\times10^6}=\frac{20}{3}$$

$2\Delta f'_{0.7}=2\times2\Delta f_{0.7}$, $Q'_0=0.5Q_0$, $R'=0.5R$, 所以应并上21kΩ电阻.

$$3-8\quad \because 4\pi\Delta f_{0.7}C=\frac{2\pi f_0 C}{f_0/2\Delta f_{0.7}}=\frac{\omega_0 C}{Q}=g_{\Sigma}$$

$$3-9 \quad \because \; C = C_i + \frac{(C_2 + C_0)C_1}{C_2 + C_0 + C_1} = 5 + \frac{(20+20)20}{20+20+20} = 18.3(pF)$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times 3.14\sqrt{0.8\times 10^{-6}\times 18.3\times 10^{-12}}} = 41.6(MHz)$$

$$R_P = Q_0\sqrt{\frac{L}{C_{12}}} = 100\times\sqrt{\frac{0.8\times 10^{-6}}{(20+20)\times 10^{-12}}} = 20.9(k\Omega)$$

$$R_\Sigma = R_i \left\| R_P \right\| \left(\frac{C_2 + C_0 + C_1}{C_1}\right)^2 R_0 = 10 \left\| 20.9 \right\| \left(\frac{20+20+20}{20}\right)^2 \times 5 = 5.88(k\Omega)$$

$$Q_L = \frac{R_\Sigma}{\omega_0 L} = \frac{5.88\times 10^3}{2\times 3.14\times 41.6\times 10^6\times 0.8\times 10^{-6}} = 28.2$$

$$2\Delta f_{0.7} = \frac{f_0}{Q_L} = \frac{41.6\times 10^6}{28.2} = 1.48(MHz)$$

3－12解：1) $Z_{f1} = 0$

2) $Z_{f1} = 0$

3) $Z_{f1} = R$

$$3-13 \quad \because 1) L_1 = L_2 = \frac{\rho_1}{\omega_{01}} = \frac{10^3}{2\times 3.14\times 10^6} = 159(\mu H)$$

$$C_1 = C_2 = \frac{1}{\omega_{01}^2 L_1} = \frac{1}{\left(2\times 3.14\times 10^6\right)^2\times 159\times 10^{-6}} = 159(pF)$$

$$M = \frac{\eta R_1}{\omega_{01}} = \frac{1\times 20}{2\times 3.14\times 10^6} = 3.18(\mu H)$$

$$2) Z_{f1} = \frac{(\omega_{01}M)^2}{R_2} = \frac{\left(2\times 3.14\times 10^6\times 3.18\times 10^{-6}\right)^2}{20} = 20(\Omega)$$

$$Z_p = \frac{L_1}{(R_1 + R_{f1})C_1} = \frac{159\times 10^{-6}}{(20+20)\times 159\times 10^{-12}} = 25(k\Omega)$$

$$3) Q_1 = \frac{\omega_{01}L_1}{R_1 + R_{f1}} = \frac{2\times 3.14\times 10^6\times 159\times 10^{-6}}{20+20} = 25$$

$$4) 2\Delta f_{0.7} = \sqrt{2}\,\frac{f_0}{Q} = \sqrt{2}\,\frac{f_0}{\rho_1/R_1} = \sqrt{2}\times\frac{10^6\times 20}{10^3} = 28.2(kHz)$$

$$5) C_2' = \frac{1}{(\omega_{02}')^2 L_2} = \frac{1}{\left(2\times 3.14\times 950\times 10^3\right)^2\times 159\times 10^{-6}} = 177(pF)$$

$$Z_{22} = R_2 + j\left(\omega_{02}L_1 - \frac{1}{\omega_{02}C_2'}\right)$$

$$= 20 + j\left(2\times 3.14\times 10^6\times 159\times 10^{-6} - \frac{1}{2\times 3.14\times 10^6\times 177\times 10^{-12}}\right) = 20 + j100$$

$$Z_{f1} = \frac{(\omega_{01}M)^2}{Z_{22}} = \frac{\left(2\times 3.14\times 10^6\times 3.18\times 10^{-6}\right)^2}{20+j100} = 0.768 - j3.84(\Omega)$$

$$3-15\text{解：}\because R = \frac{L}{R_P C} = \frac{159\times 10^{-6}}{50\times 10^3\times 159\times 10^{-12}} = 20(\Omega) = R_1$$

$$\therefore R_{f1} = 0 \to M = 0$$

$$Q = \sqrt{2}\,\frac{f_0}{2\Delta f_{0.7}} = \sqrt{2}\,\frac{10^6}{14\times 10^3} = 100$$

$$3-16 \quad \because 1)R_{f1}=\frac{(\omega_{01}M)^2}{R_2}=\frac{(10^7\times10^{-6})^2}{5}=20(\Omega)$$

$$R_{ab}=\frac{(\omega_{01}L)^2}{(R_1+R_{f1})}=\frac{(10^7\times100\times10^{-6})^2}{5+20}=40(k\Omega)$$

$$2)\eta=\frac{\omega_{01}M}{R_1}=\frac{10^7\times10^{-6}}{5}=2$$

$$3)Q=\frac{\omega_{01}L}{R_1}=\frac{10^7\times100\times10^{-6}}{5}=200$$

$$\frac{2\Delta f_{0.7}}{f_0}=\sqrt{\eta^2+2\eta-1}\cdot\frac{1}{Q}=\sqrt{2^2+2\times2-1}\times\frac{1}{200}=0.013$$

$$3-17 \quad \because \frac{I}{I_0}=\frac{1}{\sqrt{1+\left(Q'\frac{2\Delta f}{f_0}\right)^2}}=\frac{1}{\sqrt{1+\left(Q'\frac{10\times10^3}{300\times10^3}\right)^2}}=\frac{1}{1.25}\rightarrow Q'=22.5$$

$$R=\frac{1}{Q\omega_0C}=\frac{1}{22.5\times2\times3.14\times300\times10^3\times2000\times10^{-12}}=11.8$$

$$\frac{I}{I_0}=\frac{1}{\sqrt{1+\left(Q\frac{2\Delta f}{f_0}\right)^2}}=\frac{1}{\sqrt{1+\left(Q\frac{10\times10^3}{300\times10^3}\right)^2}}=\frac{1}{\sqrt{2}}\rightarrow Q=30$$

$$Q-Q'=30-22.5=7.5$$

$$3-18 \quad \because \begin{cases} 2\omega=\dfrac{1}{\sqrt{L_2C}} \\ \omega=\dfrac{1}{\sqrt{(L_1+L_2)C}} \end{cases} \rightarrow \begin{cases} L_1=375\mu H \\ L_2=125\mu \end{cases}$$

第三章　高频小信号放大器

4－5解：当$f=1MHz$　，$\beta=\dfrac{\beta_0}{\sqrt{1+\left(\dfrac{\beta_0 f}{f_T}\right)^2}}=\dfrac{50}{\sqrt{1+\left(\dfrac{50\times10^6}{250\times10^6}\right)^2}}=49$

当$f=20MHz$　，$\beta=\dfrac{\beta_0}{\sqrt{1+\left(\dfrac{\beta_0 f}{f_T}\right)^2}}=\dfrac{50}{\sqrt{1+\left(\dfrac{50\times20\times10^6}{250\times10^6}\right)^2}}=12.1$

当$f=50MHz$　，$\beta=\dfrac{\beta_0}{\sqrt{1+\left(\dfrac{\beta_0 f}{f_T}\right)^2}}=\dfrac{50}{\sqrt{1+\left(\dfrac{50\times50\times10^6}{250\times10^6}\right)^2}}=5$

4－7解：$g_{b'e}=\dfrac{I_E}{26(\beta_0+1)}=\dfrac{1}{26\times(50+1)}=0.754(mS)$

$$g_m=\frac{\beta_0}{r_{b'e}}=50\times 0.754\times 10^{-3}=37.7(mS)$$

$$C_{b'e}=\frac{g_m}{2\pi f_T}=\frac{37.7\times 10^{-3}}{2\times 3.14\times 250\times 10^6}=24(pF)$$

$$a=1+r_{bb'}g_{b'e}=1+70\times 0.754\times 10^{-3}\approx 1$$

$$b=\omega C_{b'e}r_{bb'}=2\times 3.14\times 10^7\times 24\times 10^{-12}\times 70\approx 0.1$$

$$y_{ie}=\frac{(g_{b'e}+j\omega C_{b'e})(a-jb)}{a^2+b^2}=\frac{\left(0.754\times 10^{-3}+j2\times 3.14\times 10^7\times 24\times 10^{-12}\right)\times(1-j0.1)}{1^2+0.1^2}$$

$$=0.895+j1.41(mS)$$

$$y_{re}=-\frac{(g_{b'c}+j\omega C_{b'c})(a-jb)}{a^2+b^2}\approx-\frac{j2\times 3.14\times 10^7\times 3\times 10^{-12}\times(1-j0.1)}{1^2+0.1^2}=-0.0187-j0.187(mS)$$

$$y_{fe}=\frac{g_m(a-jb)}{a^2+b^2}=\frac{37.7\times 10^{-3}\times(1-j0.1)}{1^2+0.1^2}=37.327-j3.733(mS)$$

$$y_{oe}=g_{ce}+j\omega C_{b'c}+r_{bb'}g_m\frac{(g_{b'c}+j\omega C_{b'c})(a-jb)}{a^2+b^2}\approx j\omega C_{b'c}\left(1+r_{bb'}g_m\frac{a-jb}{a^2+b^2}\right)$$

$$\approx j2\times 3.14\times 10^7\times 3\times 10^{-12}\left(1+70\times 37.7\times 10^{-3}\times\frac{1-j0.1}{1^2+0.1^2}\right)=0.049+j0.68(mS)$$

4－8解：令$\left(\dfrac{A_v}{A_{vo}}\right)^m=\left(\dfrac{2}{\sqrt{\left(4+(Q2\Delta f_{0.7}/f_0)^4\right)}}\right)^m=\dfrac{1}{\sqrt{2}}$　　得$2\Delta f_{0.7}=\sqrt[4]{4\left(2^{\frac{1}{m}}-1\right)}\cdot\dfrac{f_0}{Q}$

令$\left(\dfrac{A_v}{A_{vo}}\right)^m=\left(\dfrac{2}{\sqrt{\left(4+(Q2\Delta f_{0.1}/f_0)^4\right)}}\right)^m=\dfrac{1}{10}$　　得$2\Delta f_{0.1}=\sqrt[4]{4\left(10^{\frac{2}{m}}-1\right)}\cdot\dfrac{f_0}{Q}$

故$K_{r0.1}=\dfrac{2\Delta f_{0.1}}{2\Delta f_{0.7}}=\dfrac{\sqrt[4]{4\left(10^{\frac{2}{m}}-1\right)}}{\sqrt[4]{4\left(2^{\frac{1}{m}}-1\right)}}=\sqrt[4]{\dfrac{10^{\frac{2}{m}}-1}{2^{\frac{1}{m}}-1}}$

4－9解：$p_1 = \frac{N_{23}}{N_{13}} = \frac{5}{20} = 0.25 \qquad p_2 = \frac{N_{45}}{N_{13}} = \frac{5}{20} = 0.25$

$$g_p = \frac{1}{\omega_0 Q_0 L} = \frac{1}{2\pi \times 10.7 \times 10^6 \times 100 \times 4 \times 10^{-6}} = 37.2(\mu S)$$

$$g_\Sigma = g_p + p_1^2 g_{oe} + p_2^2 g_{ie} = 37.2 \times 10^{-6} + \frac{1}{4^2} \times 200 \times 10^{-6} + \frac{1}{4^2} \times 2860 \times 10^{-6} = 228.5(\mu S)$$

$$A_{vo} = \frac{p_1 p_2 |y_{fe}|}{g_\Sigma} = \frac{0.25 \times 0.25 \times 45 \times 10^{-3}}{228.5 \times 10^{-6}} = 12.3$$

$$A_{po} = A_{vo}^2 = 12.3^2 = 151.3$$

$$Q_L = \frac{1}{g_\Sigma \omega_0 L} = \frac{1}{228.5 \times 10^{-6} \times 2\pi \times 10.7 \times 10^6 \times 4 \times 10^{-6}} = 16.3$$

$$2\Delta f_{0.7} = \frac{f_0}{Q_L} = \frac{10.7 \times 10^6}{16.3} = 0.657(MH_Z)$$

$$K = \left(1 - \frac{Q_L}{Q_0}\right)^{-2} = \left(1 - \frac{16.3}{100}\right)^{-2} = 1.43$$

$$\xi = \tan\frac{\varphi_{fe} + \varphi_{re}}{2} = \tan\frac{-54^o - 88.5^o}{2} = -2.95$$

$$g_L' = \frac{g_p + p_2^2 g_{ie}}{p_1^2} = \frac{37.2 \times 10^{-6} + 0.25^2 \times 200 \times 10^{-6}}{0.25^2} 3008.8(\mu S)$$

$$S = \frac{(g_s + g_{ie})(g_{oe} + g_L')(1 + \xi^2)}{|y_{fe}||y_{re}|} = \frac{2 \times 2860 \times 10^{-6}(200 \times 10^{-6} + 3008.8 \times 10^{-6})(1 + 2.95^2)}{|45 \times 10^{-3}||0.31 \times 10^{-3}|} >> 1$$

$$4-10\text{解}:(1) g_p=\frac{1}{Q_0\omega_0 L}=\frac{1}{100\times 2\times 3.14\times 10.7\times 10^6\times 4\times 10^{-6}}=0.037(mS)$$

$$g_\Sigma=g_p+\frac{1}{R_5}+p_1^2 g_{oe}+p_2^2 g_{ie}=\left(0.037+0.1+0.3^2\times 0.082+0.3^2\times 0.15\right)=0.158(mS)$$

$$A_{vo}=\frac{p_1 p_2 y_{fe}}{g_\Sigma}=\frac{0.3\times 0.3\times\sqrt{38^2+4.2^2}}{0.158}=21.78$$

$$(2) 2\Delta f_{0.7}=\omega_0 L g_\Sigma f_0=2\times 3.14\times\left(10.7\times 10^6\right)^2\times 4\times 10^{-6}\times 0.158\times 10^{-3}=454.4(kHz)$$

$$(3)(A_{vo})_4=(A_{vo})^4=21.78^4=225025.38$$

$$(4)(2\Delta f_{0.7})_4=\sqrt{2^{\frac{1}{4}}-1}\cdot 2\Delta f_{0.7}=\sqrt{2^{\frac{1}{4}}-1}\times 454.4=197.65(kHz)$$

$$(5) 2\Delta f'_{0.7}=\frac{2\Delta f_{0.7}}{\sqrt{2^{\frac{1}{4}}-1}}=1044.6(kHz)$$

$$2\Delta f'_{0.7}-2\Delta f_{0.7}=1044.6-454.4=590.2(kHz)$$

$$A'_{vo}=\frac{A_{vo}2\Delta f_{0.7}}{2\Delta f'_{0.7}}=\frac{21.78\times 454.4}{1044.6}=9.47$$

$$(A'_{vo})_4=(A'_{vo})^4=9.47^4=8042.66$$

$$(A_{vo})_4-(A'_{vo})_4=225025.38\text{-}8042.66=216982.72$$

$$4-11\text{解：}C_\Sigma=C+p_1^2 C_{oe}=500+0.3^2\times 18=501.62(pF)$$

$$L=\frac{1}{(2\pi f_0)^2 C_\Sigma}=\frac{1}{\left(2\times 3.14\times 1.5\times 10^6\right)^2\times 501.62\times 10^{-12}}=22.5(\mu H)$$

$K_{r0.1}<1.9$不能满足

$$4-14\text{解}:(A_{vo})_S=\sqrt{\frac{|y_{fe}|}{2.5\omega_0 C_{re}}}=\sqrt{\frac{\sqrt{26.4^2+36.4^2}}{2.5\times 0.3}}=7.74$$

$4-17$解：$L_1=\dfrac{1}{\omega_0^2 C_1}=\dfrac{1}{\left(2\pi\times 465\times 10^3\right)^2\times 1000\times 10^{-12}}=118(\mu H)$

$$L_{36}=L_2+L_{34}+L_{56}=\frac{118}{73}+\frac{118}{73}\times 60+\frac{118}{73}\times 13.5=120$$

$$C_{12}=C_1+C_o=1000+4=1004(pF)$$

$$C_{36}=C_2+p_2^2C_i=1000+\left(\frac{13.5}{74.5}\right)^2\times 40=1004(pF)$$

$$g_{12}=g_o+\frac{\omega_0 C_1}{Q_0}=20\times 10^{-6}+\frac{2\pi\times 465\times 10^3\times 1000\times 10^{-12}}{100}=49(\mu S)$$

$$g_{36}=p_2^2 g_i+\frac{\omega_0 C_2}{Q_0}=\left(\frac{13.5}{74.5}\right)^2\times 0.62\times 10^{-3}+\frac{2\pi\times 465\times 10^3\times 1000\times 10^{-12}}{100}=49(\mu S)$$

$\therefore$ 初、次级回路参数相等。若为临界耦合，即$\eta=1$，则

$$A_{vo}=\frac{p_1p_2y_{fe}}{g}=\frac{1\times\dfrac{13.5}{74.5}\times 40\times 10^{-3}}{2\times 49\times 10^{-6}}=74$$

$$Q_L=\frac{\omega_0 C_{12}}{g_{12}}=\frac{2\pi\times 465\times 10^3\times 1004\times 10^{-12}}{49\times 10^{-6}}=60$$

$$2\Delta f_{0.7}=\sqrt{2}\frac{f_0}{Q_L}=\sqrt{2}\times\frac{465\times 10^3}{60}=10.9(kH_Z)$$

$$K_{r0.1}=3.16$$

$4-20$ ：$\sqrt{\overline{v_n^2}}=\sqrt{4kTR\Delta f_n}=\sqrt{4\times 1.38\times 10^{-23}\times 290\times 1000\times 10^7}=12.65(\mu V)$

$$\sqrt{\overline{i_n^2}}=\sqrt{4kTG\Delta f_n}=\sqrt{4\times 1.38\times 10^{-23}\times 290\times 10^{-3}\times 10^7}=12.65(nA)$$

$4-21$解：$\because \overline{v_n^2}=\overline{v_{n1}^2}+\overline{v_{n2}^2}+\overline{v_{n3}^2}=4kT_1R_1\Delta f_n+4kT_2R_2\Delta f_n+4kT_3R_3\Delta f_n$

$$=4k\left(T_1R_1+T_2R_2+T_3R_3\right)\Delta f_n$$

$$=4kT\left(R_1+R_2+R_3\right)\Delta f_n$$

$$\therefore T=\frac{T_1R_1+T_2R_2+T_3R_3}{R_1+R_2+R_3}$$

$$\because \overline{i_n^2}=\overline{i_{n1}^2}+\overline{i_{n2}^2}+\overline{i_{n3}^2}=4kT_1G_1\Delta f_n+4kT_2G_2\Delta f_n+4kT_3G_3\Delta f_n$$

$$=4k\left(T_1G_1+T_2G_2+T_3G_3\right)\Delta f_n$$

$$=4kT\left(G_1+G_2+G_3\right)\Delta f_n$$

$$\therefore T=\frac{T_1G_1+T_2G_2+T_3G_3}{G_1+G_2+G_3}=\frac{R_1R_2T_3+R_2R_3T_1+R_3R_1T_2}{R_1R_2+R_2R_3+R_3R_1}$$

$4-18$证明：1) $\dot{I}_{b1}=y_{ie}\dot{V}_{be1}+y_{re}\dot{V}_{ce1}\cdots\cdots(1)$

$\dot{I}_{c1}=y_{fe}\dot{V}_{be1}+y_{oe}\dot{V}_{ce1}\cdots\cdots(2)$

$\dot{I}_{b2}=y_{ie}\dot{V}_{be2}+y_{re}\dot{V}_{ce2}=-y_{ie}\dot{V}_{ce1}+y_{re}\left(\dot{V}_{cb2}-\dot{V}_{ce1}\right)=y_{re}\dot{V}_{cb2}-\left(y_{ie}+y_{re}\right)\dot{V}_{ce1}\cdots\cdots(3)$

$\dot{I}_{c2}=y_{fe}\dot{V}_{be2}+y_{oe}\dot{V}_{ce2}=-y_{fe}\dot{V}_{ce1}+y_{oe}\left(\dot{V}_{cb2}-\dot{V}_{ce1}\right)=y_{oe}\dot{V}_{cb2}-\left(y_{fe}+y_{oe}\right)\dot{V}_{ce1}\cdots\cdots(4)$

(2)−(3)得 $\dot{I}_{c2}=y_{fe}\dot{V}_{be1}+\left(y_{ie}+y_{re}+y_{oe}\right)\dot{V}_{ce1}-y_{re}\dot{V}_{cb2}$

$$\dot{V}_{ce1}=\frac{\dot{I}_{c2}+y_{re}\dot{V}_{cb2}-y_{fe}\dot{V}_{be1}}{y_{ie}+y_{re}+y_{oe}}\cdots\cdots(5)$$

(5)代入(4) $\dot{I}_{c2}=y_{oe}\dot{V}_{cb2}-\left(y_{fe}+y_{oe}\right)\dfrac{\dot{I}_{c2}+y_{re}\dot{V}_{cb2}-y_{fe}\dot{V}_{be1}}{y_{ie}+y_{re}+y_{oe}}$

$$\dot{I}_{c2}=\frac{\mathrm{y}_{fe}\left(\mathrm{y}_{fe}+y_{oe}\right)}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\dot{V}_{be1}+\frac{\mathrm{y}_{ie}y_{oe}-y_{re}\mathrm{y}_{fe}+y_{oe}^{2}}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\dot{V}_{cb2}\cdots\cdots(6)$$

$$\therefore y_{f}=\frac{\mathrm{y}_{fe}\left(\mathrm{y}_{fe}+y_{oe}\right)}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\approx \mathrm{y}_{fe}$$

$$y_{o}=\frac{\mathrm{y}_{ie}y_{oe}-y_{re}\mathrm{y}_{fe}+y_{oe}^{2}}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\approx -y_{re}$$

由(1)乘 $\left(y_{fe}+y_{oe}\right)$ 与(4)乘 y_{re} 后相加得

$\dot{I}_{b1}\left(y_{fe}+y_{oe}\right)+\dot{I}_{c2}\,y_{re}=y_{ie}\left(\mathrm{y}_{fe}+y_{oe}\right)\dot{V}_{be1}+y_{re}y_{oe}\dot{V}_{cb2}$

由(6)代入消去 $\dot{I}_{c2}$ 得

$$\dot{I}_{b1}=\frac{\mathrm{y}_{ie}^{2}+\mathrm{y}_{ie}y_{re}+\mathrm{y}_{ie}\mathrm{y}_{fe}+2\mathrm{y}_{ie}y_{oe}-y_{re}\mathrm{y}_{fe}}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\dot{V}_{be1}+\frac{y_{re}\left(y_{oe}+y_{re}\right)}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\dot{V}_{cb2}$$

$$y_{i}=\frac{\mathrm{y}_{ie}^{2}+\mathrm{y}_{ie}y_{re}+\mathrm{y}_{ie}\mathrm{y}_{fe}+2\mathrm{y}_{ie}y_{oe}-y_{re}\mathrm{y}_{fe}}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\approx \mathrm{y}_{ie}$$

$$y_{r}=\frac{y_{re}\left(y_{oe}+y_{re}\right)}{y_{ie}+y_{re}+\mathrm{y}_{fe}+2y_{oe}}\approx -\frac{y_{re}\left(y_{oe}+y_{re}\right)}{y_{fe}}$$

同理可证2)　略

$4-22$解：$\overline{v_{bn}^{2}}=4kTr_{b}\Delta f_{n}=4\times1.38\times10^{-23}\times(273+19)\times70\times200\times10^{3}=0.226\times10^{-12}\left(V^{2}\right)$

$\overline{i_{en}^{2}}=2qI_{E}\Delta f_{n}=2\times1.6\times10^{-19}\times10^{-3}\times200\times10^{3}=0.64\times10^{-16}\left(A^{2}\right)$

$$|\alpha|=\frac{\alpha_0}{\sqrt{1+\left(\dfrac{f}{f_\alpha}\right)^2}}=\frac{0.95}{\sqrt{1+\left(\dfrac{10\times10^{6}}{500\times10^{6}}\right)^2}}=0.95$$

$\overline{i_{cn}^{2}}=2qI_{C}\left(1-\alpha_0\right)\Delta f_{n}=2\times1.6\times10^{-19}\times10^{-3}\times(1-0.95)\times200\times10^{3}=0.32\times10^{-17}\left(A^{2}\right)$

4－23证明：$\Delta f_n = \dfrac{\int_0^{\infty} A^2(f)df}{A^2(f_0)} = \int_0^{\infty} \dfrac{1}{1+\left(2Q\dfrac{f-f_0}{f_0}\right)^2} df = \dfrac{\pi f_0}{2Q}$

4－24解：$F_n \quad = 3dB(1.995 \quad)$ $\qquad F_n \quad = 6dB(3.981 \quad)$

$$F_n \quad = 1 + \frac{T_i}{T} = 1 + \frac{60}{290} = 1.207$$

$$F_n = F_n \quad + \frac{F_n \quad -1}{A_p} + \frac{F_n \quad -1}{K_{pc}A_p} = 1.995 + \frac{1.207-1}{A_p} + \frac{3.981-1}{0.2\times A_p} = 10$$

$$A_p \quad = 1.888 \qquad 20\lg 1.888 = 2.76(dB)$$

4－25解：$F_n = \dfrac{P_{si}/P_{ni}}{P_{so}/P_{no}} = \dfrac{P_{no}}{P_{ni}A_p} = \dfrac{1}{A_p} = \dfrac{1}{P_o/P_s} = \dfrac{P_s}{P_o} = \dfrac{V_s^2/4R_s}{V_s^2/4(R_s+R)} = \dfrac{R_s+R}{R} = 1+\dfrac{R_s}{R}$

4－26解：$F_n = \dfrac{P_{si}/P_{ni}}{P_{so}/P_{no}} = \dfrac{1}{A_p} = \dfrac{P_s}{P_o} = \dfrac{I_s^2/4G_s}{I_s^2/4(G_s+G+G_L+rC/L)} = 1+\dfrac{G+G_L+rC/L}{G_s}$

4－27解：A为输入级，B为中间级，C为输出级。

$$A_{PA} = 6dB(3.981倍) \qquad A_{pB} = 12dB(15.849倍)$$

$$F_n = F_{nA} + \frac{F_{nB}-1}{A_{pA}} + \frac{F_{nC}-1}{A_{pA}\cdot A_{pB}} = 1.7 + \frac{2-1}{3.981} + \frac{4-1}{3.981\times 15.849} = 2$$

4－28解：不能满足要求。设A前置放大器，B为输入级，C为下一级。

$$F_n = \frac{P_{si}/P_{ni}}{P_{so}/P_{no}} = \frac{10^5}{10^4} \geq F_{nA} + \frac{F_{nB}-1}{A_{pA}} + \frac{F_{nC}-1}{A_{pA}\cdot A_{pB}} = F_{nA} + \frac{10-1}{10} + \frac{1.995-1}{10\times 0.1} \to F_{nA} \leq 8.1$$

第四章　非线性电路、时变参量和变频器

5－8解：$i = kv^2 = k(V_0 + V_m\cos\omega_0 t)^2$

$$= k\left(V_0^2 + 2V_0V_m\cos\omega_0 t + \frac{1}{2}V_m^2 + \frac{1}{2}V_m^2\cos^2 2\omega_0 t\right)$$

当$V_m << V_0$时，$i \approx k(V_0^2 + 2V_0V_m\cos\omega_0 t)$，该非线性元件就能近似当成线性元件来处理，即当$V_0$较大时，静态工作点选在抛物线上段接近线性部分，然后当V_m很小时，根据泰勒级数原则，可认为信号电压在特性的线性范围内变化，不会进入曲线弯曲部分，故可只取其级数的前两项得到近似线性特性。

5－12解：为了使i_C中的二次谐波振幅达到最大值，θ_C应为60^o。

$$\cos 60^o = \frac{V_{BZ}+V_{BB}}{V_m} = \frac{1}{2} \qquad \therefore V_{BB} = \frac{1}{2}V_m - V_{BZ}$$

5－13解：$i = \begin{cases} gV_m \cos\omega t & 当\cos\omega t > 0 \\ 0 & 当\cos\omega t < 0 \end{cases}$

$$i = \sum_{n=0}^{\infty} I_n \cos n\omega t$$

$$I_0 = \frac{1}{2\pi}\int_{-\pi}^{+\pi} gV_m \cos\omega t d(\omega t) = \frac{1}{\pi} gV_m$$

$$I_1 = \frac{1}{\pi}\int_{-\pi}^{+\pi} gV_m \cos^2 \omega t d(\omega t) = \frac{1}{2} gV_m$$

$$I_n = \frac{1}{\pi}\int_{-\pi}^{+\pi} gV_m \cos\omega t \cos n\omega t d(\omega t) = \begin{cases} \frac{2}{\pi} gV_m \frac{1}{n^2-1} & n为偶数 \\ 0 & n为奇数 \end{cases}$$

5－15解：$\mathrm{i} = \mathrm{i}_{D1} + \mathrm{i}_{D2}$

$$i_{D1} = \begin{cases} gV_m \cos\omega t & 当\cos\omega t > 0 \\ 0 & 当\cos\omega t < 0 \end{cases} \qquad \mathrm{i}_{D2} = \begin{cases} gV_m \cos\omega t & 当\cos\omega t < 0 \\ 0 & 当\cos\omega t > 0 \end{cases}$$

$$\mathrm{i} = \frac{2}{\pi}\mathrm{gV_m} + \frac{4}{\pi}\mathrm{gV_m}\sum_{k=1}^{\infty}\frac{(-1)^{k-1}}{(2k)^2-1}\cos 2k\omega_0 t \qquad (k = 1,2,3,\cdots)$$

5－16解：当$V_0(1+m\sin\Omega t)\sin\omega_0 t < 0$时，$i = 0$;

当$V_0(1+m\sin\Omega t)\sin\omega_0 t > 0$时，$i = gV_0(1+m\sin\Omega t)\sin\omega_0 t$

$$\mathrm{i} = \frac{2}{\pi} gV_0\left(1 + m\sin\Omega t - 2\sum_{k=1}^{\infty}\frac{\cos 2k\omega_0 t}{4k^2-1} - 2m\sum_{k=1}^{\infty}\frac{\sin\Omega t\cos 2k\omega_0 t}{4k^2-1}\right)$$

$(k = 1,2,3,\cdots)$

5－17解：$\mathrm{v}_0 = \mathrm{R_L}(\mathrm{i}_{D1} - \mathrm{i}_{D2}) = \mathrm{R_L}\left[k(\mathrm{v}_1+\mathrm{v}_2)^2 - k(\mathrm{v}_1-\mathrm{v}_2)^2\right] = 4k\mathrm{R_L}\mathrm{v}_1\mathrm{v}_2$

5－18解：$v_0 = R_L(i_2 - i_3) + R_L(i_4 - i_1) = R_L(i_2 + i_4 - i_1 - i_3)$

$$\begin{aligned} &= R_L\left[b_0 + b_1(v_1 - v_2) + b_2(v_1 - v_2)^2 + b_3(v_1 - v_2)^3\right] \\ &+ R_L\left[b_0 + b_1(-v_1 + v_2) + b_2(-v_1 + v_2)^2 + b_3(-v_1 + v_2)^3\right] \\ &- R_L\left[b_0 + b_1(v_1 + v_2) + b_2(v_1 + v_2)^2 + b_3(v_1 + v_2)^3\right] \\ &- R_L\left[b_0 + b_1(-v_1 - v_2) + b_2(-v_1 - v_2)^2 + b_3(-v_1 - v_2)^3\right] \\ &= -8R_L b_2 v_1 v_2 \end{aligned}$$

$$5-23\text{解:}(1)g_m=\frac{di_C}{dv_{BE}}=b_1+2b_2v_{BE}+3b_3v_{BE}^2+4b_4v_{BE}^3$$

$$g_m(t)=\left.\frac{di_C}{dv_{BE}}\right|_{v_{BE}=v_0}=b_1+2b_2V_{0m}\cos\omega_0t+3b_3V_{0m}^2\cos^2\omega_0t+4b_4V_{0m}^3\cos^3\omega_0t$$

$$=b_1+2b_2V_{0m}\cos\omega_0t+\frac{3}{2}b_3V_{0m}^2(1+\cos2\omega_0)+2b_4V_{0m}^3\cos\omega_0t+b_4V_{0m}^3(\cos\omega_0t+\cos3\omega_0t)$$

$$g_{m1}=2b_2V_{0m}+3b_4V_{0m}^3$$

$$g_c=\frac{1}{2}g_{m1}=b_2V_{0m}+1.5b_4V_{0m}^3$$

$$(2)g_m=\frac{di_C}{dv_{BE}}=\frac{aI_Sq}{kT}v_{BE}\cdot e^{\frac{q}{kT}v_{BE}}$$

$$g_m(t)=\left.\frac{di_C}{dv_{BE}}\right|_{v_{BE}=v_0}=\frac{aI_Sq}{kT}V_{om}\cos\omega_0t\cdot e^{\frac{q}{kT}V_{om}\cos\omega_0t}$$

$$=\frac{aI_Sq}{kT}V_{om}\cos\omega_0t\left[1+\frac{q}{kT}V_{om}\cos\omega_0t+\frac{1}{2}\left(\frac{q}{kT}V_{om}\cos\omega_0t\right)^2+\frac{1}{6}\left(\frac{q}{kT}V_{om}\cos\omega_0t\right)^3+\cdots\right]$$

$$=\alpha I_S\frac{qV_{om}}{kT}\cos\omega_0t+\alpha I_S\left(\frac{qV_{om}}{kT}\right)^2\cos^2\omega_0t+\frac{\alpha I_S}{2}\left(\frac{qV_{om}}{kT}\right)^3\cos^3\omega_0t+\frac{\alpha I_S}{6}\left(\frac{qV_{om}}{kT}\right)^4\cos^4\omega_0t$$

$$g_{m1}\approx\alpha I_S\frac{qV_{om}}{kT}+\frac{3\alpha I_S}{8}\left(\frac{qV_{om}}{kT}\right)^3$$

$$g_c=\frac{1}{2}g_{m1}=\frac{\alpha I_SqV_{om}}{2kT}+\frac{3\alpha I_S}{16}\left(\frac{qV_{om}}{kT}\right)^3$$

$$5-25\text{解：}i_\Sigma=i_1-i_3+i_2-i_4$$

$$=a_0+a_1(v_0+v_s)+a_2(v_0+v_s)^2+a_3(v_0+v_s)^3+a_4(v_0+v_s)^4+\cdots$$

$$+a_0+a_1(v_0-v_s)+a_2(v_0-v_s)^2+a_3(v_0-v_s)^3+a_4(v_0-v_s)^4+\cdots$$

$$-a_0-a_1(-v_0+v_s)-a_2(-v_0+v_s)^2-a_3(-v_0+v_s)^3-a_4(-v_0+v_s)^4-\cdots$$

$$-a_0-a_1(-v_0-v_s)-a_2(-v_0-v_s)^2-a_3(-v_0-v_s)^3-a_4(-v_0-v_s)^4-\cdots$$

$$=8a_2v_0v_s+16a_4v_0^3v_s+16a_4v_s^3v_0+\cdots$$

5－29解：$g_c = 0.5\dfrac{I_E/26}{\sqrt{1+\left(\dfrac{\omega_s}{\omega_T}\cdot\dfrac{I_E}{26}r_{bb'}\right)^2}} \approx \dfrac{0.5I_E}{26} = \dfrac{0.5\times0.5}{26} = 9.6(mS)$

$$g_{ic} \approx g_{b'e} = \frac{I_E}{26\beta_0} = \frac{0.5}{26\times35} = 0.55(mS)$$

$$g_{oc} \approx g_{ce} = 4(\mu S)$$

$$A_{pc\max} = \frac{g_c^2}{4g_{ic}g_{oc}} = \frac{9.6^2}{4\times0.55\times0.004} = 10473(\approx 40dB)$$

$$A_{pc} = A_{pc\max}\left(1-\frac{Q_L}{Q_0}\right)^2 = A_{pc\max}\left(1-\frac{\sqrt{2}f_i}{Q_0 2\Delta f_{0.7}}\right)^2 = 10473\times\left(1-\frac{\sqrt{2}\times465}{100\times10}\right)^2 = 1228(\approx 30.1dB)$$

5－30解：$g_c = 0.5\dfrac{I_E/26}{\sqrt{1+\left(\dfrac{\omega_s}{\omega_T}\cdot\dfrac{I_E}{26}r_{bb'}\right)^2}} \approx \dfrac{0.5I_E}{26} = \dfrac{0.5\times0.08}{26} = 1.54(mS)$

$$g_{ic} \approx g_{b'e} = \frac{I_E}{26\beta_0} = \frac{0.08}{26\times30} = 0.1(mS)$$

$$g_{oc} \approx g_{ce} = 10(\mu S)$$

$$A_{pc\max} = \frac{g_c^2}{4g_{ic}g_{oc}} = \frac{1.54^2}{4\times0.1\times0.01} = 592.9(\approx 28dB)$$

$$A_{pc} = \left(\frac{g_c}{g_{oc}+G_L}\right)^2\cdot\frac{G_L}{g_{ic}} = \left(\frac{1.54}{0.01+0.1}\right)^2\times\frac{0.1}{0.1} = 196(\approx 23dB)$$

5－32解：$i_\Sigma = i_1 - i_2 - i_3 + i_4$

$$\begin{aligned}
&= a_0 + a_1(v_0+v_s) + a_2(v_0+v_s)^2 + a_3(v_0+v_s)^3 + a_4(v_0+v_s)^4 + \cdots \\
&- \left[a_0 + a_1(v_0-v_s) + a_2(v_0-v_s)^2 + a_3(v_0-v_s)^3 + a_4(v_0-v_s)^4 + \cdots\right] \\
&- \left[a_0 + a_1(-v_0+v_s) + a_2(-v_0+v_s)^2 + a_3(-v_0+v_s)^3 + a_4(-v_0+v_s)^4 + \cdots\right] \\
&+ \left[a_0 + a_1(-v_0-v_s) + a_2(-v_0-v_s)^2 + a_3(-v_0-v_s)^3 + a_4(-v_0-v_s)^4 + \cdots\right] \\
&= 8a_2v_0v_s + 16a_4v_0^3v_s + 16a_4v_s^3v_0 + \cdots
\end{aligned}$$

5－34解：因存在二次项，能进行混频。只要满足$f_n = f_i$就会产生中频干扰；当$f_n = f_0 + f_i$时产生镜像干扰。由于不存在三次项，不会产生交调干扰；有二次项，可能产生互调干扰；若有强干扰信号，则能产生阻塞干扰。

$5-35$解：1. 此现象属于组合频率干扰。这是由于混频器的输出电流中，除需要的中频电流外，还存在一些谐波频率和组合频率，如果这些组合频率接近于中频放大的通带内，它就能和有用中频一道进入中频放大器，并被放大后加到检波器上，通过检波器的非线性效应，与中频差拍检波，产生音频，最终出现哨叫声。

2. 因$f_i = 465kHz$，p、q为本振和信号的谐波次数，不考虑大于3的情况。所以落于535 ~1605kHz波段内的干扰在$f_S = 930kHz$和$f_S = 1395kHz$附近，1kHz的哨叫声在929kHz、931kHz、1394kHz、1396kHz时产生。

3. 提高前端电路的选择性，合理选择中频等。

$5-36$解：若满足$\left|\pm pf_1 \pm qf_2\right| = f_s$，则会产生互调干扰：

$p=1$、$q=1$，$f_1 + f_2 = 774 + 1035 = 1.809(MHz)$，不会产生互调干扰；

$p=1$、$q=2$，$f_1 + 2f_2 = 774 + 2\times 1035 = 2.844(MHz)$，会产生互调干扰；

$p=2$、$q=1$，$2f_1 + f_2 = 2\times 774 + 1035 = 2.583(MHz)$，会产生互调干扰；

$p=2$、$q=2$，$2(f_1 + f_2) = 2\times(774 + 1035) = 3.618(MHz)$，会产生互调干扰；

$p=2$、$q=3$，$2f_1 + 3f_2 = 2\times 774 + 3\times 1035 = 4.653(MHz)$，会产生互调干扰；

$p=3$、$q=2$，$3f_1 + 2f_2 = 3\times 774 + 2\times 1035 = 4.392(MHz)$，会产生互调干扰；

$p=3$、$q=3$，$3(f_1 + f_2) = 3\times(774 + 1035) = 5.427(MHz)$，会产生互调干扰；

p、q大于3谐波较小，可以不考虑。

$5-37$解：(1) $\begin{cases}3f_S + 2f_0 < 2\\2f_S + 3f_0 < 2\end{cases} \Rightarrow f_S + f_0 < 0.8(MHz)$

$$\begin{cases}-f_S + 2f_0 < 2\\-2f_S + 3f_0 < 2\end{cases} \Rightarrow -f_S + f_0 < 0.4(MHz)$$

$$\therefore f_S = 0.2MHz \qquad f_0 < 0.6MHz$$

(2) $\begin{cases}-3f_s + 2f_0 > 30\\-2f_s + 3f_0 > 30\end{cases} \Rightarrow -f_s + f_0 > 12(MHz)$

$$\begin{cases}f_s + 2f_0 > 30\\2f_s + f_0 > 30\end{cases} \Rightarrow f_s + f_0 > 20(MHz)$$

$$\therefore f_S = 4MHz \qquad f_0 > 16MHz$$

$5-39$解：若满足$\left|\pm pf_1 \pm qf_2\right| = f_s$，则会产生互调干扰。已知$f_1 = 19.6MHz$、$f_2 = 19.2MHz$、$f_s = f_0 - f_i = 23 - 3 = 20(MHz)$，故没有互调信号输出 。

第五章　高频公路放大器

$6-4$解：$P_{=}=V_{CC}I_{CO}=24\times 0.25=6(W)$

$$\eta_C=\frac{P_0}{P_{=}}=\frac{5}{6}=83.3\%$$

$$R_p=\frac{V_{cm}^2}{2P_0}=\frac{V_{CC}^2}{2P_0}=\frac{24^2}{2\times 5}=57.6(\Omega)$$

$$I_{cm1}=\frac{2P_0}{V_{cm}}=\frac{2P_0}{V_{CC}}=\frac{2\times 5}{24}=0.417(A)$$

$$g_c(\theta_c)=\frac{I_{cm1}}{I_{c0}}=\frac{0.42}{0.25}=1.67$$

查表得$\theta_c=77^o$

$6-6$解：$g_c(\theta_c)=\dfrac{2\eta V_{CC}}{V_{cm}}=\dfrac{2\times 0.7\times 12}{10.8}=1.56$查表得$\theta_c=91^o$

$$P_0=I_k^2R=2^2\times 1=4(W)$$

$$P_C=P_{=}-P_0=\left(\frac{1}{\eta_c}-1\right)P_0=\left(\frac{1}{0.7}-1\right)\times 4=1.7(W)$$

$6-7$解：$i_{c\max}=\dfrac{I_{c0}}{\alpha_0(90^o)}=\dfrac{90}{0.319}=282(mA)$

$$I_{c1m}=\alpha_1(90^o)i_{c\max}=0.5\times 282=141(mA)$$

$$P_0=\frac{1}{2}R_pI_{c1m}^2=\frac{1}{2}\times 200\times 0.141^2=2(W)$$

$$\eta_c=\frac{P_0}{V_{CC}I_{c0}}=\frac{2}{30\times 0.09}=74\%$$

$6-8$证：$P_0=\dfrac{V_{cm}^2}{2R_P}=\dfrac{I_{km}^2\left[R^2+(\omega_0L)^2\right]}{\dfrac{2L}{RC}}=\dfrac{I_{km}^2\left[R^2+(\omega_0L)^2\right]RC}{2L}=\dfrac{I_{km}^2\left[R^2+(\omega_0L)^2\right]R}{2(\omega_0L)^2}\approx\dfrac{I_{km}^2R}{2}$

6－9解：$V_{cm}=V_{CC}-v_{c\min}=V_{CC}-\dfrac{i_{c\max}}{g_{cr}}=24-\dfrac{2.2}{0.8}=21.25(V)$

$$I_{c0}=i_{c\max}\alpha_0(70^o)=2.2\times0.253=0.5566(A)$$
$$I_{cm1}=i_{c\max}\alpha_1(70^o)=2.2\times0.436=0.9592(A)$$
$$P_{=}=V_{CC}I_{c0}=24\times0.5566=13.36(W)$$
$$P_0=\frac{1}{2}V_{cm}I_{cm1}=\frac{1}{2}\times21.25\times0.9592=10.19(W)$$
$$P_C=P_{=}-P_0=13.36-10.19=3.17(W)$$
$$\eta_C=\frac{P_0}{P_{=}}=\frac{10.19}{13.36}=76.3\%$$
$$R_p=\frac{V_{cm}^2}{2P_0}=\frac{21.25^2}{2\times10.19}=22.16(\Omega)$$

6－10解：$R_1=R_p=\dfrac{V_{cm}^2}{2P_0}\approx\dfrac{V_{CC}^2}{2P_0}=\dfrac{24^2}{2\times2}=144(\Omega)$

$$X_{C1}=\frac{R_1}{Q_L}=\frac{144}{10}=14.4(\Omega)$$
$$C_1=\frac{1}{2\pi fX_{C1}}=\frac{1}{2\times3.14\times50\times10^6\times14.4}=221(pF)$$
$$X_{L1}=\frac{R_2}{\sqrt{\frac{R_2}{R_1}(Q_L^2+1)-1}}=\frac{200}{\sqrt{\frac{200}{144}\times(100+1)-1}}=16.95(\Omega)$$
$$L_1=\frac{X_{L1}}{2\pi f}=\frac{16.95}{2\times3.14\times50\times10^6}=0.054(\mu H)$$
$$X_{C2}=\frac{Q_LR_1}{Q_L^2+1}\left(\frac{R_2}{Q_LX_{L1}}-1\right)=\frac{10\times144}{100+1}\left(\frac{200}{10\times16.95}-1\right)=2.57(\Omega)$$
$$C_2=\frac{1}{2\pi fX_{C2}}=\frac{1}{2\times3.14\times50\times10^6\times2.57}=1239(pF)$$

6－11解：(1)R_P增加一倍，放大器工作于过压状态，V_{cm}变化不大，$P_0'=V_{cm}^2/2R_P=0.5P_0$；

(2)R_P减小一半，放大器工作于欠压状态，I_{cm}变化不大，$P_0'=I_{cm}^2R_P/2=2P_0$。

6－12解：$\eta_k=\dfrac{r'}{r_1+r'}=\dfrac{1}{1+\dfrac{\omega L_1\omega L_2}{Q_1Q_2(\omega M)^2}}=\dfrac{1}{1+\dfrac{1}{Q_1Q_2k^2}}=\dfrac{1}{1+\dfrac{1}{100\times15\times0.03^2}}=57.4\%$

$$6-13\text{解：}R_P=\frac{V_{cm}^2}{2P_0}=\frac{\left(V_{CC}-V_{CE(sat)}\right)^2}{2P_0}=\frac{(12-0.5)^2}{2\times 1}=66(\Omega)$$

$$\text{设}Q_L=10\qquad \text{则}X_{C1}=\frac{R_P}{Q_L}=\frac{66}{10}=6.6(\Omega)$$

$$C_1=\frac{1}{2\pi fX_{C1}}=\frac{1}{2\times 3.14\times 10^8\times 6.6}=241(pF)$$

$$X_{C2}=\frac{R_L}{\sqrt{\left(1+Q_L^2\right)\frac{R_L}{R_P}-1}}=\frac{50}{\sqrt{\left(1+10^2\right)\times\frac{50}{66}-1}}=5.5(\Omega)$$

$$C_2=\frac{1}{2\pi fX_{C2}}=\frac{1}{2\times 3.14\times 10^8\times 5.5}=290(pF)$$

$$X_{L1}=\frac{Q_LR_P}{Q_L^2+1}\left(1+\frac{R_L}{Q_LX_{C2}}\right)=\frac{10\times 66}{10^2+1}\left(1+\frac{50}{10\times 5.5}\right)=12.5(\Omega)$$

$$L_1=\frac{X_{L1}}{2\pi f}=\frac{12.5}{2\times 3.14\times 10^8}=19.9(nH)$$

6－14证：(a)将R_1C_1和R_2C_2串联电路改为$R_1'C_1'$和$R_2'C_2'$并联电路，并设$X_{C1}=\frac{R_1}{Q_L}$

$$R_1'=\frac{X_{C1}^2}{R_1^2+X_{C1}^2}R_1 \qquad R_2'=\frac{X_{C2}^2}{R_2^2+X_{C2}^2}R_2 \qquad X_{C1}'=\frac{R_1^2}{R_1^2+X_{C1}^2}X_{C1} \qquad X_{C2}'=\frac{R_2^2}{R_2^2+X_{C2}^2}X_{C2}$$

匹配时$R_1'=R_2'$，即$R_1'=\frac{X_{C1}^2}{R_1^2+X_{C1}^2}R_1=\frac{1}{1+Q_L^2}R_1=\frac{X_{C2}^2}{R_2^2+X_{C2}^2}R_2$

$$\therefore X_{C2}=\frac{R_2}{\sqrt{\left(1+Q_L^2\right)\frac{R_2}{R_1}-1}}$$

$$X_{L1}=X_{C1}'+X_{C2}'=\frac{R_1^2}{R_1^2+X_{C1}^2}X_{C1}+\frac{R_2^2}{R_2^2+X_{C2}^2}X_{C2}$$

$$=\frac{R_1^2}{R_1^2+X_{C1}^2}X_{C1}+\frac{X_{C1}^2}{R_1^2+X_{C1}^2}\cdot\frac{R_1R_2}{X_{C2}}=\frac{R_1Q_L}{1+Q_L^2}+\frac{1}{1+Q_L^2}\cdot\frac{R_1R_2}{X_{C2}}=\frac{R_1Q_L}{1+Q_L^2}\left(1+\frac{R_2}{Q_LX_{C2}}\right)$$

(b)将R_1C_1和R_2L_1串联电路改为$R_1'C_1'$和$R_2'L_1'$并联电路，并设$X_{C1}=\frac{R_1}{Q_L}$

$$R_1'=\frac{X_{C1}^2}{R_1^2+X_{C1}^2}R_1 \qquad R_2'=\frac{X_{L1}^2}{R_2^2+X_{L1}^2}R_2 \qquad X_{C1}'=\frac{R_1^2}{R_1^2+X_{C1}^2}X_{C1} \qquad X_{L1}'=\frac{R_2^2}{R_2^2+X_{L1}^2}X_{L1}$$

匹配时$R_1'=R_2'$，即$R_1'=\frac{X_{C1}^2}{R_1^2+X_{C1}^2}R_1=\frac{1}{1+Q_L^2}R_1=\frac{X_{L1}^2}{R_2^2+X_{L1}^2}R_2$

$$\therefore X_{L1}=\frac{R_2}{\sqrt{\left(1+Q_L^2\right)\frac{R_2}{R_1}-1}}$$

$$X_{C2}=X_{L1}'-X_{C1}'=\frac{R_2^2}{R_2^2+X_{L1}^2}X_{L1}-\frac{R_1^2}{R_1^2+X_{C1}^2}X_{C1}$$

$$=\frac{X_{C1}^2}{R_1^2+X_{C1}^2}\cdot\frac{R_1R_2}{X_{L1}}-\frac{R_1Q_L}{1+Q_L^2}=\frac{R_1Q_L}{1+Q_L^2}\cdot\frac{R_2}{Q_LX_{L1}}-\frac{R_1Q_L}{1+Q_L^2}=\frac{R_1Q_L}{1+Q_L^2}\left(\frac{R_2}{Q_LX_{L1}}-1\right)$$

6－18解：(1)天线断开，工作于过压状态，集电极直流电表读数减小，天线电流表读数为0；

(2)天线接地，工作于欠压状态，集电极直流电表读数略增，天线电流表读数增加；

(3)中介回路失谐，工作于欠压状态，集电极直流电表读数略增，天线电流表读数减小。

6－19解：(1)$P_A=P_=-P_C-P_k=10-3-1=6(W)$

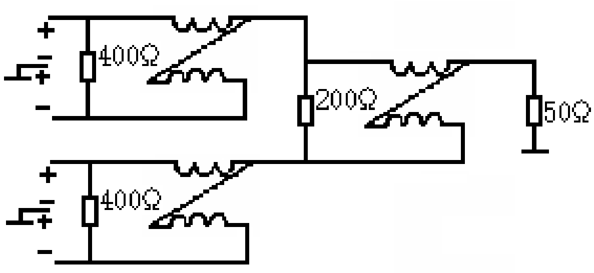
(2)$\eta_k=\frac{P_A}{P_=-P_C}=\frac{6}{10-3}=85.7\%$

(3)$\eta_c=\frac{P_=-P_C}{P_=}=\frac{10-3}{10}=70\% \qquad \eta=\frac{P_A}{P_=}=\frac{6}{10}=60\%$

$6-20$解：当$k=k_c$时，$\eta_k=1-\frac{\mathrm{r}_1}{\mathrm{r}_1+\mathrm{r}'}=50\%$则$\mathrm{r}'=\mathrm{r}_1$　　$k_\mathrm{c}=\frac{1}{\mathrm{Q}}$

若$\eta_k'=1-\frac{\mathrm{r}_1}{\mathrm{r}_1+\mathrm{r}''}=90\%$则$\mathrm{r}''=9\mathrm{r}_1$故$k=\frac{1}{\sqrt{\mathrm{Q}_1\mathrm{Q}_2}}=\frac{1}{\sqrt{\mathrm{Q}_0\frac{\mathrm{Q}_0}{9}}}=\frac{3}{\mathrm{Q}}=3\mathrm{k}_\mathrm{c}$

$6-25$解：



$6-27$解：$\because \alpha_2(60^\circ)<\alpha_1(60^\circ)$，$\therefore P_0$减小，工作于欠压状态 。

$6-28$解：$R_i=\frac{V}{I}=9\frac{\frac{V}{3}}{3I}=9R_L$

$6-29$解：$V_{bm}=\frac{V_{BZ}+V_{BB}}{\cos\theta}=\frac{0.6+1.45}{\cos 70^o}=6(V)$

$V_B=V_{bm}-V_{BB}=6-1.45=4.55(V)$

$i_{C\max}=\frac{V_B-V_{BZ}}{2}=\frac{4.55-0.6}{2}=1.98(A)$

$I_{cm1}=i_{C\max}\alpha_1(70^o)=1.98\times 0.436=0.86(A)$

$V_{cm}=V_{CC}-g_{cr}i_{C\max}=24-1.98=22.02(V)$

$P_0=\frac{I_{cm1}V_{cm}}{2}=\frac{0.86\times 22.01}{2}=9.47(W)$

$P_A=\left(1-\frac{Q_L}{Q_0}\right)P_0=\left(1-\frac{10}{100}\right)\times 9.47=8.52(W)$

$6-30$解：$V_{bm}=\dfrac{V_{BZ}+V_{BB}}{\cos\theta}=\dfrac{0.6+1.5}{\cos 70^{o}}=6.14(V)$

$V_B=V_{bm}-V_{BB}=6.14-1.5=4.64(V)$

$i_{C\max}=\dfrac{V_B-V_{BZ}}{2}=\dfrac{4.64-0.6}{2}=2.02(A)$

$I_{cm1}=i_{C\max}\alpha_1(70^o)=2.02\times 0.436=0.88(A)$

$V_{cm}=\xi V_{CC}=0.9\times 24=21.6(V)$

$P_0=\dfrac{I_{cm1}V_{cm}}{2}=\dfrac{0.88\times 21.6}{2}=9.5(W)$

$P_A=\left(1-\dfrac{Q_L}{Q_0}\right)P_0=\left(1-\dfrac{10}{100}\right)\times 9.5=8.8(W)$

第六章　正弦选频网络

$7-5$解：(a)电路可能振荡，属于电感反馈式振荡电路；

(e)电路可能振荡，属于电容反馈式振荡电路；

(h)电路可能振荡，属于电容反馈式振荡电路；

(b)、(c)、(d)电路不可能振荡；

(f)电路在$L_2C_2<L_3C_3$时有可能振荡，属于电容反馈式振荡电路

(g)电路计及C_{be}可能振荡，属于电容反馈式振荡电路。

$7-6$解：(1)有可能振荡，属于电容反馈式振荡电路，$f_1<f_2<f_0<f_3$；

(2)有可能振荡，属于电感反馈式振荡电路，$f_1>f_2>f_0>f_3$；

(4)有可能振荡；属于电容反馈式振荡电路，$f_1=f_2<f_0<f_3$；

(3)(5)(6)不可能。

$7-7$解：

$7-21$解：(1)$f_0=\dfrac{1}{2\pi\sqrt{L(C+C_d)}}=\dfrac{1}{2\times 3.14\times\sqrt{10^{-7}\times(20+5)\times 10^{-12}}}=100(MHz)$

(2)$g_d=\dfrac{1}{R_P}=\dfrac{1}{Q}\sqrt{\dfrac{C}{L}}=\dfrac{1}{3}\times\sqrt{\dfrac{(20+5)\times 10^{-12}}{10^{-7}}}=5.27(mS)$

(3)$0.06\sim 0.08V$

$$7-26解:(1) f_q=\frac{1.657\times10^6}{d}=\frac{1.657\times10^6}{0.4}=4.14(MHz)$$

$$C_q=21.1\times10^{-5}\frac{S}{d}=21.1\times10^{-5}\times\frac{200}{0.4}=0.105(pF)$$

$$L_q=43.5\frac{d^3}{S}=43.5\times\frac{0.4^3}{200}=14(mH)$$

$$r_d=42500B\frac{d}{S}=42500\times0.25\times\frac{0.4}{200}=21.2(\Omega)$$

$$C_0=3.96\times10^{-2}\frac{S}{d}=3.96\times10^{-2}\times\frac{200}{0.4}=19.8(pF)$$

$$Q_q=\frac{1.05}{B}\times10^4 d=\frac{1.05}{0.25}\times10^4\times0.4=16800$$

$$(2) d=\frac{1.657\times10^6}{f_q}=\frac{1.657\times10^6}{15\times10^6}=0.11(mm)$$

7－27解：(1) $1.5\sim1.5001(MHz)$

(2)不能

(3)不能，普通三极管没有负阻特性。

7－28解：恒温槽、稳压电源、高稳定度克拉泼振荡电路、共集电极缓冲级等。

7－29解：并联c－b型（皮尔斯）晶体振荡电路。

第七章　振幅调制与解调

9－3解：$i=I(1+m_a\cos\Omega t)\cos\omega_0 t$

$$=I\cos\omega_0 t+\frac{I}{2}m_a\cos(\omega_0+\Omega)t+\frac{I}{2}m_a\cos(\omega_0-\Omega)t$$

$$I=\sqrt{\left(\frac{I}{\sqrt2}\right)^2+\left(\frac{I}{2\sqrt2}m_a\right)^2+\left(\frac{I}{2\sqrt2}m_a\right)^2}$$

$$=\frac{I}{\sqrt2}\sqrt{1+\frac{m_a^2}{2}}$$

$$9-4\text{解:}(1)v=25(1+0.7\cos 2\pi 5000t-0.3\cos 2\pi 10000t)\sin 2\pi 10^6 t$$
$$=25\sin 2\pi 10^6 t+8.75(\sin 2\pi 1005000+\sin 2\pi 995000)$$
$$-3.75(\sin 2\pi 1010000+\sin 2\pi 990000)$$
$$(2)\text{包络}25(1+0.7\cos 2\pi 5000t-0.3\cos 2\pi 10000t)$$
$$\text{峰值调幅度m}\ =\frac{V_{\max}-V_0}{V_0}=\frac{25\times(1+0.7-0.3)-25}{25}=0.4$$
$$\text{谷值调幅度m}\ =\frac{V_0-V_{\min}}{V_0}=\frac{25-25(1-0.7-0.3)}{25}=1$$

$$9-5\text{解:}(1)m_a=1\qquad P_{(\omega_0+\Omega)}=P_{(\omega_0-\Omega)}=\frac{1}{4}m_a^2P_{0T}=\frac{1}{4}\times 100=25(W)$$
$$(2)m_a=0.3\qquad P_{(\omega_0+\Omega)}=P_{(\omega_0-\Omega)}=\frac{1}{4}m_a^2P_{0T}=\frac{1}{4}\times 0.3^2\times 100=2.25(W)$$

9－6解：$i=b_1v+b_3v^3$不包含平方项，不能产生调幅作用。

$$9-7\text{解:}(1)P_{(\omega_0+\Omega)}=P_{(\omega_0+\Omega)}=\frac{1}{4}m_a^2P_{0T}=\frac{1}{4}\times 0.7^2\times 5000=612.5(W)$$
$$P_{(\omega_0\pm\Omega)}=2P_{(\omega_0+\Omega)}=1225(W)$$
$$(2)P_{=}=\frac{P_{0av}}{\eta}=\frac{P_{0T}}{\eta}=\frac{5000}{0.5}=10(kW)$$
$$(3)P_{=}=\frac{P_{0av}}{\eta}=\frac{P_{0T}\left(1+\frac{m_a^2}{2}\right)}{\eta}=\frac{5000\times\left(1+\frac{0.7^2}{2}\right)}{0.5}=12.45(kW)$$
$$9-8\text{解:}(1)m_a=1\text{时}$$
$$P_{(\omega_0+\Omega)}=P_{(\omega_0-\Omega)}=\frac{1}{4}m_a^2P_{0T}=\frac{1}{4}\times 1000=250(W)$$
$$P_0=P_{0T}+P_{(\omega_0+\Omega)}+P_{(\omega_0-\Omega)}=1000+250+250=1500(W)$$
$$(2)m_a=0.7\text{时}$$
$$P_{(\omega_0+\Omega)}=P_{(\omega_0-\Omega)}=\frac{1}{4}m_a^2P_{0T}=\frac{1}{4}\times 0.7^2\times 1000=122.5(W)$$
$$P_0=P_{0T}+P_{(\omega_0+\Omega)}+P_{(\omega_0-\Omega)}=1000+122.5+122.5=1245(W)$$

9－9解：$f=f_0+f_1+f_2+f_3+f_4=5+20+200+1780+8000=10005(kHz)$

9－10解：$i_1 = b_0 + b_1(v + v_\Omega) + b_2(v + v_{\cdots}$

$i_2 = b_0 + b_1(v - v_\Omega) + b_2(v - v_{\cdots}$

$v_0 = (i_1 - i_2)R = R[2b_1 v_\Omega + 4b_2 v \cdots$

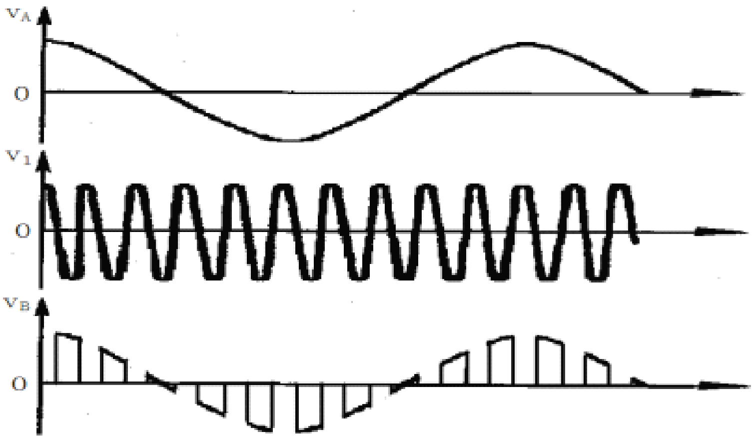
$= 2b_1 R V_\Omega \cos\Omega t + 3b_3 R V_0^2 V \cdots$

$+ 2b_2 R V_0 V_\Omega \cos(\omega_0 + \Omega)t \cdots$

$+ 1.5 b_3 R V_0^2 V_\Omega \cos(2\omega_0 + \Omega \cdots$

$+ 0.5 b_3 R V_\Omega^3 \cos 3\Omega t$

输出端的频率分量：Ω、3Ω、



9－12解：$m_1 = \sqrt{2\left(\frac{P_0}{P_{0T}} - 1\right)} = \sqrt{2 \times \left(\frac{1}{\cdots}\right.}$

$P_0' = P_0 + \frac{1}{2} m_2^2 P_{0T} = 10.125 + \frac{1}{2}\cdots$

9－13(1)$v_A(t) = v_\Omega(t) = V_\Omega \cos\Omega t$

$v_B(t) = v(t)$

(2)若$D_1 D_2$开路，则$v_A(t) = v_B \cdots$

$v_{AB} = 0$

(3)若$D_1 D_2$短路，则$v_A(t) = v_\Omega \cdots$

$v_B = 0 \qquad v_{AB}(t) = V_\Omega \cos \cdots$

9－18解：$R_\Omega = R_1 + \frac{R_2 r_{i2}}{R_2 + r_{i2}} = 510 + \frac{4700 \times 1000}{4700 + 1000} = 1335(\Omega)$

$$\theta = \sqrt[3]{\frac{3\pi R_d}{R}} = \sqrt[3]{\frac{3 \times 3.14 \times 100}{510 + 4700}} = 0.57$$

$$K_d = \cos\theta = 0.87$$

$$V_\Omega = K_d m_a V_{im} = 0.87 \times 0.3 \times 0.5 = 0.13$$

$$P_\Omega = \frac{V_\Omega^2}{2R_\Omega} = \frac{0.13^2}{2 \times 1335} = 6.33(\mu W)$$

$$P_\omega = \frac{V_{im}^2}{2R_{id}} = \frac{V_{im}^2 K_d}{R} = \frac{0.5^2 \times 0.87}{510 + 4700} = 41.7(\mu W)$$

$$A_P = \frac{P_\Omega}{P_\omega} = \frac{6.33}{41.7} = 0.152$$

9－19解：(1)中间位置$\frac{R_\Omega}{R}=\frac{R_1+R_2/2+\frac{R_2/2\cdot r_{i2}}{R_2/2+r_{i2}}}{R_1+R_2}=\frac{510+2350+\frac{2350\times1000}{2350+1000}}{510+4700}=0.55$

(2)最高端$\frac{R_\Omega}{R}=\frac{R_1+\frac{R_2 r_{i2}}{R_2+r_{i2}}}{R_1+R_2}=\frac{510+\frac{4700\times1000}{4700+1000}}{510+4700}=0.26$

$\therefore R_2$的触点在中间位置会产生负峰切割失真，而在最高端不会。

9－20解：由$R=R_1+R_2=(5\sim10)k\Omega$　　$R_1=\left(\frac{1}{5}\sim\frac{1}{10}\right)R_2$　　取$R_2=6k\Omega$　　$R_1=1.5k\Omega$

$$R_\Omega=R_1+\frac{R_2 r_{i2}}{R_2+r_{i2}}=1.5+\frac{6\times2}{6+2}=3(k\Omega)\qquad m_a<\frac{R_\Omega}{R}=\frac{3}{9}=\frac{1}{3}\qquad 取m_a=0.3$$

$$C<\frac{\sqrt{1-m_a^2}}{m_a R\Omega_{max}}=\frac{\sqrt{1-0.3^2}}{0.3\times9000\times2\times3.14\times3000}=0.0187(\mu F)\qquad 取C_1=C_2=0.01\mu F$$

$$C_e>>\frac{1}{\Omega_{min}r_{i2}}=\frac{1}{2\times3.14\times300\times2000}=0.26(\mu F)\qquad 取C_e=20\mu F$$

$$\theta=\sqrt[3]{\frac{3\pi R_d}{R}}=\sqrt[3]{\frac{3\times3.14\times100}{6000+1500}}=0.5$$

$$K_d=\cos\theta=0.9$$

$$R_{id}=\frac{R}{2K_d}=\frac{9000}{2\times0.9}=5(k\Omega)能满足要求$$

9－21解：$G_P=\frac{\omega_0 C}{Q_0}=\frac{2\times3.14\times465\times10^3\times200\times10^{-12}}{100}=5.84(\mu S)$

$$Q_L=\frac{f_0}{2\Delta f_{0.7}}=\frac{465}{20}=23.5$$

$$p_{34}=\sqrt{\frac{\frac{Q_0}{Q_L}G_P-p_{24}^2 g_{oe}-G_P}{g_{id}}}=\sqrt{\frac{\left(\frac{100}{23.5}\times5.84-0.3^2\times100-5.84\right)\times10^{-6}}{\frac{2}{4700}}}=0.153$$

$9-24$解：(1) $v_1 = mV_1\cos\Omega t\cos\omega_1 t$

$$i = kmV_1\cos\Omega t\cos\omega_1 t V_0\cos(\omega_0 t+\varphi)$$

$$=\frac{1}{4}kmV_1V_0\{\cos[(\omega_1+\omega_0+\Omega)t+\varphi]+\cos[(\omega_1-\omega_0+\Omega)t-\varphi]$$

$$+\cos[(\omega_1+\omega_0-\Omega)t+\varphi]+\cos[(\omega_1-\omega_0-\Omega)t-\varphi]\}$$

当$\omega_0=\omega_1$时，$v_S=\frac{1}{4}kmR_LV_1V_0[\cos(\Omega t-\varphi)+\cos(\Omega t+\varphi)]=\frac{1}{2}kmR_LV_1V_0\cos\varphi\cos\Omega t$

无失真，φ只影响输出幅度。

当$\omega_0\neq\omega_1$时，$v_S=\frac{1}{2}kmR_LV_1V_0\cos[(\omega_1-\omega_0)t-\varphi]\cos\Omega t$

有失真。

(2) $v_1=\frac{1}{2}mV_1\cos(\omega_1+\Omega)t$

$$i=\frac{1}{2}kmV_1\cos(\omega_1+\Omega)tV_0\cos(\omega_0 t+\varphi)$$

$$=\frac{1}{4}kmV_1V_0\{\cos[(\omega_1+\omega_0+\Omega)t+\varphi]+\cos[(\omega_1-\omega_0+\Omega)t-\varphi]\}$$

$$v_S=\frac{1}{4}kmR_LV_1V_0\cos[(\omega_1-\omega_0+\Omega)t-\varphi]$$

当$\omega_0=\omega_1$时，φ只产生相移；当$\omega_0\neq\omega_1$时，有失真。